



# Geotechnical Engineering Report

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**Woodmoor Lake Pump Station and Water Line  
Monument, Colorado**

December 17, 2020

Terracon Project No. 23205117

**Prepared for:**

JVA, Inc.  
Boulder, Colorado

**Prepared by:**

Terracon Consultants, Inc.  
Colorado Springs, Colorado



December 17, 2020

JVA, Inc.  
1319 Spruce Street  
Boulder, Colorado 80302



Attn: Mr. Adam J. Teunissen P.E – Project Manager  
P: (303) 565-4936  
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Re: Geotechnical Engineering Report  
Woodmoor Lake Pump Station and Water Line  
Woodmoor Drive and Lake Woodmoor Drive  
Monument, Colorado  
Terracon Project No. 23205117

Dear Mr. Teunissen:

We have completed Geotechnical Engineering services for the above referenced project. This study was performed in general accordance with Terracon Proposal No. P23205117 dated October 12, 2020, and email supplemental scope of service for slope stability on December 7, 2020. This report presents the findings of the subsurface exploration and provides geotechnical recommendations concerning earthwork and the design and construction of foundations and slabs, 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.**

For: Nathan D. Hukkanen, E.I.  
Staff Engineer

Robert M. Hernandez, P.E.  
Geotechnical Services Manager



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**Note:** This report was originally delivered in a web-based format. **Orange Bold** text in the report indicates a referenced section heading. The PDF version also includes hyperlinks which direct the reader to that section and clicking on the **GeoReport** logo will bring you back to this page. For more interactive features, please view your project online at [client.terracon.com](http://client.terracon.com).

## ATTACHMENTS

EXPLORATION AND TESTING PROCEDURES  
PHOTOGRAPHY LOG  
SITE LOCATION AND EXPLORATION PLANS  
EXPLORATION RESULTS  
SUPPORTING INFORMATION

**Note:** Refer to each individual Attachment for a listing of contents.

## REPORT SUMMARY

Topic <sup>1</sup>	Overview Statement <sup>2</sup>
<b>Project Description</b>	The proposed project will consist of the design and construction of a new pump station (Lake Pump Station) and pipeline. The pump station is planned to consist of an approximately 50-foot deep by 12-foot by 12-foot rectangular wet well and an approximately 20-foot by 25-foot Process Valve/Instrumentation Building. A raw water transmission pipeline will also be constructed as part of the project. Conventional cut-and-cover techniques have been assumed for the pipeline installation. Reportedly the underground pipeline will be constructed within 6 to 8 feet of existing grades.
<b>Geotechnical Characterization</b>	Fill sand soils encountered in three test borings to depths of about 3.5 to 6 feet Native sand soils to depths of about 3.5 to 8.5 feet, and the full depth of exploration in Borings SB-3 (a depth of about 10 feet). Weathered and unweathered sandstone bedrock to the full depths of exploration beneath native sand soils, depths of approximately 10 to 65 feet.
<b>Earthwork</b>	The on-site fill and native sand soils are considered acceptable for re-use as structural fill. The on-site sand soils may also be re-used as general fill outside of structural areas. On-site sandstone bedrock may be reused as either structural and/or general fill after processing to a soil like consistency meeting the recommended gradation presented herein for imported soils. Although not encountered in our boring, claystone bedrock is known to be encountered in the area. If encountered during construction, claystone bedrock may be reused in non-structural areas as general fill after processing to a soil like consistency with a maximum particle size of 3 inches.
<b>Deep Foundations</b>	Deep foundations are recommended for support of the planned buildings for this project.
<b>Shallow Foundations</b>	Shallow foundations are not recommended at this time due to the potential for excessive differential movement and the potential differing bearing conditions based on the planned earthwork at this site.
<b>Pavements</b>	None reported
<b>General Comments</b>	This section contains important information about the limitations of this geotechnical engineering report.
<ol style="list-style-type: none"> <li>1. If the reader is reviewing this report as a pdf, the topics above can be used to access the appropriate section of the report by simply clicking on the topic itself.</li> <li>2. This summary is for convenience only. It should be used in conjunction with the entire report for design purposes.</li> </ol>	

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## INTRODUCTION

This report presents the results of our subsurface exploration and geotechnical engineering services performed for the proposed project to be located near the intersection of Woodmoor Drive and Lake Woodmoor Drive in Monument, Colorado. The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Subsurface soil and rock conditions
- Site preparation and earthwork
- Excavation considerations
- Foundation design and construction
- Global slope stability
- Floor slab design and construction
- Seismic site classification per IBC
- Lateral earth pressures
- Water line construction

The geotechnical engineering Scope of Services for this project included the advancement of six test borings to depths of about 9½ to 65 feet below existing site grades.

Maps showing the site and boring locations are shown in the **Site Location** and **Exploration Plan** sections, respectively. The results of the laboratory testing performed on soil and bedrock samples obtained from the site during the field exploration are included on the boring logs and as separate graphs in the **Exploration Results** section.

## SITE CONDITIONS

The following description of site conditions is derived from our site visit in association with the field exploration and our review of publicly available geologic and topographic maps.

Item	Description
Parcel Information	The project is located near the intersection of Woodmoor Drive and Deer Creek Road in Monument, Colorado. See <b>Site Location</b>

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Item	Description
Existing Improvements	The subject water line alignment passes through areas previously developed with school buildings, asphalt concrete paved roadways, and single-family, residential homes. Overall the project alignment is bordered to the north by Deer Creek Road, to the west by Interstate 25, to the south by Lake Woodmoor Drive, and to the east by Lower Lake Road.
Current Ground Cover	Earthen, lightly- moderately vegetated, paved.

We also collected photographs at the time of our field exploration program. Representative photos are provided in our [Photography Log](#).

## PROJECT DESCRIPTION

Our initial understanding of the project was provided in our proposal and was discussed during project planning. A period of collaboration has transpired since the project was initiated, and our final understanding of the project conditions is as follows:

Item	Description
Information Provided	<ul style="list-style-type: none"><li>■ Emails between Terracon and JVA from October 7 to present day.</li><li>■ Woodmoor Lake Pump Station Request for Proposal for Geotechnical Services, received electronically on October 7, 2020.</li><li>■ LPS and Pipeline 30% Review Set, dated October 2020.</li></ul>
Project Description	The proposed project will consist of the design and construction of a new pump station (Lake Pump Station) and pipeline. The pump station is planned to consist of an approximately 50-foot deep by 12-foot by 12-foot rectangular wet well and an approximately 20-foot by 25-foot Process Valve/Instrumentation Building. A raw water transmission pipeline will also be constructed as part of the project. Conventional cut-and-cover techniques have been assumed for the pipeline installation. Reportedly the underground pipeline will be constructed within 6 to 8 feet of existing grades.
Maximum Loading	Columns – 50 to 100 kips (assumed) Walls – 4.5 k/ft at Process Valve/Instrumentation Building (reported) Floor slab – 150 to 250 psf (assumed)
Foundations	Based on the reported amount of excavation and fill planned at the site, it is our understanding that the proposed buildings will be supported on a deep, drilled pier foundation system.
Grading/Excavation	New fill placement up to 20 feet, with total fill placement up to 48 feet after pump station construction. Excavation depth of approximately 48 feet for Pump Station and 4 feet for Process Valve/Instrumentation Building.

## GEOTECHNICAL CHARACTERIZATION

We have developed a general characterization of the subsurface conditions based upon our review of the subsurface exploration, laboratory data, geologic setting and our understanding of the project. This characterization, termed GeoModel, forms the basis of our geotechnical calculations and evaluation of site preparation and foundation options. Conditions encountered at the exploration points are indicated on the individual logs. The individual logs can be found in the **Exploration Results** section and the GeoModel can be found in the **Figures** section of this report.

As part of our analyses, we identified the following model layers within the subsurface profile. For a more detailed view of the model layer depths at the boring location, refer to the GeoModel.

Model Layer	Layer Name	General Description
1	Fill	Generally consisting of sand with various amounts of clay and silt; fine to coarse grained; tan, brownish gray, gray, brown, and dark brown; very loose to medium dense.
2	Sand	With various amounts of clay and silt; fine to coarse grained; tan, light brown, brown, dark brown, reddish brown, light gray, and dark gray; loose to dense.
3	Weathered Sandstone Bedrock	With silt; fine to coarse grained; light brown; firm to medium hard.
4	Sandstone Bedrock	With various amounts of silt and clay; fine to coarse grained; tan, light brown, light grayish brown, and light gray; medium hard to very hard.

As noted in the **General Comments**, the characterization is based upon widely spaced borings at the site, and variations are likely. 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.

### Groundwater Conditions

The boreholes were observed while drilling and sampling for the presence and level of groundwater and about 48 hours after drilling. The water levels encountered in the boreholes can be found on the boring logs in the **Exploration Results** and are summarized in the table on the following page:

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Boring Number	Approximate Depth to Bottom of Boring (feet) <sup>1</sup>	Approximate Depth to Groundwater While Drilling (feet) <sup>1</sup>	Approximate Depth to Groundwater Approximately 48 Hours After Drilling (feet) <sup>1</sup>
SB-1	65	27	12.5
SB-2	10	Not Observed	Not Observed
SB-3	10	8	4
SB-4	9.5	Not Observed	Not Observed
SB-5	10	Not Observed	Not Observed
SB-6	10	Not Observed	Not Observed

<sup>1</sup>. Below ground surface

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 structures 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.

Zones of perched and/or trapped groundwater may also 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, seasonal fluctuations, and weather conditions.

## Laboratory Testing

Selected laboratory test results are presented in the paragraph below. The results of laboratory testing completed for this project can be found in the **Exploration Results** section of this report.

Sand soils tested exhibit low consolidation when subjected to incremental loads up to 500 pounds per square foot (psf) at in-situ water contents. When exposed to increases in moisture content at an applied load of 500 psf, sand soils tested exhibit non- to low expansive potential followed by low to moderate consolidation at increased loadings up to 4,000 psf.

## GEOTECHNICAL OVERVIEW

Based on the results of our field investigation, laboratory testing program and geotechnical analyses, development of the site is considered feasible from a geotechnical viewpoint provided that the conclusions and considerations provided herein are incorporated into the design and construction of the project.



The proposed pump station building and wet well structure can be supported on deep drilled pier foundations with floor slabs-on-grade. Additional foundation and floor slab information pertaining to the structures can be found in the **Deep Foundations**, and **Floor Slabs** sections of this report. The **General Comments** section provides an understanding of the report limitations.

We have identified the following geotechnical conditions that could impact design and construction of the proposed project.

## **Excavations**

Excavations into the on-site soils can likely be accomplished with conventional earthwork equipment. Excavations into the weathered and hard to very hard bedrock may require heavy duty earthwork equipment or other specialized techniques. A local contractor experienced with bedrock excavations in the area should be consulted regarding pricing and schedule.

## **Loose Soils**

Test boring data indicate that loose soils are present along the proposed water line alignment and near surface at the location of the pump station. Loose soils could be encountered in excavations and these conditions will likely require some corrective work. Corrective work could involve removal and re-compaction or replacement, the use of geotextiles, or deepening excavations to suitable bearing materials. Terracon should be contacted to observe excavations to evaluate conditions and to provide guidance concerning corrective work (if needed).

## **Groundwater**

Groundwater was encountered as shallow as 4 to 12 feet in Borings SB-3 and SB-1, respectively. Groundwater should be expected during construction. At a minimum, temporary dewatering measures will be required to properly construct portions of the proposed pump station and water line. Although water was not observed within the other borings performed along the water line, it has been our experience that zones of perched and/or trapped groundwater may also 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, seasonal fluctuations, and weather conditions. We recommend the contractor be aware of the possibility of localized groundwater collection that may need to be dewatered during construction. We also recommend a sump and pump be incorporated into the final construction documents to remove water that may become trapped within tank excavations after project completion.

## **Buoyancy Forces**

Based on our experience in the area and the subsurface conditions encountered in the exploratory boring, we recommend the underground wet well be designed to resist uplift forces from buoyancy.

## **Shoring**

Excavations on the order of 45 to 50 feet are anticipated to install the proposed wet well for the pump station building. Shoring may be required to reach the planned excavation depths. The depth of excavation and subsurface soils and bedrock will influence the type of shoring system that may be used. A qualified shoring contractor should be contacted to design and install the shoring system.

The lateral earth pressure parameters provided in this report may be used for temporary shoring design; however, the use of these parameters is at the discretion of the designer. It has been our experience that shoring designers have proprietary or various earth pressure diagrams to base the shoring design. It is up to the shoring designer to interpret the provided parameters as necessary for their design, as well as recommend supplemental exploration or parameters they feel are appropriate to complete their design.

## **Deep Backfill Zones/Settlement**

Excavations for the wet well will result in backfills on the order of 48 feet in thickness based on the provided 30 percent plans. Backfill between 1 to 41 feet will also be required during installation of three, approximate 16-inch diameter intake pipes. The magnitude of settlement of the deep backfill zones associated with these fills will be directly related to the type of fill material used, the degree of compaction, and the thickness of the fill zone. If the on-site sand soils, properly processed sandstone bedrock, and/or imported soils meeting the recommendations of this report are used as the backfill material, the settlement of fill zones about 50 feet or less in thickness are estimated to be about 6 to 12 inches. This assumes that the degree of compaction for fill zones is maintained in accordance with this report.

It is our understanding that the proposed pump station building will be constructed on drilled pier foundations bottomed into the onsite sandstone bedrock. The proposed pump station slab and associated utilities are anticipated to be constructed on top and within the reported backfill. Due to the granular nature of the on-site soils it is anticipated that a majority of the settlement will occur during fill placement and within three weeks after fill placement is complete. We recommend settlement monitoring pins be installed in fills that are greater than about 15 feet thick immediately after completion of fill placement.

The settlement monitoring pins should be monitored for a period of at least three weeks prior to construction of slabs, utilities, ancillary structures and flatwork. Utilities should be designed with

restrained joints and designed to accommodate potential differential movement as an added design precaution to reduce the potential for underground utility leaks. If the planned intake pipes will be constructed at the time of fill placement, we recommend these pipes be designed for additional settlement of the backfill soils to reduce the potential for pipe breaks and leaks.

## **EARTHWORK**

Earthwork is anticipated to include clearing and grubbing, excavations, and fill placement. The following sections provide recommendations for use in the preparation of specifications for the work. Recommendations include critical quality criteria, as necessary, to render the site in the state considered in our geotechnical engineering evaluation for foundations and floor slabs.

### **Site Preparation**

Pipe bedding and trench backfill within open cut excavations to construct the proposed water line should conform to the applicable local municipality guidelines.

Prior to placing fill, existing vegetation and root mat should be removed. Complete stripping of the topsoil should be performed in the proposed building, wet well, and water line areas. Stripped materials consisting of vegetation, unsuitable fills, and organic materials should be wasted from the site or used to revegetate landscaped areas after completion of grading operations. All exposed surfaces to receive fill should be free of mounds and depressions that could prevent uniform compaction.

Although evidence of underground facilities such as grease pits and septic tanks were 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 of these materials and loose soils prior to backfill placement and/or construction.

Foundation and floor slab subgrades should be proof-rolled with an adequately loaded vehicle such as a fully-loaded tandem-axle dump truck. The proof-rolling should be performed under the direction of the Geotechnical Engineer. Areas excessively deflecting under the proof-roll should be delineated and subsequently addressed by the Geotechnical Engineer. The bottom of foundation and floor slab excavations should also be probed with a metal T-probe to aid in locating loose, soft, or otherwise undesirable areas. Unacceptable areas delineated by the proof-roll or probing should be removed or mitigated in place prior to placing fill or foundation and slab concrete. Such areas should either be removed or modified by stabilizing with geotextile. Material that is determined to be excessively wet or dry should be removed, or moisture conditioned and re-compacted.

## Fill Slopes

Reconstructed fill slopes will be performed as part of pump station construction. Based on the provided site topography and grading plan, reconstructed slopes with gradients between 10:1 to 2.5:1 (horizontal:vertical) are planned during construction. Where fill is placed on existing or temporary slopes steeper than 5H:1V, benches should be cut into the existing slopes prior to fill placement. The benches should have a minimum vertical face height of 1 foot and a maximum vertical face height of 3 feet and should be cut wide enough to accommodate compaction equipment. This benching will help provide a positive bond between the fill/ natural soils and bedrock and reduce the possibility of failure along the fill/natural soil and bedrock interface. We also recommend similar construction methods be implemented within other cut/fill transitions areas at the site.

## Fill Material Types

Fill required to achieve design grade should be classified as structural fill and general fill. Structural fill is material used below or within 10 feet of structures. General fill is material used to achieve grade outside of these areas. Earthen materials used for structural and general fill should meet the following material property requirements:

Soil Type <sup>1</sup>	USCS Classification	Acceptable Locations for Placement
On-site sand soils	SW-SM	The on-site sand soils are considered acceptable for re-use as structural fill after water conditioning and recompaction. The on-site sand soils may also be re-used as general fill outside of structural areas.
On-site sandstone bedrock	N/A	On-site sandstone bedrock may be reused as either structural and/or general fill after processing to a soil like consistency meeting the gradation presented herein for imported soils with a maximum particle size of 3 inches.
On-site claystone bedrock	N/A	Although not encountered in our borings, claystone bedrock is known to be encountered in the area. If encountered during construction, claystone bedrock is not considered suitable for reuse as structural fill but may be reused in non-structural areas as general fill after processing to a soil like consistency with a maximum particle size of 3 inches.
Imported soils	Varies	Imported soils meeting the gradation outlined herein can be considered suitable for use as structural and/or general fill.

1. Structural and general fill should consist of approved materials 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 prior to use on this site.

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Imported soils for use as structural and/or general fill should conform to the following:

Gradation	Percent finer by weight (ASTM C136)
3"	100
No. 4 Sieve	50-100
No. 200 Sieve	20 (max)

Soil Properties	Value
Liquid Limit	NP
Plastic Index	NP

## Fill Compaction Requirements

Structural and general fill should meet the following compaction requirements.

Item	Structural Fill
Maximum 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
Minimum compaction requirements <sup>1, 2, 3</sup>	95% of the materials maximum dry density for fill less than 6 feet in thickness below final grades. 98% of the materials maximum dry density for fill 6 feet in thickness or greater below final grades.
Water content range <sup>2, 4</sup>	Within three percent of optimum water content (granular soils)

1. We recommend that engineered fill be tested for water content and compaction during placement. Should the results of the in-place density tests indicate the specified water or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified water and compaction requirements are achieved.
2. Maximum dry density and optimum water content as determined by the Modified Proctor test (D1557).
3. If the granular material is a coarse sand or gravel, or of a uniform size, or has a low fines content, compaction comparison to relative density may be more appropriate. In this case, granular materials should be compacted to at least 70% relative density (ASTM D4253 and D4254).
4. Moisture contents should be maintained low enough to allow for satisfactory compaction to be achieved without the compacted fill material becoming unstable under the weight of construction equipment or during proof-rolling. Indications of unstable soil can include pumping or rutting.

## Shrinkage and Bulking Factors

For balancing grading plans, estimated shrink or swell of soils when used as compacted fill following recommendations in this report are as follows:

Material	Estimated Shrink (-) / Swell (+) Based on ASTM D698
On-Site Sands	-10% to -15%

## Grading and Drainage

All grades must provide effective drainage away from the structure during and after construction and should be maintained throughout the life of the structure. Water retained next to the structure can result in soil and bedrock movements greater than those discussed in this report. Greater movements can result in unacceptable differential slab and/or foundation movements, cracked slabs and walls, and roof leaks. The roof should have gutters/drains with downspouts that discharge onto splash blocks at a distance of at least 10 feet from the structure perimeter.

Exposed ground should be sloped and maintained at a minimum 5% away from the structure for at least 10 feet beyond the structure perimeter. Locally, flatter grades may be necessary to transition ADA access requirements for flatwork. After construction and landscaping (if incorporated) have been completed, final grades should be verified to document effective drainage has been achieved. Grades around the structure should also be periodically inspected and adjusted, as necessary, as part of the structure's maintenance program. Where flatwork abuts the structure, a maintenance program should be established to effectively seal and maintain joints and prevent surface water infiltration.

## Earthwork Construction Considerations

Shallow excavations for the proposed structure are anticipated to be accomplished with conventional construction equipment within the overburden sand soils. Deeper excavations that encounter bedrock may become more difficult and necessitate the use of specialized equipment and/or techniques. A local excavation contractor should be consulted about pricing within bedrock excavations.

Upon completion of filling and grading, care should be taken to maintain the subgrade water content prior to construction of foundations and floor slabs. Construction traffic over the completed subgrades should be avoided. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. Water collecting over or adjacent to construction areas should be removed. If the subgrade freezes, desiccates, saturates, or is disturbed, the affected material should be removed, or the materials should be scarified, moisture conditioned, and recompacted prior to foundation and floor slab construction.

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Depending on seasonal groundwater fluctuations, groundwater may be encountered during construction and if encountered will likely cause difficulties. Dewatering of excavations and utility trenches may be required during construction. Groundwater seeping into excavations at this site could most likely be controlled by the use of well points or shallow trenches leading to a sump pit where the water could be removed by pumping; however, the requirements for properly dewatering excavations are beyond the scope of services provided for this project.

As a minimum, excavations should be performed in accordance with OSHA 29 CFR, Part 1926, Subpart P, "Excavations" and its appendices, and in accordance with any applicable local, and/or state regulations.

Construction site safety is the sole responsibility of the contractor who controls the means, methods, and sequencing of construction operations. Under no circumstances shall the information provided herein be interpreted to mean Terracon is assuming responsibility for construction site safety, or the contractor's activities; such responsibility shall neither be implied nor inferred.

### **Construction Observation and Testing**

The earthwork efforts should be monitored under the direction of the Geotechnical Engineer. Monitoring should include documentation of adequate removal of vegetation and topsoil, proofrolling, and mitigation of areas delineated by the proofroll to require mitigation.

Compacted fill should be tested, evaluated, and reworked, as necessary, until approved by the Geotechnical Engineer prior to placement of additional lifts. The bearing subgrade should be evaluated under the direction of the Geotechnical Engineer. If unanticipated conditions are encountered, the Geotechnical Engineer should prescribe mitigation options.

In addition to the documentation of the essential parameters necessary for construction, the continuation of the Geotechnical Engineer into the construction phase of the project provides the continuity to maintain the Geotechnical Engineer's evaluation of subsurface conditions, including assessing variations and associated design changes.



## DEEP FOUNDATIONS

### Drilled Shaft Design Parameters

Deep drilled shaft foundations are recommended for support of proposed buildings at this site. For this project, we recommend the following:

Description	Value
Minimum shaft length <sup>1</sup>	20 feet and a minimum embedment of 5 feet into bearing stratum, or one shaft diameter, whichever is greater
Minimum shaft diameter <sup>1</sup>	16 inches
Minimum spacing between shafts	3 shaft diameters
Minimum bedrock embedment <sup>1</sup>	5 feet
Pier concrete slump (cased piers)	7 to 9 inches
Approximate total movement <sup>2</sup>	Less than 1-inch

1. Drilled shafts should be embedded into competent bedrock materials. Actual structural loads may dictate larger shaft diameters and/or shaft lengths/embedment deeper than the recommended minimums contained herein.
2. The foundation movement will depend upon the variations within the subsurface soil and bedrock profile, the structural loading conditions, the quality of the earthwork operations, and maintaining uniform soil and bedrock water content throughout the life of the structure. The estimated movements are based on maintaining uniform soil and bedrock water content during the life of the structure. Additional foundation movements could occur if water from any source infiltrates the foundation soils and bedrock; therefore, proper drainage and irrigation practices should be incorporated into the design and operation of the facility. Failure to maintain soil and bedrock water content and positive drainage will nullify the movement estimates provided above.

Design parameters are provided below in the **Drilled Shaft Design Summary** table for the design of deep foundations. The values presented for allowable side friction and end bearing include a factor of safety. We recommend neglecting skin friction for the upper 36 inches of foundations because of the potential for disturbance.

Drilled Shaft Design Summary <sup>1</sup>			
Stratigraphy <sup>2</sup>		Allowable Skin Friction (psf) <sup>3</sup>	Allowable End Bearing Pressure (psf) <sup>4</sup>
GeoModel No.	Material		
N/A	Compacted Sand Structural Fill	100	End Bearing within Sand Soils Not Recommended
2	Native Sand	100	End Bearing within Sand Soils Not Recommended



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Drilled Shaft Design Summary <sup>1</sup>			
Stratigraphy <sup>2</sup>		Allowable Skin Friction (psf) <sup>3</sup>	Allowable End Bearing Pressure (psf) <sup>4</sup>
GeoModel No.	Material		
4	Sandstone Bedrock	800	20,000

1. Design capacities are dependent upon the method of installation, and quality control parameters. Skin friction values should not be used within the subsurface profile if slurry or other "wet" shaft techniques are used for installation.
2. See **Subsurface Profile** in **Geotechnical Characterization** for more details on stratigraphy.
3. Applicable for compressive loading only. Reduce to 2/3 of values shown for uplift loading. Effective weight of shafts can be added to uplift load capacity.
4. Shafts should extend at least 5 feet into the bearing stratum for end bearing to be considered.

The structural engineer should determine the reinforcement necessary for foundations. Tensile reinforcement should extend to the bottom of shafts subjected to uplift loading. Buoyant unit weights of the soil and concrete should be used in the calculations below groundwater elevation. Due to seasonal fluctuations in the groundwater elevation, we anticipate the groundwater level could vary about 5 feet above observed levels at the time of our field exploration.

Shafts should be considered to work in group action if the horizontal spacing is less than three pier diameters. A minimum practical horizontal clear spacing between shafts of at least three diameters should be maintained, and adjacent shafts should bottom at the same elevation. The capacity of individual shafts must be reduced when considering the effects of group action. Capacity reduction is a function of spacing and the number of foundations within a group. The following table presents capacity reductions for closely spaced shafts.

Description	Value <sup>1</sup>		
Shaft spacing (center to center)	>3 diameters	>2 to 3 diameters	2 diameters
Capacity reduction	None	30 percent	50 percent

1. End bearing values do not need to be reduced for closely spaced shafts if the bottoms of foundations bear at the same elevation. Spacing closer than 2 diameters is not recommended.

## Drilled Shaft Lateral Loading

The following table lists input values for use in LPILE analyses. The provided lateral parameter design values do not include a factor-of-safety, which should be applied. We recommend neglecting lateral resistance for the upper 36 inches of foundations because of the potential for disturbance.

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Stratigraphy <sup>1</sup>		L-Pile Soil Model	ϕ <sup>2</sup>	γ (pcf) <sup>2</sup>	ε <sub>50</sub> <sup>2</sup>	K (pci) <sup>2</sup>	
GeoModel No.						Static	Cyclic
N/A	Compacted Sand Structural Fill	Sand	32°	120 <sup>3</sup>	Allow L-Pile to choose these parameters based on the undrained shear strength or friction angle provided in this table.		
2	Native Sand	Sand	32°	115 <sup>3</sup>			
4	Sandstone Bedrock	Sand	36°	125			

1. See **Subsurface Profile** in **Geotechnical Characterization** for more details on Stratigraphy.

2. Definition of Terms:

$\phi$ : Internal friction angle

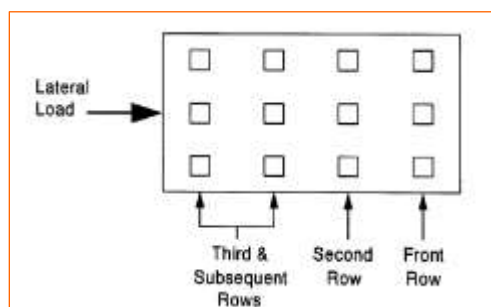
$\gamma$ : Moist unit weight (above groundwater), Saturated unit weight (below groundwater)

$\epsilon_{50}$ : E50 strain

K: Horizontal modulus of subgrade reaction

3. Saturated unit weight value of 50 pcf should be used below water table for sand soils.

When shafts are used in groups, the lateral capacities of the shafts in the second, third, and subsequent rows of the group should be reduced as compared to the capacity of a single, independent shaft. Guidance for applying p-multiplier factors to the p values in the p-y curves for each row of foundations within a group are as follows:



- Front row:  $P_m = 0.8$ ;
- Second row:  $P_m = 0.4$
- Third and subsequent row:  $P_m = 0.3$ .

For the case of a single row of shafts supporting a laterally loaded grade beam, group action for lateral resistance of shafts would need to be considered when spacing is less than three diameters (measured center-to-center). However, spacing closer than 3D (where D is the diameter of the shaft) is not recommended, due to potential for the installation of a new shaft disturbing an adjacent installed shaft, likely resulting in axial or lateral capacity reduction.

## **Drilled Shaft Construction Considerations**

Drilling to design depths should be possible with heavy duty power augers equipped with rock teeth. Difficult drilling should be anticipated due to the presence of very hard bedrock, groundwater, and caving associated with sand soils. Casing, mud or slurry drilling, and other specialized installation techniques will be required to properly drill and clean shafts prior to concrete placement. Shaft concrete should be placed soon after completion of drilling and cleaning. Due to potential sloughing and raveling, foundation concrete quantities may exceed calculated geometric volumes.

A tremie or casing should be used for concrete placement. If casing is used for shaft construction, it should be withdrawn in a slow, continuous manner maintaining a sufficient head of concrete to prevent infiltration of water or the creation of voids in pier concrete. Shaft concrete should have a relatively high fluidity when placed in cased shaft holes or through a tremie.

Free-fall of concrete is not considered acceptable for placement in shafts. The use of a bottom-dump hopper, or an elephant's trunk discharging near the bottom of the hole where concrete segregation will be minimized, is recommended. Shaft bearing surfaces must be free of loose materials prior to concrete placement.

The drilled shaft installation process should be performed under the direction of the Geotechnical Engineer. The Geotechnical Engineer should document the shaft installation process including soil/rock and groundwater conditions encountered, consistency with expected conditions, and details of the installed shaft.

## **SEISMIC CONSIDERATIONS**

The seismic design requirements for buildings and other structures are based on Seismic Design Category. Site Classification is required to determine the Seismic Design Category for a structure. The Site Classification is based on the upper 100 feet of the site profile defined by a weighted average value of either shear wave velocity, standard penetration resistance, or undrained shear strength in accordance with Section 20.4 of ASCE 7 and the International Building Code (IBC). Based on the soil and bedrock properties encountered at the site and as described on the exploration logs and results, it is our professional opinion that the **Seismic Site Classification is C**. Subsurface explorations at this site were extended to a maximum depth of 65 feet. The site properties below the boring depth to 100 feet were estimated based on our experience and knowledge of geologic conditions of the general area. Additional deeper borings or geophysical testing may be performed to confirm the conditions below the current boring depth.

## FLOOR SLABS

Design parameters for slabs assume the requirements for **Earthwork** have been followed. Specific attention should be given to positive drainage away from the structure.

### Floor Slab Design Parameters

Item	Description
<b>Slab Support <sup>1</sup></b>	<p>Slabs should bear on undisturbed sandstone bedrock or a minimum of 8 inches of newly placed, structural fill, but not a combination of both (either bearing on sandstone or on structural fill.)</p> <p>Although not encountered in our boring, localized lenses of claystone bedrock have been known to be encountered. If observed at the time of construction, claystone will need to be removed from foundation excavations. We estimate up to 2 feet of additional excavation may be necessary to remove the claystone lens, if observed.</p>
<b>Estimated Modulus of Subgrade Reaction <sup>2</sup></b>	150 pounds per square inch per inch (psi/in) for point loads
<p>1. Slabs should be structurally independent of foundations or walls to reduce the possibility of slab cracking caused by differential movements between the slab and foundation. It is critical to maintain moisture contents of slab subgrade as close to final preparation conditions as practical.</p> <p>2. Modulus of subgrade reaction is an estimated value based upon our experience with the subgrade condition, the requirements noted in <b>Earthwork</b>, and the slab support as noted in this table. It is provided for point loads. For large area loads the modulus of subgrade reaction would be lower.</p>	

The use of a vapor retarder should be considered beneath concrete slabs on grade 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 should refer to ACI 302 and/or ACI 360 for procedures and cautions regarding the use and placement of a vapor retarder.

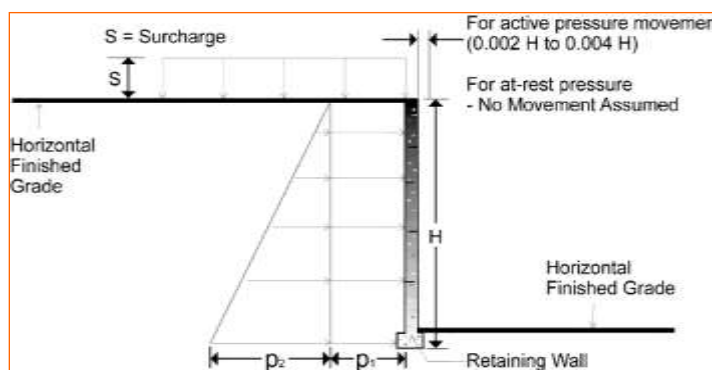
Saw-cut control joints should be placed in the slab to help control the location and extent of cracking. For additional recommendations refer to the ACI Design Manual. Joints or cracks should be sealed with a water-proof, non-extruding compressible compound specifically recommended for this application and wet environments.

## LATERAL EARTH PRESSURES

### Design Parameters

Structures with unbalanced backfill levels on opposite sides should be designed for earth pressures at least equal to values 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 in the diagram below. 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 and is commonly used for basement walls, loading dock walls, or other walls restrained at the top. The recommended design lateral earth pressures do not include a factor of safety and do not provide for possible hydrostatic pressure on the walls (unless stated).



Lateral Earth Pressure Design Parameters				
Earth Pressure Condition <sup>1</sup>	Coefficient for Backfill Type <sup>2</sup>	Surcharge Pressure <sup>3, 4, 5</sup> $p_1$ (psf)	Effective Fluid Pressures (psf) <sup>2, 4, 5</sup>	
			Unsaturated <sup>6</sup>	Submerged <sup>6</sup>
Active ( $K_a$ )	Granular - 0.36	$(0.36)S$	$(45)H$	$(85)H$
At-Rest ( $K_o$ )	Granular - 0.53	$0.53S$	$(65)H$	$(95)H$
Passive ( $K_p$ )	Granular - 2.77	---	$(330)H$	$(220)H$

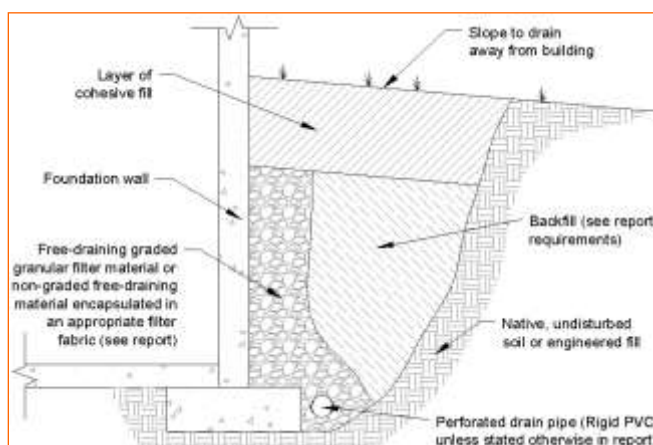
1. For active earth pressure, wall must rotate about base, with top lateral movements 0.002 H to 0.004 H, where H is wall height. For passive earth pressure, wall must move horizontally to mobilize resistance.
2. Uniform, horizontal backfill, compacted to at least 98% of the ASTM D1557 maximum dry density, rendering a maximum unit weight of 120 pcf.
3. Uniform surcharge, where S is surcharge pressure.
4. Loading from heavy compaction equipment is not included.
5. No safety factor is included in these values.
6. To achieve “Unsaturated” conditions, follow guidelines in **Subsurface Drainage for Below-Grade Walls** below. “Submerged” conditions are recommended when drainage behind walls is not incorporated into the design.

Backfill placed against structures should consist of granular soils. For the granular values to be valid, the backfill must extend out and up from the base of the wall at an angle of at least 45 and 60 degrees from vertical for the active and passive cases, 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 retaining walls to prevent lateral pressures more than those provided.

### Subsurface Drainage for Below-Grade Walls

A perforated rigid plastic drain line installed behind the base of walls and extends below adjacent grade is recommended to prevent hydrostatic loading on the walls. The invert of a drain line around a below-grade building area or exterior retaining wall should be placed near foundation bearing level. The drain line should be sloped to provide positive gravity drainage to daylight or to a sump pit and pump. The drain line should be surrounded by free-draining granular material having less than 5% passing the No. 200 sieve, such as No. 57 aggregate. The free-draining aggregate should be encapsulated in a filter fabric. The granular fill should extend to within 2 feet of final grade, where it should be capped with compacted cohesive fill to reduce infiltration of surface water into the drain system.



As an alternative to free-draining granular fill, a pre-fabricated drainage structure may be used. A pre-fabricated drainage structure is a plastic drainage core or mesh which is covered with filter fabric to prevent soil intrusion and is fastened to the wall prior to placing backfill.

The wall designer should perform standard wall design practices including analysis for overturning, sliding, bearing capacity, and global stability, and results of these analyses should be provided for our review. Additional sampling, laboratory testing and document review associated with retaining walls is beyond the original scope of work but can be performed as a separate scope, for a separate fee.

## SLOPE STABILITY

### Mechanics of Stability

Slope stability analyses take into consideration material strength, presence and orientation of weak layers, water, surcharge loads, and the slope geometry. Mathematical computations are performed using computer-assisted simulations to calculate a Factor of Safety (FS). Minor changes to slope geometry, surface water flow and/or groundwater levels could result in slope instability. Reasonable FS values are dependent upon the confidence in the parameters utilized in the analyses performed, among other factors related to the project itself.

### Geometric Analysis Results

One slope stability analysis was performed for the pump station wet well using geometries obtained from the Intake Piping Profile, Sheet C1.2, dated October 2020. Parameters for the analyses were derived from our exploratory borings, experience, and laboratory tests. Stability analyses were conducted using the computer program Slide Version 6.033 developed by Rocscience Inc.

Soil and bedrock properties used in the analyses are shown below:

Material	Moist Unit Weight (pcf)	Drained Cohesion (psf)	Drained Friction Angle (degrees)
Clayey Sand	120	25	28
New Compacted Sand Fill	120	25	32
Sandstone	120	500	34

Where encountered, we recommend that the existing fill soils be completely removed and replaced as compacted structural fill prior to placement of new fill soils. It appears the existing fill soils will be removed as part of remedial earthwork operations to construct the pump house and wet well. The existing fill soils were modeled as newly compacted fill soils in our analysis.

Based on the analyses, the calculated factor of safety (FS) for the critical surface identified at the section under several scenarios are shown below. The slope stability results are included in the **Supporting Information** of this report.

Cross-Section	Minimum Calculated FS
Section A-A' without groundwater	1.8
Section A-A' with groundwater	1.7
Section A-A' with rapid drawdown (short-term)	0.9



Cross-Section	Minimum Calculated FS
Section A-A' with rapid drawdown and reinforced zone (short-term)	1.3

The typically accepted minimum Factor of Safety (FS) for long-term global stability is 1.5, and the FS for short-term global stability is 1.2. Short-term conditions were considered when water from Woodmoor Lake would be drained and the adjacent soils remained saturated.

Results indicate that the slope section analyzed satisfies the conditions for long-term stability. Under conditions of rapid drawdown, the analysis shows that the slope does not satisfactorily provide short-term stability without modification.

Potential solutions to increase the stability of the slopes include installing a gravel or concrete keyway near the toe of the slope, flattening the slope by adding additional compacted soils near the toe, the use of ground improvement methods such as rammed aggregate piers, or reinforcing the slopes with geotextiles. Given the area will be an open excavation at the time of construction, it is our opinion adding three layers of geogrid reinforcement spaced evenly throughout the fill at the time of fill placement would adequately reinforce the area for short-term stability.

### **Surficial Slope Stability**

It is anticipated that vegetation will be disturbed during construction. We recommend that surficial stability be considered in the development of the property. Surficial slope instability typically impacts the upper 3 feet of the subsurface profile, predominantly during extended wet periods. Regular maintenance should be anticipated to identify and address changes in natural drainage creating potential for soil creep or erosion near improvements. This includes replacing or replanting trees and grasses, as necessary, and grading the slope to reduce soil creep and erosion. If future surficial slope erosion occurs near the crest of slopes, we recommend the slope face be restored as soon as practical. Irrigated landscaping should not be used on or near the crest of slopes. We recommend that the existing vegetation and native vegetation not requiring additional irrigation be used to vegetate slopes.

Fill slopes should be re-vegetated as soon as possible after grading and protected from erosion until vegetation is established. Slope planting should consist of ground cover, shrubs, and trees possessing deep, dense root structures that require minimal irrigation. It is the responsibility of the owner to maintain such planting.

## **CORROSIVITY**

The table below lists the results of laboratory soluble sulfate, soluble chloride, electrical resistivity, and pH testing. The 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.

Corrosivity Test Results Summary						
Boring	Sample Depth (feet)	Soil Description	Soluble Sulfate (%)	Soluble Chloride (%)	Electrical Resistivity ( $\Omega$ -cm)	pH
SB-1	19	Sandstone Bedrock	0.004	0.0010	5,291	8.0
SB-3	4	Fill-Clayey Sand	0.002	0.0013	2,947	6.2
SB-6	1-5	Clayey sand/Silty Sandstone	<0.001	0.0011	7,077	7.4

We recommend a certified corrosion engineer be employed to determine the need for corrosion protection and to design appropriate protective measures. Results of water-soluble sulfate testing indicate that samples of the on-site soils have an exposure class of S0 when classified in accordance with Table 19.3.1.1 of the American Concrete Institute (ACI) Design Manual. The results of the testing indicate ASTM Type I Portland Cement is suitable for project concrete in contact with on-site soils. However, if there is little impact to cost, we recommend the use of ASTM Type I/II Modified Portland Cement for additional sulfate resistance of construction concrete. Concrete should be designed in accordance with the provisions of the ACI Design Manual, Section 318, Chapter 19.

## GENERAL COMMENTS

Our analysis and opinions are based upon our understanding of the project, the geotechnical conditions in the area, and the data obtained from our site exploration. Natural variations will occur beyond the exploration point locations or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. Terracon should be retained as the Geotechnical Engineer, where noted in this report, to provide observation and testing services during pertinent construction phases. If variations appear, we can provide further evaluation and supplemental recommendations. If variations are noted in the absence of our observation and testing services on-site, we should be immediately notified so that we can provide evaluation and supplemental recommendations.

Our Scope of Services 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.

Our services and any correspondence or collaboration are intended for the sole benefit and exclusive use of our client for specific application to the project discussed and are accomplished in accordance with generally accepted geotechnical engineering practices with no third-party

## Geotechnical Engineering Report

Woodmoor Lake Pump Station and Water Line ■ Monument, Colorado

December 17, 2020 ■ Terracon Project No. 23205117



beneficiaries intended. Any third-party access to services or correspondence is solely for information purposes to support the services provided by Terracon to our client. Reliance upon the services and any work product is limited to our client, and is not intended for third parties. Any use or reliance of the provided information by third parties is done solely at their own risk. No warranties, either express or implied, are intended or made.

Site characteristics as provided are for design purposes and not to estimate excavation cost. Any use of our report in that regard is done at the sole risk of the excavating cost estimator as there may be variations on the site that are not apparent in the data that could significantly impact excavation cost. Any parties charged with estimating excavation costs should seek their own site characterization for specific purposes to obtain the specific level of detail necessary for costing. Site safety, and cost estimating including, excavation support, and dewatering requirements/design are the responsibility of others. If changes in the nature, design, or location of the project are planned, our conclusions and recommendations shall not be considered valid unless we review the changes and either verify or modify our conclusions in writing.

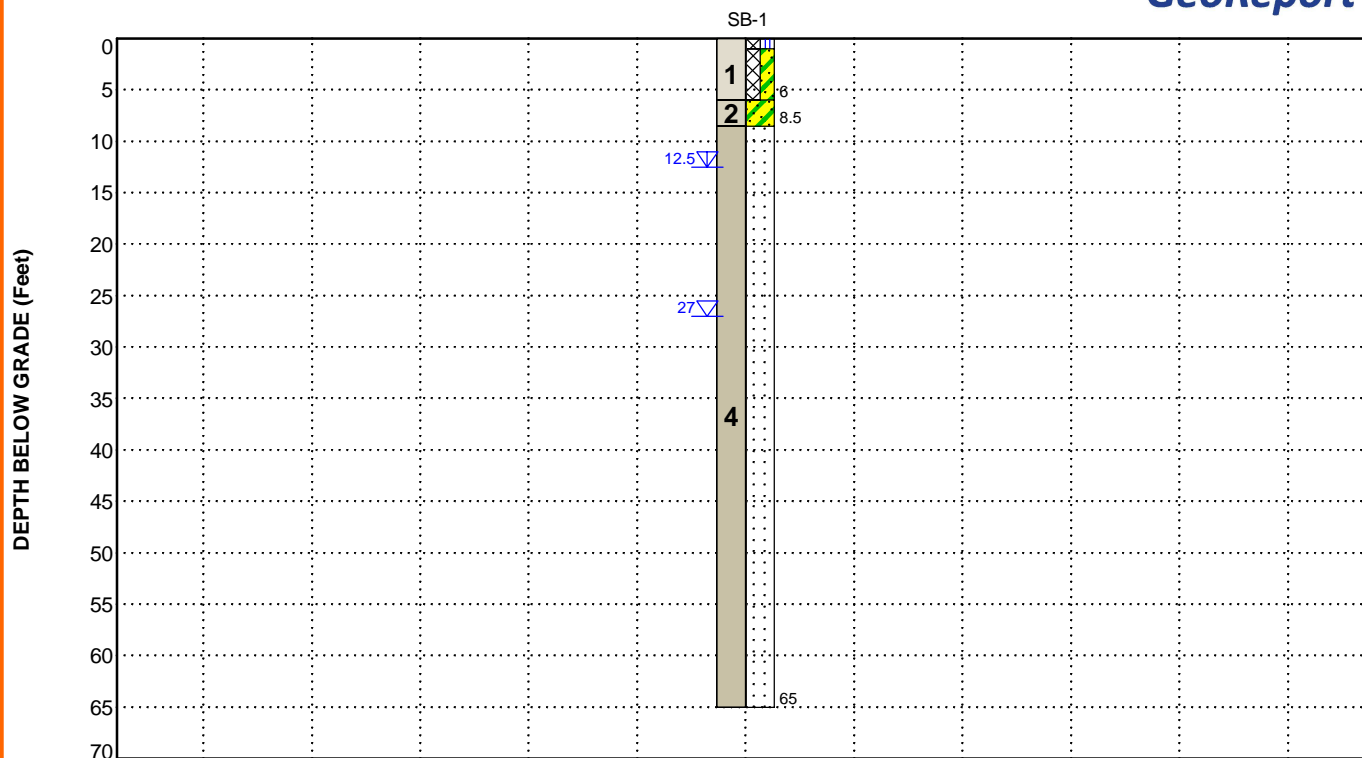
## FIGURES

### Contents:

GeoModel (2 pages)

## GEOMODEL

Woodmoor Lake Pump Station and Pipeline ■ Monument, CO  
Terracon Project No. 23205117



This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions.

Model Layer	Layer Name	General Description
1	Fill	Generally consisting of sand with various amounts of clay and silt; fine to coarse grained; tan, brownish gray, gray, brown, and dark brown; very loose to medium dense.
2	Sand	With various amounts of clay and silt; fine to coarse grained; tan, light brown, brown, dark brown, reddish brown, light gray, and dark gray; loose to dense.
3	Weathered Sandstone Bedrock	With silt; fine to coarse grained; light brown; firm to medium hard.
4	Sandstone Bedrock	With various amounts of silt and clay; fine to coarse grained; tan, light brown, light grayish brown, and light gray; medium hard to very hard.

## LEGEND

Well-graded Sand with Silt

Clayey Sand

Sandstone

First Water Observation

Second Water Observation

Groundwater levels are temporal. The levels shown are representative of the date and time of our exploration. Significant changes are possible over time. Water levels shown are as measured during and/or after drilling. In some cases, boring advancement methods mask the presence/absence of groundwater. See individual logs for details.

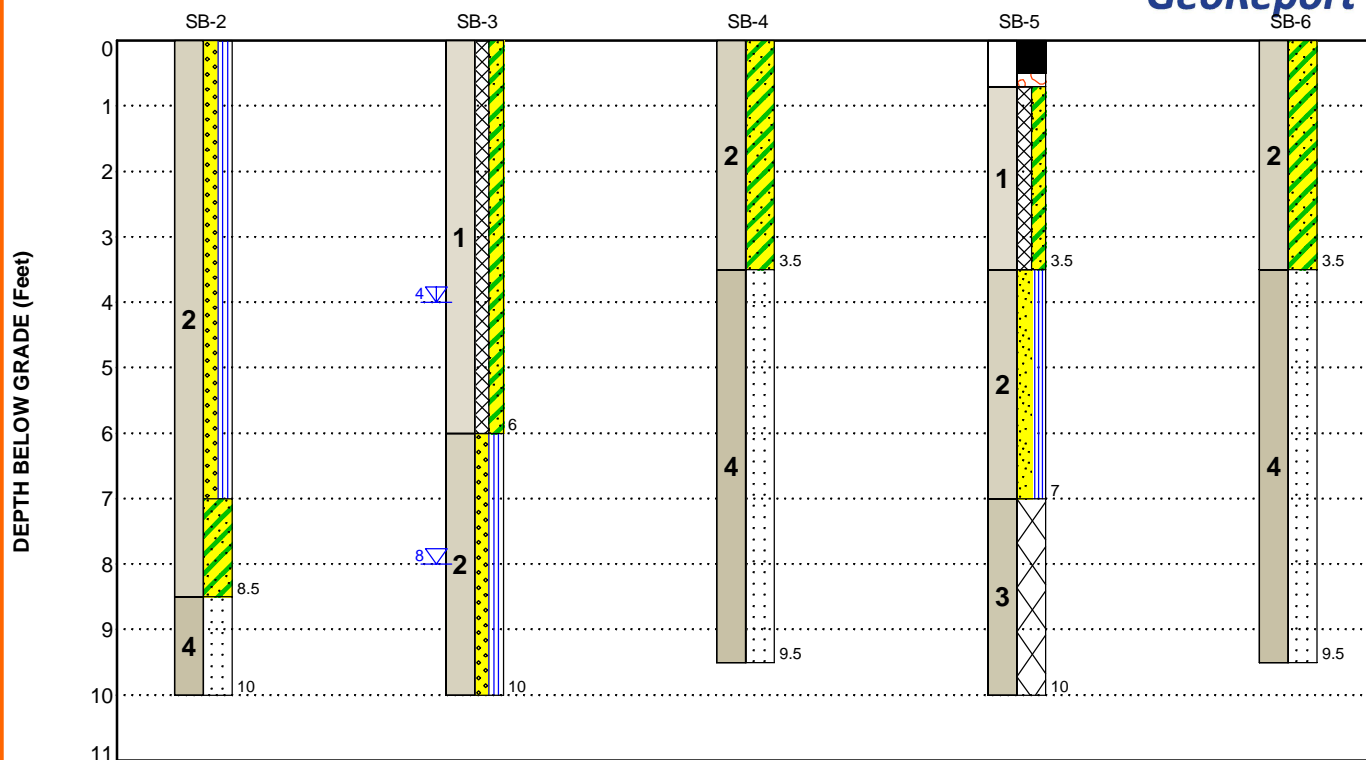
## NOTES:

Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project.

Numbers adjacent to soil column indicate depth below ground surface.

## GEOMODEL

Woodmoor Lake Pump Station and Pipeline ■ Monument, CO  
Terracon Project No. 23205117



This is not a cross section. This is intended to display the Geotechnical Model only. See individual logs for more detailed conditions.

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3	Weathered Sandstone Bedrock	With silt; fine to coarse grained; light brown; firm to medium hard.
4	Sandstone Bedrock	With various amounts of silt and clay; fine to coarse grained; tan, light brown, light grayish brown, and light gray; medium hard to very hard.

## LEGEND

Well-graded Sand with Silt	Asphalt	Weathered Rock
Clayey Sand	Aggregate Base Course	
Sandstone	Poorly-graded Sand with Silt	

- First Water Observation
- Second Water Observation

Groundwater levels are temporal. The levels shown are representative of the date and time of our exploration. Significant changes are possible over time. Water levels shown are as measured during and/or after drilling. In some cases, boring advancement methods mask the presence/absence of groundwater. See individual logs for details.

## NOTES:

Layering shown on this figure has been developed by the geotechnical engineer for purposes of modeling the subsurface conditions as required for the subsequent geotechnical engineering for this project. Numbers adjacent to soil column indicate depth below ground surface.

## ATTACHMENTS

## EXPLORATION AND TESTING PROCEDURES

### Field Exploration

Number of Borings	Boring Depth (feet)	Location
1	65	Planned pump station
5	10	Planned water line

**Boring Layout and Elevations:** We used handheld GPS equipment to locate the borings with an estimated horizontal accuracy of  $\pm 20$  feet. Elevations were not obtained in the field.

**Subsurface Exploration Procedures:** We advanced the soil borings with an ATV-mounted drill rig using continuous flight augers. Four samples were obtained in the upper 10 feet and at intervals of 5 feet thereafter. In the split-barrel sampling procedure, a standard 2-inch outer diameter split-barrel sampling spoon was driven into the ground by a 140-pound automatic hammer falling 30 inches. The number of blows required to advance the sampling spoon the last 12 inches of a normal 18-inch penetration was recorded as the Standard Penetration Test (SPT) resistance value. The SPT resistance values, also referred to as N-values, are indicated on the boring logs at the test depths. A 3-inch outer diameter split-barrel sampling spoon with 2.5-inch inner diameter ring lined sampler was used for sampling in the upper 14 feet. Ring-lined, split-barrel sampling procedures were similar to standard split spoon sampling procedure; however, blow counts were recorded for 6-inch intervals for a total of 12 inches of penetration. The samples were placed in appropriate containers, taken to our soil laboratory for testing, and classified by a geotechnical engineer. Groundwater was not encountered within the boring at the time of drilling and sampling.

Our exploration team prepared field boring logs as part of standard drilling operations which included the sampling depths, penetration distances, and other relevant sampling information. The field log includes visual classifications of materials encountered during drilling, and our interpretation of subsurface conditions between samples. The final boring logs, prepared from the field logs, represents the geotechnical engineer's interpretation, and include modifications based on observations and laboratory tests.

### Laboratory Testing

The project engineer reviewed the field data and assigned laboratory tests to understand the engineering properties of the various soil and rock strata, as necessary, for this project. The following testing was performed:

- Water content
- Unit dry weight
- Atterberg limits

## Geotechnical Engineering Report

Woodmoor Lake Pump Station and Water Line ■ Monument, Colorado

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- Grain size analyses
- Consolidation/expansion
- Chemical Analyses – pH, Sulfates, Chloride Ion, Electrical Resistivity

The laboratory testing program included examination of the soil samples by an engineer. Based on the material's texture and plasticity, we described and classified the soil samples in accordance with the Unified Soil Classification System. Rock classification was performed using locally accepted procedures.



## Geotechnical Engineering Report

Woodmoor Lake Pump Station and Water Line ■ Monument, Colorado

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## PHOTOGRAPHY LOG



Near Boring SB-1 Facing Northwest



Near Boring SB-1 Facing East

## Geotechnical Engineering Report

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Near Boring SB-1 Facing South



Near Boring SB-1 Facing Southwest

## **SITE LOCATION AND EXPLORATION PLANS**

### **Contents:**

Site Location Plan

Exploration Plan

Slope Stability Cross Section Location Plan

Note: All attachments are one page unless noted above.



## SITE LOCATION

Woodmoor Lake Pump Station and Pipeline ■ Monument, CO  
December 14, 2020 ■ Terracon Project No. 23205117

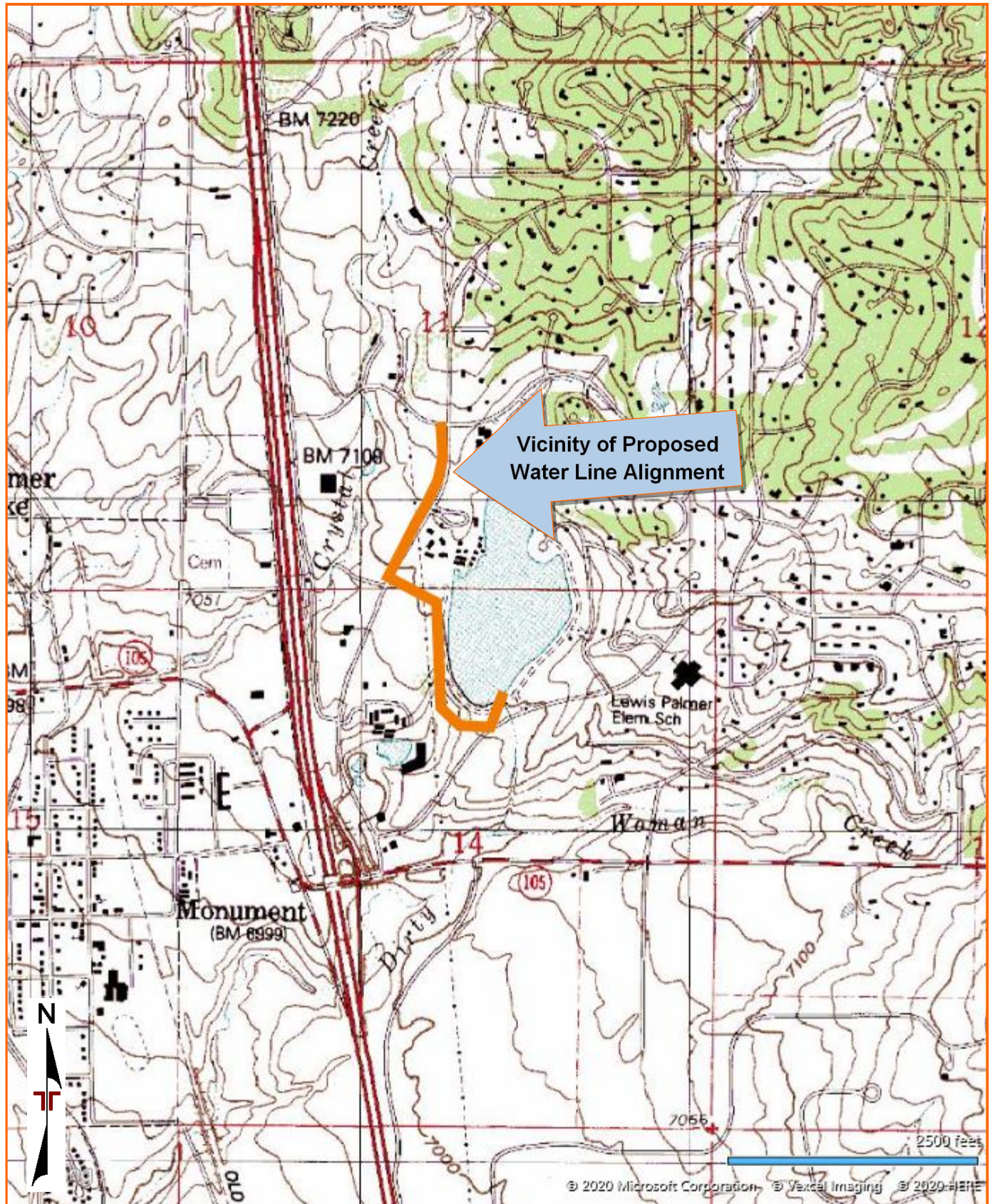


DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS  
NOT INTENDED FOR CONSTRUCTION PURPOSES

TOPOGRAPHIC MAP IMAGE COURTESY OF THE U.S. GEOLOGICAL SURVEY  
QUADRANGLES INCLUDE: PALMER LAKE, CO (1994) and MONUMENT, CO (1986).  
VICINITY OF PROPOSED WATER LINE ALIGNMENT PROVIDED BY JVA.



## EXPLORATION PLAN

Woodmoor Lake Pump Station and Pipeline ■ Monument, CO  
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DIAGRAM IS FOR GENERAL LOCATION ONLY, AND IS  
NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED  
BY MICROSOFT BING MAPS



## SLOPE STABILITY CROSS SECTION LOCATION PLAN

Woodmoor Lake Pump Station and Pipeline ■ Monument, CO

December 14, 2020 ■ Terracon Project No. 23205117

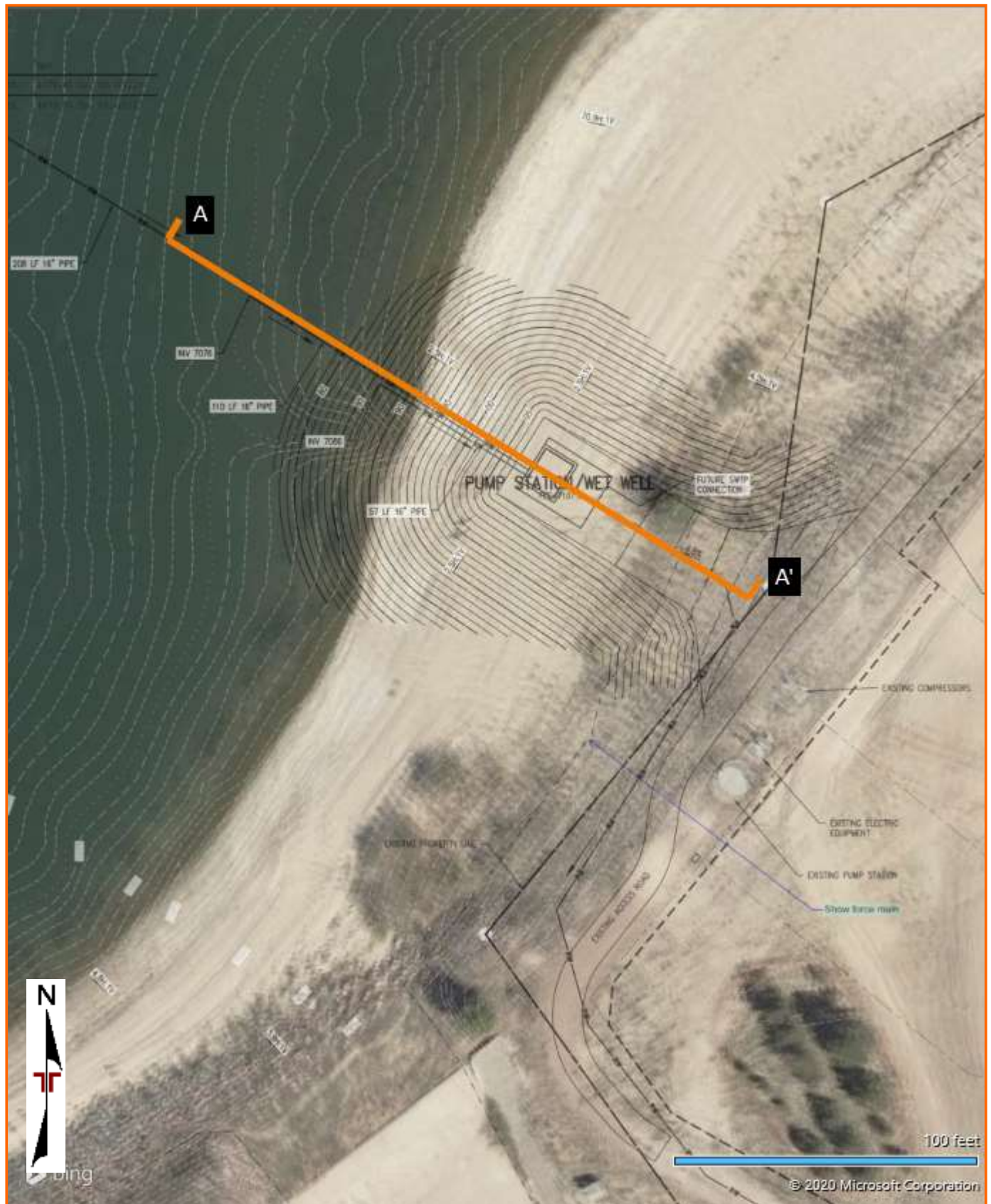


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NOT INTENDED FOR CONSTRUCTION PURPOSES

AERIAL PHOTOGRAPHY PROVIDED  
BY MICROSOFT BING MAPS

## **EXPLORATION RESULTS**

### **Contents:**

Boring Logs (SB-1 to SB-6)

Atterberg Limits

Grain Size Distribution

Consolidation/Expansion (2 pages)

Corrosivity

Note: All attachments are one page unless noted above.

# BORING LOG NO. SB-1

Page 1 of 1

PROJECT: Woodmoor Lake Pump Station and Pipeline

CLIENT: JVA Inc  
Boulder, CO

SITE: Woodmoor Drive and Lake Woodmoor Drive  
Monument, CO

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL\_23205117 WOODMOOR LAKE PUMP - CHECKEDOUTNDH.GPJ TERRACON\_DATATEMPLATE.GDT 12/7/20

MODEL LAYER	GRAPHIC LOG	LOCATION See <a href="#">Exploration Plan</a> Latitude: 39.098° Longitude: -104.8566°	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		DEPTH								
1		4.0 <b>FILL - WELL GRADED SAND WITH SILT (SW-SM)</b> , fine to coarse grained, tan				6-7	9	116		
		6.0 <b>FILL - CLAYEY SAND (SC)</b> , fine to coarse grained, brownish gray, loose White fragment of plastic encountered in 2-foot sample.	5			5-8	7	117		
2		8.5 <b>CLAYEY SAND (SC)</b> , fine to coarse grained, light gray, medium dense				12-33	8	122		
		<b>SANDSTONE</b> , with clay, light gray, hard to very hard	10			50/8"	10	117		
			15			40-50/4"	11	123		
			20			33-50/5" N=83/11"	16			
			25			29-43-50/6" N=93	14			
			30			33-50/5" N=50/5"	15			
			35			40-50/2" N=50/2"	14			
			40			36-34-44 N=78	12			
			45			33-50/5" N=50/5"	16			
			50			35-50/5" N=50/5"	14			
			55			46-50/3" N=50/3"	16			
			60			40-50/3" N=50/3"	14			
			65			42-50/4" N=50/4"	18			
		<b>Boring Terminated at 65 Feet</b>								

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

Hammer Type: Automatic

Advancement Method:  
8-inch hollow stem auger

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:  
Boring backfilled with Auger Cuttings after subsequent groundwater readings.

See [Supporting Information](#) for explanation of symbols and abbreviations.

## WATER LEVEL OBSERVATIONS

27 feet while drilling  
 12.5 feet about 48 hours after drilling

**Terracon**

4172 Center Park Dr  
Colorado Springs, CO

Boring Started: 11-12-2020

Boring Completed: 11-12-2020

Drill Rig: CME-55 Track

Driller: Vine Laboratories

Project No.: 23205117



## Page 1 of 1

**CLIENT: JVA Inc**  
**Boulder, CO**

**SITE:** Woodmoor Drive and Lake Woodmoor Drive Monument, CO

MODEL LAYER	GRAPHIC LOG	LOCATION    See <a href="#">Exploration Plan</a>  Latitude: 39.0967° Longitude: -104.8572°  DEPTH	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS  LL-PL-PI	PERCENT FINES
2		<b>WELL GRADED SAND WITH SILT (SW-SM)</b> , fine to coarse grained, light brown, medium dense to dense	5			21-32	1	122		
		33-48				5	115			
		7.0								
		<b>CLAYEY SAND (SC)</b> , fine to coarse grained, reddish brown, medium dense				15-28	14	117	32-20-12	36
		8.5								
4		<b>SANDSTONE</b> , with silt, fine to coarse grained, light grayish brown, very hard	10			26-50/6"	11	120		
		10.0								
		<b>Boring Terminated at 10 Feet</b>								

Hammer Type: Automatic

Project No.: 23205117

# BORING LOG NO. SB-3

Page 1 of 1

**PROJECT:** Woodmoor Lake Pump Station and Pipeline

**CLIENT:** JVA Inc  
Boulder, CO

**SITE:** Woodmoor Drive and Lake Woodmoor Drive  
Monument, CO

MODEL LAYER	GRAPHIC LOG	LOCATION See <a href="#">Exploration Plan</a> Latitude: 39.0969° Longitude: -104.859°	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
1		<b>FILL - CLAYEY SAND (SC)</b> , medium to coarse grained, gray and dark brown, very loose to loose	6.0							
						10-8	6	107		
			5			2-2	26	88		
2		<b>WELL GRADED SAND WITH SILT (SW-SM)</b> , fine to coarse grained, dark gray and dark brown, loose to medium dense  Rootlets and possible decomposed grass encountered in 7-foot sample.	10.0			2-8	20	103		
						9-12	12	120	26-25-1	11
		<b>Boring Terminated at 10 Feet</b>	10							

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

Hammer Type: Automatic

Advancement Method:  
4-inch solid stem auger

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:  
Boring backfilled with Auger Cuttings after subsequent groundwater readings.

See [Supporting Information](#) for explanation of symbols and abbreviations.

## WATER LEVEL OBSERVATIONS

- 8 feet while drilling
- 4 feet about 48 hours after drilling

**Terracon**

4172 Center Park Dr  
Colorado Springs, CO

Boring Started: 11-13-2020

Boring Completed: 11-13-2020

Drill Rig: CME-55

Driller: Vine Laboratories

Project No.: 23205117

# BORING LOG NO. SB-4


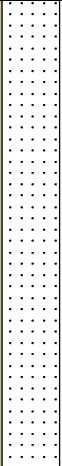
Page 1 of 1

**PROJECT:** Woodmoor Lake Pump Station and Pipeline

**CLIENT:** JVA Inc  
Boulder, CO

**SITE:** Woodmoor Drive and Lake Woodmoor Drive  
Monument, CO

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL\_23205117 WOODMOOR LAKE PUMP - CHECKEDOUTNDH.GPJ TERRACON\_DATATEMPLATE.GDT 12/7/20

MODEL LAYER	GRAPHIC LOG	LOCATION See <a href="#">Exploration Plan</a> Latitude: 39.0993° Longitude: -104.8591°  DEPTH	DEPTH (Ft)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS  LL-PL-PI	PERCENT FINES
2		<b>CLAYEY SAND (SC)</b> , fine to coarse grained, tan, medium dense								
		3.5				12-21	11	124		
4		<b>SILTY SANDSTONE</b> , fine to coarse grained, tan, medium hard to very hard	5			26-50/6"	8	123	27-23-4	16
						50/5"	9	112		
						50/6"	10	106		
		<b>Boring Terminated at 9.5 Feet</b>								

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

Hammer Type: Automatic

Advancement Method:  
4-inch solid stem auger

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:  
Boring backfilled with Auger Cuttings after subsequent groundwater readings.

See [Supporting Information](#) for explanation of symbols and abbreviations.

## WATER LEVEL OBSERVATIONS

*Not encountered while drilling*

*Not encountered about 48 hours after drilling*

**Terracon**  
4172 Center Park Dr  
Colorado Springs, CO

Boring Started: 11-13-2020

Boring Completed: 11-13-2020

Drill Rig: CME-55

Driller: Vine Laboratories

Project No.: 23205117

# BORING LOG NO. SB-5

Page 1 of 1

**PROJECT:** Woodmoor Lake Pump Station and Pipeline

**CLIENT:** JVA Inc  
Boulder, CO

**SITE:** Woodmoor Drive and Lake Woodmoor Drive  
Monument, CO

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 23205117 WOODMOOR LAKE PUMP - CHECKEDOUTNDH.GPJ TERRACON.DATATEMPLATE.GDT 12/7/20

MODEL LAYER	GRAPHIC LOG	LOCATION See <a href="#">Exploration Plan</a> Latitude: 39.1023° Longitude: -104.8598°	DEPTH (Ft.)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
		DEPTH								
		0.5 <b>ASPHALT</b> , approximately 5-inches thick								
		0.7 <b>APPARENT AGGREGATE BASE COURSE</b> , brown, approximately 2-inches thick								
1		<b>FILL - CLAYEY SAND (SC)</b> , trace gravel, fine to medium grained, brown, medium dense				12-12	6	125		
		3.5								
2		<b>POORLY GRADED SAND WITH SILT (SP-SM)</b> , light brown, medium dense	5			7-19	21	98		
		7.0								
3		<b>WEATHERED SANDSTONE</b> , with silt, fine to coarse grained, light brown, firm to medium hard				17-18	5	114		
		With clay at 9 feet.								
		10.0				25-38	10	119		
		<b>Boring Terminated at 10 Feet</b>	10							

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

Hammer Type: Automatic

Advancement Method:  
4-inch solid stem auger

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:  
Boring backfilled with Auger Cuttings and capped with asphalt after subsequent groundwater readings.

See [Supporting Information](#) for explanation of symbols and abbreviations.

## WATER LEVEL OBSERVATIONS

Not encountered while drilling

Not encountered about 48 hours after drilling

**Terracon**  
4172 Center Park Dr  
Colorado Springs, CO

Boring Started: 11-13-2020

Boring Completed: 11-13-2020

Drill Rig: CME-55

Driller: Vine Laboratories

Project No.: 23205117

# BORING LOG NO. SB-6


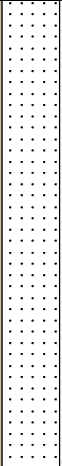
Page 1 of 1

PROJECT: Woodmoor Lake Pump Station and Pipeline

CLIENT: JVA Inc  
Boulder, CO

SITE: Woodmoor Drive and Lake Woodmoor Drive  
Monument, CO

THIS BORING LOG IS NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GEO SMART LOG-NO WELL 23205117 WOODMOOR LAKE PUMP - CHECKEDOUTNDH.GPJ TERRACON\_DATATEMPLATE.GDT 12/7/20

MODEL LAYER	GRAPHIC LOG	LOCATION See <a href="#">Exploration Plan</a> Latitude: 39.1049° Longitude: -104.8589°	DEPTH (Ft)	WATER LEVEL OBSERVATIONS	SAMPLE TYPE	FIELD TEST RESULTS	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ATTERBERG LIMITS LL-PL-PI	PERCENT FINES
2		<b>CLAYEY SAND (SC)</b> , fine to coarse grained, brown, loose								
		3.5				5-11	4	104		
4		<b>SILTY SANDSTONE</b> , fine to coarse grained, light brown, hard to very hard	5			37-50/4"	9	119		
						50/6"	9	121	31-27-4	31
						50/4"	9	94		
		<b>Boring Terminated at 9.5 Feet</b>								

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

Hammer Type: Automatic

Advancement Method:  
4-inch solid stem auger

See [Exploration and Testing Procedures](#) for a description of field and laboratory procedures used and additional data (if any).

Notes:

Abandonment Method:  
Boring backfilled with Auger Cuttings after subsequent groundwater readings.

See [Supporting Information](#) for explanation of symbols and abbreviations.

## WATER LEVEL OBSERVATIONS

Not encountered while drilling

Not encountered about 48 hours after drilling

**Terracon**  
4172 Center Park Dr  
Colorado Springs, CO

Boring Started: 11-13-2020

Boring Completed: 11-13-2020

Drill Rig: CME-55

Driller: Vine Laboratories

Project No.: 23205117

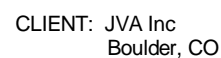
## ASTM D4318



LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. ATTERBERG LIMITS 23205117 WOODMOOR LAKE PUMP - CHECKEDOUTNDH.GPJ TERRACON\_DATATEMPLATE.GDT 12/2/2020

CLIENT: JVA Inc  
Boulder, CO

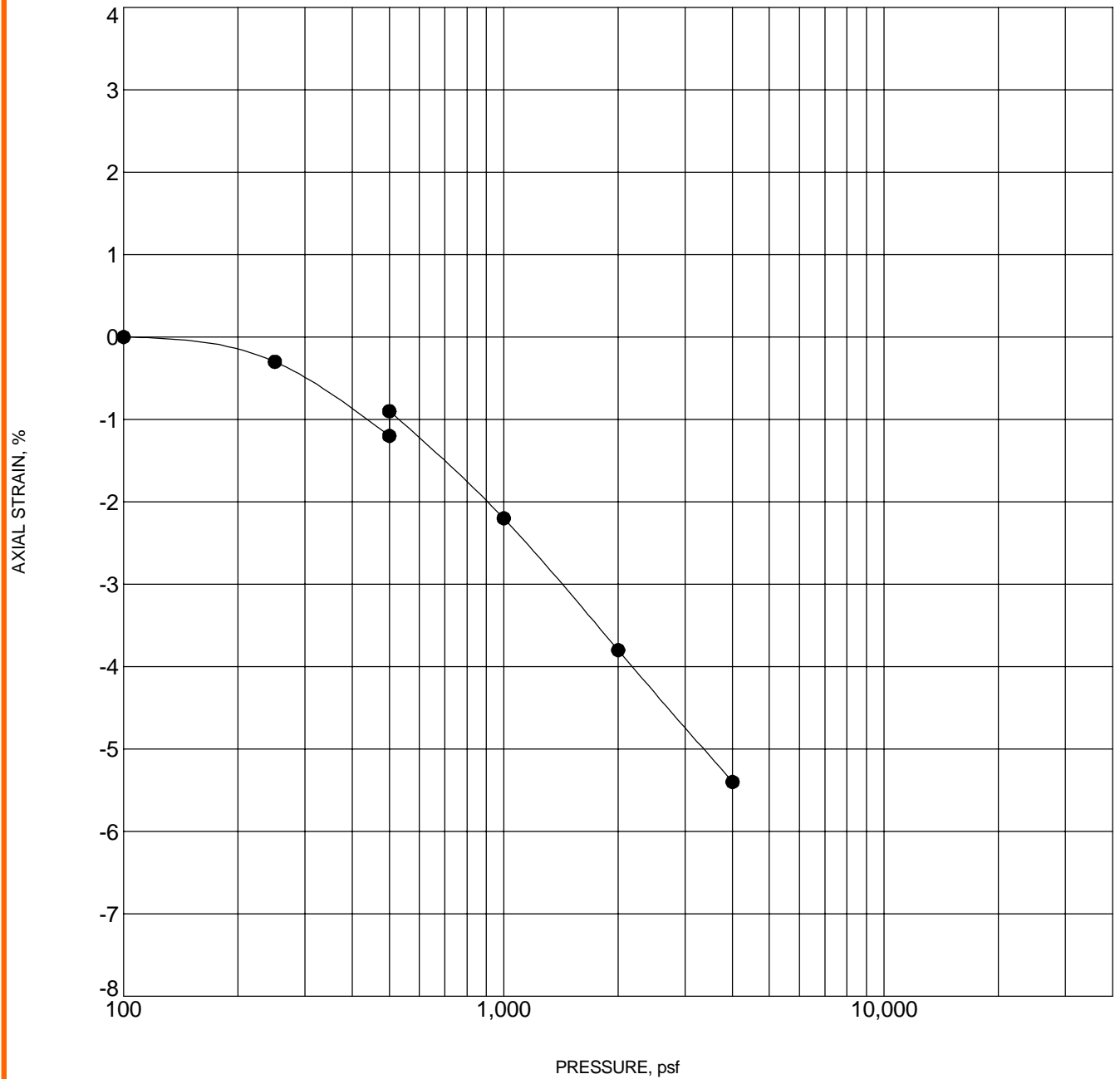
## ASTM D422 / ASTM C136



LABORATORY TESTS ARE NOT VALID IF SEPARATED FROM ORIGINAL REPORT. GRAIN SIZE: USCS-2 23205117 WOODMOOR LAKE PUMP - CHECKEDOUTNDH;GPJ TERRACON\_DATATEMPLATE.GDT 12/2/2020

# SWELL CONSOLIDATION TEST

ASTM D4546



Specimen Identification			Classification	$\gamma_d$ , pcf	WC, %
●	SB-2	7 - 8 ft	CLAYEY SAND(SC)	117	14

NOTES: Sample inundated with water at an applied pressure of 500 pounds per square foot (psf).

PROJECT: Woodmoor Lake Pump Station and Pipeline

SITE: Woodmoor Drive and Lake  
Woodmoor Drive  
Monument, CO

**Terracon**  
4172 Center Park Dr  
Colorado Springs, CO

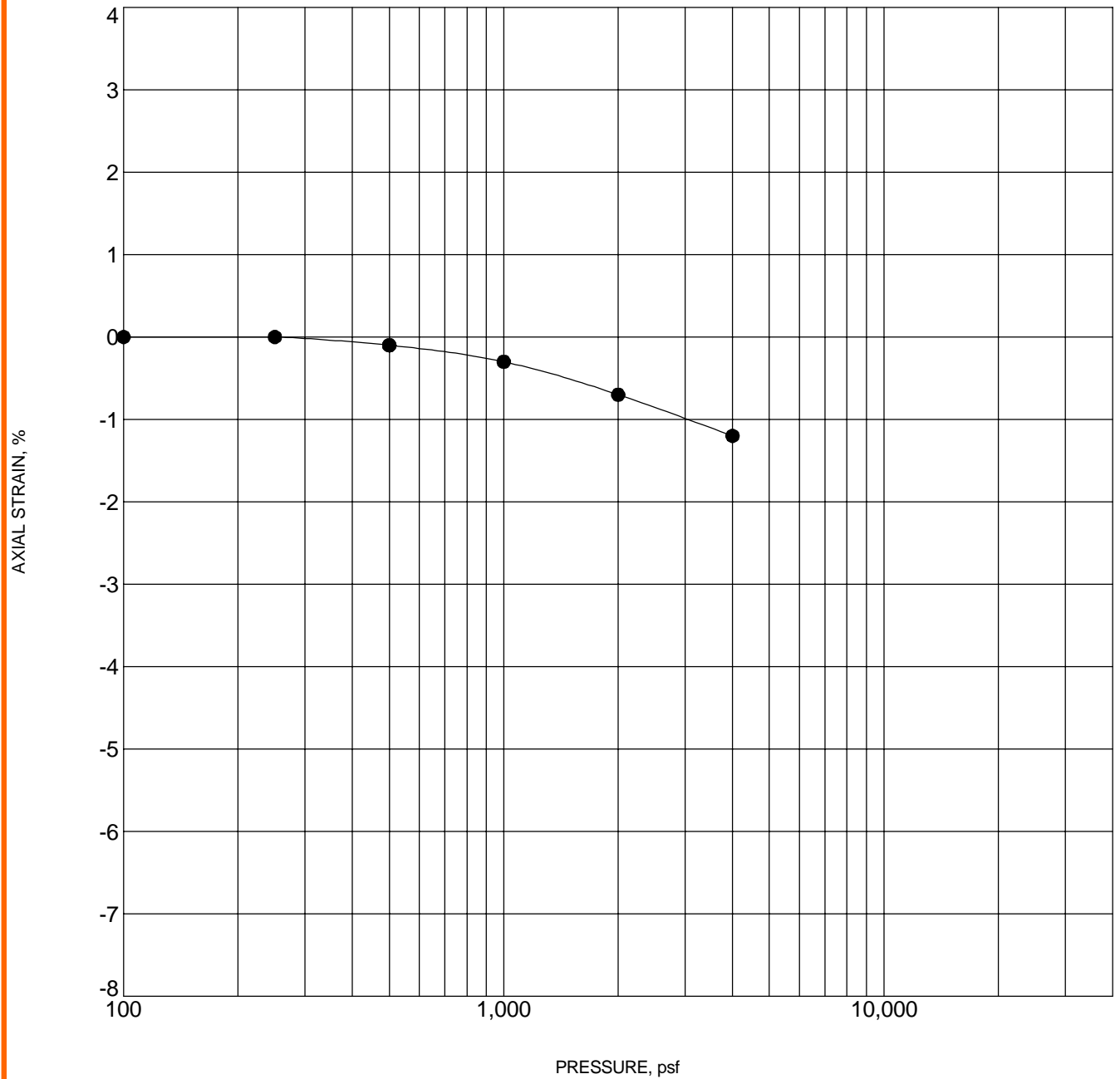
PROJECT NUMBER: 23205117

CLIENT: JVA Inc  
Boulder, CO



# SWELL CONSOLIDATION TEST

ASTM D4546



Specimen Identification			Classification	$\gamma_d$ , pcf	WC, %
●	SB-3	7 - 8 ft	WELL-GRADED SAND WITH SILT (SW-SM)	103	20

NOTES: Sample inundated with water at an applied pressure of 500 pounds per square foot (psf).

PROJECT: Woodmoor Lake Pump Station and Pipeline

SITE: Woodmoor Drive and Lake Monument, CO

**Terracon**  
4172 Center Park Dr  
Colorado Springs, CO

PROJECT NUMBER: 23205117

CLIENT: JVA Inc  
Boulder, CO

## Analytical Results

**TASK NO: 201117056**

**Report To:** Tyler Compton

**Company:** Terracon, Inc. - Colo Springs  
4172 Center Park Drive  
Colo. Springs CO 80916

**Bill To:** Tyler Compton

**Company:** Terracon, Inc. - Accounts Payable  
18001 W. 106th St  
Suite 300  
Olathe KS 66061

**Task No.:** 201117056  
**Client PO:**  
**Client Project:** Woodmoor Lake Pump 23205117

**Date Received:** 11/17/20  
**Date Reported:** 11/23/20  
**Matrix:** Soil - Geotech

**Customer Sample ID** SB-1 @ 19  
**Lab Number:** 201117056-01

Test	Result	Method
Chloride - Water Soluble	0.0010 %	AASHTO T291-91/ ASTM D4327
pH	8.0 units	AASHTO T289-91
Resistivity	5291 ohm.cm	AASHTO T288-91
Sulfate - Water Soluble	0.004 %	AASHTO T290-91/ ASTM D4327

**Customer Sample ID** SB-3 @ 4 Ft  
**Lab Number:** 201117056-02

Test	Result	Method
Chloride - Water Soluble	0.0013 %	AASHTO T291-91/ ASTM D4327
pH	6.2 units	AASHTO T289-91
Resistivity	2947 ohm.cm	AASHTO T288-91
Sulfate - Water Soluble	0.002 %	AASHTO T290-91/ ASTM D4327

**Customer Sample ID** SB-6 @ 1 - 5 Ft  
**Lab Number:** 201117056-03

Test	Result	Method
Chloride - Water Soluble	0.0011 %	AASHTO T291-91/ ASTM D4327
pH	7.4 units	AASHTO T289-91
Resistivity	7077 ohm.cm	AASHTO T288-91
Sulfate - Water Soluble	< 0.001 %	AASHTO T290-91/ ASTM D4327

### Abbreviations/ References:

AASHTO - American Association of State Highway and Transportation Officials.  
ASTM - American Society for Testing and Materials.  
ASA - American Society of Agronomy.  
DIPRA - Ductile Iron Pipe Research Association Handbook of Ductile Iron Pipe.



DATA APPROVED FOR RELEASE BY

## **SUPPORTING INFORMATION**

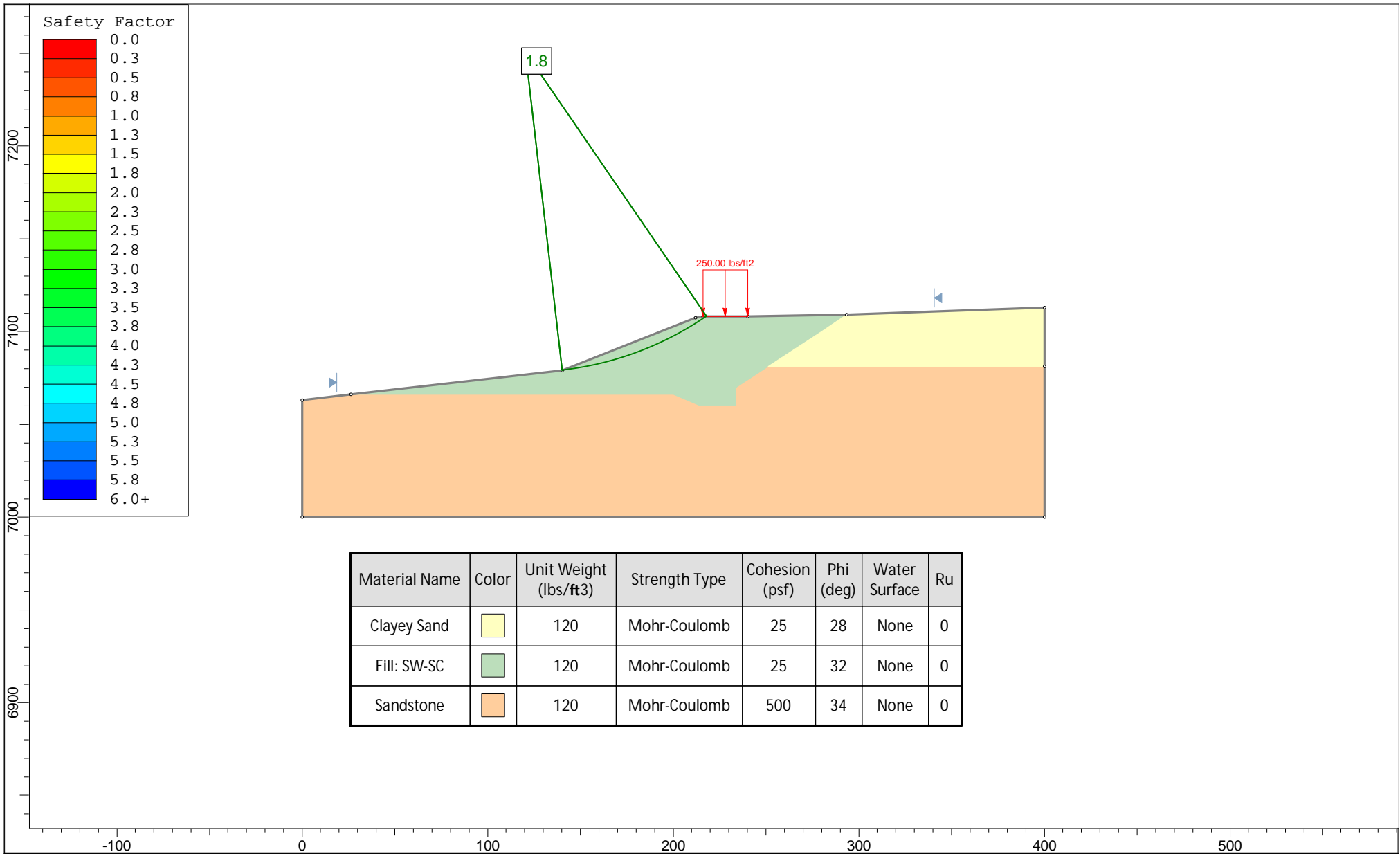
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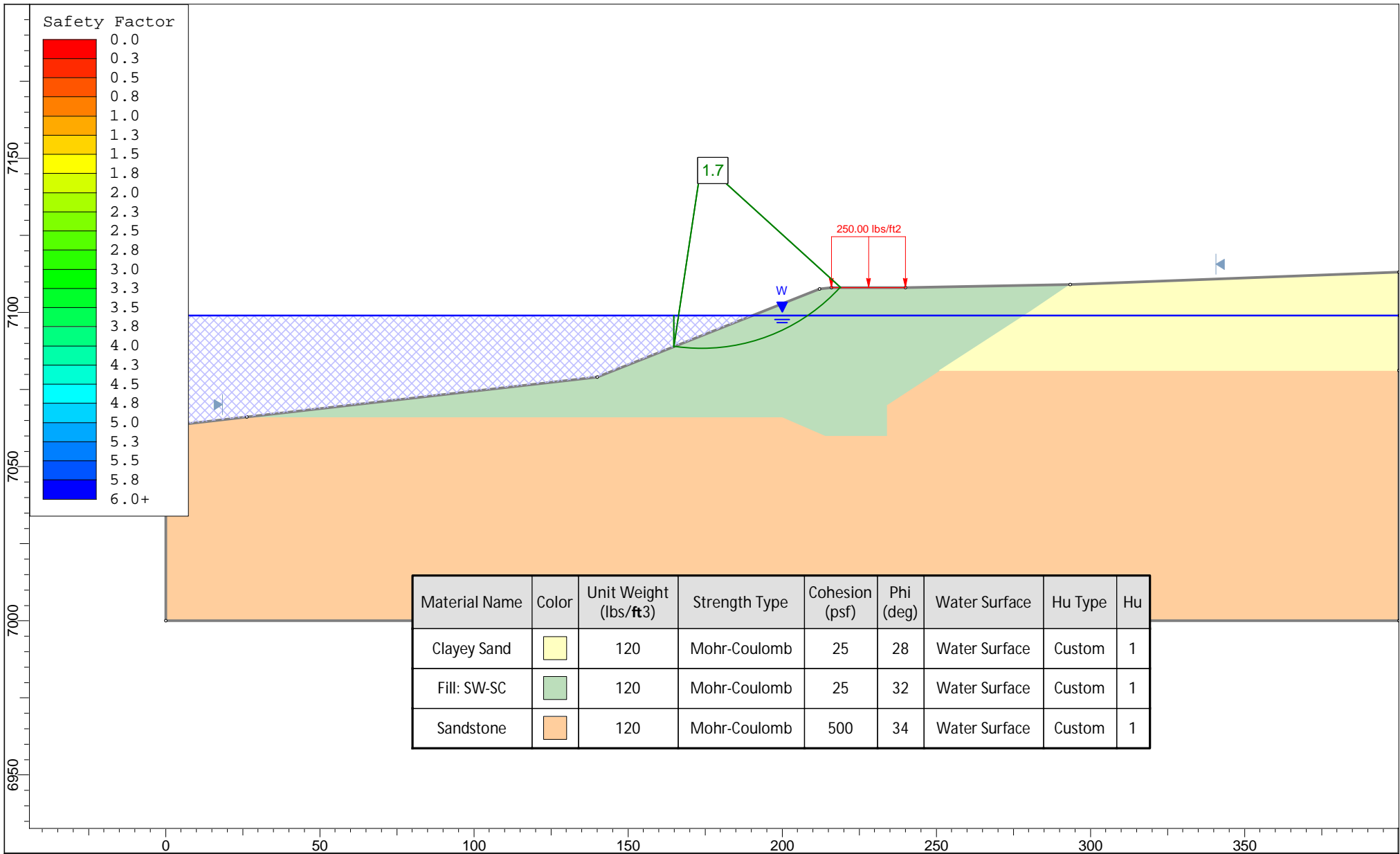
Slope Stability Output (4 pages)

General Notes

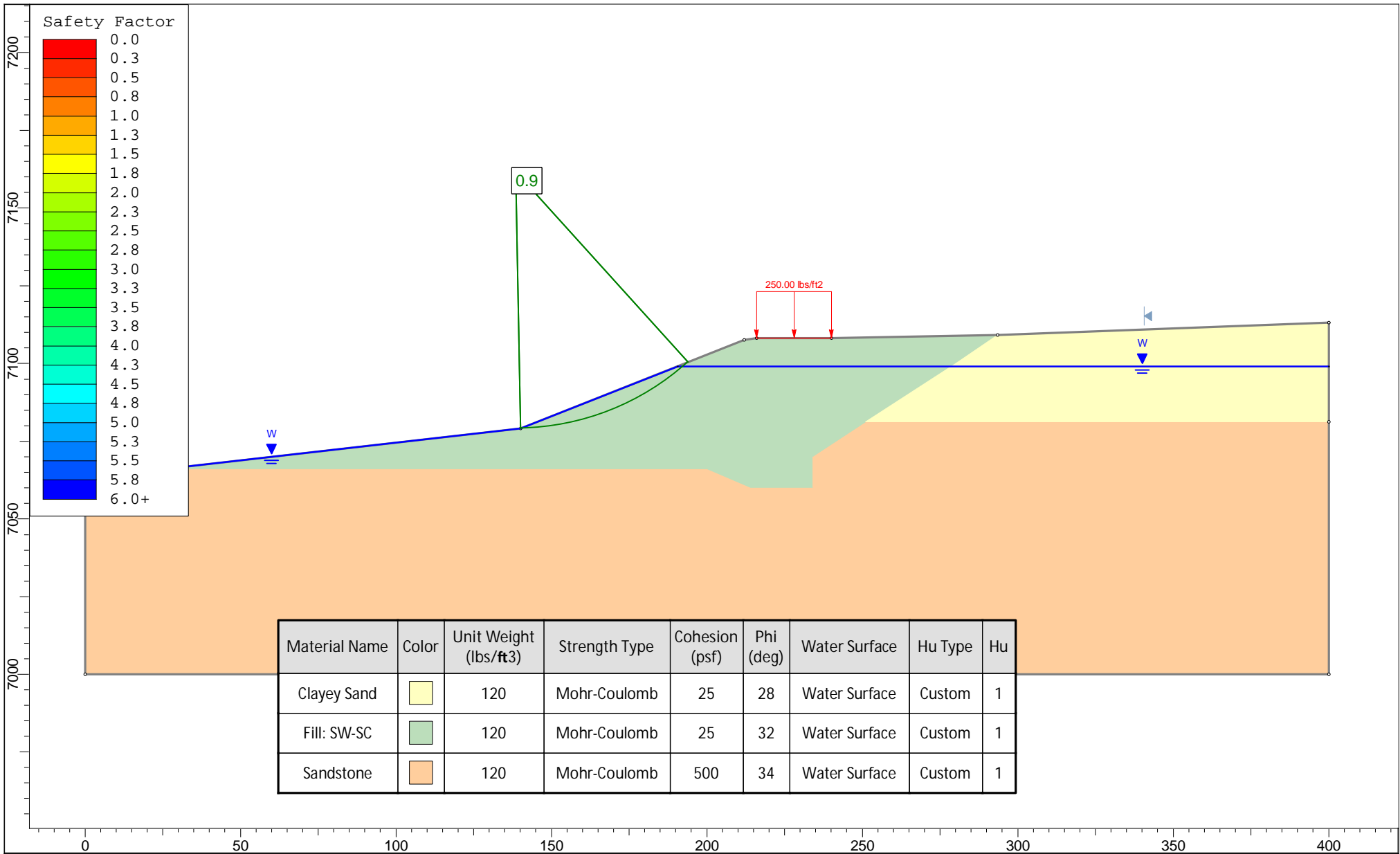
Unified Soil Classification System

Note: All attachments are one page unless noted above.

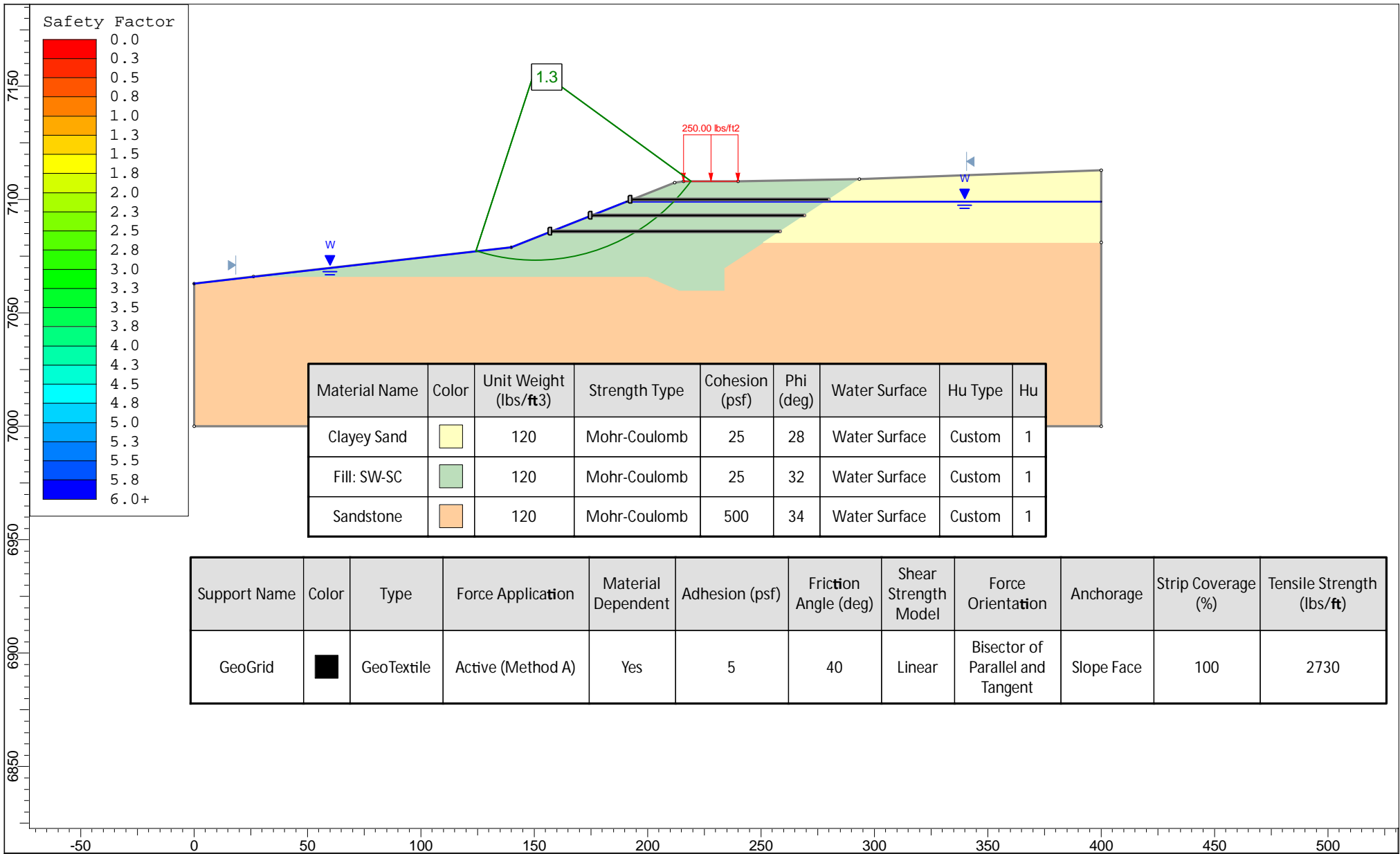




Project			Woodmoor Lake Pump Station - Full Lake		
Analysis					
Drawn By		Scale	1:517	Company	
Date		12/11/2020, 11:25:44 AM		File Name	
				Slide - Woodmoor Lake Pump Station.slim	



Project			Woodmoor Lake Pump Station - Rapid Lake Drain		
Analysis					
Drawn By		Scale	1:513	Company	
Date		12/11/2020, 11:25:44 AM		File Name	
				Slide - Woodmoor Lake Pump Station Rapid Lake Drain.slim	










# GENERAL NOTES

## DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

Woodmoor Lake Pump Station and Pipeline ■ Monument, CO

Terracon Project No. 23205117

SAMPLING	WATER LEVEL	FIELD TESTS
 Modified Dames & Moore Ring Sampler  Grab Sample  Standard Penetration Test	 Water Initially Encountered  Water Level After a Specified Period of Time  Water Level After a Specified Period of Time  Cave In Encountered <p>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.</p>	<p><b>N</b> Standard Penetration Test Resistance (Blows/Ft.)</p> <p><b>(HP)</b> Hand Penetrometer</p> <p><b>(T)</b> Torvane</p> <p><b>(DCP)</b> Dynamic Cone Penetrometer</p> <p><b>UC</b> Unconfined Compressive Strength</p> <p><b>(PID)</b> Photo-Ionization Detector</p> <p><b>(OVA)</b> Organic Vapor Analyzer</p>

## DESCRIPTIVE SOIL CLASSIFICATION

Soil classification as noted on the soil boring logs is based Unified Soil Classification System. Where sufficient laboratory data exist to classify the soils consistent with ASTM D2487 "Classification of Soils for Engineering Purposes" this procedure is used. ASTM D2488 "Description and Identification of Soils (Visual-Manual Procedure)" is also used to classify the soils, particularly where insufficient laboratory data exist to classify the soils in accordance with ASTM D2487. In addition to USCS classification, coarse grained soils are classified on the basis of their in-place relative density, and fine-grained soils are classified on the basis of their consistency. See "Strength Terms" table below for details. The ASTM standards noted above are for reference to methodology in general. In some cases, variations to methods are applied as a result of local practice or professional judgment.

## LOCATION AND ELEVATION NOTES

Exploration point locations as shown on the Exploration Plan and as noted on the soil boring logs in the form of Latitude and Longitude are approximate. See [Exploration and Testing Procedures](#) in the report for the methods used to locate the exploration points for this project. 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			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, (tsf)	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 0.25	0 - 1	< 3	< 30	< 20	Weathered
Loose	4 - 9	7 - 18	Soft	0.25 to 0.50	2 - 4	3 - 4	30 - 49	20 - 29	Firm
Medium Dense	10 - 29	19 - 58	Medium Stiff	0.50 to 1.00	4 - 8	5 - 9	50 - 89	30 - 49	Medium Hard
Dense	30 - 50	59 - 98	Stiff	1.00 to 2.00	8 - 15	10 - 18	90 - 119	50 - 79	Hard
Very Dense	> 50	≥ 99	Very Stiff	2.00 to 4.00	15 - 30	19 - 42	> 119	> 79	Very Hard
			Hard	> 4.00	> 30	> 42			

## RELEVANCE OF SOIL BORING LOG

The soil boring logs contained within this document are intended for application to the project as described in this document. Use of these soil boring logs for any other purpose may not be appropriate.



Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests <sup>A</sup>					Soil Classification	
					Group Symbol	Group Name <sup>B</sup>
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 <sup>C</sup>	Cu ≥ 4 and 1 ≤ Cc ≤ 3 <sup>E</sup>		GW	Well-graded gravel <sup>F</sup>
			Cu < 4 and/or [Cc<1 or Cc>3.0] <sup>E</sup>		GP	Poorly graded gravel <sup>F</sup>
		Gravels with Fines: More than 12% fines <sup>C</sup>	Fines classify as ML or MH		GM	Silty gravel <sup>F, G, H</sup>
			Fines classify as CL or CH		GC	Clayey gravel <sup>F, G, H</sup>
	Sands: 50% or more of coarse fraction passes No. 4 sieve	Clean Sands: Less than 5% fines <sup>D</sup>	Cu ≥ 6 and 1 ≤ Cc ≤ 3 <sup>E</sup>		SW	Well-graded sand <sup>I</sup>
			Cu < 6 and/or [Cc<1 or Cc>3.0] <sup>E</sup>		SP	Poorly graded sand <sup>I</sup>
		Sands with Fines: More than 12% fines <sup>D</sup>	Fines classify as ML or MH		SM	Silty sand <sup>G, H, I</sup>
			Fines classify as CL or CH		SC	Clayey sand <sup>G, H, I</sup>
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”		CL	Lean clay <sup>K, L, M</sup>
			PI < 4 or plots below “A” line <sup>J</sup>		ML	Silt <sup>K, L, M</sup>
		Organic:	Liquid limit - oven dried	< 0.75	OL	Organic clay <sup>K, L, M, N</sup>
			Liquid limit - not dried			Organic silt <sup>K, L, M, O</sup>
	Silts and Clays: Liquid limit 50 or more	Inorganic:	PI plots on or above “A” line		CH	Fat clay <sup>K, L, M</sup>
			PI plots below “A” line		MH	Elastic Silt <sup>K, L, M</sup>
		Organic:	Liquid limit - oven dried	< 0.75	OH	Organic clay <sup>K, L, M, P</sup>
			Liquid limit - not dried			Organic silt <sup>K, L, M, Q</sup>
Highly organic soils:	Primarily organic matter, dark in color, and organic odor				PT	Peat

<sup>A</sup> Based on the material passing the 3-inch (75-mm) sieve.

<sup>B</sup> If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

<sup>C</sup> 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.

<sup>D</sup> 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.

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

<sup>F</sup> If soil contains  $\geq 15\%$  sand, add "with sand" to group name.

<sup>G</sup> If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

<sup>H</sup> If fines are organic, add "with organic fines" to group name.

<sup>I</sup> If soil contains  $\geq 15\%$  gravel, add "with gravel" to group name.

<sup>J</sup> If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

<sup>K</sup> If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

<sup>L</sup> If soil contains  $\geq 30\%$  plus No. 200 predominantly sand, add "sandy" to group name.

<sup>M</sup> If soil contains  $\geq 30\%$  plus No. 200, predominantly gravel, add "gravelly" to group name.

<sup>N</sup>  $PI \geq 4$  and plots on or above "A" line.

<sup>O</sup>  $PI < 4$  or plots below "A" line.

<sup>P</sup>  $PI$  plots on or above "A" line.

<sup>Q</sup>  $PI$  plots below "A" line.

