GEOTECHNICAL ENGINEERING REPORT
NAVAJO TECHNICAL UNIVERSITY (NTU)
NAVAJO CENTER FOR THE ENVIRONMENT AND LABORATORY
CHINLE, ARIZONA

Submitted To:

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Submitted By:

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January 12, 2023
GEOMAT Project 222-4248

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January 12, 2023

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RE: Geotechnical Engineering Report
Navajo Center for the Environment and Laboratory
Navajo Technical University
Chinle, Arizona
GEOMAT Project No. 222-4248

GEOMAT Inc. (GEOMAT) has completed the geotechnical engineering exploration for the proposed Navajo Center for the Environment and Laboratory located at the Navajo Technical University (NTU) in Chinle, Arizona. This study was performed in general accordance with our Proposal No. 212-03-06 – Rev. 1, dated November 4, 2022.

The results of our engineering study, including the geotechnical recommendations, site plan, boring records, and laboratory test results are attached. Based on the geotechnical engineering analyses, subsurface exploration and laboratory test results, the proposed building could be supported on shallow spread footings, and the water storage tank could be supported on a concrete ring wall foundation, both bearing on engineered fill. Slab on grade floors may be utilized for the interior floor systems for the building. Other design and construction details, based upon geotechnical conditions, are presented in the report.

We have appreciated being of service to you in the geotechnical engineering phase of this project. If you have any questions concerning this report, please contact us.

Sincerely yours,
GEOMAT Inc.

Douglas N. Hood
Staff Professional

Registered Professional Engineer (Civil)
CERTIFICATE NO.
52003
MATTHEW J.
CRAMER
Date Signed 1/12/23
ARIZONA U.S.A.
EXPIRES 3/31/23

Matthew J. Cramer, P.E.
President

Copies to: Addressee (1); (sent via E-mail)

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NAVAJO TECHNICAL UNIVERSITY (NTU)
NAVAJO CENTER FOR THE ENVIRONMENT AND LABORATORY
CHINLE, ARIZONA
GEOMAT PROJECT NO. 222-4248

INTRODUCTION

This report contains the results of our geotechnical engineering exploration for the proposed Navajo Center for the Environment and Laboratory for the NTU located in Chinle, Arizona, as shown on the Site Plan in Appendix A of this report.

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

- subsurface soil conditions
- groundwater conditions
- lateral soil pressures
- earthwork
- foundation design and construction
- slab design and construction
- parking lot pavement design
- drainage

The opinions and recommendations contained in this report are based upon the results of field and laboratory testing, engineering analyses, and experience with similar soil conditions, structures, and our understanding of the proposed project as stated below.

PROPOSED CONSTRUCTION

We understand the project will consist of a single-story building that is approximately 8,622 square feet in size. Building loads were not provided; however, we anticipate that maximum column loads will be on the order of 150 kips and maximum wall loads will be up to 4 kips/foot. The project will also include a water storage tank on the order of 80,000 to 100,000 gallons in storage size. We anticipate that the water tank will be supported on a concrete ring wall foundation. We understand that no below-grade structures are planned and that minor fills and/or cuts will be required to achieve final site grades. We also understand that the project will include paved parking and driveway areas around the single-story building.

SITE EXPLORATION

Our scope of services performed for this project included a site reconnaissance by a staff professional, a subsurface exploration program, laboratory testing and engineering analyses.

Field Exploration:

Subsurface conditions at the site were explored on November 28, 2022 by drilling a total of seven (7) exploratory borings. Four borings were drilled within the footprint of the building with three borings having a planned depth of 30 feet below existing ground surface (bgs) and one boring having a planned depth of 45 feet bgs. Another boring was drilled in the area of the water storage tank with the depth of 30 feet bgs and two borings were drilled within the parking areas/driving lanes with a planned depth of 5 feet bgs. All borings are shown at the approximate locations on the Site Plan in Appendix A.

The borings were advanced using a CME-55 truck-mounted drill rig with continuous-flight, 7.25-inch O.D. hollow-stem auger. The borings were continuously monitored by a professional from our office who examined and classified the subsurface materials encountered, obtained representative samples, observed groundwater conditions, and maintained a continuous log of each boring.

Soil samples were obtained from the borings using a combination of standard 2-inch O.D. split spoon and 3-inch O.D. ring-lined split-barrel samplers. The samplers were driven using a 140-pound hammer falling 30 inches. The standard penetration resistance was determined by recording the number of hammer blows required to advance the sampler in six-inch increments. Representative bulk samples of subsurface materials were also obtained.

Groundwater evaluations were made in each boring at the time of site exploration. Soils were classified in accordance with the Unified Soil Classification System described in Appendix A. Boring logs were prepared and are presented in Appendix A.

Laboratory Testing:

Samples retrieved during the field exploration were transported to our laboratory for further evaluation. At that time, the field descriptions were confirmed or modified as necessary, and laboratory tests were performed to evaluate the engineering properties of the subsurface materials.

SITE CONDITIONS

The site of the proposed construction is located approximately 2,000 feet north of the intersection of Indian Service Route 102 and U.S. Highway 191 in Chinle, Arizona. The site had evidence of being previously graded, as there was no evidence of vegetation and a row of debris running in the southwest to northeast direction in addition to tire tracks. The site was relatively level, with a water detention pond east of the proposed building location, an educational building south of the proposed building, and undeveloped land to the north and west.

The following photographs depict the site at the time of our exploration.

Project Site with Row of Debris
View towards the Northeast

View from Boring B-2
View towards the East

View of Detention Pond
View towards the Southwest

SUBSURFACE CONDITIONS

Soil Conditions:

As presented on the Boring Logs in Appendix A, in boring B-1, we encountered sandy soils with inclusions of clayey layers that extended to approximately 23 feet bgs. The sandy soils were underlain by clayey soils that extended to approximately 26.5 feet bgs. Beneath the clayey soils, there were sandy soils that extended the remaining depth of exploration of approximately 46.5

feet bgs. In boring B-2, we encountered sandy soils that extended to approximately 6.5 feet bgs. The sandy soils were underlain by clayey soils that extended to approximately 8 feet bgs. Beneath the clayey soils, there were sandy soils that extended the remaining depth of exploration of approximately 31.5 feet bgs. In boring B-3, we encountered sandy soils that extended to approximately 8 feet bgs. The sandy soils were underlain by clayey soils that extended to approximately 9 feet bgs. Beneath the clayey soils, there were sandy soils that extended to approximately 26.5 feet bgs which were underlain by alternating clayey soils and sandy soils for the remaining depth of exploration of 31 feet bgs. In boring B-4, we encountered sandy soils that extended to approximately 26 feet bgs and were underlain by alternating clayey soils and sandy soils that extended the remaining depth of exploration. In boring B-5, we encountered sandy soils that extended to approximately 11 feet bgs. The sandy soils were underlain by clayey soils that extended to approximately 12.5 feet bgs and were followed by sandy soils that extended to approximately 22.5 feet bgs. Beneath the sandy soils were clayey soils that extended to approximately 24.5 feet bgs and were underlain by sandy soils that extended the remaining depth of exploration of approximately 31 feet bgs. In boring B-6, we encountered sandy soils the full depth of exploration of approximately 5 feet bgs. In boring B-7, we encountered sandy soils that extended to approximately 2.5 feet bgs. The sandy soils were underlain by clayey soils that extended to approximately 4 feet bgs. Beneath the clayey soils were sandy soils that extended the remaining depth of exploration of approximately 5 feet bgs.

The sandy soils encountered were generally loose to medium dense and ranged in color from tan to red to brown with moisture of slightly damp to damp and were generally fine- to coarse-grained. The clayey soils encountered were generally very stiff and ranged in color from brown to gray with moisture content of slightly damp to damp.

Groundwater Conditions:

Groundwater was not encountered in the borings to the depths explored. Groundwater elevations can fluctuate over time depending upon precipitation, irrigation, runoff and infiltration of surface water. We do not have any information regarding the historical fluctuation of the groundwater level in this vicinity.

Laboratory Test Results:

Laboratory analyses of samples tested indicate the on-site sandy soils have fines contents (silt- and/or clay-sized particles passing the U.S. No. 200 sieve) ranging from approximately 23 to 45 percent. The plasticity indices of the sample of the sandy soils tested ranged from non-plastic to 19. In-place dry densities of the sandy soils ranged from approximately 93 to 107 pounds per cubic foot (pcf), with a natural moisture content ranging from approximately 1 to 7 percent. The clayey soils have a fines content of approximately 63 percent. The plasticity index of the clayey sample tested was 10. In-place dry density of the clayey soils were approximately 101 pcf, with a natural moisture content of approximately 10 percent.

A representative sample of the sandy soils from boring B-3 was tested for its moisture-density relationship (proctor) and remolded swell potential. The maximum dry density and optimum moisture content, as determined by ASTM D1557 (modified proctor), were 120.5 pcf and 11.3 percent, respectively. The swell test was performed on a sample compacted at approximately 95 percent of the ASTM D1557 maximum dry density at approximately 3 percent below optimum moisture content, the sample was confined under a 144-psf surcharge and submerged with the resulting change in volume measured. The results show a swell potential of 0 percent.

Laboratory consolidation/expansion testing was performed on undisturbed ring samples of the subgrade soils beneath the proposed building and water storage tank. Results of these tests indicate that the sandy soils undergo slight to moderate compression when subjected to anticipated foundation stresses at the existing moisture contents. When subjected to increased moisture conditions at these stresses, the sandy soils underwent slight to moderate compression, followed by additional compression under additional loading.

Results of all laboratory tests are presented in Appendix B.

OPINIONS AND RECOMMENDATIONS

Geotechnical Considerations:

The site is considered suitable for the proposed building based on the geotechnical conditions encountered and tested for this report. To reduce the potential for heaving and/or settlement of structures supported on shallow foundations, and provide more uniform and higher allowable bearing pressures, the footings should bear on engineered fill. Historically, thick deposits of expansive clayey soils and shales have been encountered in the Chinle vicinity. These deposits have caused significant damage to some structures over the years. Additionally, some buildings in the Chinle vicinity have experienced settlement due to loosely deposited soil conditions. Both conditions generally dictate buildings being supported on deep foundations. However, we did not encounter either of these types of subsurface conditions on this site.

Consolidation testing indicates that the existing soils experience compression when subjected to loads in their current moisture state. When the moisture content of the existing soils is increased, tests indicate an increase in compressibility. It is of paramount importance to provide good positive drainage away from the building to ensure that surface water is transmitted away from the structure. The area surrounding the building on all sides should be paved or surfaced to prevent water infiltration next to the building. Raising the site grade may also help improve drainage and reduce the potential for moisture related movements to occur.

If there are any significant deviations from the assumed floor elevations, structure locations and/or loads noted at the beginning of this report, the opinions and recommendations of this report should be reviewed and confirmed/modified as necessary to reflect the final planned design conditions.

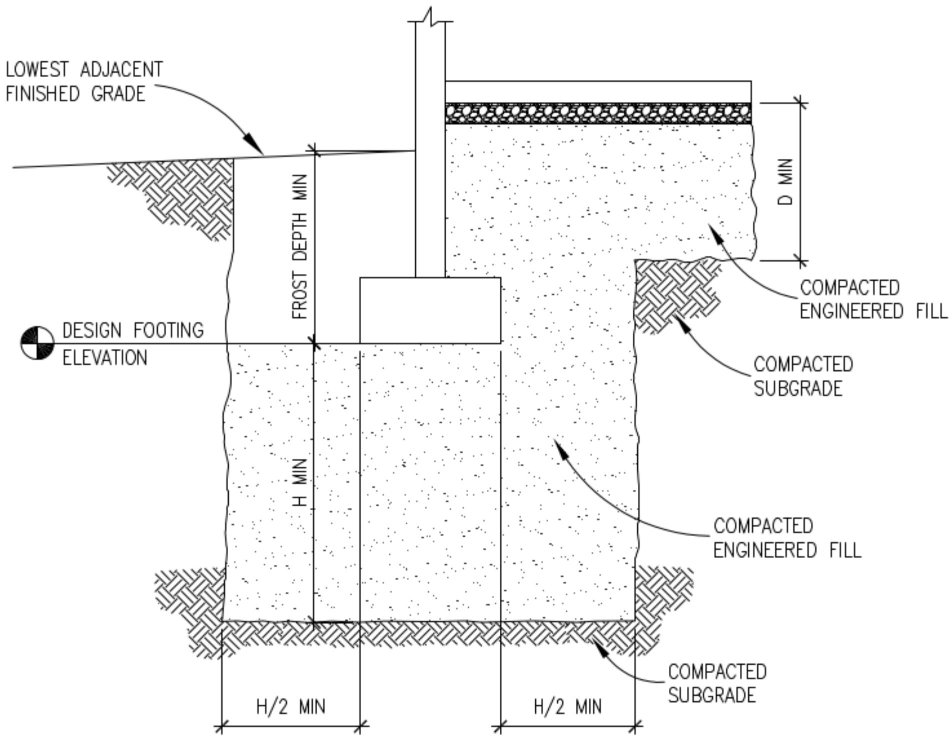
Foundations:

Building Foundation:

Based on our understanding of the type of structure to be built and the results of our field subsurface exploration and laboratory testing, the building could be founded on conventional shallow spread footings bearing on engineered fill. The engineered fill should be provided for a depth below the footing, H, of at least the width of wall footings and the width of column footings, but not less than four (4.0) feet for either case. The engineered fill should extend beyond the edges of the footings for a distance of one-half the depth of engineered fill below the footings, H/2, but not less than two (2.0) feet. If the entire building area is excavated for the engineered fill placement, the engineered fill should extend at least five (5.0) feet beyond the perimeter of the building.

Materials and compaction criteria for the engineered fill should be as recommended in the **Earthwork** section of this report. Adequate drainage should be provided to prevent the supporting soils from undergoing significant moisture changes.

A generalized depiction of a shallow spread footing supported on engineered fill is shown in the following illustration.



The recommended design bearing capacity and footing depths are presented in the following table.

Footing Depth[1] (ft)	Allowable Bearing Pressure (psf)	Bearing Soil
2.5[2]	**2,500**	**Engineered Fill**

[1]Footing depth referenced below lowest adjacent finished grade. Finished grade is the lowest adjacent grade for perimeter footings and floor level for interior footings.
[2]Minimum footing depth for frost protection.

Recommendations for earthwork beneath the floor slab can be found in the **Floor Slab Design and Construction** section of this report.

Total and differential settlements resulting from the assumed structural loads are estimated to be on the order of three fourths (3/4) of an inch or less. Proper drainage should be provided in the final design and during construction and areas adjacent to the structure should be designed to prevent water from ponding or accumulating next to the structures.
Total and differential settlements should not exceed predicted values, provided that:

- Foundations are constructed as recommended, and
- Essentially no changes occur in water contents of foundation soils.

For foundations adjacent to descending slopes, a minimum horizontal setback of five (5) feet should be maintained between the foundation base and slope face. In addition, the setback should be such that an imaginary line extending downward at 45 degrees from the nearest foundation edge does not intersect the slope.

Footings and foundations should be reinforced as necessary to reduce the potential for distress caused by differential foundation movement. Minimum recommended widths of square and continuous footings are two (2) feet and 1 and one-third (1.33) feet, respectively.

Foundation excavations should be observed by GEOMAT. If the soil conditions encountered differ significantly from those presented in this report, supplemental recommendations will be required.

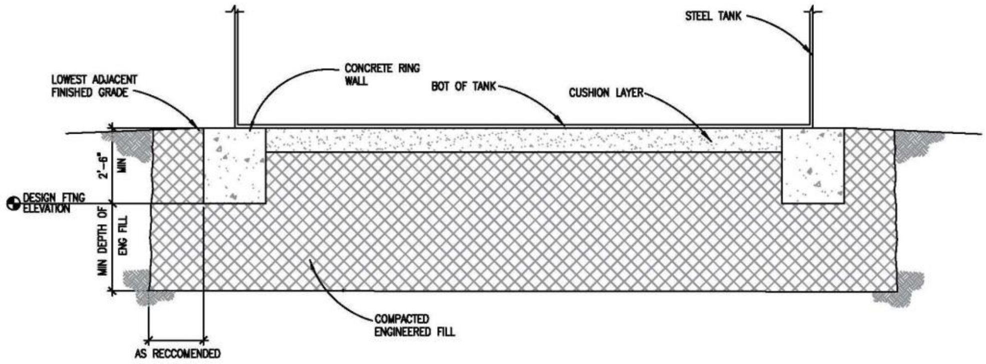
Storage Tank Foundation:

Based on our understanding of the structure to be built, the water storage tank could be founded on a conventional concrete ring wall footing bearing on compacted engineered fill. To reduce the potential for settlement and/or heaving and to provide a more uniform bearing surface, the concrete ring wall footings should bear entirely on engineered fill. The existing soils should be removed as necessary (overexcavated) to provide a minimum thickness of four (4.0) feet of engineered fill below the bottom of the ring wall footing under the entire tank. The engineered fill should extend laterally a minimum distance of two (2.0) feet beyond the edge of the footing.

Materials and compaction criteria for the engineered fill should be as recommended in the **Earthwork** section of this report. Adequate drainage should be provided to prevent the supporting soils from undergoing significant moisture changes.

Consideration should be given to supporting the tank bottoms on a minimum 3-inch thick cushion layer consisting of oiled sand, compacted crushed stone, fine gravel, clean sand, hydrated lime-sand mix, asphaltic road mix or similar material. The cushion layer should be a minimum of 3 inches thick, or thicker as necessary, to reduce the potential for damage to the tank bottom by protrusions or other irregularities in the surface. The chloride and sulfate contents of the cushion material should be less than 100 ppm and 200 ppm, respectively.

The following diagram depict the recommended configurations for tank foundations supported on engineered fill.



TANK FOUNDATION ON ENGINEERED FILL

The recommended design bearing capacity and footing depths are presented in the following table.

Footing Depth[1] (ft)	Allowable Bearing Pressure (psf)	Bearing Soil
2.5[2]	**2,500**	**Engineered Fill**

[1]Footing depth referenced below lowest adjacent finished grade. Finished grade is the lowest adjacent grade for perimeter footings and floor level for interior footings.
[2]Minimum footing depth for frost protection.

Total and differential settlements resulting from the assumed structural loads are estimated to be on the order of ¾ inch or less. Proper drainage should be provided in the final design and during construction and areas adjacent to the structure should be designed to prevent water from ponding or accumulating next to the structure.

Total and differential settlements should not exceed predicted values, provided that:

- Foundations are constructed as recommended, and
- Essentially no changes occur in water contents of foundation soils.

For foundations adjacent to descending slopes, a minimum horizontal setback of five (5) feet should be maintained between the foundation base and slope face. In addition, the setback should be such that an imaginary line extending downward at 45 degrees from the nearest foundation edge does not intersect the slope.

Foundation excavations should be observed by GEOMAT. If the soil conditions encountered differ significantly from those presented in this report, supplemental recommendations will be required.

Floor Slab Design and Construction:

Based upon the subsurface conditions encountered, the building may be founded with a concrete slab-on-grade bearing on engineered fill. The ground floor slab should be placed on a minimum thickness, D, of two (2.0) feet of engineered fill including a minimum 4-inch layer of aggregate base course.
On-site or imported soils with low expansive potentials should be used in fills that will support the floor slabs. Some differential movement of a slab-on-grade floor system is possible if the subgrade soils become elevated in moisture content. Such movements are considered within general tolerance for normal slab-on-grade construction. To reduce potential slab movements, the subgrade soils should be prepared as outlined in the **Earthwork** section of this report.

For structural design of concrete slabs-on-grade, a modulus of subgrade reaction of 200 pounds per cubic inch (pci) may be used for floors supported on compacted engineered fill.

Additional floor slab design and construction recommendations are as follows:

- Control joints should be provided in slabs to control the location and extent of cracking. Joint spacing should be designed by the structural engineer.

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

- In areas subjected to normal loading, a minimum 4-inch layer of clean-graded gravel, aggregate base course should be placed beneath interior slabs. For heavy loading, re-evaluation of slab and/or base course thickness may be required.

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

- If moisture sensitive floor coverings are used on interior slabs, consideration should be given to the use of membranes to help reduce the potential for vapor rise through the slab.

Subgrade preparation and moisture control recommendations provided in this report help to reduce soil related problems that may result in distress of concrete floor slabs on grade. However, concrete drying shrinkage, temperature induced volume change and curling can create cracking and distress in the concrete slab on grade. To reduce distress from these causes, properly proportioned concrete mixes with adequate curing and proper joint spacing must be provided. These options should be discussed with the project Architect/Engineer.

Site Classification:

Based on the subsurface conditions encountered in the borings, we estimate that Site Class D is appropriate in accordance with the International Building Code. This parameter was estimated based on extrapolation of data beyond the deepest depth explored, using methods allowed by the code. Actual shear wave velocity testing/analysis and/or exploration to a depth of 100 feet were not performed as part of our scope of services for this project.

Seismic design parameters for the project site were determined in accordance with the procedure in the International Building Code. These values are based on a Risk Category of II and Site Class D. The seismic design parameters are presented in the table below.

Seismic Design Parameters	
S_S	0.152g
S_1	0.049g
S_{MS}	0.243g
S_{M1}	0.117g
S_{DS}	0.162g
S_{D1}	0.078g

Ss = mapped spectral response acceleration at short periods
S_1 = mapped spectral response acceleration at 1-second period
S_{MS} = maximum considered earthquake spectral response acceleration for short periods
S_{M1} = maximum considered earthquake spectral response acceleration for 1-second period
S_{DS} = five-percent damped design spectral response acceleration at short periods
S_{D1} = five-percent damped design spectral response acceleration at 1-second period
g = gravitational acceleration, approximately 9.8 m/sec^2 or 32.2 ft/sec^2

Corrosion and Cement Type:

A representative sample of the soil from boring B-2 was tested to evaluate the potential for the on-site soils to corrode buried metal and/or concrete. The sample was tested for pH, electrical resistivity, and soluble sulfates. Results of these tests are summarized in the following table.

Corrosivity Test Results					
Sample No.	**Boring No.**	**Sample Depth (ft)**	**pH**	**Resistivity (ohm-cm)**	**Sulfates (% by weight)**
11227	B-1	3.0	8.07	1,200	0.04

Corrosion of Concrete:

The soluble sulfate content of the sample tested was 0.04 percent (by weight), which may be characterized as having mild potential for corrosion (IBC Table 1904.3). According to the American Concrete Institute Building Code 318, when the sulfate content is less than 0.1 percent by weight in soil there are no restrictions placed on the cement type to be used. All concrete should be designed, mixed, placed, finished, and cured in accordance with the guidelines presented by the American Concrete Institute (ACI).

Corrosion of Metals:

Corrosion of buried ferrous metals can occur when electrical current flows from the metal into the soil. As the resistivity of the soil decreases, the flow of electrical current increases, increasing the potential for corrosion. A commonly accepted correlation between soil resistivity and corrosion of ferrous metals is shown in the following table.

Resistivity (ohm-cm)	Corrosivity
0 to 1,000	Severely Corrosive
1,000 to 2,000	Corrosive
2,000 to 10,000	Moderately Corrosive
>10,000	Mildly Corrosive

The sample tested had a resistivity value of 1,200 ohm-cm. Based on these laboratory results and the table above, the on-site soils would be characterized as corrosive toward ferrous metals. The potential for corrosion should be accounted for during the design process. If using metals resistant to these corrosive conditions presents an economic consideration for this project, we recommend performing a field resistivity test to compare to the laboratory test.

Lateral Earth Pressures:

For soils above any free water surface, recommended equivalent fluid pressures for unrestrained foundation elements are presented in the following table:

- **Active:**
  Granular soil backfill .... 35 psf/ft
  Undisturbed subsoil ....30 psf/ft

- **<u>Passive</u>:**
  Shallow foundation walls ....250 psf/ft
  Shallow column footings....................……………..........350 psf/ft

- **<u>Coefficient of base friction</u>**: 0.40
  The coefficient of base friction should be reduced to 0.30 when used in conjunction with passive pressure.

Where the design includes restrained elements, the following equivalent fluid pressures are recommended:

- **At rest:**
  Granular soil backfill ....50 psf/ft
  Undisturbed subsoil...60 psf/ft

Fill against grade beams and retaining walls should be compacted to densities specified in **Earthwork**. Medium to high plasticity clay soils should not be used as backfill against retaining walls. Compaction of each lift adjacent to walls should be accomplished with hand-operated tampers or other lightweight compactors. Over compaction may cause excessive lateral earth pressures that could result in wall movement.

Pavement Design and Construction:

We are presenting options for both flexible (asphalt) and rigid (concrete) pavement sections. We are also presenting a heavy-duty rigid pavement section for areas that will be subjected to heavy, sustained, concentrated loads, such as dumpster and truck loading areas.

Design of pavements for the project has been based on the procedures outlined in the Guideline for Design of Pavement Structures by the American Association of State Highway and Transportation Officials (AASHTO), and on the Guide for the Design and Construction of Concrete Parking Lots by the American Concrete Institute (ACI 330). An estimated R-value of 47 was used in determination of pavement sections.

Traffic information for the project was not available at the time of this report. The paving section recommendations contained herein are based on routine access by lightly loaded vehicles. GEOMAT should be contacted to review our recommendations and make appropriate modifications should plans be made for access by heavier vehicles or traffic information become available.

The recommended pavement sections are presented in the tables below.

Recommended Pavement Sections for Light Vehicle Parking Areas			
Option	**Hot Mix Asphalt** (inches)	**Aggregate Base Course** (inches)	**Portland Cement Concrete** (inches)
Asphalt	3.0	6.0	--
Concrete	--	--	4.5

Recommended Heavy Duty Pavement Section	
Portland Cement Concrete (inches)	**Aggregate Base Course** (inches)
6.5	0.0

*Construction Recommendations for **Asphalt and Concrete** Pavements:*

In paved areas, the exposed ground surface should be scarified to a minimum depth of 8 inches and watered as necessary to bring the upper 1.0 foot to within ±2 percent of optimum moisture content and compacted to a minimum of 95 percent of ASTM D1557 maximum dry density prior to placement of fill or construction of pavement sections.

After preparation of the pavement subgrade, the areas to be paved should be proof-rolled under the observation of a representative of GEOMAT. The proof-rolling should be conducted utilizing a fully loaded, single axle water truck with a minimum 2,000 gallon capacity or other vehicle that will provide an equivalent weight on the subgrade. The proof-rolling should consist of driving the truck across all the areas to be paved with asphalt at a slow speed (less than 5 mph) and observing any deflections or distress caused to the subgrade. Areas that show distress should be repaired by removing and replacing the soft material with suitable fill.

Asphalt Pavements:

Aggregate base course should conform to Section 303 of the 2008 Arizona Department of Transportation (ADOT) "*Standard Specifications for Road and Bridge Construction.*" ('ADOT specifications").

Aggregate base course should be placed in lifts not exceeding six inches and should be compacted to a minimum of 95% Modified Proctor density (ASTM D-1557), within a moisture content range of 4 percent below, to 2 percent above optimum. In any areas where base course thickness exceeds 6 inches, the material should be placed and compacted in two or more lifts of equal thickness.

If the hot-mix asphalt (HMA) is placed in more than one mat, the surface of each underlying mat should be treated with a tack coat immediately prior to placement of the subsequent mat of hot-mix asphalt.

Asphalt concrete should be obtained from an engineer-approved mix design prepared in accordance with ADOT specifications. The hot-mix paving should be placed and compacted in accordance with ADOT specifications.

Concrete Pavements:

Concrete should be placed directly on the prepared subgrade or on aggregate base course as indicated above. Reinforcing steel is not required or recommended for rigid pavement sections. Concrete used for pavement sections should have a minimum 28-day compressive strength of 4,000 pounds per square inch (psi). Concrete materials and placement should be in accordance with recommendations in the latest edition of ACI-330R of the American Concrete Institute "*Guide for the Design and Construction of Concrete Parking Lots*".

General Pavement Considerations:

The performance of the recommended pavement sections can be enhanced by minimizing excess moisture that can reach the subgrade soils. The following recommendations should be considered at minimum:

- Site grading at a minimum 2% grade away from the pavements;
- Compaction of any utility trenches to the same criteria as the pavement subgrade.

The recommended pavement sections are considered minimal sections based on the anticipated traffic volumes and the subgrade conditions encountered during our exploration. They are expected to perform adequately when used in conjunction with preventive maintenance and good drainage. Preventive maintenance activities are intended to slow the rate of pavement deterioration and to preserve the pavement investment.

Slopes:

Assuming fill specifications, compaction requirements, and recommended setbacks provided in this report are followed, cut and fill slopes as steep as to 2.5:1 (horizontal:vertical) should be stable. Depending upon specific project conditions, adequate factors of safety against slope failure may be available for steeper configurations. However, such a determination would require additional analysis.

Earthwork:

General Considerations:

The opinions contained in this report for the proposed construction are contingent upon compliance with recommendations presented in this section. Although underground facilities such as foundations, septic tanks, cesspools, basements and irrigation systems were not encountered during site reconnaissance, such features could exist and might be encountered during construction.

Site Clearing:

1. Strip and remove all existing pavement, fill, debris and other deleterious materials from the proposed construction area. Any existing structures should be completely removed from below any building, including foundation elements and any associated development such as underground utilities, septic tanks, etc. All exposed surfaces below footings and slabs should be free of mounds and depressions which could prevent uniform compaction.

2. If unexpected fills or underground facilities are encountered during site clearing, we should be contacted for further recommendations. All excavations should be observed by GEOMAT prior to backfill placement.

3. Stripped materials consisting of vegetation and organic materials should be removed from the site, or used to re-vegetate exposed slopes after completion of grading operations. If it is necessary to dispose of organic materials on-site, they should be placed in non-structural areas, and in fill sections not exceeding 5 feet in height.

4. Sloping areas steeper than 5:1 (horizontal:vertical) should be benched to reduce the potential for slippage between existing slopes and fills. Benches should be level and wide enough to accommodate compaction and earth moving equipment.

5. All exposed areas which will receive fill, once properly cleared and benched where necessary, should be scarified to a minimum depth of eight inches, conditioned to near optimum moisture content, and compacted to at least 95% of modified proctor (ASTM D1557).

Excavation:

1. We present the following general comments regarding our opinion of the excavation conditions for the designers' information with the understanding that they are opinions based on our boring data. More accurate information regarding the excavation conditions should be evaluated by contractors or other interested parties from test excavations using the equipment that will be used during construction. Based on our subsurface evaluation it appears that excavations in soils at the site will be possible using standard excavation equipment.

2. On-site soils may pump or become unstable or unworkable at high water contents, especially for excavations near the water table. Dewatering may be necessary to achieve a stable excavation. Workability may be improved by scarifying and drying. Over-excavation of wet zones and replacement with granular materials may be necessary. Lightweight excavation equipment may be required to reduce subgrade pumping.

Slab Subgrade Preparation:

1. After site clearing is complete, the existing soil below the building area should be prepared as recommended in the **Floor Slab Design and Construction** and **Site Clearing** sections of this report. Soils should be removed to provide at least a two (2.0) foot thickness of compacted soil and base course below the floor slab.

2. A minimum 4-inch layer of aggregate base course should be placed beneath floor slabs on grade.

Foundation Preparation:

Footings should bear on engineered fill as recommended in the **Foundations** section of this report. All loose and/or disturbed soils should either be compacted or removed from the bottoms of footing excavations prior to placement of reinforcing steel and/or concrete.

Fill Materials:

1. Based upon the conditions encountered and tested, it is anticipated that the native sandy soils will be suitable for use as structural (engineered) fill. However, clayey soils were also encountered in areas of the site that will not be suitable for engineered fill. Periodic testing should be performed during construction to confirm the suitability of the native soils for use as structural (engineered) fill per the recommended requirements given below. It is the responsibility of the contractor to determine the appropriate methods for providing suitable engineered fill prior to bidding the work.
   - general site grading
   - foundation areas
   - interior floor slab areas
   - foundation backfill
   - exterior slab areas
   - pavement areas

2. Select granular materials should be used as backfill behind walls that retain earth.

3. On site or imported soils to be used in structural fills should conform to the following:

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

Maximum expansive potential (%)* 1.5

* Measured on a sample compacted to approximately 95 percent of the ASTM D1557 maximum dry density at about 3 percent below optimum water content. The sample is confined under a 144-psf surcharge and submerged.

4. Aggregate base should conform to Class I Aggregate Base as specified in Section 303 of the 2008 Arizona Department of Transportation (ADOT) *"Standard Specifications for Road and Bridge Construction."*

Placement and Compaction:

1. Place and compact fill in horizontal lifts, using equipment and procedures that will produce recommended moisture contents and densities throughout the lift.

2. Un-compacted fill lifts should not exceed 10 inches loose thickness.

3. Materials should be compacted to the following:

Material	**Minimum Percent (ASTM D1557)**
Subgrade soils beneath fill areas	95
On site or imported soil fills:	
Beneath footings, slabs on grade and pavements	95
Aggregate base beneath slabs and pavements	95
Miscellaneous backfill	90

4. On-site and imported soils should be compacted at moisture contents near optimum.

Compliance:

Recommendations for slabs-on-grade and foundation elements supported on compacted fills depend upon compliance with **Earthwork** recommendations. To assess compliance, observation and testing should be performed by GEOMAT.

Drainage:

Surface Drainage:

1. Positive drainage should be provided during construction and maintained throughout the life of the proposed project. Infiltration of water into utility or foundation excavations must be prevented during construction. Planters and other surface features that could retain water should not be placed in areas adjacent to the building.

2. We recommend that the area surrounding the building be paved. Protective slopes having a minimum grade of approximately 5 percent should be provided for at least 10 feet from perimeter walls. Backfill against footings, exterior walls, and in utility and sprinkler line trenches should be well compacted and free of all construction debris to reduce the possibility of moisture infiltration.

3. Downspouts, roof drains or scuppers should discharge a minimum of 10 feet from the building. The drainage system should be inspected and maintained periodically to ensure that it discharges water away from the building as intended.

4. Irrigated landscaping should not be placed within 10 feet of the building perimeter.

Subsurface Drainage:

Free-draining, granular soils containing less than five percent fines (by weight) passing a No. 200 sieve should be placed adjacent to walls which retain earth. A drainage system consisting of either weep holes or perforated drain lines (placed near the base of the wall) should be used to intercept and discharge water which would tend to saturate the backfill. Where used, drain lines should be embedded in a uniformly graded filter material and provided with adequate clean-outs for periodic maintenance. An impervious soil should be used in the upper layer of backfill to reduce the potential for water infiltration.

GENERAL COMMENTS

It is recommended that GEOMAT be retained to provide a general review of final design plans and specifications in order to confirm that grading and foundation recommendations in this report have been interpreted and implemented. In the event that any changes of the proposed project are planned, the opinions and recommendations contained in this report should be reviewed and the report modified or supplemented as necessary.

GEOMAT should also be retained to provide services during excavation, grading, foundation, and construction phases of the work. Observation of footing excavations should be performed prior to placement of reinforcing and concrete to confirm that satisfactory bearing materials are present and is considered a necessary part of continuing geotechnical engineering services for the project. Construction testing, including field and laboratory evaluation of fill, backfill, pavement materials, concrete and steel should be performed to determine whether applicable project requirements have been met.

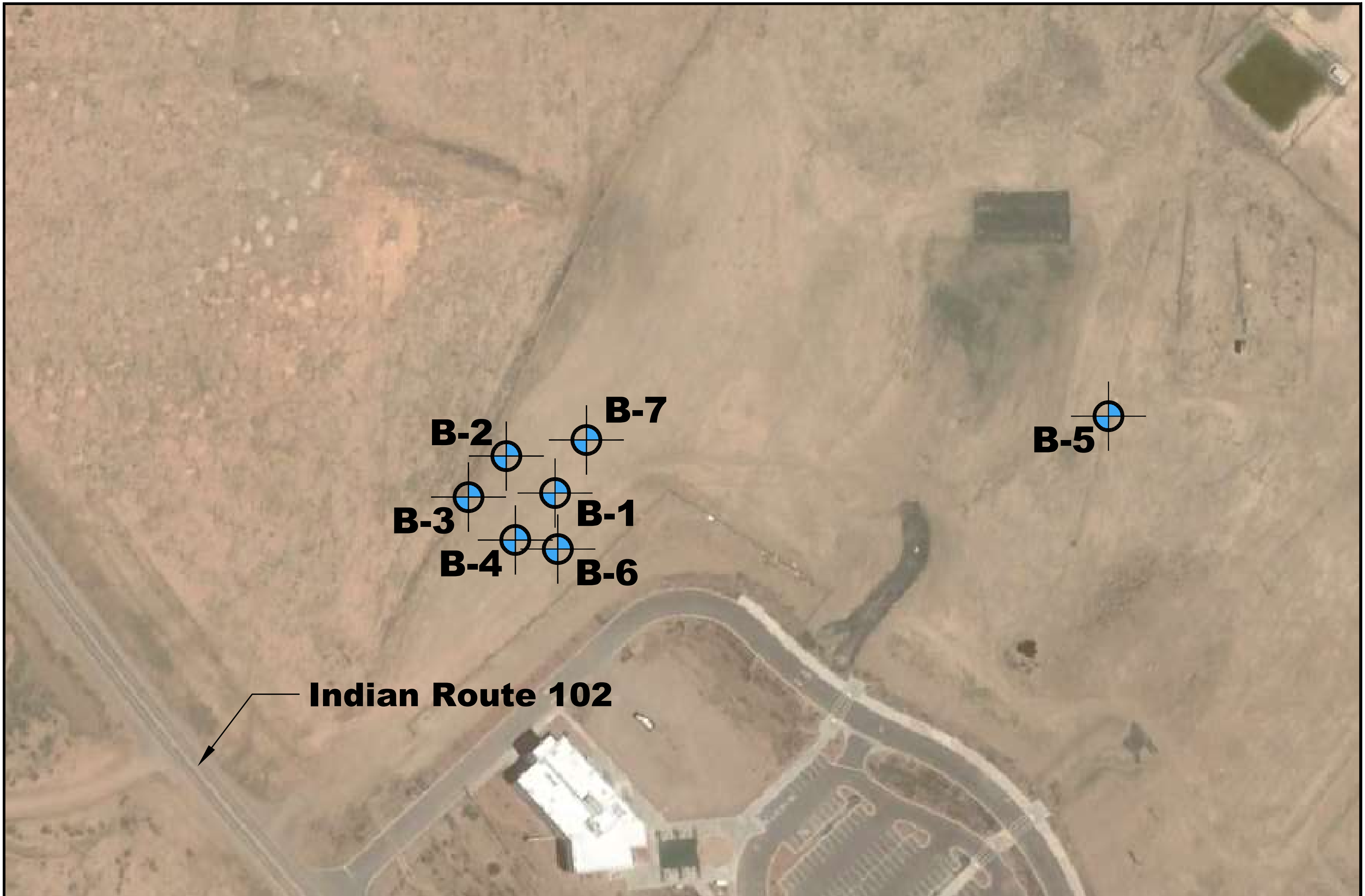
The analyses and recommendations in this report are based in part upon data obtained from the field exploration. The nature and extent of variations beyond the location of test borings may not become evident until construction. If variations then appear evident, it may be necessary to re-evaluate the recommendations of this report.

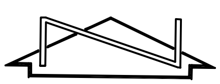
Our professional services were performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical engineers practicing in this or similar localities at the same time. No warranty, express or implied, is intended or made. We prepared the report as an aid in design of the proposed project. This report is not a bidding document. Any contractor reviewing this report must draw his own conclusions regarding site conditions and specific construction equipment and techniques to be used on this project.

This report is for the exclusive purpose of providing geotechnical engineering and/or testing information and recommendations. The scope of services for this project does not include, either specifically or by implication, any environmental assessment of the site or identification of contaminated or hazardous materials or conditions. If the owner is concerned about the potential for such contamination, other studies should be undertaken. This report has also not addressed any geologic hazards that may exist on or near the site.

This report may be used only by the Client and only for the purposes stated, within a reasonable time from its issuance. Land use, site conditions (both on and off site), or other factors may change over time and additional work may be required with the passage of time. Any party, other than the Client, who wishes to use this report, shall notify GEOMAT in writing of such intended use. Based on the intended use of the report, GEOMAT may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements, by the Client or anyone else, will release GEOMAT from any liability resulting from the use of this report by an unauthorized party.

Appendix A





SITE PLAN	PROJECT
Boring Locations (approximate)	NTU Navajo Center for the Environment and Laboratory Chinle, Arizona
GEOMAT Project No. 222-4248 Date of Exploration: November 28, 2022	

GEOMAT INC.

GEOMAT INC.
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Fax (505) 326-5721

Boring B-1

Project Name:	NTU Lab	Date Drilled:	11/28/2022
Project Number:	222-4248	Latitude:	Not Determined
Client:	DMA	Longitude:	Not Determined
Site Location:	Chinle, Arizona	Elevation:	Not Determined
Rig Type:	CME-55	Boring Location:	See Site Plan
Drilling Method:	7.25" O.D. Hollow Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Bulk, Ring and Split spoon samples	Logged By:	DH
Hammer Weight:	140 lbs	Remarks:	None
Hammer Fall:	30 inches		

Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Material Type	Depth (ft)	Soil Description
						SM	1	Silty SAND, tan with brown, fine- to coarse-grained, very loose to medium dense, slightly damp to damp
103.9			4.4	5-6	GRAB R		3	
				6-7-6	SS		5–7	clay layer, brown with white, calcium carbonation, slightly damp
93.3			4.5	7-15	R		10–11	reddish tan to tan
				6-5-6	SS		15–16	pockets of clay, gray with red and white
				9-15	R		20	
						CL	23	Sandy Lean CLAY, brown with white, very stiff, slightly damp
	63	10		7-9-11	SS		25–26	slight calcium carbonation
						SM	27	Silty SAND, tan, fine- to coarse-grained, loose to medium dense, slightly damp
				10-13	R		30–32	red to tan clay lense
				6-10-15	SS		35	
						SC	38	Clayey SAND, reddish brown, fine- to coarse-grained, slightly damp
99.2			4.4	6-10	R	SM	40	Silty SAND, tan, fine- to coarse-grained, loose to medium dense, slightly damp to damp
				4-4-7	SS		45–46	damp
							46 ½	Total Depth 46 ½ feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample SH = Shelby Tube Sampler

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Boring B-2

Project Name:	NTU Lab	Date Drilled:	11/28/2022
Project Number:	222-4248	Latitude:	Not Determined
Client:	DMA	Longitude:	Not Determined
Site Location:	Chinle, Arizona	Elevation:	Not Determined
Rig Type:	CME-55	Boring Location:	See Site Plan
Drilling Method:	7.25" O.D. Hollow Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Ring and Split spoon samples	Logged By:	DH
Hammer Weight:	140 lbs	Remarks:	None
Hammer Fall:	30 inches		

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Material Type	Depth (ft)	Soil Description
						SM	1–2	Silty SAND, tannish brown to tan, fine- to coarse-grained, loose to medium dense, slighty damp to damp
				7-7-8	SS	SM	3–4	clay layer, brown with white, slight calcium carbonation, slightly damp
95.1			4.6	7-9	R	SM	5–6	
						SM	7	pockets of clay, brown and gray
						CL	8	Sandy Lean CLAY, brown and gray, slightly damp
						SM	9–10	Silty SAND, tannish brown, fine- to coarse-grained, loose to medium dense, slightly damp
				7-10-11	SS	SM	11	reddish tan
99.3			1.3	8-10	R	SM	16	tan
				10-7-10	SS	SM	20–21	
						SM	22	clay lense
				8-14	R	SM	25–26	
				11-11-11	SS	SM	31	interlayered with clay, red to tan, fine- to coarse-grained, slightly damp
							33	Total Depth 31 ½ feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample SH = Shelby Tube Sampler

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Boring B-3

Project Name:	NTU Lab	Date Drilled:	11/28/2022
Project Number:	222-4248	Latitude:	Not Determined
Client:	DMA	Longitude:	Not Determined
Site Location:	Chinle, Arizona	Elevation:	Not Determined
Rig Type:	CME-55	Boring Location:	See Site Plan
Drilling Method:	7.25" O.D. Hollow Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Bulk, Ring and Split spoon samples	Logged By:	DH
Hammer Weight:	140 lbs	Remarks:	None
Hammer Fall:	30 inches		

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Material Type	Depth (ft)	Soil Description
	24	NP			A	SM	1–2	Silty SAND, tan, fine- to coarse-grained, loose to medium dense, slightly damp to damp
				6-8	R		3	
				4-7-6	SS		5–6	clay lense
						CL	9	Sandy Lean CLAY, brown, slightly damp
				7-13	R	SM	10–11	Silty SAND, tan, fine- to coarse-grained, loose to medium dense, slightly damp
100.6			2.4	7-12	R		15–16	
106.5			3.2	9-22	R		20–21	
							24	clay lense
				10-10-13	SS		25–26	
						CL	27	Sandy Lean CLAY, brown, slightly damp
						SM	28–30	Silty SAND, tan, fine- to coarse-grained, slighlty damp
				8-10	R	CL	31	Sandy Lean CLAY, brown, stiff, slightly damp to damp
							32	Total Depth 31 feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample SH = Shelby Tube Sampler

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Boring B-4

Project Name:	NTU Lab	Date Drilled:	11/28/2022
Project Number:	222-4248	Latitude:	Not Determined
Client:	DMA	Longitude:	Not Determined
Site Location:	Chinle, Arizona	Elevation:	Not Determined
Rig Type:	CME-55	Boring Location:	See Site Plan
Drilling Method:	7.25" O.D. Hollow Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Bulk, Ring and Split spoon samples	Logged By:	DH
Hammer Weight:	140 lbs	Remarks:	None
Hammer Fall:	30 inches		

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Material Type	Depth (ft)	Soil Description
						SC	1–2	Clayey SAND, tannish brown, fine- to coarse-grained, slightly damp to damp
				5-5-3	SS	SM	3–4	Silty SAND, tan, fine- to coarse-grained, loose to medium dense, slighlty damp
105.1			6.8	7-8	R		6	clay lense, gray with black and red
							7	tan to reddish tan
							9	clay lense
				5-7-9	SS		11	tan
103.9			1.7	10-16	R		16	
				6-9-8	SS		21	clay lense
				8-11	R		26	
					GRAB	CL	27–28	Sandy Lean CLAY, brown, slightly damp
						SM	28–30	Silty SAND, tannish brown, fine- to coarse-grained, slighlty damp
				7-9-11	SS	CL	30–31½	Sandy Lean CLAY, tannish brown to tannish red, slight calcium carbonation, very stiff slightly damp
								Total Depth 31 ½ feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample SH = Shelby Tube Sampler

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Boring B-5

Project Name:	NTU Lab	Date Drilled:	11/28/2022
Project Number:	222-4248	Latitude:	Not Determined
Client:	DMA	Longitude:	Not Determined
Site Location:	Chinle, Arizona	Elevation:	Not Determined
Rig Type:	CME-55	Boring Location:	See Site Plan
Drilling Method:	7.25" O.D. Hollow Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Bulk, Ring and Split spoon samples	Logged By:	DH
Hammer Weight:	140 lbs	Remarks:	None
Hammer Fall:	30 inches		

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Material Type	Depth (ft)	Soil Description
					A	SM	1–2	Silty SAND, tan, fine- to coarse-grained, loose to medium dense, slightly damp
95.8			2.7	7-7	R	SM	3	
				5-7-7	SS	SM	5–6	
				5-8	R	SM	11	trace white
101.0			10.3	10-19	R	CL	12	Sandy Lean CLAY, brown with trace white, slight calcium carbonation, very stiff, slightly damp
						SM	13–15	Silty SAND, tannish brown, fine- to coarse-grained, loose to medium dense, slightly damp
				6-9-9	SS	SM	16	clay lense
						SM	17	clay lense
				6-10	R	SM	21	
	45	19			GRAB	SC	23–24	Clayey SAND, brown, fine- to medium-grained, slightly damp
				6-9-10	SS	SM	25–26	Silty SAND, tan, fine- to coarse-grained, loose to medium dene, slightly damp
						SM	27	clay layer
				5-10	R	SM	31	
							32	Total Depth 31 feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample SH = Shelby Tube Sampler

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Boring B-6

Project Name:	NTU Lab	Date Drilled:	11/28/2022
Project Number:	222-4248	Latitude:	Not Determined
Client:	DMA	Longitude:	Not Determined
Site Location:	Chinle, Arizona	Elevation:	Not Determined
Rig Type:	CME-55	Boring Location:	See Site Plan
Drilling Method:	7.25" O.D. Hollow Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Bulk sample from auger cuttings	Logged By:	DH
Hammer Weight:	N/A	Remarks:	None
Hammer Fall:	N/A		

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Symbol	Material Type	Soil Symbol	Depth (ft)	Soil Description
	23	2			GRAB		SM		0–5	Silty SAND, tan, fine- to coarse-grained, slightly damp
									5–10	Total Depth 5 feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample SH = Shelby Tube Sampler

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Boring B-7

Project Name:	NTU Lab	Date Drilled:	11/28/2022
Project Number:	222-4248	Latitude:	Not Determined
Client:	DMA	Longitude:	Not Determined
Site Location:	Chinle, Arizona	Elevation:	Not Determined
Rig Type:	CME-55	Boring Location:	See Site Plan
Drilling Method:	7.25" O.D. Hollow Stem Auger	Groundwater Depth:	None Encountered
Sampling Method:	Bulk sample from auger cuttings	Logged By:	DH
Hammer Weight:	N/A	Remarks:	None
Hammer Fall:	N/A		

Laboratory Results: Dry Density (pcf)	% Passing #200 Sieve	Plasticity Index	Moisture Content (%)	Blows per 6"	Sample Type & Length (in)	Symbol	Material Type	Soil Symbol	Depth (ft)	Soil Description
							SM		0–2.5	Silty SAND, tan to brown, fine- to coarse-grained, slightly damp to damp
					GRAB				~2.2	
					GRAB		CL		2.5–4	Sandy Lean CLAY, gray with black and brown, slightly damp
							SM		4–5	Silty SAND, tan, fine- to coarse-grained, slightly damp
									5	Total Depth 5 feet

A = Auger Cuttings R = Ring-Lined Barrel Sampler SS = Split Spoon GRAB = Manual Grab Sample D = Disturbed Bulk Sample SH = Shelby Tube Sampler

UNIFIED SOIL CLASSIFICATION SYSTEM				
Major Divisions			Group Symbols	Typical Names
Coarse-Grained Soils More than 50% retained on No. 200 sieve	**Gravels** 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		Gravels with Fines	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean Sands	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		Sands with Fines	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
Fine-Grained Soils 50% or more passes No. 200 sieve	**Silts and Clays** Liquid Limit 50 or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays Liquid Limit greater than 50		MH	Inorganic silts, micaceous or diatomaceous free sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly Organic Soils			PT	Peat, mucic & other highly organic soils

CONSISTENCY OR RELATIVE DENSITY CRITERIA

Standard Penetration Test
Density of Granular Soils

Penetration Resistance, N (blows/ft.)	Relative Density
0-4	Very Loose
5-10	Loose
11-30	Medium Dense
31-50	Dense
>50	Very Dense

Standard Penetration Test
Density of Fine-Grained Soils

Penetration Resistance, N (blows/ft.)	Consistency	Unconfined Compressive Strength (Tons/ft2)
<2	Very Soft	<0.25
2-4	Soft	0.25-0.50
4-8	Firm	0.50-1.00
8-15	Stiff	1.00-2.00
15-30	Very Stiff	2.00-4.00
>30	Hard	>4.0

U.S. Standard Sieve Sizes

>12"	12"	3"	3/4"	#4	#10	#40	#200	
Boulders	Cobbles	Gravel		Sand			Silt or Clay	
		coarse	fine	coarse	medium	fine		

MOISTURE CONDITIONS

Dry	Absence of moist, dusty, dry to the touch
Slightly Damp	Below optimum moisture content for compaction
Moist	Near optimum moisture content, will moisten the hand
Very Moist	Above optimum moisture content
Wet	Visible free water, below water table

MATERIAL QUANTITY

trace	0-5%
few	5-10%
little	10-25%
some	25-45%
mostly	50-100%

OTHER SYMBOLS

R Ring Sample
S SPT Sample
B Bulk Sample
▼ Ground Water

BASIC LOG FORMAT:
Group name, Group symbol, (grain size), color, moisture, consistency or relative density. Additional comments: odor, presence of roots, mica, gypsum, coarse particles, etc.

EXAMPLE:
SILTY SAND w/trace silt (SM-SP), Brown, loose to med. Dense, fine to medium grained, damp

UNIFIED SOIL CLASSIFICATION SYSTEM

TEST DRILLING EQUIPMENT & PROCEDURES

Description of Subsurface Exploration Methods

Drilling Equipment – Truck-mounted drill rigs powered with gasoline or diesel engines are used in advancing test borings. Drilling through soil or softer rock is performed with hollow-stem auger or continuous flight auger. Carbide insert teeth are normally used on bits to penetrate soft rock or very strongly cemented soils which require blasting or very heavy equipment for excavation. Where refusal is experienced in auger drilling, the holes are sometimes advanced with tricone gear bits and NX rods using water or air as a drilling fluid.

Coring Equipment – Portable electric core drills are used when recovery of asphalt or concrete cores is necessary. The core drill is equipped with either a 4" or 6" diameter diamond core barrel. Water is generally used as a drilling fluid to facilitate cooling and removal of cuttings from the annulus.

Sampling Procedures - Dynamically driven tube samples are usually obtained at selected intervals in the borings by the ASTM D1586 test procedure. In most cases, 2" outside diameter, 1 3/8" inside diameter, samplers are used to obtain the standard penetration resistance. "Undisturbed" samples of firmer soils are often obtained with 3" outside diameter samplers lined with 2.42" inside diameter brass rings. The driving energy is generally recorded as the number of blows of a 140-pound, 30-inch free fall drop hammer required to advance the samplers in 6-inch increments. These values are expressed in blows per foot on the boring logs. However, in stratified soils, driving resistance is sometimes recorded in 2- or 3-inch increments so that soil changes and the presence of scattered gravel or cemented layers can be readily detected and the realistic penetration values obtained for consideration in design. "Undisturbed" sampling of softer soils is sometimes performed with thin-walled Shelby tubes (ASTM D1587). Tube samples are labeled and placed in watertight containers to maintain field moisture contents for testing. When necessary for testing, larger bulk samples are taken from auger cuttings. Where samples of rock are required, they are obtained by NX diamond core drilling (ASTM D2113).

Boring Records - Drilling operations are directed by our field engineer or geologist who examines soil recovery and prepares boring logs. Soils are visually classified in accordance with the Unified Soil Classification System (ASTM D2487), with appropriate group symbols being shown on the logs.

Appendix B

LAB NO.	BORING / TEST PIT	SAMPLE DEPTH (ft)	ASTM D1557		MOISTURE CONT. (%)	DENSITY		SIEVE ANALYSIS, CUMULATIVE PERCENT PASSING											ATTERBERG LIMITS			SWELL (%)	CONSOL TEST	CLASSIFICATION
			Density	Moisture		WET (pcf)	DRY (pcf)	1/2"	3/8"	No. 4	No. 8	No. 10	No. 16	No. 30	No. 40	No. 50	No. 100	No. 200	LL	PL	PI			
11227*	B-1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Silty **SAND** (SM)
11228	B-1	2.5	-	-	4.4	108.5	103.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Silty **SAND** (SM)
11229	B-1	10	-	-	4.5	97.5	93.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Attached	Siilty **SAND** (SM)
11230	B-1	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	63	26	16	10	-	-	Sandy Lean **CLAY** (CL)
11231	B-1	40	-	-	4.4	103.5	99.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Silty **SAND** (SM)
11232	B-2	5	-	-	4.6	99.5	95.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Attached	Silty **SAND** (SM)
11233	B-2	15	-	-	1.3	100.6	99.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Silty **SAND** (SM)
11234	B-3	0 TO 5	120.5	11.3	-	-	-	100	100	100	100	100	100	98	97	95	75	24	NLL	NPL	NP	0	-	Silty **SAND** (SM)
11235	B-3	15	-	-	2.4	103.0	100.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Attached	Silty **SAND** (SM)
11236	B-3	20	-	-	3.2	109.9	106.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Silty **SAND** (SM)
11237	B-4	5	-	-	6.8	112.3	105.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Silty **SAND** (SM)
11238	B-4	15	-	-	1.7	105.6	103.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Silty **SAND** (SM)
11239	B-5	2.5	-	-	2.7	98.4	95.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Attached	Silty **SAND** (SM)
11240	B-5	11	-	-	10.3	111.4	101.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Sandy Lean **CLAY** (CL)
11241	B-5	23.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45	33	14	19	-	-	Clayey **SAND** (SC)
11242	B-6	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	21	19	2	-	-	Silty **SAND** (SM)

NLL = No Liquid Limit
NPL = No Plastic Limit
NP = Non-Plastic
* = Corrosivity Sample

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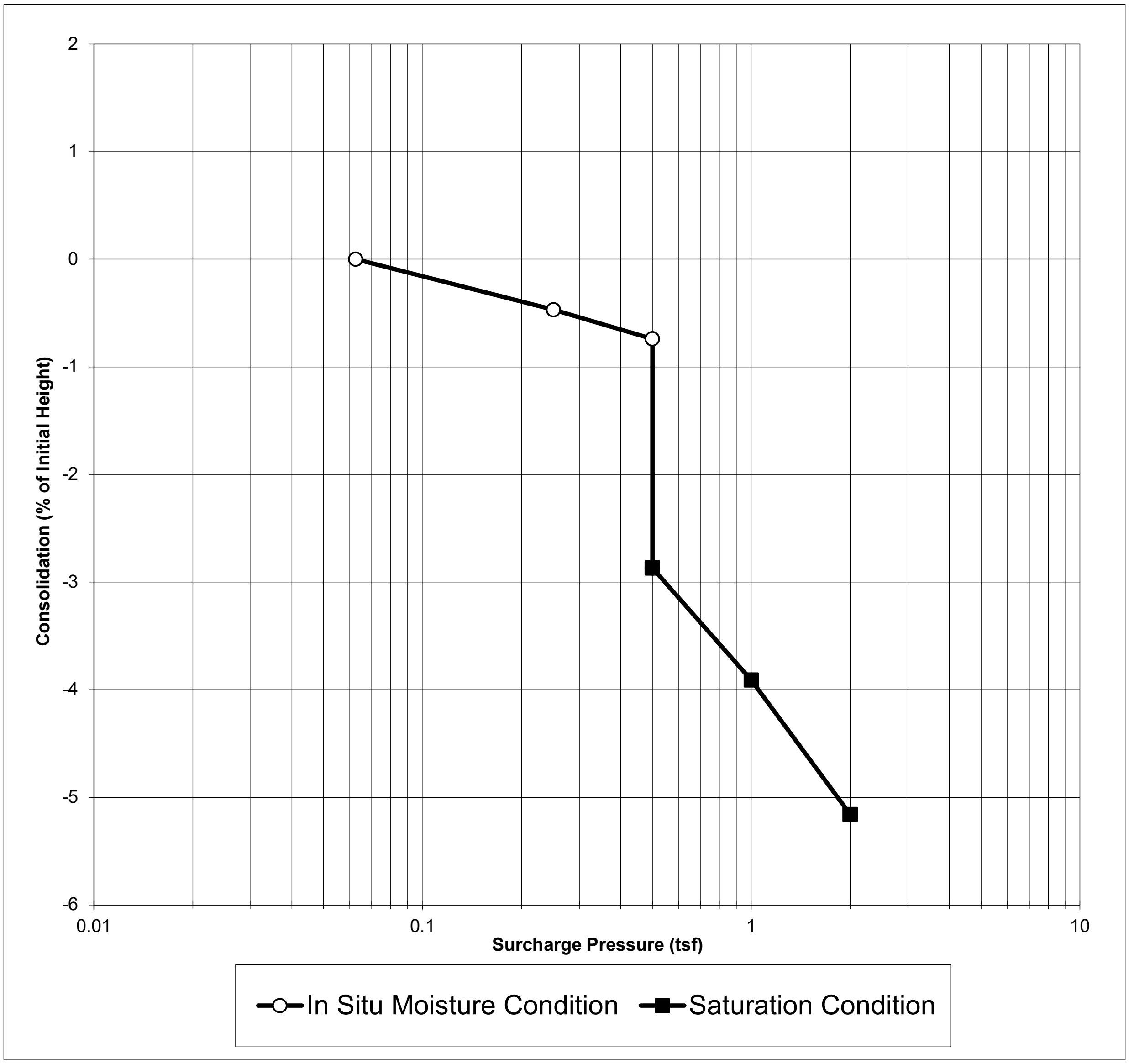
SUMMARY OF SOIL TESTS

Project	NTU Navajo Center for the Environment and Laboratory
Job No.	222-4248
Location	Chinle, Arizona
Date of Exploration	November 28, 2022

PROJECT:	Navajo Center for the Environment and Laboratory	**JOB NO:**	222-4248
CLIENT:	Navajo Technical University	**WORK ORDER NO:**	NA
MATERIAL:	Silty SAND (SM)	**LAB NO:**	11229
SAMPLE SOURCE:	B-1 @ 10'	**DATE SAMPLED:**	11/28/2022
SAMPLE PREP.:	In Situ	**SAMPLED BY:**	DH

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (ASTM D2435)

INITIAL VOLUME (cu.in)	4.60	FINAL VOLUME (cu.in)	4.37
INITIAL MOISTURE CONTENT	4.5%	FINAL MOISTURE CONTENT	21.4%
INITIAL DRY DENSITY(pcf)	93.3	FINAL DRY DENSITY(pcf)	97.9
INITIAL DEGREE OF SATURATION	12%	FINAL DEGREE OF SATURATION	63%
INITIAL VOID RATIO	0.78	FINAL VOID RATIO	0.69
ESTIMATED SPECIFIC GRAVITY	2.651	SATURATED AT	0.5 tsf



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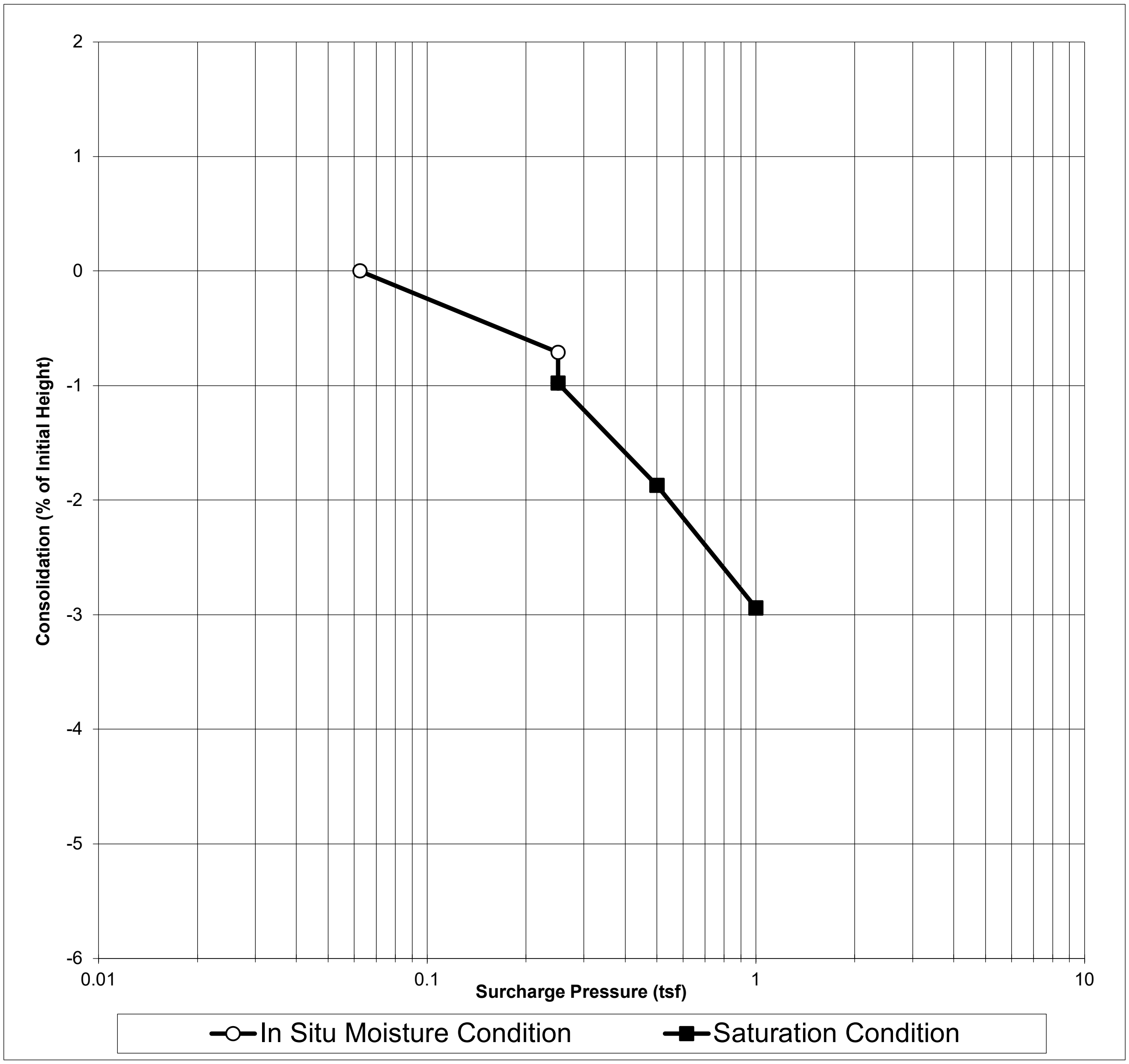
PROJECT:	Navajo Center for the Environment and Laboratory	**JOB NO:**	222-4248
CLIENT:	Navajo Technical University	**WORK ORDER NO:**	NA
MATERIAL:	Silty SAND (SM)	**LAB NO:**	11232
SAMPLE SOURCE:	B-2 @ 5'	**DATE SAMPLED:**	11/28/2022
SAMPLE PREP.:	In Situ	**SAMPLED BY:**	DH

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (ASTM D2435)

INITIAL VOLUME (cu.in)	4.60	FINAL VOLUME (cu.in)	4.47
INITIAL MOISTURE CONTENT	4.6%	FINAL MOISTURE CONTENT	21.4%
INITIAL DRY DENSITY(pcf)	95.1	FINAL DRY DENSITY(pcf)	97.5
INITIAL DEGREE OF SATURATION	13%	FINAL DEGREE OF SATURATION	63%
INITIAL VOID RATIO	0.75	FINAL VOID RATIO	0.70
ESTIMATED SPECIFIC GRAVITY	2.651	SATURATED AT	0.25 tsf



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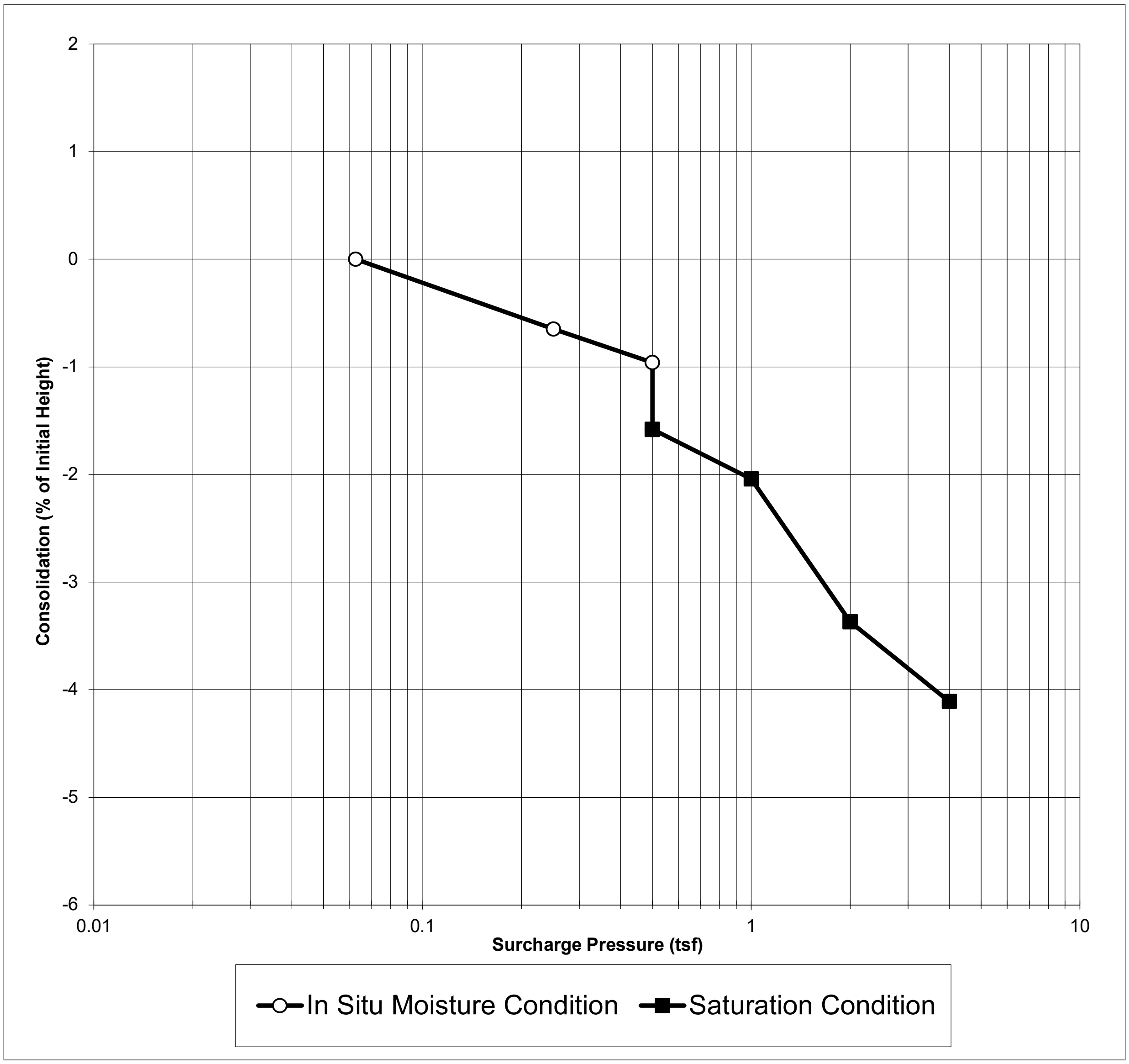
PROJECT:	Navajo Center for the Environment and Laboratory	**JOB NO:**	222-4248
CLIENT:	Navajo Technical University	**WORK ORDER NO:**	NA
MATERIAL:	Silty SAND (SM)	**LAB NO:**	11235
SAMPLE SOURCE:	B-3 @ 15'	**DATE SAMPLED:**	11/28/2022
SAMPLE PREP.:	In Situ	**SAMPLED BY:**	DH

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (ASTM D2435)

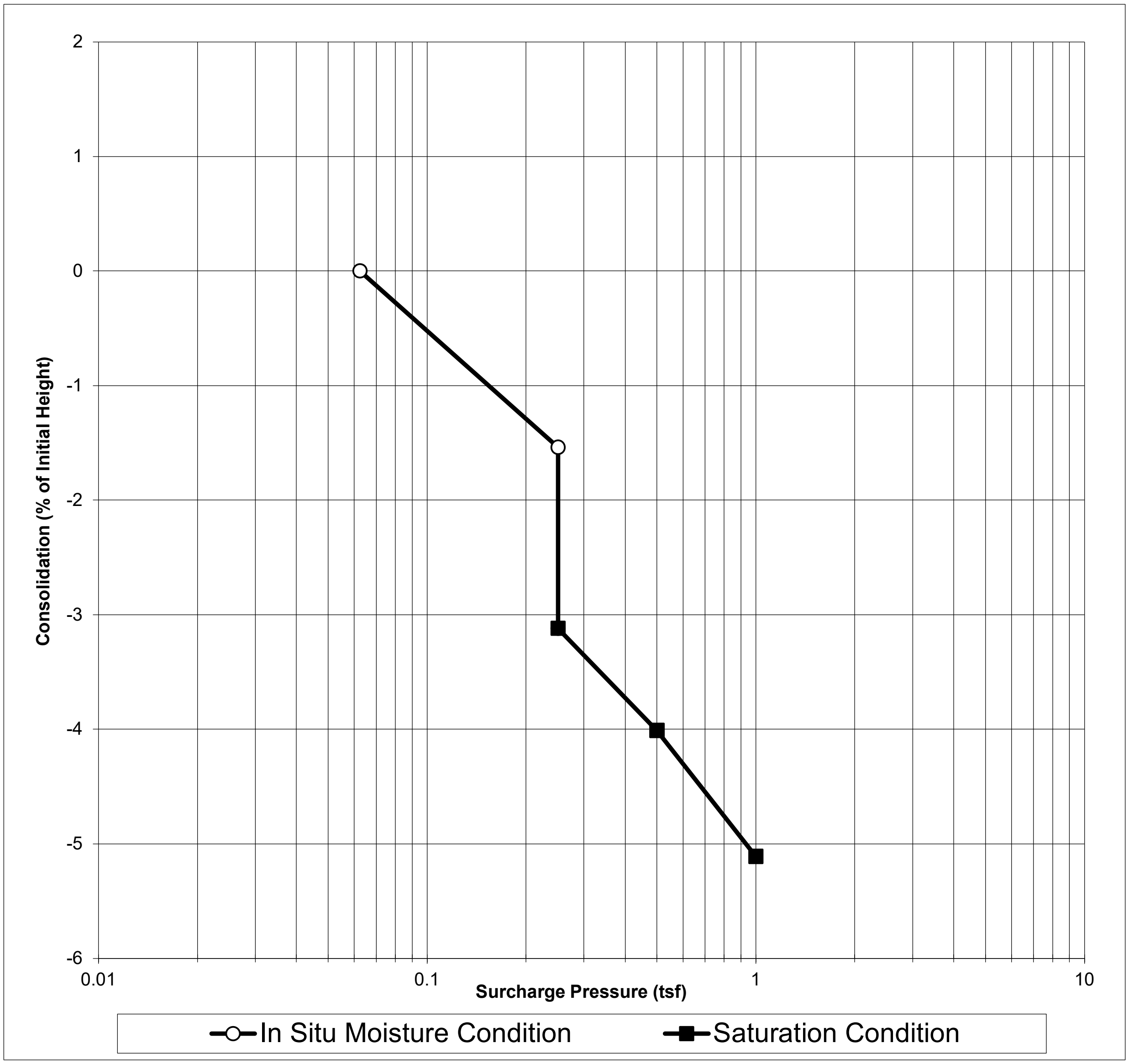
INITIAL VOLUME (cu.in)	4.60	FINAL VOLUME (cu.in)	4.42
INITIAL MOISTURE CONTENT	2.4%	FINAL MOISTURE CONTENT	18.6%
INITIAL DRY DENSITY(pcf)	100.6	FINAL DRY DENSITY(pcf)	104.4
INITIAL DEGREE OF SATURATION	8%	FINAL DEGREE OF SATURATION	62%
INITIAL VOID RATIO	0.65	FINAL VOID RATIO	0.58
ESTIMATED SPECIFIC GRAVITY	2.651	SATURATED AT	0.5 tsf



PROJECT:	Navajo Center for the Environment and Laboratory	**JOB NO:**	222-4248
CLIENT:	Navajo Technical University	**WORK ORDER NO:**	NA
MATERIAL:	Silty SAND (SM)	**LAB NO:**	11239
SAMPLE SOURCE:	B-5 @ 2.5'	**DATE SAMPLED:**	11/28/2022
SAMPLE PREP.:	In Situ	**SAMPLED BY:**	DH

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (ASTM D2435)

INITIAL VOLUME (cu.in)	4.60	FINAL VOLUME (cu.in)	4.37
INITIAL MOISTURE CONTENT	2.7%	FINAL MOISTURE CONTENT	22.6%
INITIAL DRY DENSITY(pcf)	95.8	FINAL DRY DENSITY(pcf)	100.4
INITIAL DEGREE OF SATURATION	8%	FINAL DEGREE OF SATURATION	70%
INITIAL VOID RATIO	0.74	FINAL VOID RATIO	0.65
ESTIMATED SPECIFIC GRAVITY	2.651	SATURATED AT	0.25 tsf



GEOMAT INC.

LABORATORY TESTING PROCEDURES

Laboratory testing is performed by trained personnel in our accredited laboratory or may be subcontracted by GEOMAT through a qualified outside laboratory if necessary. Actual types and quantities of tests performed for any project will be dependent upon subsurface conditions encountered and specific design requirements.

The following is an abbreviated table of laboratory testing that may be performed by GEOMAT with the applicable standards listed. Testing for a specific project may include all or a selected subset of the laboratory work listed. Laboratory testing beyond those listed may be available and could be incorporated into the project scope at the discretion of GEOMAT.

PROCEDURE	ASTM	AASHTO
Moisture Content	ASTM D2216	AASHTO T 265
Sieve Analysis	ASTM C136	AASHTO T 27
Fines Content	ASTM D1140	T 11
Hydrometer	ASTM D422	T 88
Atterberg Limits	ASTM D4318	AASHTO T 89/T 90
Soil Compression/Expansion	ASTM D2435	T 216
Soil Classification	ASTM D2487	M 145
Direct Shear	ASTM D3080	T 236
Unconfined Compressive Strength of Soils	ASTM D2166	T 208
Unconfined Compressive Strength of Rock Cores	ASTM D4543	-

Appendix C

Important Information about This

Geotechnical-Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

The Geoprofessional Business Association (GBA) has prepared this advisory to help you – assumedly a client representative – interpret and apply this geotechnical-engineering report as effectively as possible. In that way, you can benefit from a lowered exposure to problems associated with subsurface conditions at project sites and development of them that, for decades, have been a principal cause of construction delays, cost overruns, claims, and disputes. If you have questions or want more information about any of the issues discussed herein, contact your GBA-member geotechnical engineer. Active engagement in GBA exposes geotechnical engineers to a wide array of risk-confrontation techniques that can be of genuine benefit for everyone involved with a construction project.

Understand the Geotechnical-Engineering Services Provided for this Report

Geotechnical-engineering services typically include the planning, collection, interpretation, and analysis of exploratory data from widely spaced borings and/or test pits. Field data are combined with results from laboratory tests of soil and rock samples obtained from field exploration (if applicable), observations made during site reconnaissance, and historical information to form one or more models of the expected subsurface conditions beneath the site. Local geology and alterations of the site surface and subsurface by previous and proposed construction are also important considerations. Geotechnical engineers apply their engineering training, experience, and judgment to adapt the requirements of the prospective project to the subsurface model(s). Estimates are made of the subsurface conditions that will likely be exposed during construction as well as the expected performance of foundations and other structures being planned and/or affected by construction activities.

The culmination of these geotechnical-engineering services is typically a geotechnical-engineering report providing the data obtained, a discussion of the subsurface model(s), the engineering and geologic engineering assessments and analyses made, and the recommendations developed to satisfy the given requirements of the project. These reports may be titled investigations, explorations, studies, assessments, or evaluations. Regardless of the title used, the geotechnical-engineering report is an engineering interpretation of the subsurface conditions within the context of the project and does not represent a close examination, systematic inquiry, or thorough investigation of all site and subsurface conditions.

Geotechnical-Engineering Services are Performed for Specific Purposes, Persons, and Projects, and At Specific Times

Geotechnical engineers structure their services to meet the specific needs, goals, and risk management preferences of their clients. A geotechnical-engineering study conducted for a given civil engineer will <u>not</u> likely meet the needs of a civil-works constructor or even a different civil engineer. Because each geotechnical-engineering study is unique, each geotechnical-engineering report is unique, prepared *solely* for the client.

Likewise, geotechnical-engineering services are performed for a specific project and purpose. For example, it is unlikely that a geotechnical-engineering study for a refrigerated warehouse will be the same as one prepared for a parking garage; and a few borings drilled during a preliminary study to evaluate site feasibility will <u>not</u> be adequate to develop geotechnical design recommendations for the project.

Do <u>not</u> rely on this report if your geotechnical engineer prepared it:

- for a different client;
- for a different project or purpose;
- for a different site (that may or may not include all or a portion of the original site); or
- before important events occurred at the site or adjacent to it; e.g., man-made events like construction or environmental remediation, or natural events like floods, droughts, earthquakes, or groundwater fluctuations.

Note, too, the reliability of a geotechnical-engineering report can be affected by the passage of time, because of factors like changed subsurface conditions; new or modified codes, standards, or regulations; or new techniques or tools. *If you are the least bit uncertain* about the continued reliability of this report, contact your geotechnical engineer before applying the recommendations in it. A minor amount of additional testing or analysis after the passage of time – if any is required at all – could prevent major problems.

Read this Report in Full

Costly problems have occurred because those relying on a geotechnical-engineering report did not read the report in its entirety. Do <u>not</u> rely on an executive summary. Do <u>not</u> read selective elements only. *Read and refer to the report in full.*

You Need to Inform Your Geotechnical Engineer About Change

Your geotechnical engineer considered unique, project-specific factors when developing the scope of study behind this report and developing the confirmation-dependent recommendations the report conveys. Typical changes that could erode the reliability of this report include those that affect:

- the site's size or shape;
- the elevation, configuration, location, orientation, function or weight of the proposed structure and the desired performance criteria;
- the composition of the design team; or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project or site changes – even minor ones – and request an assessment of their impact. *The geotechnical engineer who prepared this report cannot accept* *responsibility or liability for problems that arise because the geotechnical engineer was not informed about developments the engineer otherwise would have considered.*

Most of the "Findings" Related in This Report Are Professional Opinions

Before construction begins, geotechnical engineers explore a site's subsurface using various sampling and testing procedures. *Geotechnical engineers can observe actual subsurface conditions only at those specific locations where sampling and testing is performed.* The data derived from that sampling and testing were reviewed by your geotechnical engineer, who then applied professional judgement to form opinions about subsurface conditions throughout the site. Actual sitewide-subsurface conditions may differ – maybe significantly – from those indicated in this report. Confront that risk by retaining your geotechnical engineer to serve on the design team through project completion to obtain informed guidance quickly, whenever needed.

This Report's Recommendations Are Confirmation-Dependent

The recommendations included in this report – including any options or alternatives – are confirmation-dependent. In other words, they are <u>not</u> final, because the geotechnical engineer who developed them relied heavily on judgement and opinion to do so. Your geotechnical engineer can finalize the recommendations *only after observing actual subsurface conditions* exposed during construction. If through observation your geotechnical engineer confirms that the conditions assumed to exist actually do exist, the recommendations can be relied upon, assuming no other changes have occurred. *The geotechnical engineer who prepared this report cannot assume responsibility or liability for confirmation-dependent recommendations if you fail to retain that engineer to perform construction observation.*

This Report Could Be Misinterpreted

Other design professionals' misinterpretation of geotechnical-engineering reports has resulted in costly problems. Confront that risk by having your geotechnical engineer serve as a continuing member of the design team, to:

- confer with other design-team members;
- help develop specifications;
- review pertinent elements of other design professionals' plans and specifications; and
- be available whenever geotechnical-engineering guidance is needed.

You should also confront the risk of constructors misinterpreting this report. Do so by retaining your geotechnical engineer to participate in prebid and preconstruction conferences and to perform construction-phase observations.

Give Constructors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can shift unanticipated-subsurface-conditions liability to constructors by limiting the information they provide for bid preparation. To help prevent the costly, contentious problems this practice has caused, include the complete geotechnical-engineering report, along with any attachments or appendices, with your contract documents, *but be certain to note conspicuously that you've included the material for information purposes only.* To avoid misunderstanding, you may also want to note that "informational purposes" means constructors have no right to rely on the interpretations, opinions, conclusions, or recommendations in the report. Be certain that constructors know they may learn about specific project requirements, including options selected from the report, *only* from the design drawings and specifications. Remind constructors that they may perform their own studies if they want to, and *be sure to allow enough time* to permit them to do so. Only then might you be in a position to give constructors the information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions. Conducting prebid and preconstruction conferences can also be valuable in this respect.

Read Responsibility Provisions Closely

Some client representatives, design professionals, and constructors do not realize that geotechnical engineering is far less exact than other engineering disciplines. This happens in part because soil and rock on project sites are typically heterogeneous and not manufactured materials with well-defined engineering properties like steel and concrete. That lack of understanding has nurtured unrealistic expectations that have resulted in disappointments, delays, cost overruns, claims, and disputes. To confront that risk, geotechnical engineers commonly include explanatory provisions in their reports. Sometimes labeled "limitations," many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are <u>Not</u> Covered

The personnel, equipment, and techniques used to perform an environmental study – e.g., a "phase-one" or "phase-two" environmental site assessment – differ significantly from those used to perform a geotechnical-engineering study. For that reason, a geotechnical-engineering report does not usually provide environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated subsurface environmental problems have led to project failures.* If you have not obtained your own environmental information about the project site, ask your geotechnical consultant for a recommendation on how to find environmental risk-management guidance.

Obtain Professional Assistance to Deal with Moisture Infiltration and Mold

While your geotechnical engineer may have addressed groundwater, water infiltration, or similar issues in this report, the engineer's services were not designed, conducted, or intended to prevent migration of moisture – including water vapor – from the soil through building slabs and walls and into the building interior, where it can cause mold growth and material-performance deficiencies. Accordingly, ***proper implementation of the geotechnical engineer's recommendations will <u>not</u> of itself be sufficient to prevent moisture infiltration. Confront the risk of moisture infiltration*** by including building-envelope or mold specialists on the design team. ***Geotechnical engineers are <u>not</u> building-envelope or mold specialists.***

GEOPROFESSIONAL BUSINESS ASSOCIATION

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