Applied GeoTech

GEOTECHNICAL INVESTIGATION

BLACK STONE SUBDIVISION

IVINS, UTAH

PREPARED FOR:

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PROJECT NO. 2211603

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TABLE OF CONTENTS

SUMMARY

1. The subsurface profile observed within the borings drilled at the site consists of silty sand to clayey sand with occasional layers of sandy lean clay and lean to fat clay to the maximum depth investigated, approximately 25½ feet. Expansive mudstone bedrock was encountered at depths ranging from 2½ to 20 feet below the existing grade in Borings B-1 to B-3, B-6, B-10 to B-12, B-14 and B-17 to B-19.

2. Subsurface water encountered in borings B-3, B-6, B-14 and B-16 at depths ranging from 4 to 14 feet below the existing grade. Water was not encountered within the other borings drilled at the site. Fluctuations in the groundwater level may occur over time. An evaluation of such fluctuations is beyond the scope of this report.

3. The on-site soils and bedrock in their existing condition are not suitable to support the proposed construction. The site is suitable for the proposed construction provided recommendations within this report are followed.

4. Our observations of the subsurface soil indicate the upper 1 to 3 feet of the silty sand soil is loose.

   The underlying mudstone bedrock is highly expansive when wetted. Due to the presence of the near surface loose sand and expansive mudstone, special foundation and grading considerations will be necessary to properly support the proposed residences.

5. The structures may be supported on conventional spread footings bearing on a properly prepared and compacted subgrade. At least 17 feet of non-expansive soil or properly compacted fill is necessary above the underlying expansive mudstone to reduce potential surface heave to within tolerable limits. Additionally, the full depth of the near surface loose sand should be removed and replaced in properly moisture conditioned and compacted lifts. Difficulty may be encountered when overexcavating mudstone if groundwater is present.

   If 17 feet of separation cannot be provided above the expansive mudstone, the residences should be supported on deep foundation elements consisting of drilled and grouted micropiles or steel shaft helical piers in conjunction with a raised structural floor.

6. Additional borings are necessary, in addition to what has been completed, to further define and verify the depth to expansive mudstone. Nine additional boring locations are shown on Figure 2. Alternatively, additional investigation can be completed by observation of subsurface conditions when grading and building pad preparation begins.

7. The on-site silty sand, clayey sand and sandy lean clay free of organics, debris and material greater than 4 inches in size, are suitable for use as site grading fill, low permeable fill, structural fill, wall backfill and utility trench backfill. The expansive mudstone bedrock and fat clay should be removed and disposed of off site or used as fill in non-structural areas which do not support hard surfaces, pavement or other site improvements. Consideration may be given to mixing the mudstone or fat clay with non-plastic soil and placed as fill greater than 5 feet below design grade in areas which will support roadways or greater than 14 feet in areas which will support buildings.

8. To reduce the risk of settlement or heave of site improvements (flatwork, block walls, etc.) from densification of the remaining loose/collapsible sand or expansive bedrock, precautionary measures including strict site drainage and desert landscaping should be implemented as recommended in the site drainage section of this report.

9. Detailed recommendations for subgrade preparation, materials, foundations, and drainage are included in the report.

10. The information provided in this summary should not be used independent of that provided within the body of this report.

SCOPE

This report presents the results of a geotechnical investigation for the proposed Black Stone subdivision located in Ivins, Utah, as shown in Figure 1. This report presents the subsurface conditions encountered, laboratory test results, and recommendations for the project. This report was prepared in general accordance with our proposal for Professional Geotechnical Services under Project No. 2211603, dated April 21, 2022

Field exploration was conducted to obtain information on the subsurface conditions and to obtain samples for laboratory testing. Information obtained from the field and laboratory was used to define conditions at the site and to develop recommendations for the proposed development. AGEC also reviewed and used information from a previously prepared report which included the western portion of the subject site. The report is entitled: "Preliminary Subsurface Investigation, Mercier Parcel", prepared by AGEC under Project No 2211603, dated July 19, 2021.

This report has been prepared to summarize the data obtained during the study and to present our conclusions and recommendations based on the proposed construction and the subsurface conditions encountered. Design parameters and a discussion of geotechnical engineering considerations related to construction are included in the report.

SITE CONDITIONS

The site consists of approximately 11.9 acres of undeveloped property in Ivins, Utah as shown on Figure 1. The property slopes gently down from the northwest to the south and east. The site is currently an agricultural/cultivated property. The site is bounded on the north by a cultivated field, on west by Main Street, on the south by Highway 91 and on the east by 200 East Street and a subdivision further to the east.

FIELD STUDY

On July 12 and 13, 2021 and May 3, 2022 an engineer from AGEC visited the site to observe the drilling of 20 borings on the subject site as shown on Figure 2. The borings were drilled utilizing a truck mounted drill rig equipped with 8-inch hollow-stem augers. The subsurface soil profile was logged and soil samples were obtained at this time for laboratory testing.

SUBSURFACE SOIL CONDITIONS

The subsurface profile observed within the borings drilled at the site consists of silty sand to clayey sand with occasional layers of sandy lean clay and lean to fat clay to the maximum depth investigated, approximately 25½ feet. Expansive mudstone bedrock was encountered at depths ranging from 2½ to 20 feet below the existing grade in Borings B-1 to B-3, B-6, B-10 to B-12, B-14 and B-17 to B-19. Descriptions of the soil and bedrock types encountered follow.

Sandy Lean Clay - The sandy lean clay is stiff, moist, and is dark red in color.

Laboratory tests conducted on a sample of the sandy lean clay indicate an in-place moisture content of 15 percent, an in-place dry density of 111 pounds per cubic foot (pcf), a gravel content (percent retained on the No. 4 sieve) of 2 percent and a fines content (percent passing the No. 200 sieve) of 54 percent.

Lean to Fat Clay - The lean to fat clay is stiff, moist, high plastic and red-brown to purple in color.

Laboratory tests conducted on a sample of the high plastic lean clay indicates an in-place moisture content of 21 percent, an in-place dry density of 105 pcf, and a fines content of 96 percent. An Atterberg Limits test indicates a liquid limit of 44 percent and a plasticity index of 27 percent.

Clayey Sand - The clayey sand contains red silty sand layers. It is medium dense to very dense, slightly moist to moist to wet (in boring B-16) and is reddish brown in color.

Laboratory tests conducted on samples of the clayey sand indicate in-place moisture contents ranging from 7 to 18 percent, in-place dry densities ranging from 95 to 149 pcf, gravel contents (percent retained on the No. 4 sieve) ranging from 0 to 18 percent and fines contents ranging from 23 to 48 percent. Atterberg Limits tests indicate liquid limits ranging from 22 to 37 percent and plasticity indexes ranging from 6 to 22 percent. A water soluble sulfate test indicates a water soluble sulfate concentration of 80 parts per million (ppm).

One dimensional consolidation/collapse tests conducted on relatively undisturbed samples of the clayey sand indicate it is non to slightly collapsible when wetted under a constant pressure of 1,000 pounds per square foot (psf) and slightly compressible under additional loading. Collapse potentials ranging from 0 to 1¾ percent were measured.

Silty Sand - The silty sand contains varied amounts of gravel and occasional silt layers. It is loose to very dense, slightly moist to moist to wet (in borings B-3 and B-14) and is red to reddish brown in color.

Laboratory tests conducted on samples of the silty sand (and silt layers) indicate in-place moisture contents ranging from 1 to 21 percent, in-place dry densities ranging from 101 to 150 pcf, gravel contents ranging from 1 to 3 percent and fines contents ranging from 6 to 68 percent. A water soluble sulfate test indicates a water soluble sulfate concentration of 50 ppm.

One dimensional consolidation/collapse tests conducted on relatively undisturbed samples of the silty sand to sandy silt indicate it is non to slightly collapsible when wetted under a constant pressure of 1,000 pounds per square foot (psf) and slightly compressible under additional loading. Collapse potentials ranging from 0 to 1¼ percent were measured.

Mudstone Bedrock - The mudstone bedrock is soft, moist to very moist, and is grey to purple to reddish-purple in color.

Laboratory tests conducted on samples of the mudstone bedrock indicate in-place moisture contents ranging from 10 to 20 percent, in-place dry densities ranging from 102 to 116 pcf, and fines contents ranging from 43 to 98 percent. Atterberg Limits tests indicate liquid limits ranging from 39 to 59 percent and plasticity indexes ranging from 19 to 36 percent.

Several one dimensional consolidation/swell test conducted on a remolded and relatively undisturbed samples of the mudstone bedrock indicate it is slight to highly expansive when wetted under a constant pressure of 1,000 psf.

The Logs of Exploratory Borings are shown on Figures 3 - 6. Legend and Notes of Exploratory Borings are shown on Figure 7. The laboratory test results are also shown on Figures 3 - 6 and are summarized in the Summary of Laboratory Test Results, Table 1. The One-dimensional Consolidation/Collapse/Swell Test Results are shown graphically on Figures 8 - 17.

SUBSURFACE WATER

Subsurface water encountered in borings B-3, B-6, B-14 and B-16 at depths ranging from 4 to 14 feet below the existing grade. Water was not encountered within the other borings drilled at the site. Fluctuations in the groundwater level may occur over time. An evaluation of such fluctuations is beyond the scope of this report.

PROPOSED CONSTRUCTION

We understand it is proposed to develop the property into a 35 lot subdivision. Residences may be supported on conventional spread footings with slab-on-grade floors underlain by a properly prepared subgrade. Deep foundation elements may also be considered to support residences which are underlain by expansive bedrock.

The residences will be constructed with wood framing, stucco or rock veneer, and tile roofs. For design purposes, we have assumed wall loads of up to 3 kips per linear foot and column loads of up to 50 kips. Interior, 43 foot right of way (ROW) paved roadways and portions of 200 East Street and the proposed Western Corridor will also be constructed. We anticipate the Western Corridor will be an 80 foot ROW and 200 East Street will be a 50 foot ROW. We anticipate cut and fill depths ranging from 1 to 2 feet to grade the site.

If the proposed construction, or building loads are significantly different from those listed, we should be notified so that we can reevaluate our recommendations.

RECOMMENDATIONS

Based on our experience in the area, the subsurface conditions encountered, engineering analysis, laboratory test results, and the proposed construction, the following recommendations are given:

A. Site Grading

1. Subgrade Preparation

General - Prior to placing fill or concrete beneath building areas, flatwork or improvements, site should be grubbed to remove the existing vegetation and soil containing significant roots and organics. The thickness may vary across the site, but we estimate this will generally require the removal of approximately 4 to 6 inches of soil. The grubbed soil may be stockpiled for use in landscaped areas. Loose, disturbed soils should also be removed the full depth.

Building Pads - Prior to placing site grading fill or concrete, the full depth of the near surface loose soil and a portion of the underlying expansive mudstone should be removed from beneath the proposed structures to provide at least 17 feet of non-expansive, low permeable cover soil over the expansive bedrock. The near surface loose sandy soil extends 1 to 3 feet below the existing grade.

The removed silty to clayey sand to sandy lean clay may be stockpiled for reuse as site grading/low permeable fill beneath the residences as described in the Materials section of this report. Difficulty may be encountered when overexcavating mudstone if groundwater is present.

The following process should be implemented when placing fill in the overexcavated area which will support the structures:

- The onsite mudstone or lean to fat clay may be placed as site grading fill in the zone from 17 feet to 14 feet below finished pad grade provided it is mixed with the onsite sand soil. We estimate that a ratio of 2:1 (sand:mudstone) will likely provide an appropriate blend. This mixed soil should be processed such that the moisture content is 4 to 6 percent above the optimum moisture content as determined by ASTM

D-1557 and should also meet the low permeable fill criteria in the Material section of this report.

- The onsite silty the clay sand may be reused as site grading/structural fill from 14 feet below finished grade to the surface. It should be placed in properly moisture conditioned and compacted lifts.

Additional borings are necessary, in addition to what has been completed, to further define and verify the depth to expansive mudstone. Nine additional boring locations are shown on Figure 2. Alternatively, additional investigation can be completed by observation of subsurface conditions when grading and building pad preparation begins.

Flatwork, Roads, Walls - We recommend flatwork, pavement and block walls be supported on an appropriate thickness of non-expansive, low permeable fill. The thickness of low permeable fill should be based on the acceptable magnitude of potential differential vertical movement. The low permeable fill layer is intended to provide a low permeable barrier and reduce the risk of wetting of the underlying mudstone.

If the mudstone is wetted subsequent to construction, heave of the surface improvements will still occur. Therefore, strict site drainage is critical to the satisfactory performance of flatwork or other surface supported features. The estimated potential surface heave along with the associated overexcavation depths are provided in the following table.

Depth to Expansive Mudstone Bedrock (feet)	Estimated Potential Differential Slab Heave (inches)
0	3½ to 4¼
2	3 to 3¾
4	2½ to 3¼
6	2 to 2¾
8	1½ to 2
12	1 to 1¾
16	½ to 1
18	< ½ to ¾

As a minimum, we recommend at least 5 feet of non-expansive, low permeable fill be placed above the mudstone bedrock in areas which will support flatwork, pavement, curbing or walls/fences. The risk of heave potential may also be reduced by increasing the overexcavation depth and by providing strict drainage and implementing desert landscaping. The thickness of non-expansive fill can be increased if the estimated heave listed above is not acceptable. The removed mudstone should be disposed of off site.

Risk - Even with the 17 feet of non-expansive cover soil over the underlying mudstone, we estimate that on the order of ½ to ¾ inch of surface heave could still occur after construction if the remaining underlying mudstone is wetted. This could result in foundation/slab movement and subsequent cosmetic damage to the buildings. Distress could include drywall cracking, sticking doors/windows, etc. Therefore, the drainage recommendations provided in this report should be strictly followed.

If this risk is not acceptable, additional overexcavation can be completed or the structures should be supported on deep foundation elements. The estimated potential surface heave associated with corresponding non-expansive overburden depths are provided in the table shown on Page 10.

Lateral Extent and Compaction - All overexcavation and subgrade preparation procedures should extend at least 5 feet beyond the perimeter of the proposed construction. Prior to placing approved fill, the exposed subgrade should be moisture conditioned and compacted as recommended in the Compaction section of this report. Fill placed at the site should be placed in properly moisture conditioned and compacted lifts as recommended in the compaction section of this report. Each lift of fill placed should be tested to verify moisture content and compaction are appropriate.

2. Excavation

We anticipate that excavation of the overburden soils and soft mudstone bedrock at the site can be accomplished with typical excavation equipment.

3. Grading Slopes and Trenches

The following table summarizes recommendations for excavation of temporary and permanent cut slope excavations, trench excavations and permanent fill slope construction. Slopes should include benches in accordance with the 2018 IBC.

Slope Condition	**Maximum Slope (Horizontal:Vertical)**
Permanent Cut Slopes in Overburden Soils and Soft Mudstone	2:1
Permanent Fill Slopes - Compacted Fill	2½:1
Utility Trenches in On-site Soils and Soft Mudstone (OSHA Soil Class C)	1½:1*
Utility Trenches in Firm Mudstone (OSHA Soil Class A)	¾:1*

*Steeper trenches will require the use of shoring or a trench box to provide a safe work environment. Safe trench excavation is the responsibility of the contractor.

Fill slopes should be graded by overbuilding and then cutting back to the desired grade to provide a compacted slope face. Fill placed on existing slopes steeper than 3:1 should be placed using a benching procedure to key the fill into the existing slope. Benches should be of sufficient width to allow adequate area for the compaction equipment. Slopes should include benches in accordance with the 2018 IBC.

The cut and fill slopes will be highly susceptible to erosion, particularly resulting from run off from the adjacent slopes. Water should be directed around slopes using drainage swales to reduce potential erosion. A lot specific drainage study should be conducted by the civil engineer to control localized runoff.

4. Materials

Import materials should be non-expansive, non-gypsiferous, granular soil. Listed below are the materials recommended for imported fill.

Area	**Fill Type**	**Recommendations**
Footings/Pad	Structural Fill	35% < -**#200** (Silt and Clay Particles) **LL** < 25% Maximum Size: 4 inches Solubility < 1% USC Soil Class: SM, SP, SC, GM, GC, GP or similar dual soil classification
Under Slab (Upper 4 Inches)	Base Course	**-200** < 12% Maximum Size: 1 inch Solubility < 1%

-200 = Percent Passing the No. 200 Sieve
LL = Liquid Limit

The on-site silty to clayey sand and sandy lean clay free of organics, debris and material greater than 4 inches in size, are suitable for use as site grading fill, low permeable fill, structural fill, wall backfill and utility trench backfill. The expansive mudstone bedrock and high plastic lean to fat clay should be removed and disposed of off site or used as fill in non-structural areas which do not support hard surfaces, pavement or other site improvements. Consideration may be given to mixing the mudstone or lean to fat clay with non-plastic soil and placed as fill greater than 5 feet below design grade in areas which will support roadways or greater than 14 feet in areas which will support buildings.

The potential impact of the expansive characteristics of the underlying mudstone bedrock to surface improvements can be reduced by protecting the bedrock from becoming wet. Placement of relatively low permeable fill above the bedrock can help reduce the possibility of water coming in contact with the expansive bedrock. Low permeable fill used to replace removed mudstone should meet one of the following set of criteria.

Liquid Limit (%)	Percent Passing the No. 200 Sieve
45+	15-20
30-45	20-40
0-30	30-100

Laboratory testing indicates most of the on-site sand will meet the low permeable fill criteria. Mixing the underlying processed mudstone bedrock with on site or imported, non-plastic sand soil may be considered to meet the low permeable fill criteria. Typically a mixture of 2 parts non-expansive granular soil to 1 part processed mudstone may be appropriate. Additional laboratory testing should be completed to verify this process prior to implementation. This mixed material could be considered at greater than 14 feet below pad grade in building areas and 3 feet below design subgrade under roadways. The mudstone should be processed to particle sizes less than 1 inch in size prior to mixing.

5. <u>Compaction</u>

Compaction of fill materials placed at the site should equal or exceed the following percentages when compared to the maximum dry density as determined ASTM D-1557:

Area	Moisture Content (%)	Compaction (%)
Sand Subgrade	±2 of w_{opt}	≥90
Mudstone Subgrade	4 - 6 over w_{opt}	≥90
Building Pad, Improvements - Import Granular/Structural Fill	±2 of w_{opt}	≥95
Building Pad, Improvements - Low Perm. Fill (On-site silty to clayey sand, sandy lean clay)	0 - 4 over w_{opt}	≥95
Building Pad, Improvements - Mixed Silt/Sand and Mudstone	4 - 6 over w_{opt}	92 - 96
Footings/Foundation Subgrade	±2 of w_{opt}	≥95
Site Grading - Non Structural Areas	±2 of w_{opt}	≥90
Site Grading - Structural Areas	±2 of w_{opt}	≥95
Wall Backfill - Nonstructural	±2 of w_{opt}	≥90
Wall Backfill - Supporting Structure	±2 of w_{opt}	≥95
Utility Trenches	±2 of w_{opt}	≥95

* Fine-grained low permeable fill/processed mudstone.
** Granular site grading fill/granular low permeable fill/structural fill.

Fill placed at the site should be tested to verify proper compaction. Fill tested should be compared to the maximum dry density and optimum moisture content as determined by ASTM D-1557. Fill should be placed in lift thicknesses which are appropriate to the type of compaction equipment used.

Typically, lift thicknesses of 6 to 8 inches are appropriate for heavy equipment. Lift thicknesses should be reduced to 4 inches for hand compaction equipment.

6. <u>Surface Drainage</u>

Positive site drainage should be maintained during the course of construction. After construction has been completed, positive drainage of the surface water away from the buildings in each direction must be maintained. To reduce infiltration adjacent to foundations we recommend the following:

a. A minimum slope of 6 inches in the first 10 feet from the perimeters of the structures should be provided.

b. Roof gutter systems should be installed around the perimeters of the structures. Roof downspouts should discharge away from the buildings so as to prevent ponding adjacent to foundations. We recommend piping roof gutter downspouts of site and directly storm drain.

c. Placement of 3 to 4 foot wide concrete aprons around the perimeters of the structures.

d. Landscaping requiring water is not recommended due to the underlying expansive mudstone on the south end of the site. If landscaping requiring water is desired, those areas should be underlain with an impermeable membrane and excess water which infiltrates should be captured and directed off site.

e. Below grade portions of walls/fences which are backfilled with soil should be protected with an impermeable membrane and a subsurface drain. A gravel covered, perforated PVC pipe should also be placed at the base of the wall to carry water to a discharge point. This is intended to reduce the potential for salt weathering on concrete/masonry.

B. Conventional Foundations - Residence Support

We understand it is currently proposed to implement conventional spread footing foundations to support the residences. The proposed structures may be supported on conventional spread footings bearing on a properly prepared and compacted subgrade. Specifically, at least 17 feet of non-expansive fill and/or suitable, natural silty to clayey sand and sandy lean clay should be provided above the mudstone as recommended on the Subgrade Preparation Section of this report.

If the pads are underlain by expansive mudstone at a depth less than 17 feet, the most positive method to support the proposed buildings would consist of deep foundation elements in conjunction with a raised structural floor.

Recommendations for design of conventional spread and spot footing are provided below.

1. <u>Bearing Material</u>

   The proposed buildings may be supported on conventional spread footings bearing on a properly prepared and compacted subgrade. Specifically, the subgrade should be prepared during site grading by overexcavating the building pads to remove the appropriate thickness of the near surface, loose silty sand and underlying expansive mudstone as recommended in the Subgrade Preparation section of this report.

2. Bearing Pressure

   Conventional spread footings bearing on properly compacted structural fill may be designed for the a net allowable bearing pressure of 2,000 psf.

3. Footing Width and Embedment

   Footings should have a minimum width of 18 inches and exterior or unheated footings should be embedded at least 12 inches below the lowest adjacent grade.

4. Temporary Loading Conditions

   The allowable bearing pressures may be increased by one-half for temporary loading conditions such as wind or seismic loads.

5. Settlement/heave

   We estimate that settlement will be approximately 1 inch for footings designed as indicated above due to the load of the structure. Differential settlement is estimated to be approximately ½ inch. Potential heave of foundations/slabs is discussed in the Subgrade Preparation section of this report. Drainage recommendations should be strictly implemented to reduce the potential for future foundation/slab movement.

6. Foundation Base

   The base of excavations should be cleared of loose or deleterious material prior to placement of fill or concrete.

7. Foundation Setback

   Foundations should be set back from the top crest of slope a horizontal distance equal to are greater than ⅓ the total slope height.

C. **Deep Foundation Elements - Residence Support**

If the underlying expansive mudstone is within 17 feet of finished pad grade, we recommend buildings be supported on deep foundation elements (micropiles or steel shaft helical piers) due to the presence of the underlying expansive bedrock. The following recommendations should be followed for foundation design and construction.

1. Deep Foundations

- The deep foundations (proposed to be micropiles or helical piers) should extend at least 20 feet into the underlying expansive mudstone with a minimum total length of 25 feet. Steel shaft helical piers should be implemented in lieu of micropiles where groundwater is present.

- End bearing should not be considered for micropile capacity. Steel shaft helical piers should be designed as end bearing elements. A net allowable bearing capacity of 35,000 psf should be used for design of steel shaft helical piers bearing on expansive mudstone.

- Micropiles should be of sufficient diameter to allow for placement of grout around reinforcing steel.

- Deep foundation elements should be designed using the parameters listed in Table 2. Axial values only apply to drilled and grouted micropiles.

- The piles should be structurally reinforced to resist tensile forces on the pile due to negative skin friction. The tensile force may be calculated utilizing at least 10 feet of pier length with an ultimate skin friction of 1,050 psf. A "greased PVC bond breaker" may also be considered to reduce uplift forces on the micropiles. Bond breakers should be verified by load testing.

- Piles and piers should be placed as far apart as practical in order to achieve minimum dead load recommendations and a minimum of three diameters apart, center to center.

- Care should be taken to assure the micropiles are not oversized (mushroomed) at the ground surface, which could provide an area where swelling soil/rock could exert uplift forces on the piles. If a PVC bond breaker or a steel pipe are placed at the surface to provide a straight pile, the uplift from a potential surface "mushroom" should not be a concern.

- Grout should be placed using a tremmie extended to near the bottom of the drill hole to ensure the drill hole is filled without voids. The tremmie should be raised as the grout is pumped.

- The water cement ratio of the grout should be on the order of 0.45 to 0.50. This should be verified during construction using a grout scale to verify the grout has a specific gravity on the order of 1.8 to 1.9. The grout volume should be recorded for each micropile constructed to ensure the appropriate volume is placed.

- Grout should be placed in the micropiles immediately after they are drilled using a tremmie pipe which extends to the bottom of the drill hole and is raised at the grout is placed to ensure the micropile is free of air voids. If water enters the pile holes, it would be necessary to place grout immediately after the hole is completed using a tremmie. The tremmie will also displace water out of the hole as grout is placed. Failure to place grout the day of drilling may require re-drilling for additional bedrock penetration.

- Micropile holes should also be inspected to verify caving does not occur below the ground surface which could also result in additional uplift forces. Casing the drill hole may be necessary if the caving occurs to ensure a straight shaft with a consistent diameter.

- Centralizers should be used on the steel reinforcing bar at approximately a 7 to 10 foot spacing to ensure the appropriate grout cover on the reinforcing.

D. **Interior Concrete Slab-on-Grade**

1. Slab Support

Concrete slabs may be supported on a zone of properly prepared (overexcavated) and compacted fill as stated in the Subgrade Preparation section of this report.

2. Underslab Base Course

A 4-inch layer of properly compacted base course should be placed below slabs to provide a firm and consistent subgrade and promote even curing of the concrete.

3. Vapor Barrier

A vapor barrier should be placed below slabs in areas which will receive sensitive floor coverings or coverings which are impermeable. Vapor barriers also provide protection from salt and sulfate attack.

E. **Lateral Earth Pressures**

1. Lateral Resistance for Footings

Lateral resistance for spread footings is controlled by sliding resistance developed between the footing and the subgrade soil. An ultimate friction value of 0.45 may be used in design for ultimate lateral resistance of footings bearing on properly compacted on-site soils.

2. Retaining Structures

The following equivalent fluid weights are given for design of subgrade walls and retaining structures. The active condition is where the wall moves away from the soil. The passive condition is where the wall moves into the soil and the at-rest condition is where the wall does not move. We recommend basement walls or below grade beams be designed in an at-rest condition.

The values listed below assume a horizontal surface adjacent the top and bottom of the wall.

Description	Condition		
	Active	At-Rest	Passive
On-site or Imported Granular Backfill	35 pcf	55 pcf	325 pcf
On-site or Imported Granular Backfill - Earth Pressure Coefficient	0.28	0.44	-
On-site Processed Mudstone/Fat Clay*	45 pcf	65 pcf	200 pcf
On-site Processed Mudstone/Fat Clay - Earth Pressure Coefficient	0.41	0.59	--

* We recommend that on-site clay soils used as backfill be mixed with at least 2 parts on-site or imported granular soil.

The above values account for the lateral earth pressures due to the soil and level backfill conditions and do not account for hydrostatic pressures or surcharge loads.

Lateral loading should be increased to account for surcharge loading using the appropriate earth pressure coefficient and a rectangular distribution if structures are placed above the wall and are within a horizontal distance equal to the height of the wall. If the ground surface slopes up away from the wall, the equivalent fluid weights should also be increased.

Care should be taken to prevent percolation of surface water into the backfill material adjacent to the retaining walls. The risk of hydrostatic buildup can be reduced by placing a subdrain behind the walls consisting of free-draining gravel wrapped in a filter fabric.

3. Seismic Conditions

Under seismic conditions, the equivalent fluid weights should be modified as follows according to the Mononobe-Okabe method assuming a level backfill condition:

Lateral Earth Pressure Condition	Seismic Modification (2% PE in 50 yrs)	
	Granular Backfill	**Clay Backfill**
Active	7 pcf increase	8 pcf increase
At-rest	no increase	no increase
Passive	18 pcf decrease	13 pcf decrease

The seismic increases and decrease assume a peak ground acceleration (PGA) of 0.21g and a 1 second period ground acceleration (S_1) of 0.16g using the Mononobe-Okabe pressure distribution. The resultant of the seismic increase should be placed up ⅓ from the base of the wall.

4. Safety Factors

The values recommended assume mobilization of the soil to achieve the assumed soil strength. Conventional safety factors used for structural analysis for such items as overturning and sliding resistance should be used in design.

F. Seismicity, Liquefaction and Faulting

1. Seismic design parameters are provided below:

Description	Seismic Parameter
	2,500 yr event (≈2% PE in 50 yrs)
2018 IBC/ASCE 7-16	C
PGA - Site Class B	0.21g
S_s (0.2 second period) - Site Class B	0.47g
S_1 (1 second period) - Site Class B	0.15g
F_{pga} - Site Class Factor	1.20
F_a - Site Class Factor	1.30
F_v - Site Class Factor	1.50

The data provided above was determined using the ASCE 7 Seismic Hazard Tool. Based on the subsurface conditions encountered, the seismic parameters mapped for the site as per ASCE 7-16, and our understanding of the proposed construction, a ground motion hazard analysis (GMHA) is not required by the 2018 IBC.

2. Liquefaction

   Based on subsurface conditions encountered in the borings drilled, the subsurface soils observed are non-liquefiable during a seismic event.

3. Faulting

   Based on a review of available geologic literature and review of the referenced report, there are no mapped faults extending through the site.

G. **Soil Corrosion**

Our experience and laboratory testing has also shown the on-site bedrock and many import soils may contain sulfates in sufficient concentration to be corrosive to concrete. Therefore, we recommend concrete elements that will be exposed to the on-site soils be designed in accordance with provisions provided in the American Concrete Institute Manual of Concrete Practice (ACI) 318-14. Tables 19.3.1.1 and 19.3.2.1 should be referenced for design of concrete elements utilizing a Sulfate Exposure Class of S2.

Consideration should also be given to cathodic protection of buried metal pipes. We recommend utilizing PVC pipes where local building codes allow.

H. **Pavement**

1. Subgrade Support

We anticipate that the subgrade materials beneath the pavement areas will consist of properly compacted silty to clayey sand. Prior to placement of road base, the subgrade should be prepared as recommended in the subgrade preparation section of this report. A California Bearing Ratio (CBR) of 7 percent was assumed for a properly compacted silt to sand subgrade for purposes of design.

2. Pavement Thickness

Based on the assumed traffic loadings, a 20-year design life, and AASHTO design methods, the following pavement sections are recommended.

Roadway	Design Traffic Index	Asphalt (in.)	Base Course (in.)	Granular Borrow (in.)
43 - 50 ft ROW	5	2½	6	0
80 ft ROW	7	4	6	0

3. Pavement Materials

The pavement materials should meet Ivins City specifications for gradation and quality. The pavement thicknesses indicated above assume that the base course is a high quality material with a CBR of at least 50 percent and the asphaltic concrete has a minimum Marshall stability of 1,800 pounds. Other materials may be considered for use in the pavement section. The use of other materials may result in other pavement material thicknesses.

4. Drainage

The collection and diversion of drainage away from the pavement surface is extremely important to the satisfactory performance of the pavement section. Proper drainage should be provided.

I. Construction Testing and Observations

We recommend the following testing and observations be done as a minimum as required by the Ivins City.

1. Observe grubbing and verify removal of soil containing roots and organics.

2. Verify that recommended overexcavation depths are achieved in the building pads, pavement, canopies, flatwork and decking. The lateral extent of the building pad should be located by survey (not included in AGEC's Scope of Services) and include the area which extends at least 5 feet beyond the buildable area as per city set-back requirements.

3. Verify that recommended structural fill depths are provided below foundations and slabs.

4. Conduct compaction testing on fill placed below foundations and in building pads. We recommend testing each foot of fill placed.

5. Conduct construction materials testing on city improvements at a frequency which meets or exceeds Ivins City requirements.

6. If deep foundations are implemented, full time observation will be required in accordance with the 2018 IBC.

7. Special inspections will also be necessary in reinforced concrete elements.

J. **Geotechnical Recommendation Review**

The client should familiarize themselves with the information contained in this report. If specific questions arise or if the client does not fully understand the conclusions/recommendations provided, AGEC should be contacted to provide clarification.

LIMITATIONS

This report has been prepared in accordance with generally accepted soil and foundation engineering practices in the area for the use of the client for design purposes. The conclusions and recommendations included within the report are based on the information obtained from the borings drilled, the data obtained from laboratory testing, our experience in the area and information from the referenced geotechnical investigation. Variations in the subsurface conditions may not become evident until excavation is conducted. If the subsurface conditions or groundwater level are found to be significantly different from those described above, we should be notified to reevaluate our recommendations.

If you have any questions or if we can be of further service please call.

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

LICENSED PROFESSIONAL ENGINEER
Arnold
DeCastro
6/17/22
STATE OF UTAH

Arnold DeCastro, P.E.

Reviewed by: JRH, P.E.

AD P:\2021 Project Files\2211600\2211603 - GT Mercier Parcel\2:

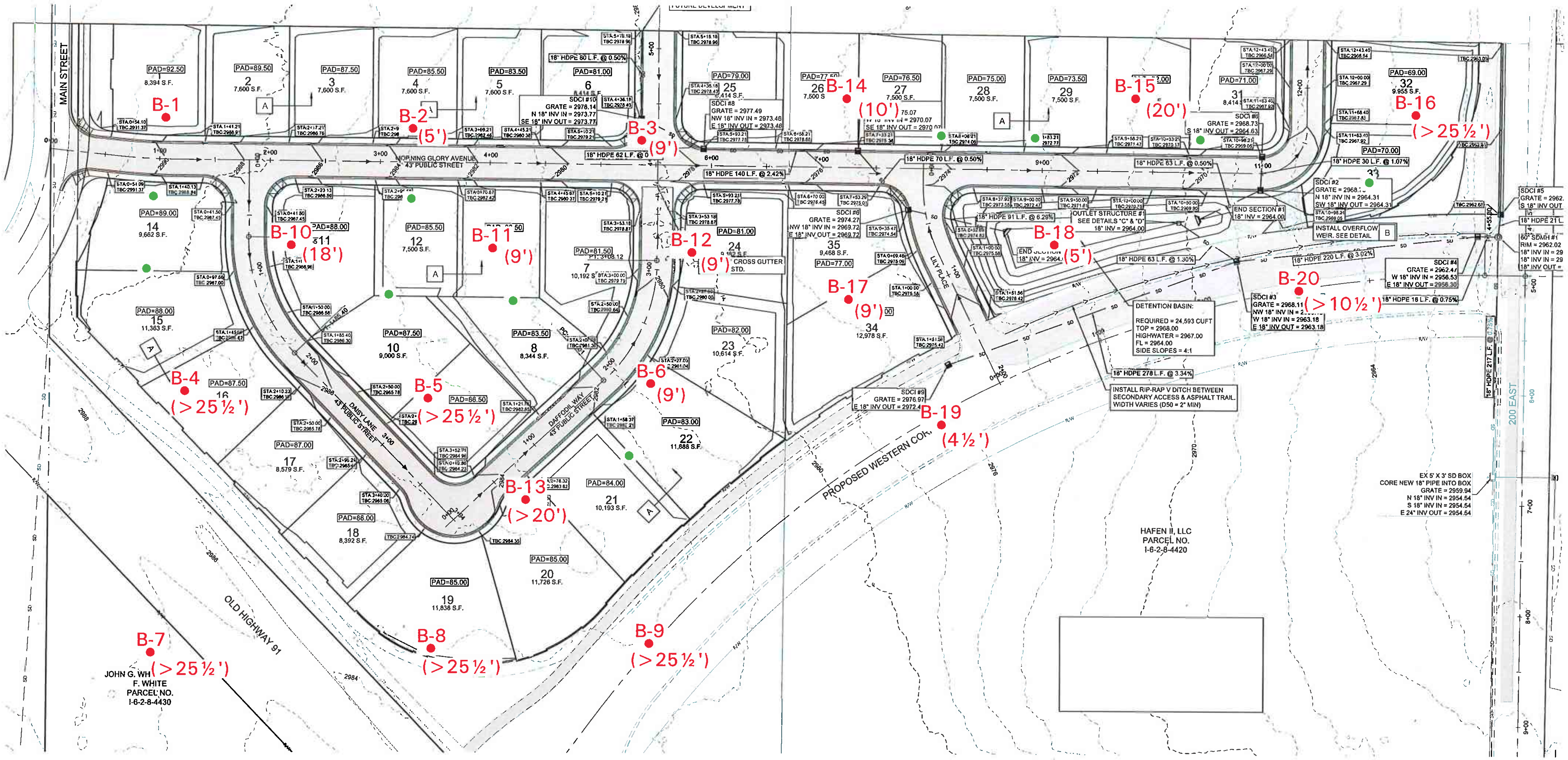
BLACK STONE SUBDIVISION
IVINS, UTAH

N

Not to Scale

2211603	AGEC	Vicinity Map	Figure 1

BLACK STONE SUBDIVISION
IVINS, UTAH

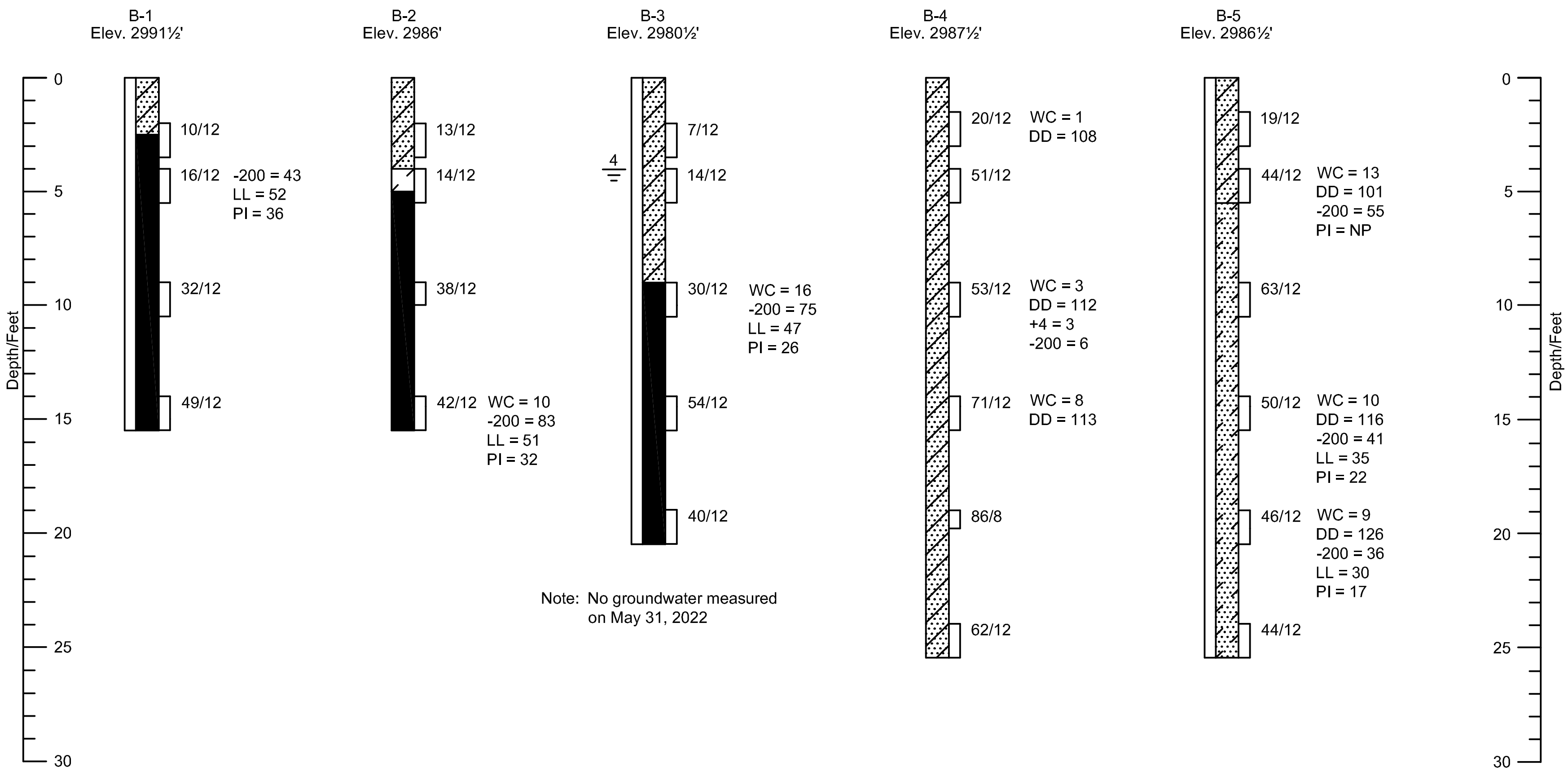


N

0 100 200 feet

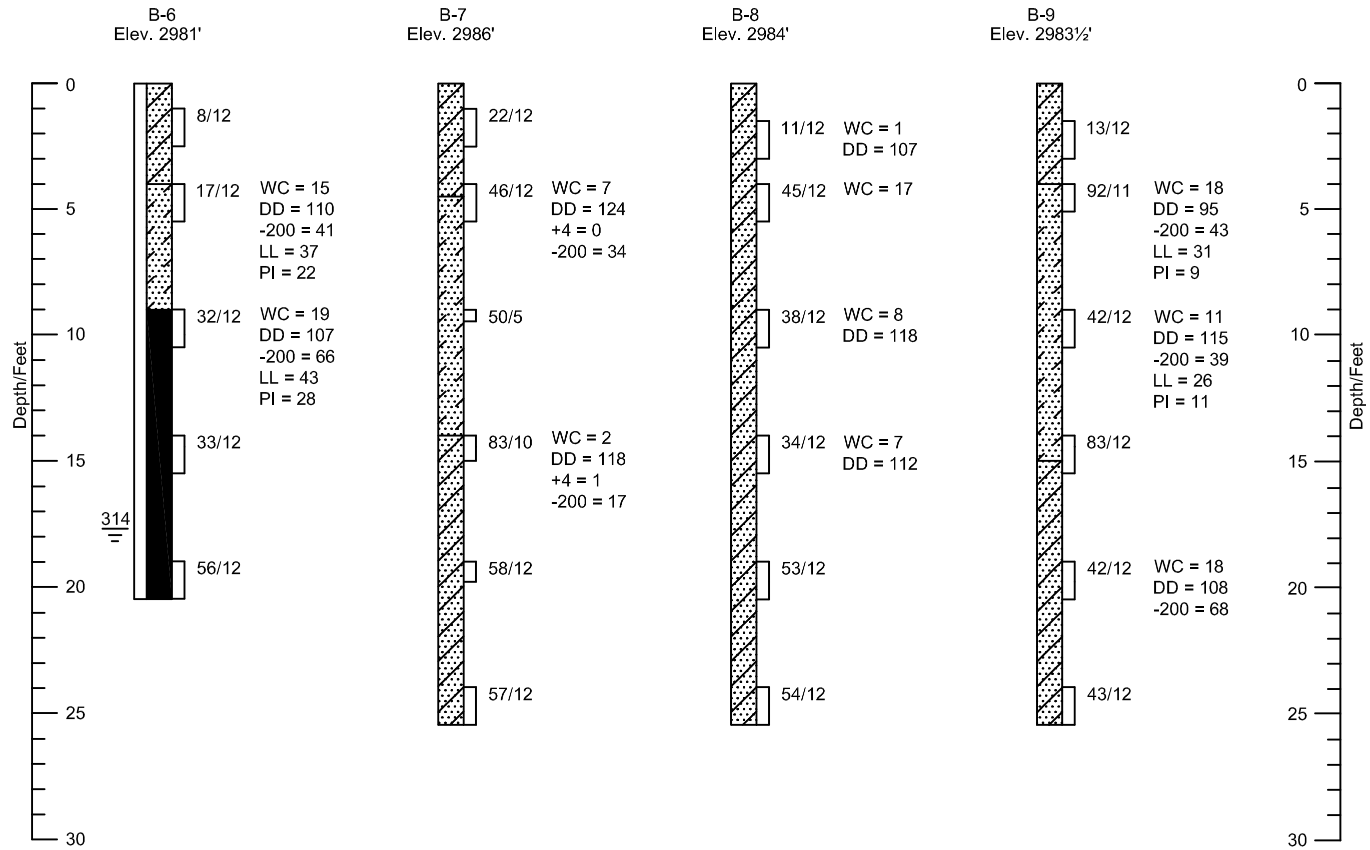
- ● Approximate boring location
- (5') Indicates expansive mudstone is encountered at 5' below existing grade
- ● Additional investigation necessary to further define subsurface conditions (or observe when overexcavating)

2211603	AGEC	Site Plan	Figure 2



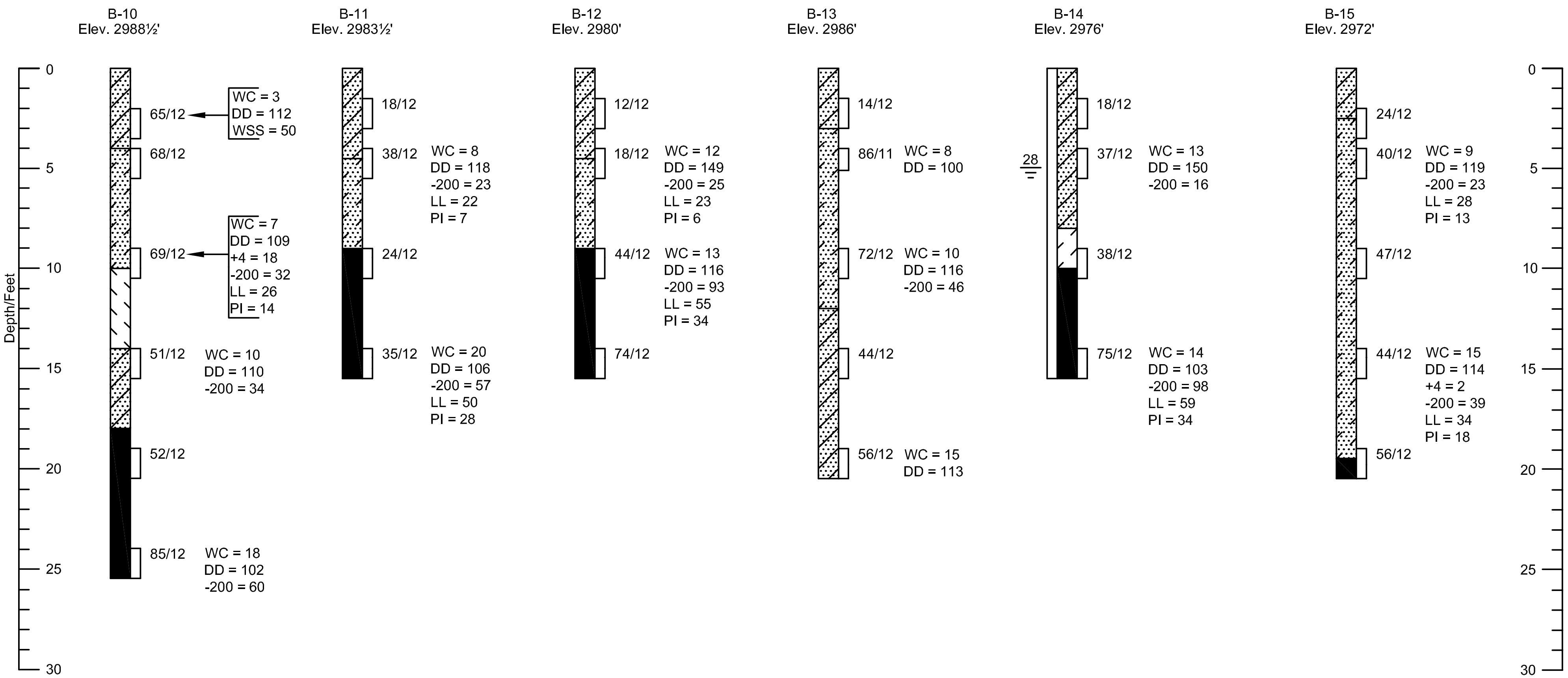
See Figure 7 for Legend and Notes

2211603	AGEC	Logs of Exploratory Borings	Figure 3



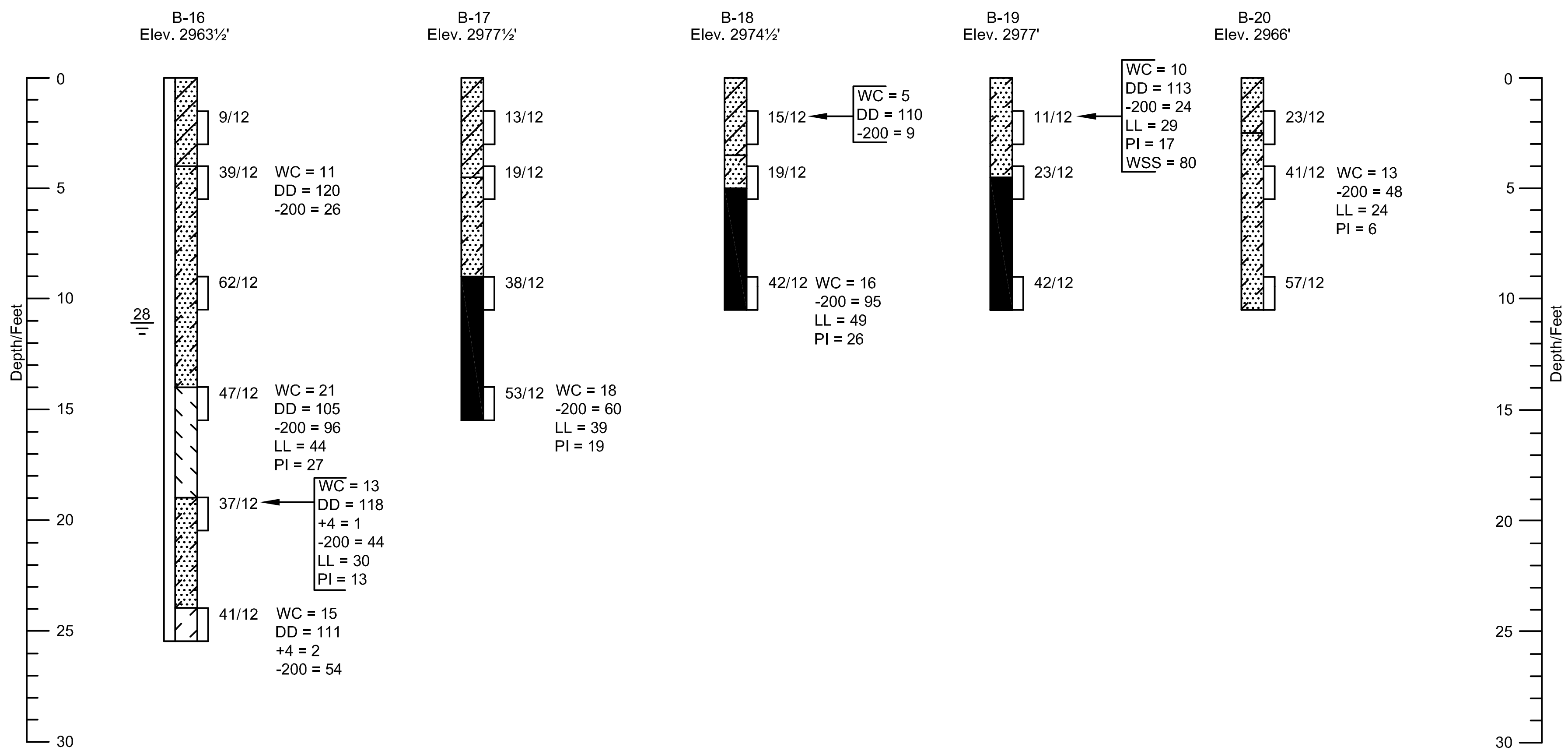
See Figure 7 for Legend and Notes

2211603	AGEC	Logs of Exploratory Borings	Figure 4



See Figure 7 for Legend and Notes

2211603	AGEC	Logs of Exploratory Borings	Figure 5



See Figure 7 for Legend and Notes

LEGEND:

Sandy Lean Clay (CL); stiff, moist, dark red in color.

Lean to Fat Clay (CH); stiff, moist, high plastic, red-brown to purple brown in color.

Clayey Sand (SC); contains red silty sand layers, medium dense to very dense, slightly moist to moist to wet (in B16), reddish brown in color.

Silty Sand (SM); contains varied amounts of gravel, loose to very dense, slightly moist to moist to wet (in B-3 and B-14) and red to reddish brown in color.

Mudstone Bedrock; soft, moist to very moist, and grey to purple to reddish-purple in color.

10/12 California drive sample taken. The symbol 10/12 indicates that 10 blows from a 140 pound hammer falling 30 inches were required to drive the sampler 12 inches.

Indicates slotted 1 inch PVC pipe installed in the boring to the depth shown.

0 Indicates the depth to free water and the number days after excavation the measurement was taken.

NOTES:

1. The borings were drilled on July 12 and 13, 2021 and May 3, 2022 with a truck mounted drill rig equipped with 8-inch hollow-stem augers.
2. The locations of the borings were measured by pacing from features shown on Figure 2.
3. The elevations of the borings were measured with a hand level and refer to the benchmark shown on Figure 2.
4. The boring locations and elevations should be considered accurate only to the degree implied by the method used.
5. The lines between the materials shown on the logs represent the approximate boundaries between material types and the transitions may be gradual.
6. Water level readings shown on the logs were made at the time and under the conditions indicated. Fluctuations in the water level may occur with time.
7. WC = water content (%);
   DD = dry density (pcf);
   +4 = percent retained on the No. 4 sieve;
   -200 = percent passing No. 200 sieve;
   LL = liquid limit (%);
   PI = plasticity index (%);
   WSS = water soluble sulfate (ppm).

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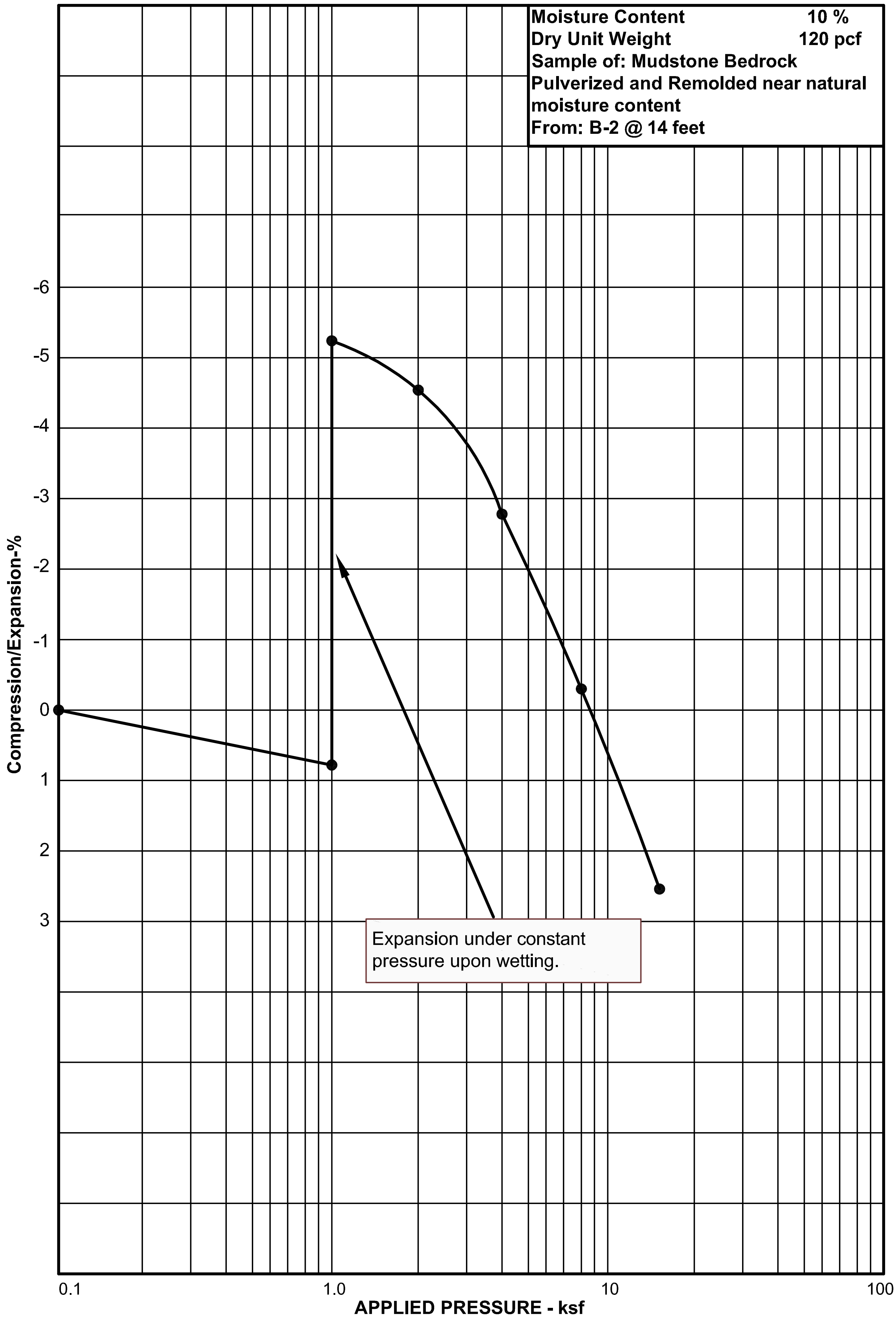
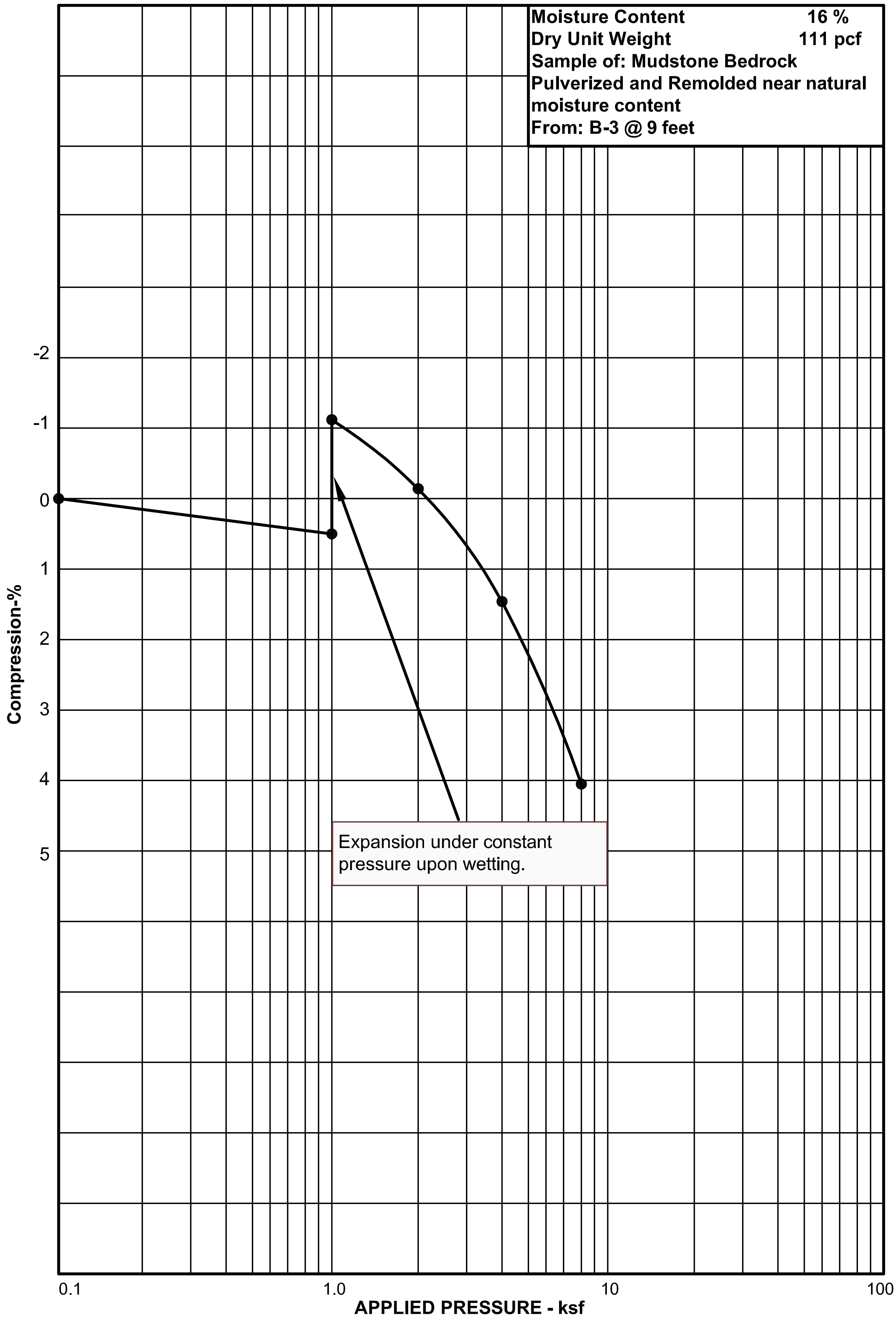
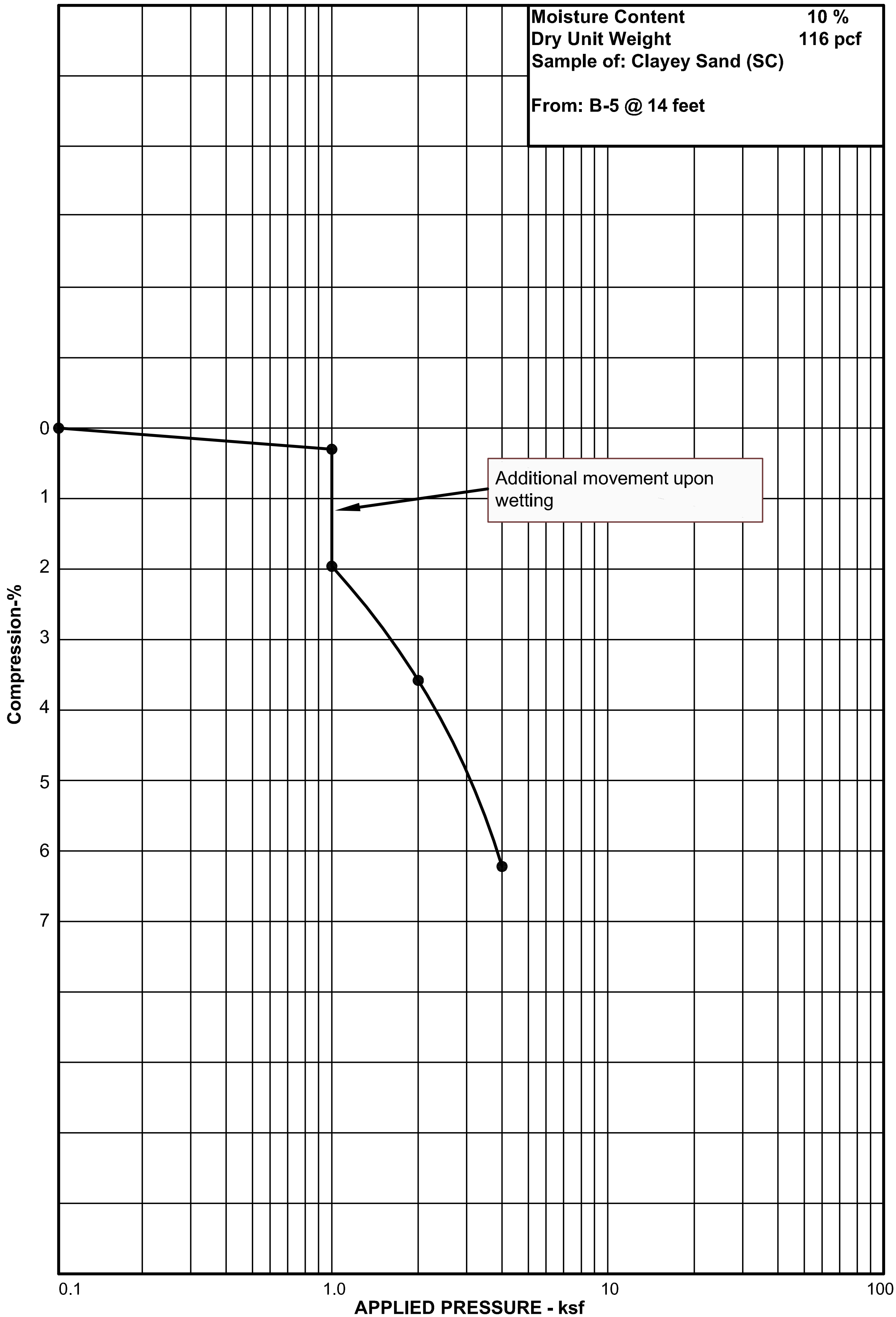
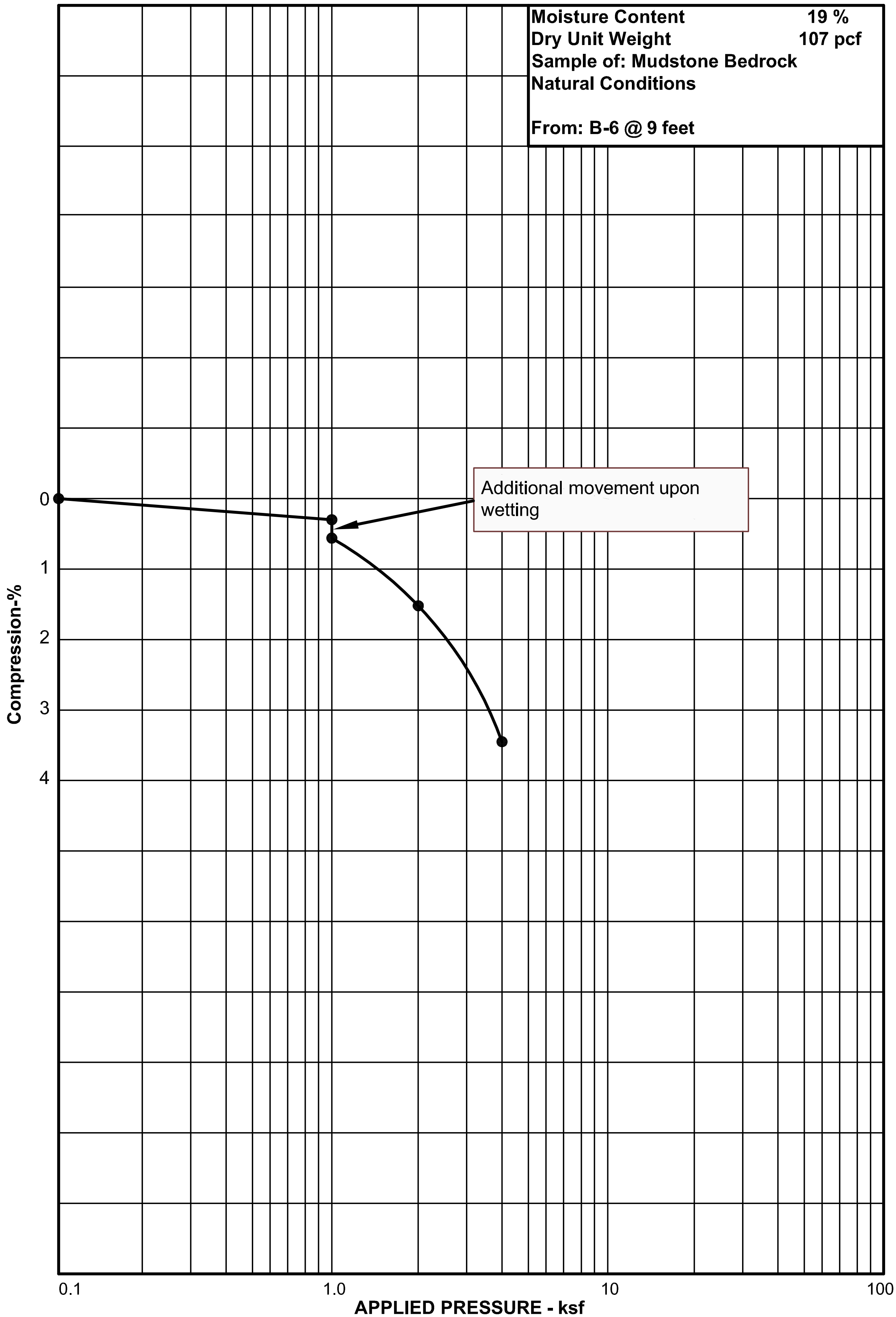



Moisture Content 16 %
Dry Unit Weight 111 pcf
Sample of: Mudstone Bedrock
Pulverized and Remolded near natural moisture content
From: B-3 @ 9 feet
-2
-1
0
1
2
3
4
5
Compression-%
Expansion under constant pressure upon wetting.
0.1
1.0
10
100
APPLIED PRESSURE - ksf

Applied Geotechnical Engineering Consultants, Inc.



Applied Geotechnical Engineering Consultants, Inc.



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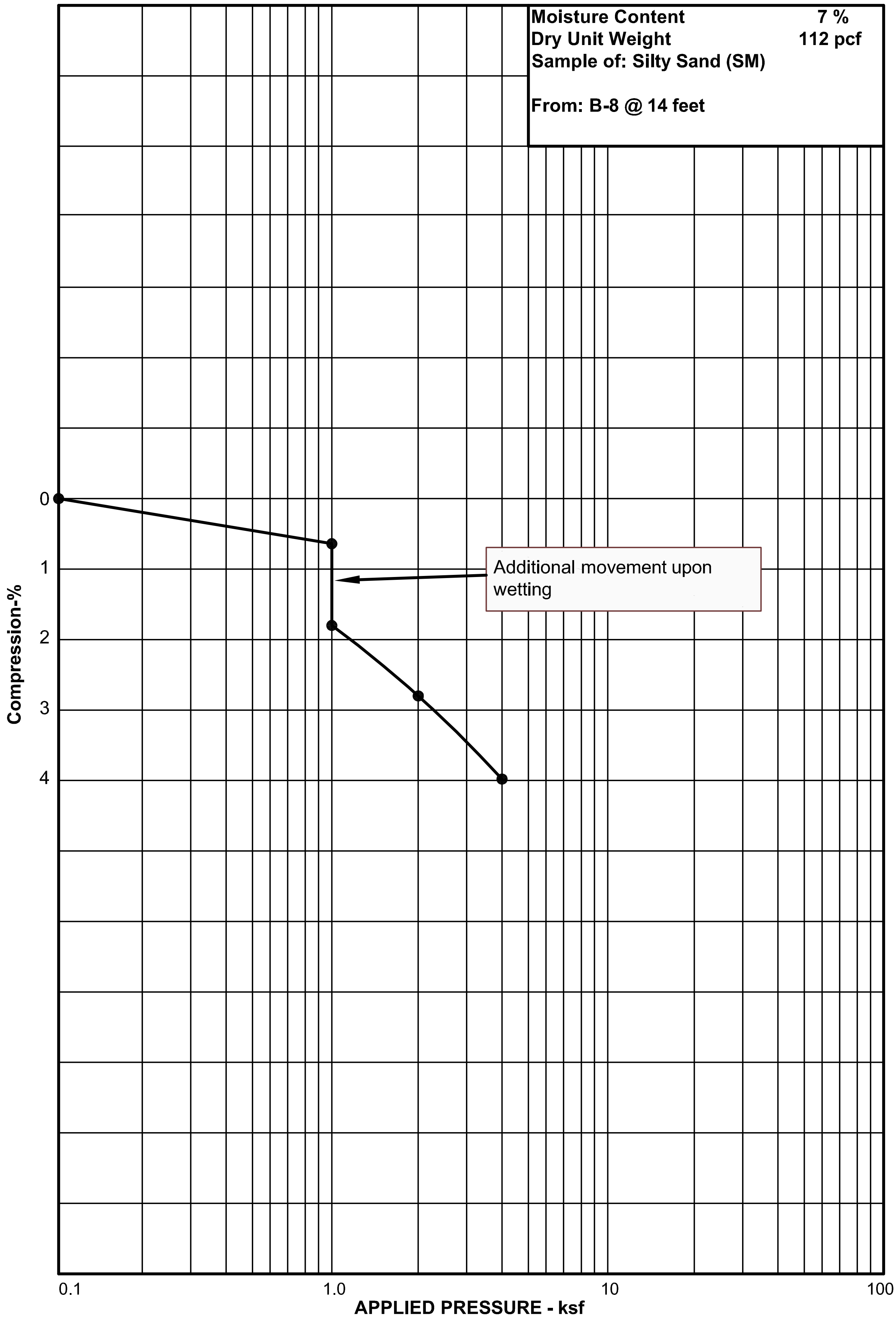
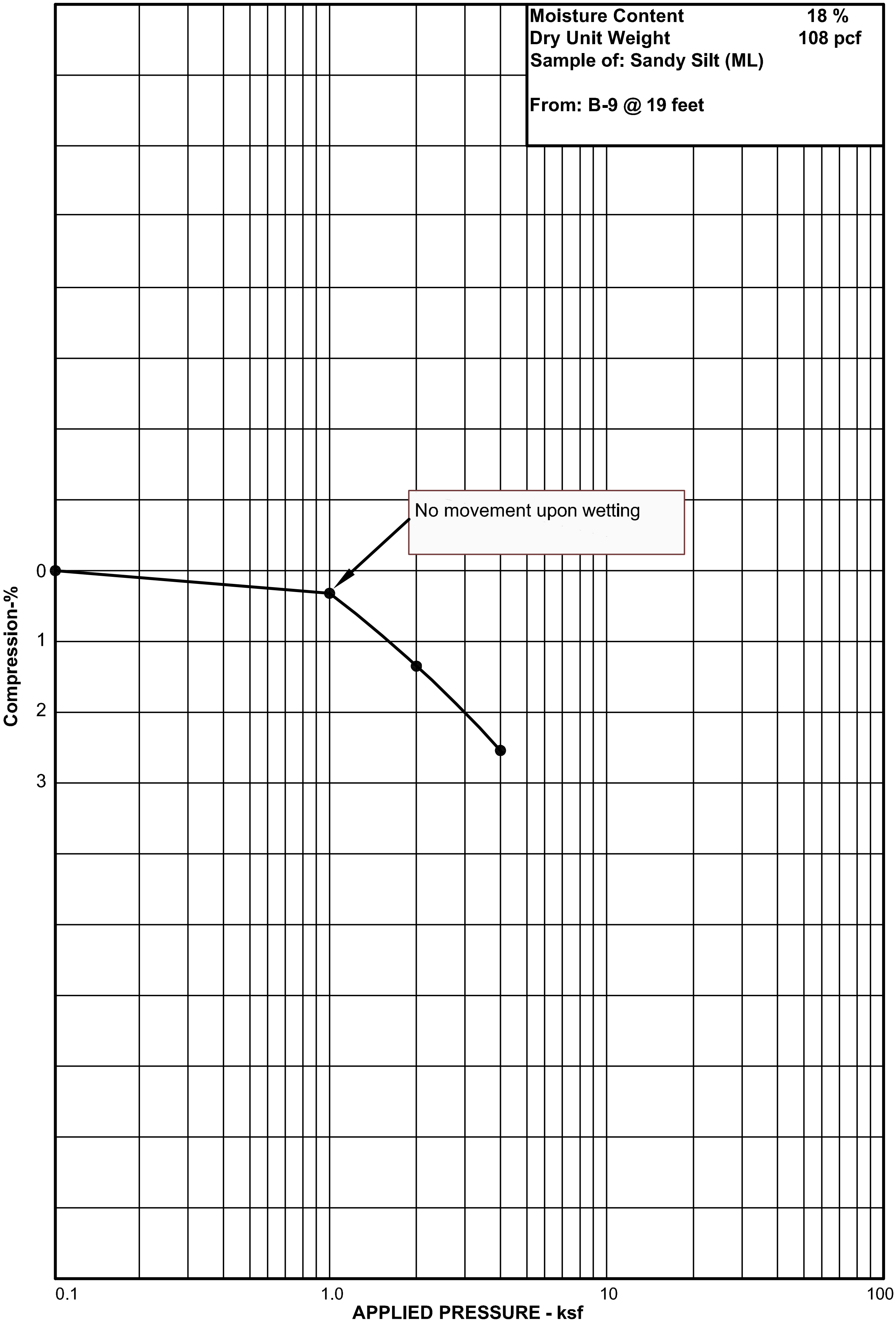
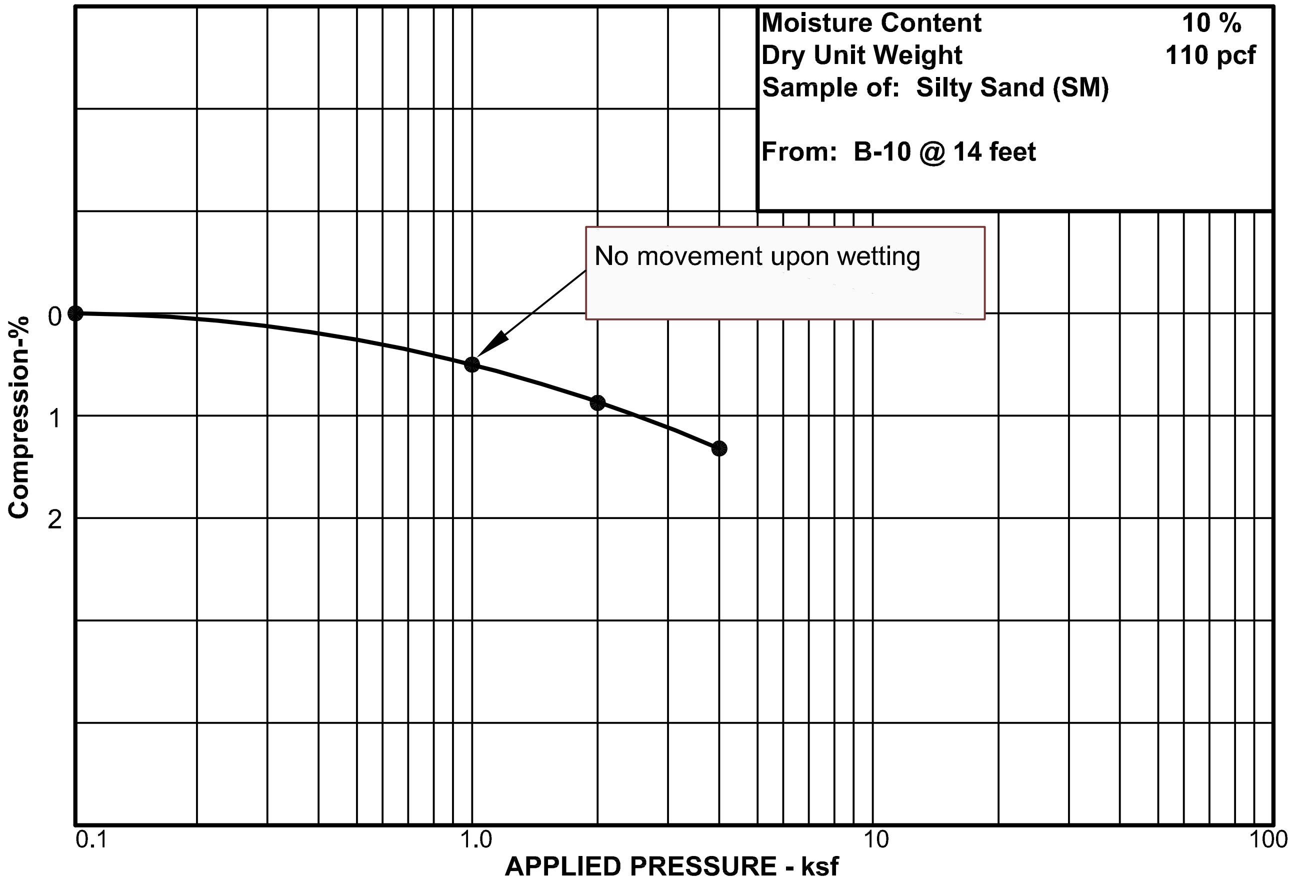


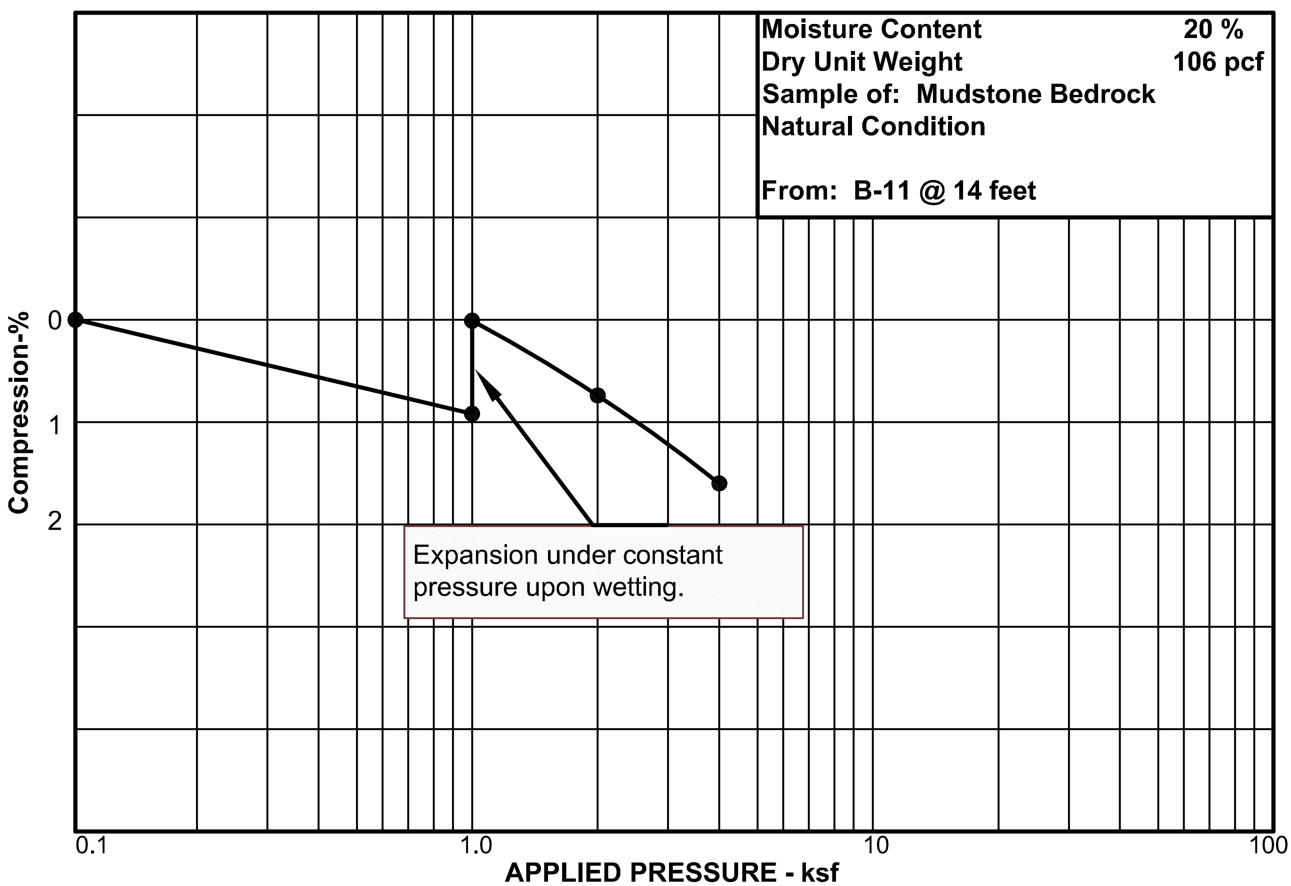
Applied Geotechnical Engineering Consultants, Inc.



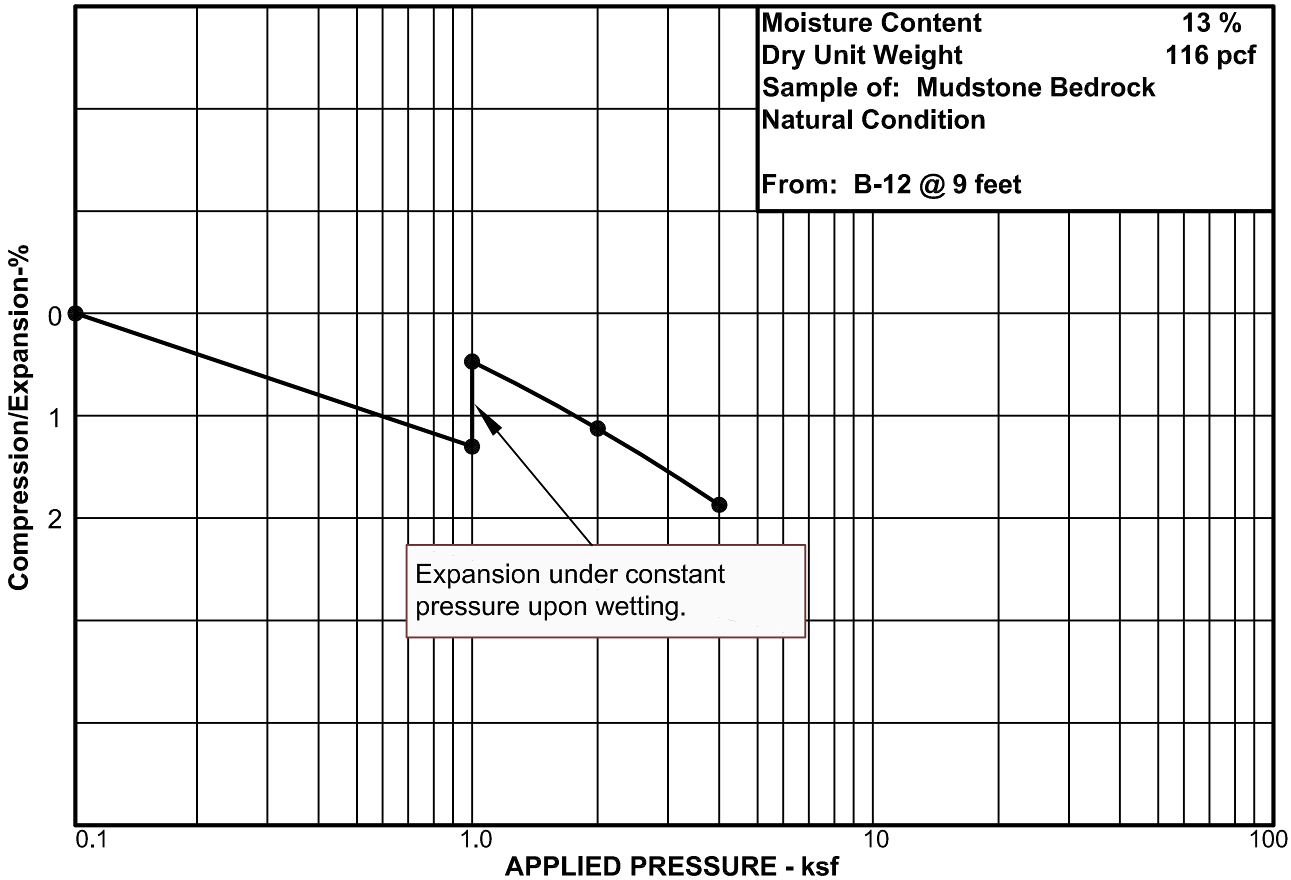
Project No. 2211603 CONSOLIDATION TEST RESULTS Figure 13

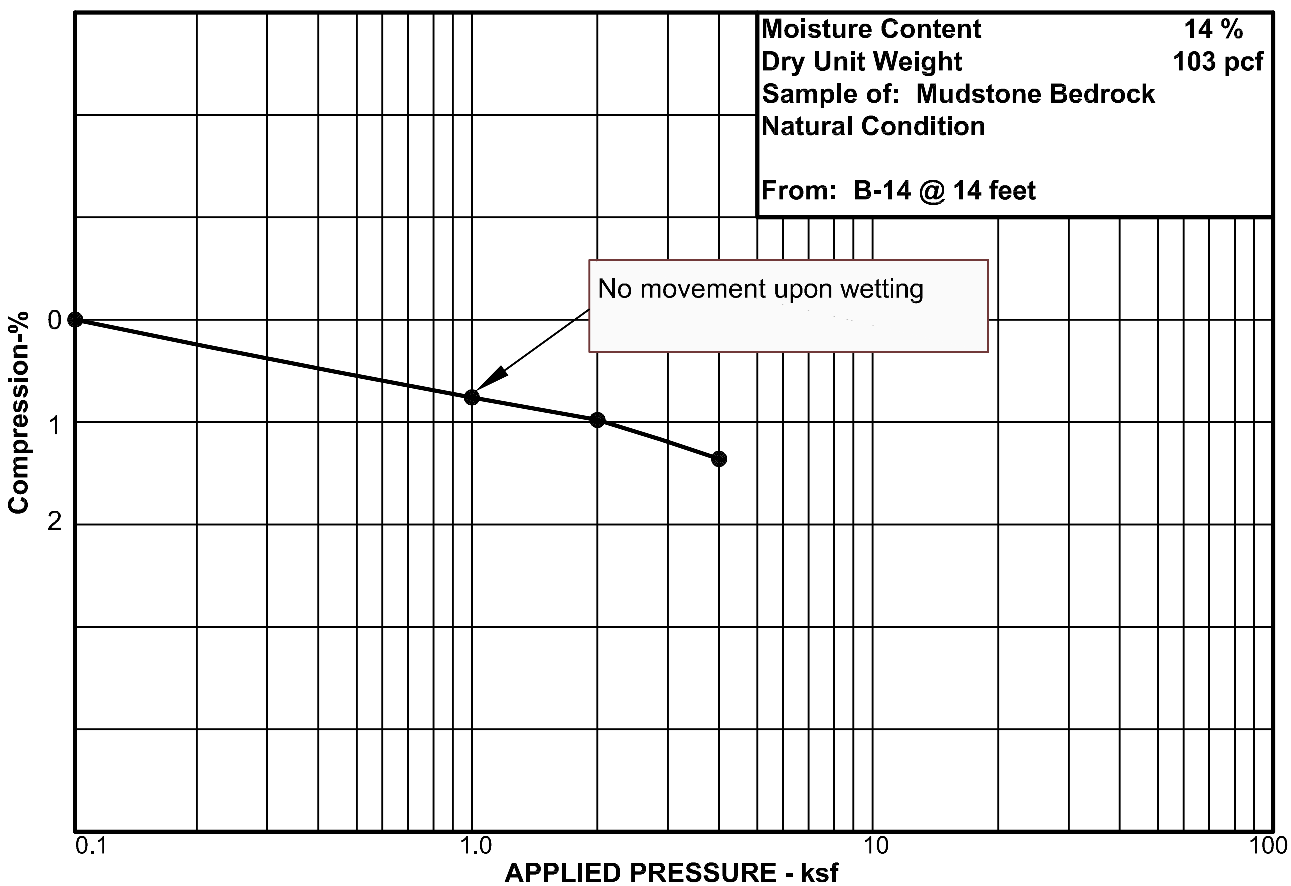
Applied Geotechnical Engineering Consultants, Inc.





Applied Geotechnical Engineering Consultants, Inc.





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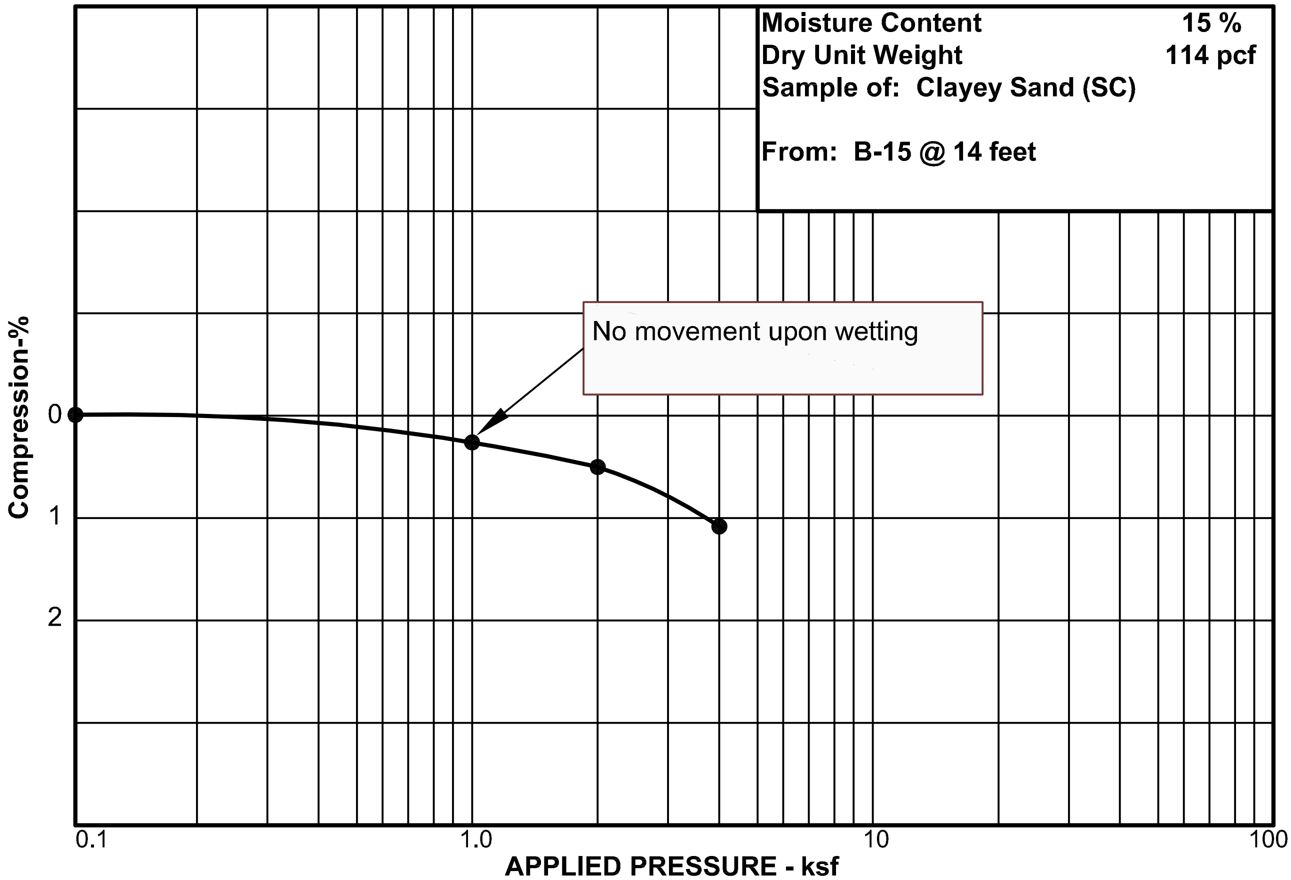

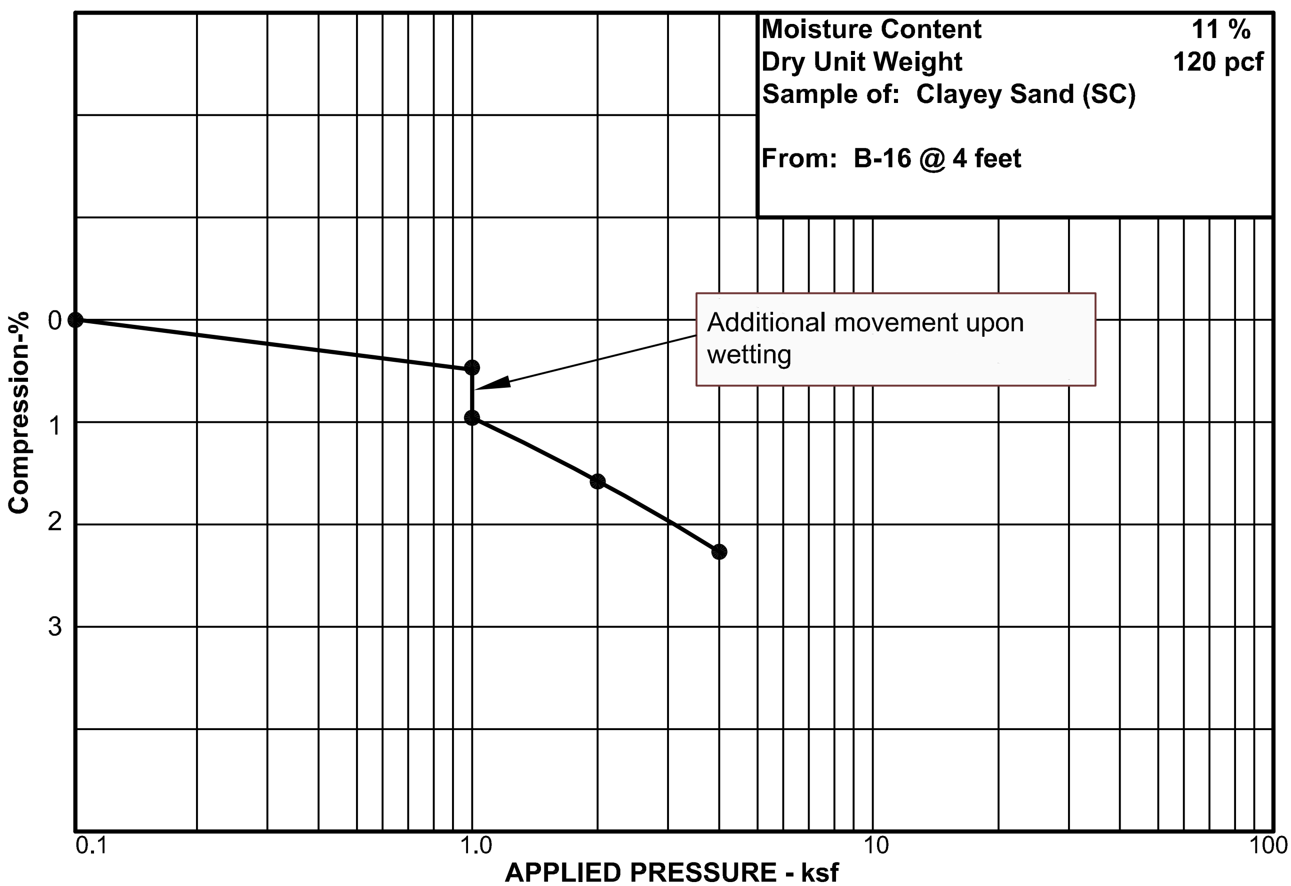

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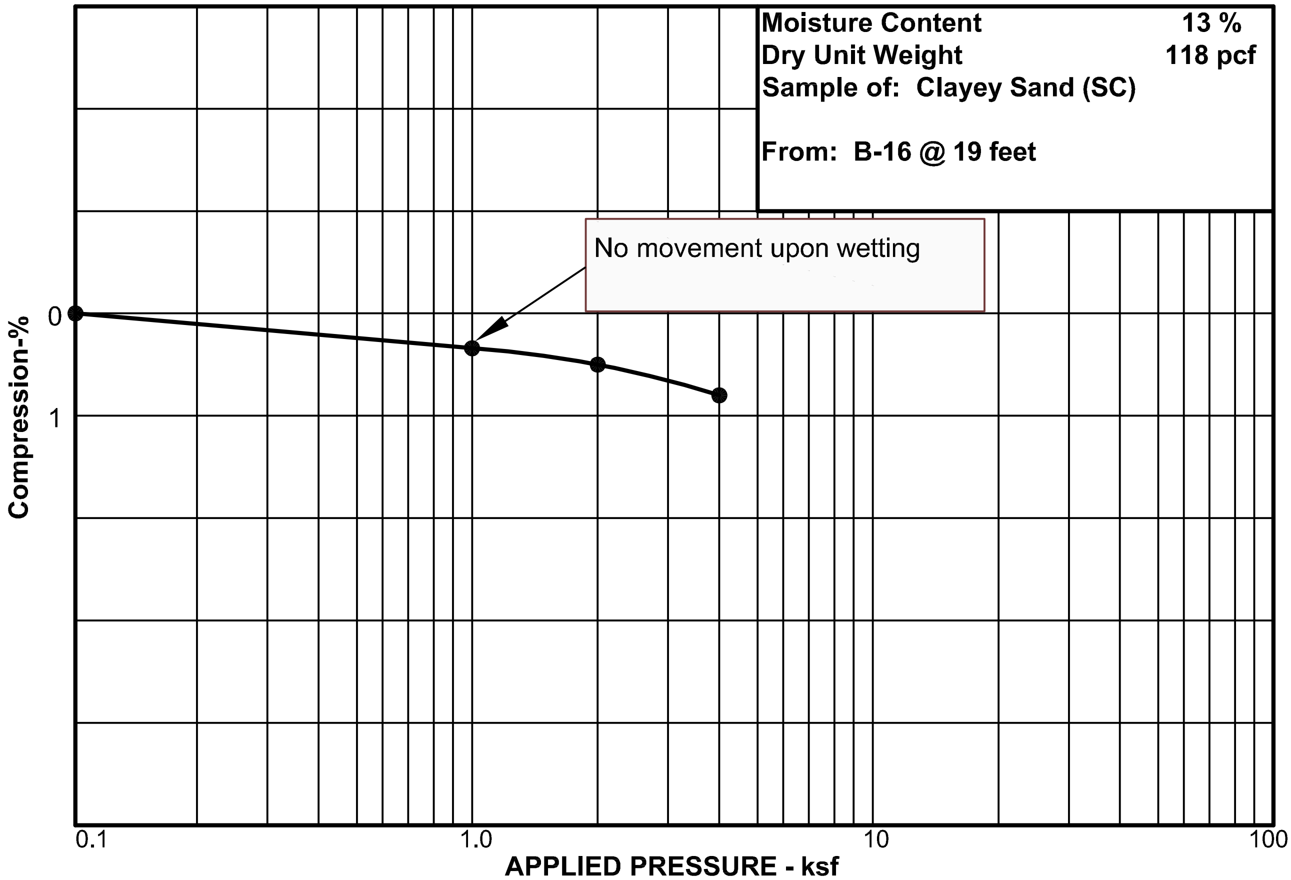

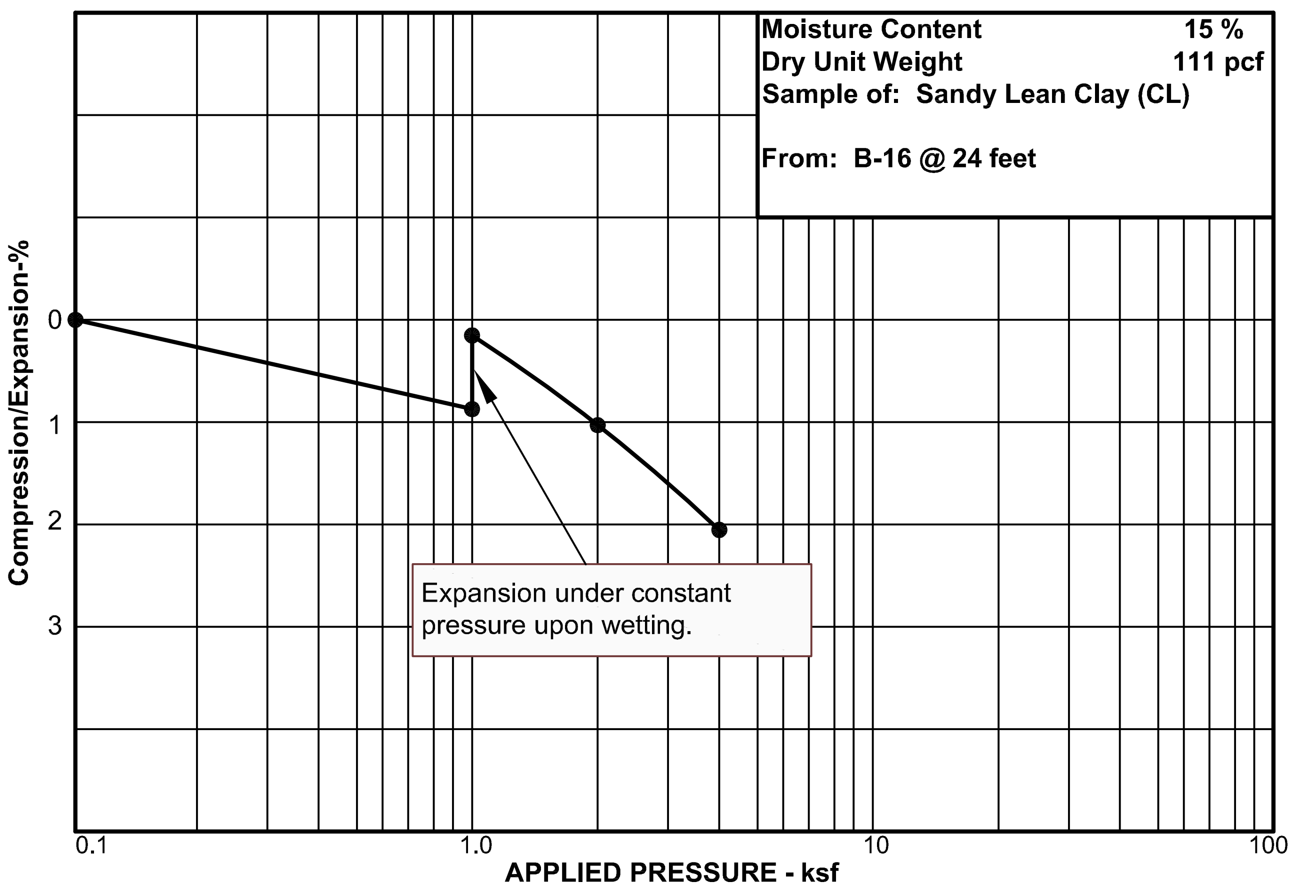

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

TABLE I
SUMMARY OF LABORATORY TEST RESULTS

Black Stone Subdivision

Project Number 2211603

SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		WATER SOLUBLE SULFATE (PPM)	SAMPLE CLASSIFICATION
BORING NO.	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)		
B-1	4					43	52	36		Mudstone Bedrock
B-2	14	10				83	51	32		Mudstone Bedrock
B-3	9	16				75	47	26		Mudstone Bedrock
B-4	1½	1	108							Silty Sand (SM)
B-4	9	3	112	3	91	6				Poorly Graded Sand with Silt (SP-SM)
B-4	14	8	113							Silty Sand (SM)
B-5	4	13	101			55		NP		Sandy Silt (ML)
B-5	14	10	116			41	35	22		Clayey Sand (SC)
B-5	19	9	126			36	30	17		Clayey Sand (SC)
B-6	4	15	110			41	37	22		Clayey Sand (SC)
B-6	9	19	107			66	43	28		Mudstone Bedrock
B-7	4	7	124	0	66	34				Clayey Sand (SC)
B-7	14	2	118	1	82	17				Silty Sand (SM)
B-8	1½	1	107							Silty Sand (SM)
B-8	4	17								Silty Sand (SM)
B-8	9	8	118							Silty Sand (SM)

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Black Stone Subdivision

Project Number 2211603

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BORING NO.	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)		
B-8	14	7	112							Silty Sand (SM)
B-9	4	18	95			43	31	9		Clayey Sand (SC)
B-9	9	11	115			39	26	11		Clayey Sand (SC)
B-9	19	18	108			68				Sandy Silt (ML)
B-10	2	3	112						50	Silty Sand (SM)
B-10	9	7	109	18	50	32	26	14		Clayey Sand (SC)
B-10	14	10	110			34				Silty Sand (SM)
B-10	24	18	102			60				Mudstone Bedrock
B-11	4	8	118			23	22	7		Clayey Sand (SC)
B-11	14	20	106			57	50	28		Mudstone Bedrock
B-12	4	12	149			25	23	6		Clayey Sand (SC)
B-12	9	13	116			93	55	34		Mudstone Bedrock
B-13	4	8	100							Clayey Sand (SC)
B-13	9	10	116			46				Clayey Sand (SC)
B-13	19	15	113							Silty Sand (SM)
B-14	4	13	150			16				Silty Sand (SM)

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

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SUMMARY OF LABORATORY TEST RESULTS

Black Stone Subdivision

Project Number 2211603

SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		WATER SOLUBLE SULFATE (PPM)	SAMPLE CLASSIFICATION
BORING NO.	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)		
B-14	14	14	103			98	59	34		Mudstone Bedrock
B-15	4	9	119			23	28	13		Clayey Sand (SC)
B-15	14	15	114	2	59	39	34	18		Clayey Sand (SC)
B-16	4	21	120			26				Silty Sand (SM)
B-16	14	21	105			96	44	27		Lean Clay (CL)
B-16	19	13	118	1	55	44	30	13		Clayey Sand (SC)
B-16	24	15	111	2	44	54				Sandy Lean Clay (CL)
B-17	14	18				60	39	19		Mudstone Bedrock
B-18	1½	5	110			9				Poorly Graded Sand with Silt (SP-SM)
B-18	9	16				95	49	26		Mudstone Bedrock
B-19	1½	10	113			24	29	17	80	Clayey Sand (SC)
B-20	4	13				48	24	6		Clayey Sand (SC)

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

TABLE 2

DRILLED MICROPILE DESIGN PARAMETERS

Black Stone Subdivision | Project No. 2211603

Soil Type	**Soil Properties**				**Lateral Design Parameters**			**Axial Design Parameters**	
	Effective Unit Weight (pcf)	**Unconfined Compressive Strength (psf)**	**Cohesion (psf)**	**Friction Angle (Degrees)**	**Horizontal Modulus (pci)**	**Ultimate Passive Resistance (psf)**	**Strain @ 50% Yield (k_{rm})**	**Ultimate Skin Friction (psf)**	**Ultimate Uplift Skin Friction (psf)**
Silty to Clayey Sand (0 to 3 ft)	100	0	0	34	75	2,000	0	100	65
Silty to Clayey Sand (≥3 ft)	110	0	0	36	125	3,500	0	400	265
Lean Clay	100	2000	1000	0	100	500	0.007	500	333
Active Mudstone (Upper 10 feet)	110	4,000	2,000	0	1,000	18,000	0.006	1,000	650
Firm Mudstone (> 10 feet)	130	8,000	4,000	0	2,000	36,000	0.005	1,600	1,050