GEOTECHNICAL ENGINEERING REPORT
FOR
CROCKETT ENGINEERING CONSULTANTS

DENTAL OFFICE
LEE'S SUMMIT, MISSOURI

JUNE 10, 2019

Crockett GTL Project Number: G19422

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June 10, 2019

Crockett Engineering Consultants
1000 W Nifong Blvd. – Bldg 1
Columbia, MO 65203

Attn: Mr. Tim Crockett, P.E.

Re: Geotechnical Engineering Report
Dental Office
Lee´s Summit, Missouri
Crockett GTL Project Number: G19422

Dear Mr. Crockett:

Crockett Geotechnical – Testing Lab (CGTL) has completed the geotechnical engineering services for the referenced project. This report should be read in its entirety. This report presents the results of our field explorations, laboratory testing, and recommendations for design and construction of the referenced project.

We appreciate the opportunity to be of service and look forward to working with you during the construction phase of this project. If you have any questions concerning this report, or if we may be of further service, please contact us.

Sincerely,

Aaron Grimm, E.I.T.
Project Manager

Eric H. Lidholm, P.E.
Principal Engineer
Missouri: E-23265

STATE OF MISSOURI
ERIC H. LIDHOLM
NUMBER
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PROFESSIONAL ENGINEER

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1 INTRODUCTION

Crockett Geotechnical - Testing Lab (CGTL) has conducted a geotechnical exploration for the proposed development. The purpose of our exploration was to:

- characterize and evaluate the subsurface conditions,
- provide design and construction recommendations for:
    - subsurface soil conditions
    - groundwater
    - past site construction activities
    - existing possible undocumented fill
    - possible topsoil
    - shrink/swell prone soils
    - shallow rock excavation
    - earthwork
    - foundations
    - floor slabs
    - seismic considerations
    - lateral earth pressures
    - pavement recommendations
    - special inspection requirements

2 SITE AND PROJECT INFORMATION

2.1 Site Location and Description

Item	Description
Location	This project is located about 850 feet southeast of the intersection of Northeast Independence Avenue and 83rd Street in Lee's Summit, Missouri A Site Location Map showing the approximate location of this site is included in the Appendix of this report
Approximate GPS Coordinates	Latitude: 38.966356° Longitude: -94.359793°
Existing improvements	The subject tract is an undeveloped lot
Current ground cover	Grasse and weeds
Existing topography	Gently sloping with approximately 3 feet of relief on the site

2.2 Project Description

Item	Description
Proposed structure	A new one-story building is planned with a planned footprint of approximately 5,600 square feet with a possible future addition of approximately 2,000 square feet and associated parking lots and driving lanes
Building construction	Assumed to be wood framed with steel columns
Finished floor elevation (FFE)	992 feet (provided)
Maximum loads (assumed)	Column Loads: 50 kips Strip Loads: 2.5 klf Floor Loads: 150 psf
Grading	For this project we have assumed site grading to consist of less than approximately 3 feet of cut or fill
Cut and fill slopes	Final slopes are assumed to be no steeper than 3H:1V (Horizontal to Vertical)
Free-standing retaining walls	None
Below grade areas	Stem walls

3 SUBSURFACE CONDITIONS

3.1 Field Exploration and Laboratory Testing

Eight (8) borings were drilled for this project at the approximate locations indicated on the Boring Location Plan included in the Appendix of this report. Additional information follows:

Field Exploration	
Boring Locations [1]	Designated by a Crockett GTL geotechnical engineer and staked by the drill crew
Boring Elevations [1]	Boring elevations were obtained using a draft site plan provided by Crockett Engineering Consultants The elevations were rounded to the nearest foot
Drill Rig	CME45 track-mounted drill rig equipped with 4-inch solid stem augers
Sampling Methods [2]	Representative samples were obtained using thin-walled tube sampling and split-barrel tube sampling procedures

1. The location and elevation of the borings should be considered accurate only to the degree implied by the means and methods used to define them.
2. A CME automatic SPT hammer was used to advance the split-barrel sampler in the borings performed on this site. A significantly greater efficiency is achieved with the automatic hammer compared to the conventional safety hammer operated with a cathead and rope. This higher efficiency has an appreciable effect on the standard penetration resistance blow count (N) value. The effect of the automatic hammer's efficiency has been considered in the interpretation and analysis of the subsurface information for this report.

The samples were tagged for identification, sealed to reduce moisture loss, and taken to our laboratory for further examination, testing, and classification. Information provided on the boring logs attached to this report includes soil descriptions, consistency evaluations, boring depths, sampling intervals, and groundwater conditions. The borings were backfilled with auger cuttings prior to the drill crew leaving the site.

The field logs were prepared by the drill crew. Final logs included with this report represent the engineer's interpretation of the field logs and include modifications based upon laboratory tests and observation made of the samples. Detailed information regarding the material encountered and the results of field sampling and laboratory testing are shown on the Boring Logs included in the Appendix of this report. The descriptions of the soil on the final boring logs are in general accordance with the Unified Soil Classification System which is included in the Appendix of this report.

3.2 ENCOUNTERED SUBSURFACE CONDITIONS

From the ground surface all of the borings approximately 6 to 8 inches of topsoil. Topsoil thickness should be expected to vary elsewhere on the site.

Underlying the topsoil in borings B-1 through B-6 and B-8 was either native fat clay or shaley fat clay. These materials extended to depths ranging from 1.5 to 4.1 feet. These materials had slickensides (pre-determined fracture planes) throughout which contributed to lower unconfined compression test results.

Soil that with the appearance possible topsoil was encountered borings B-1, B-4 and B-5 to depths of about 3.0 feet. Additional testing was performed on samples of this material and are discussed in section 4.3 of this report.

Underlying the topsoil in boring B-7 was lean to fat clay that was identified as possible undocumented fill. Undocumented fill is fill material that appears to be compacted to a relatively high degree but for which no compaction test reports are available to verify satisfactory compaction and moisture control was achieved throughout the fill area. The possible undocumented fill extended to approximately 1.7 feet.

Underlying the fat clay, shaley fat clay or possible undocumented fill in each boring was weathered limestone. Split spoon sampler and auger refusal was achieved in the weathered limestone at depths ranging from 2.0 to 4.5 feet.

Detailed descriptions of the encountered materials are listed on the individual boring logs included in the Appendix of this report. Strata lines indicate the approximate location of changes in material types. The transition between material types may be gradual.

3.3 GROUNDWATER

Groundwater was not encountered in any of the borings while drilling, at the completion of drilling or for the short duration the borings remained open after the completion of drilling. However, this does not necessarily mean the borings terminated above groundwater or that the water levels summarized above are stable groundwater levels. Due to the low permeability of the soils encountered in the borings, a relatively long period of time may be necessary for a groundwater level to develop and stabilize in a borehole in these materials.

Perched groundwater can develop over low permeability soil or rock strata following periods of heavy or prolonged precipitation. This possibility should be considered when developing design and construction plans and specifications for the project. Groundwater levels depend on seasonal and climatic variations and may be present at different levels in the future.

The boreholes were backfilled prior to departing the project site. Groundwater records are indicated on the boring logs included in the Appendix of this report.

4 GEOTECHNICAL RECOMMEDATIONS

4.1 PAST SITE CONSTRUCTION ACTIVITIES

Historical photography indicates that this site has had grading and construction activities performed in the past. Based upon a review of historical aerial photography, the extent of activity is not well defined but it appears as is the entire site has been graded. Possible undocumented fill was encountered in boring B-7 to a depth of approximately 1.7 feet. Undocumented fill could be encountered elsewhere on the site.

4.2 EXISTING POSSIBLE UNDOCUMENTED FILL

Existing possible undocumented fill was encountered in boring B-7 to a depth of about 1.7 feet. Undocumented fill is fill material that appears to be compacted to a relatively high degree but for which no compaction test reports are available to verify satisfactory compaction and moisture control was achieved throughout the fill area.

Undocumented fill could be encountered elsewhere on this site. Historic photographs indicate past site activity but are unclear as to the extent or scope of activity.

Owners sometimes choose to allow undocumented fill to remain on a project site in pavement areas. Although not encountered in the building borings, we do not recommend supporting footings on the undocumented fill. In order to reduce, but not eliminate, the risk of supporting pavement on existing undocumented fill, we recommend that the subgrade be thoroughly evaluated after stripping of topsoil and creation of all cut areas but prior to the start of fill operations. Additional evaluations may require the excavation of test pits. Risk can be also reduced by removing and replacing a portion of the existing undocumented fill with new structural fill. Risk associated with construction on existing undocumented fill must be assumed by the owner. These risks can be eliminated by completely removing and replacing the existing undocumented fill with new structural fill.

4.3 POSSIBLE TOPSOIL

Soil that with the appearance possible topsoil was encountered in borings B-1, B-4 and B-5 to depths of about 3.0 feet. To further evaluate these soils, organic content tests were performed. Results are as follows:

Organic Content			
Boring Number	Sample Number	Sample Depth, ft.	Organic Content, %
B-1	S-1	1 – 3	4.5
B-4	S-1	1 – 3	4.7
B-5	S-1	1 – 3	4.5

Depending on the reference, topsoil is classified as soil with an organic content of 5% or 6%, or more. Although the soils on this site had an organic content that were slightly less than 5%, they are likely to perform similarly to a topsoil. Topsoil is not recommended for use in structural areas.

Risk associated with construction on topsoil-like materials must be assumed by the owner. These risks can be eliminated by completely removing and replacing the topsoil-like material with new structural fill.

4.4 SWELLING SOILS

Soil that has the capability to shrink or swell is present on this site. This report provides recommendations to help mitigate the effects of soil shrinkage and expansion. However, even if these procedures are followed, some movement and at least minor cracking in the structure should be anticipated. The severity of cracking and other cosmetic damage such as uneven floor slabs will probably increase if any modification of the site results in excessive wetting or drying of the expansive soils. Eliminating the risk of movement and cosmetic distress may not be feasible, but it may be possible to further reduce the risk of movement if significantly more expensive measures are used during construction. We would be pleased to discuss other construction alternatives with you upon request.

The procedures for constructing a low volume change zone, as recommended in this report, may not eliminate all future subgrade volume change and resultant floor slab movements, however, the procedures outlined should significantly reduce the potential for subgrade volume change. Additional reductions in floor slab movements could be achieved by using a thicker low volume change zone. Details regarding this low volume change zone are provided in the Floor Slab section of this report. Any compacted structural fill placed in the upper 18-inches beneath the building areas should meet the requirements for Low Volume Change (LVC) Material which is defined in the Earthwork section of this report.

In addition, all grades must provide effective drainage away from the buildings during and after construction. Water permitted to pond next to the structure can result in greater soil movement and can result in unacceptable structural performance. After building construction and landscaping has been completed, we recommend verifying final grades to document effective drainage has been achieved. Grades around the structure should also be periodically inspected and adjusted as necessary, as part of the structure's maintenance program.

4.4.1 Estimated Swell

A swell estimation technique that uses soil index properties (liquid limit, dry density, and moisture content) was utilized to evaluate the potential for swell of the existing soils at the floor slab on-grade level. Based upon the results of this method, the potential swell of the existing near surface soils is estimated to be on the order of 0.5% to 2.75% and averaged about 1.60%.

4.4.2 Swell Discussion

Literature indicates swell greater than 1.5% is considered high, or critical. Swell less than 0.5% is considered low or non-critical. Swell on the order of 0.5% to 1.5% is considered marginal. Because of the measured and estimated swell potential of the near surface soils, differential movement of lightly loaded, grade supported structures (i.e. floor slabs) is possible. For this reason we recommend a low volume change (LVC) zone be constructed beneath all at-grade floor slabs.

4.5 Shallow Bedrock/Rock Excavation

Weathered limestone was encountered at shallow depths in all borings and is expected to be encountered during construction activities. Rippability of this material will vary.

Experience has indicated that rock formations which can be penetrated with flight augers can sometimes be excavated using heavy duty construction equipment such as track-hoes with rock teeth or ripper equipped dozers. Excavation in rock formations which cannot be penetrated with flight augers is usually much more difficult and often requires the use of other techniques such as jackhammers, rock splitters, pneumatic breakers, or blasting. Rippability of boulders is often a function of boulder size; however, large boulders often behave similar to bedrock, as previously described. It should be noted that the rippability of boulders and/or bedrock is more dependent on the type and size of the equipment used, the fracturing or quality of the bedrock, and the amount of effort expended, than it is on the type of rock.

We recommend the contractor consider making test excavations to determine the rippability of the rock penetrated by the flight augers. We also recommend the contractor submit unit rate rock excavation costs as part of the bidding process. Or if the grading and utility plan, along with our boring data, suggests that rock excavation may be encountered, additional exploration can be performed to better quantify the rock surface.

4.6 Earthwork

At the completion of stripping and grubbing, we recommend the exposed subgrade be thoroughly evaluated before the start of any fill operations, including placement of low volume change material. We recommend the geotechnical engineer be retained to evaluate the bearing material for the foundations and subgrade soils. Subsurface conditions, as identified by the field and laboratory testing programs have been reviewed and evaluated with respect to the proposed project plans known to us at this time.

4.6.1 Site Preparation

All unsuitable material should be removed from the construction areas prior to placing structural fill. After stripping and grubbing, the site should be proofrolled to aid in locating loose or soft areas. Proofrolling can be performed with a loaded tandem axle dump truck. Soft, wet, dry and low-density soil should be removed or be moisture conditioned and recompacted in place as structural fill prior to placing new structural fill.

Where fill is placed on existing slopes steeper than 5H:1V, benches should be cut into the existing slopes prior to fill placement. The benches should have a vertical face height of 1 to 3 feet and should be cut wide enough to accommodate the compaction equipment. We recommend structural fill slopes be overfilled and then cut back to develop an adequately compacted slope face.

4.6.2 Structural Fill Requirements

Compacted structural fill should consist of approved materials free of organic matter and debris. Frozen material should not be used and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted for evaluation prior to use.

Structural Fill Material Requirements		
Material Type	USCS Classification	Acceptable Uses
Lean Clay and Clayey Sand	CL & SC (LL<40)	All locations
Lean to Fat Clay	CL-CH (40<LL<50)	>18-inches below slabs on grade unless PI<23
Fat Clay	CH (LL≥50+)	>18-inches below floor slab

Structural Fill Material Requirements	
Low Volume Change Material	• Similar to MoDOT Type 1 or 5 crushed limestone aggregate, limestone screenings, or granular material such as sand, gravel or crushed stone containing at least 18% low plasticity fines. • Low plasticity cohesive soil or granular soil having at least 18% low plasticity fines. • Can also consist of chemically treated soil such as hydrated lime, Code-L, etc.

4.6.3 Structural Fill Compaction Requirements

Structural Fill Compaction Requirements	
Soil Fill Lift Thickness	• 9 inches or less when using heavy self-propelled compaction equipment • 6-inches or less when using hand guided or light self-propelled equipment
Compaction Requirements [1, 2]	95% of standard Proctor dry density (ASTM D-698) 1. We recommend engineered fill be tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved. 2. As stated within ASTM D698, this procedure is intended for soils with 30% or less material larger than ¾˝. Accordingly, we recommend full time proof-roll observation be performed instead of moisture density testing for materials containing more than 30% aggregate retained on the ¾˝ sieve.
Compaction Moisture Content Requirements • Lean to Fat Clay and Fat Clay • Lean Clay and Silt • Granular	 • Optimum moisture content (OMC) to 4% above the standard Proctor optimum moisture content • 2% below to 3% above standard Proctor OMC • Workable moisture content. Shall not pump when proofrolled

4.6.4 Grading and Drainage

Final surrounding grades should be sloped away from the structure on all sides to prevent ponding of water. Gutters and downspouts that drain water a minimum of 10 feet beyond the footprint of the proposed structures are recommended. This can be accomplished through the use of splash-blocks, downspout extensions, and flexible pipes designed to attach to the end of the downspout. Flexible pipe should only be used if it is daylighted in such a manner that it gravity-drains collected water. Splash-blocks should also be considered below hose bibs and water spigots.

4.6.5 Underground Utilities

Underground utilities can provide a pathway for water to migrate below at-grade slabs. Drain and utility pipes beneath at-grade slabs should have tight joints to prevent leakage. If utility trenches are backfilled with relatively free-draining granular material, they should be effectively sealed to restrict water intrusion and flow through the trenches that could migrate below the structure and a-grade slabs. In addition, we recommend constructing an impermeable cut-off consisting of an effective clay plug at least 3 feet in length where underground utilities enter or exit the perimeter of the structure.

With the exception of individual service lines to the buildings that intersect foundations perpendicularly, below grade utilities should not be located within the stress influence zone of the building foundations. Accordingly, below grade utilities should be located outside a zone extending 45-degrees downward and outward from the edge of the footings.

4.6.6 Earthwork Construction

In periods of dry weather, the surficial soils may be of sufficient strength to allow fill construction on the stripped and grubbed ground surface. However, unstable subgrade conditions could develop if the soils are wet or subjected to repetitive construction traffic. Should unstable subgrade conditions be encountered, stabilization measures will need to be employed.

Upon completion of filling and grading, care should be taken to maintain the subgrade moisture content prior to construction. Construction traffic over the completed subgrade should be avoided to the extent practical. The site should also be graded to prevent ponding of surface water on the prepared subgrades or in excavations. If the subgrade should become frozen, desiccated, saturated, or disturbed, the affected material should be removed or these materials should be scarified, moisture conditioned, and recompacted prior construction.

The geotechnical engineer should be retained during the construction phase of the project to observe earthwork/fill placement and to perform necessary tests and observations during subgrade preparation; proofrolling; placement and compaction of structural fills; backfilling of excavations into the completed subgrade, and just prior to construction.

4.6.7 Trees or Vegetation with Significant Root Systems

Trees or other vegetation whose root systems have the ability to remove excessive moisture from the subgrade and foundation soils should not be planted next to or near the structure. The drying effect of the root system can cause the existing subgrade soils to shrink which can appear as slab movement or foundation settlement. Because of this, we suggest the owner consider using a root control barrier around the perimeter of the structure.

4.6.8 Temporary Excavations

The Occupational Safety and Health Administration (OSHA) has developed regulations to provide for the safety of workers entering excavations. Temporary excavations will probably be required during grading operations. All operations should be performed under the supervision of qualified site personnel in accordance with OSHA Excavation and Trench Safety Standards.

4.7 Foundations

We recommend that the proposed structure be supported on spread footings bearing on suitable native soil or new structural fill. If bedrock is encountered in, or near, the design excavation, the footings be overexcavated 2 feet below the design bearing elevation. Additional recommendations are provided in section 4.6.3 below if bedrock is encountered in footing excavations. Design recommendations and construction considerations for shallow foundations follow:

4.7.1 Shallow Foundation Design Recommendations

Design recommendations for shallow foundations are as follows:

Shallow Foundation Design Recommendations	
Allowable bearing pressure • Isolated foundations • Continuous foundations • Allowable overstress for transient loads (i.e. snow, wind, seismic) 1. Assumes all foundations will bear directly upon native soil or new structural fill.	 2,500 psf 2,100 psf 33%
Minimum foundation dimensions • Isolated foundations • Continuous foundations	 30 inches 18 inches
Ultimate passive pressure (equivalent fluid pressure) 1. The sides of the spread footing foundation excavations must be nearly vertical and the concrete should be placed neat against the vertical faces for the passive earth pressure values to be valid. 2. Passive resistance in the frost zone should be neglected. 3. Some movement of the footing will be required to mobilize resistance from passive pressure and sliding friction.	270 pcf
Ultimate coefficient of sliding friction	0.32
Minimum embedment below finished grade for frost protection	30 inches

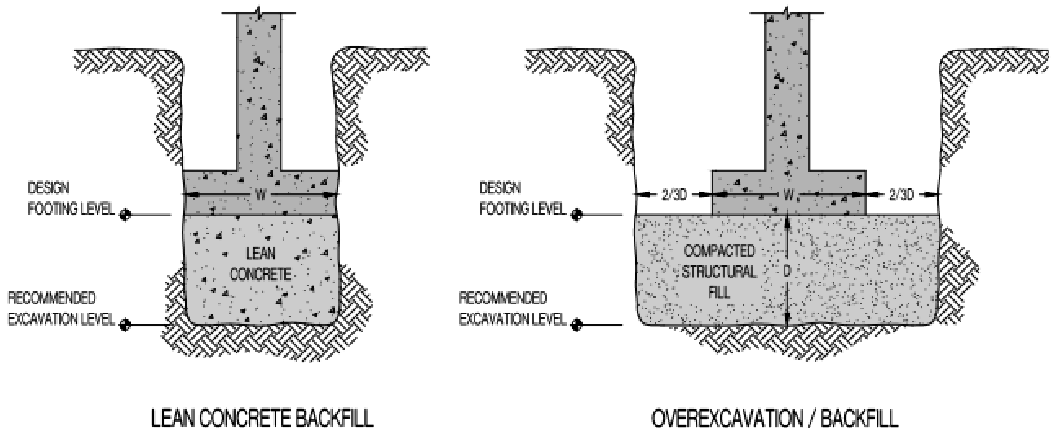
Shallow Foundation Design Recommendations	
Uplift Resistance • Soil Total Unit Weight • Concrete Total Unit Weight 1. Only the soil directly overlying the foundation should be used for uplift resistance 2. Unit weight values do not include factors of safety 3. Assumes foundations are drained and are constructed above the highest groundwater level	120 pcf 150 pcf
Approximate Foundation Settlement • Total • Differential 1. Assumes maximum footing size of 4.5 feet for isolated foundations and 1.5 feet for continuous foundations. Assumes footings bear on native soil or new structural fill but not on the existing undocumented fill.	< 1 inch < ¾ inch

4.7.2 Shallow Foundation Construction Considerations

The base of all foundation excavations should be free of water and loose soil and rock prior to placing concrete. Concrete should be placed soon after excavating to reduce bearing soil disturbance. Should the soil at the foundation bearing level become excessively dry, disturbed, saturated, or frozen the affected soil should be removed prior to placing concrete. Place a lean concrete mud-mat over the bearing soils if the excavations must remain open over night or for an extended period of time. It is recommended the geotechnical engineer be retained to observe and test the soil foundation bearing materials.

Although groundwater was not encountered in the borings, conditions may develop such that it may be encountered during foundation excavation. In addition, some surface and/or perched groundwater may enter foundation excavations during construction. It is anticipated any water entering foundation excavations from these sources can be removed using sump pumps or gravity drainage.

If unsuitable bearing soils are encountered in footing excavations, the excavations should be extended deeper to suitable soils and the footings should bear directly on these soils at the lower level or on lean concrete backfill placed in the excavations. The footings could also bear on properly compacted backfill extending down to the suitable soils. Overexcavation for compacted backfill placement below footings should extend laterally beyond all edges of the footings at least 8 inches per foot of overexcavation depth below footing base elevation. The overexcavation should then be backfilled up to the footing base elevation with well graded granular material placed in lifts of 9 inches or less in loose thickness and compacted to at least 98 percent of the material's maximum standard effort maximum dry density (ASTM D 698). The lean concrete backfill and overexcavation-and-backfill procedures are described in the diagram below.



4.7.3 Rock Excavation for Shallow Foundations

Some foundation excavations may extend into difficult excavation conditions (i.e. encountering bedrock, weathered rock, or boulders). We recommend, if bedrock is encountered in, or near, the design excavation, the footings be overexcavated 2 feet below the design bearing elevation and extended laterally a sufficient distance to provide room for a bond-break with the sides of the excavation. The side-of-footing bond break can consist of insulation board, plywood, or other rigid material that will prevent the fresh concrete from creating a cold joint with the irregular surface on the side-of-footing excavation in the rock.

The overexcavation should be backfilled with compacted, well graded crushed limestone aggregate similar to crushed limestone screenings or MoDOT Type I base rock. Compactive effort should be in accordance with the recommendations provided in the Earthwork section of this report (95% MDD, workable moisture levels).

4.8 Floor Slabs

Active soils that are prone to volume change with variations in moisture content are present near the anticipated at-grade floor slab subgrade level. Because of this, we recommend a low volume change zone be constructed beneath all at-grade floor slabs. Details follow:

Floor Slab Design Recommendations [1, 2]	
Floor slab support	18-inch low volume change zone
Modulus of subgrade reaction • For point loading conditions	100 (psi/in)
Aggregate base course/capillary break • Free draining granular material • Free-draining granular material should have less than 5 percent fines (material passing the #200 sieve)	4 to 6 inches Aggregate base course can be considered as part of the low volume change zone.
1. Floor slabs should be structurally independent of any building footings or walls to reduce the possibility of floor slab cracking caused by differential movement between the slab and foundation. However, if floor slabs are tied to perimeter walls or turn-down slabs to meet structural or other construction objectives, our experience indicates that any differential movement between the walls and slabs will likely be observed in adjacent slab expansion joints or slab cracks that occur beyond the length of the structural dowels. The structural engineer should account for this potential differential settlement through use of sufficient control joints, appropriate reinforcing or other means. 2. If the subgrade should become desiccated or saturated prior to construction of floor slabs, the affected material should be removed or the materials scarified, moistened, and recompacted. Care should be taken to maintain the recommended subgrade moisture content and density until construction of the building floor slabs.	

Control joints should be utilized in the slab to help control the location and extent of cracking. For additional recommendations refer to the ACI Design Manual. Joints or any cracks that develop should be sealed with a water-proof, non-extruding compressible compound specifically recommended for heavy duty concrete pavement and wet environments.

The use of a vapor retarder should be considered beneath concrete slabs on grade that will be covered with wood, tile, carpet or other moisture sensitive or impervious coverings, or when the slab will support equipment sensitive to moisture. When conditions warrant the use of a vapor retarder, the slab designer should refer to ACI 302 and/or ACI 360 for procedures and cautions regarding the use and placement of a vapor retarder.

4.9 Seismic Considerations

The International Building Code and ASCE 7 requires the average properties in the upper 100 feet of the subsurface profile be determined for seismic site classification. The drilling scope performed for this project had borings that extended to a maximum depth of approximately 4.5 feet. As such, we provide the following seismic site classification:

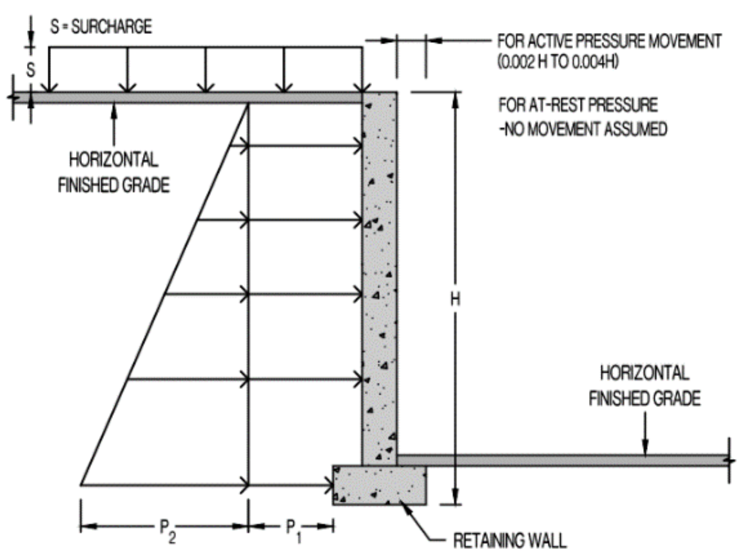
Seismic Site Classification	
Code Used	International Building Code (IBC) and ASCE 7
Site Classification	C

Additional exploration to greater depths could be considered to confirm the conditions below the current depth of exploration. Alternatively, a geophysical exploration could be utilized in order to attempt to justify a more favorable seismic site class.

4.10 Lateral Earth Pressures

The lateral earth pressure recommendations given in the following paragraphs are applicable to the design of rigid retaining walls subject to slight rotation, such as cantilever, or gravity type concrete walls. These recommendations are not applicable to the design of modular block - geogrid reinforced backfill walls. Recommendations covering these types of wall systems are beyond the scope of services for this assignment.

Reinforced concrete walls with unbalanced backfill levels may be utilized on this site. Walls should be designed using the earth pressures indicated on the following table. Earth pressures will be influenced by structural design of the walls, conditions of wall restraint, methods of construction and/or compaction and the strength of the materials being restrained. Two wall restraint conditions are shown. Active earth pressure is commonly used for design of free-standing cantilever retaining walls and assumes wall movement. The "at-rest" condition assumes no wall movement. The recommended design lateral earth pressures do not include a factor of safety and do not provide for possible hydrostatic pressure on the walls.



Earth Pressure Coefficients			
Backfill Type	Active (K_a)	At Rest (K_o)	Passive (K_p)
Cohesive Equivalent Fluid Unit Weights	50 pcf	70 pcf	280 pcf
Granular Equivalent Fluid Unit Weights	40 pcf	60 pcf	360 pcf
Surcharge Pressure, P_1 (psf) Cohesive Granular	(0.42)S (0.33)S	(0.58)S (0.46)S	--- ---
Earth Pressure, P_2 (psf) Cohesive Granular	(50)H (40)H	(70)H (55)H	--- ---
Sliding Resistance	0.32 (coefficient of friction)		

- The values are applicable when the surface of the backfill behind the wall is horizontal. Increased values will result with steeper than horizontal slopes.
- No safety factor included in soil parameters
- Does not include loading from heavy compaction equipment
- No hydrostatic pressures acting on wall
- Backfill compacted to 95% standard Proctor dry density, or 80% relative density, as appropriate for material type.
- Soil backfill unit weight a maximum of 120 pcf
- No dynamic loading.
- For active earth pressure, wall must rotate about base, with top lateral movements of about 0.002 H to 0.004 H, where H is wall height
- For passive earth pressures to develop, the wall must move horizontally.
- Ignore passive pressure in the frost zone
- For the granular values to be valid, the granular backfill must extend out from the base of the wall at an angle of at least 45 and 60 degrees from vertical for the active and passive cases, respectively.
- Exterior granular backfill should be capped with approximately 2 feet of cohesive soil to reduce the potential for surface water infiltration into the granular backfill.
- Uniform surcharge, where S is surcharge pressure.

We recommend all below-grade walls be provided with a drainage system. A minimum 4-inch diameter, perforated drainpipe should be placed at the foundation level. Granular drainage material, consisting of 1-inch clean crushed rock, classified as GP by ASTM D 2487, with less than 5 percent passing the No. 200 sieve, should be placed a minimum of 6 inches in all directions around the drainage pipe. Synthetic filter fabric, such as Mirafi 140N or equivalent, should encapsulate the drainpipe and granular drainage material.

The pipe should be sloped to drain by gravity or through weep holes located on approximately 10-foot centers for above-grade retaining walls, or to a sump with a pump for below-grade walls where positive drainage by gravity cannot be achieved. Any interior sumps must be isolated "watertight" from the interior subgrade to prevent the movement of moisture from the sump into the underlying soils.

4.11 PAVEMENTS

Existing possible undocumented fill was encountered in boring B-7 drilled for this investigation. Undocumented fill is fill that appears to have been placed in a controlled fashion but for which no compaction tests reports are available. Soil with significant organic content was also encountered in borings B-1, B-4 and B-5. Owners sometimes choose to allow undocumented fill and high-organic content soils to remain on a project site in pavement areas. Risk associated with construction on existing undocumented fill must be assumed by the owner.

In order to reduce, but not eliminate, the risk of supporting new pavement on existing undocumented fill and/or high organic content soils, we recommend the subgrade be thoroughly evaluated after stripping and creation of all cut areas but prior to the start of fill operations. Additional evaluations may require the excavation of test pits. Risk can be also reduced by removing and replacing a portion of the existing undocumented fill and/or high organic content soil with new structural fill. Additional reductions in risk could be achieved by removing and replacing a thicker portion of the undocumented fill and/or high organic content soils with new structural fill. The risks associated with construction on undocumented fill can be eliminated by completely removing and replacing the existing undocumented fill with new structural fill.

4.11.1 Subgrade Preparation

Pavement subgrades, initially prepared early in the project, should be carefully evaluated as the time for pavement construction approaches. At a minimum, we recommend the moisture content and density of the top 9 inches of the subgrade be evaluated and the pavement subgrades be proofrolled immediately prior to paving operations. Areas not in compliance with the required ranges of moisture or density should be moisture conditioned and recompacted prior to placement of the base rock.

The subgrade should be reviewed by qualified personnel immediately prior to paving. The subgrade should be in its finished form at the time of the final review.

4.11.2 Design Considerations

Traffic patterns and anticipated loading conditions were not available at the time this report was prepared. However, we anticipate traffic loads will be produced primarily by automobile traffic and occasional delivery and trash removal trucks. The thickness of pavements subjected to heavy truck traffic should be determined using expected traffic volumes, vehicle types, and vehicle loads and should be in accordance with local, city or county ordinances.

Pavement thickness can be determined using AASHTO, Asphalt Institute and/or other methods if specific wheel loads, axle configurations, frequencies, and desired pavement life are provided. CGTL can provide thickness recommendations for pavements subjected to loads other than personal vehicle and occasional delivery and trash removal truck traffic if this information is provided.

4.11.3 Estimated Minimum Pavement Thickness

The following estimated pavement design parameters were established based upon the boring information, an assumed CBR of 2.25 and experience with similar projects and soil conditions.

Estimated Pavement Section Thickness

Traffic Area	Pavement Type [1]	Asphalt Cement Concrete		Portland Cement Concrete[2] (inches)	Aggregate Base Course[3] (inches)	Total Thickness (inches)
		Surface Course (inches)	Base Course (inches)			
Light Duty (Car Parking)	PCC	--	--	5.0	4.0	9.0
	ACC	2.0	3.0	--	6.0	11.0
Heavy Duty (Drive Lanes)	PCC	--	--	6.0	4.0	10.0
	ACC	2.0	4.0	--	6.0	12.0
Trash Container Pad [4]	PCC	--	--	7.0	4.0	11.0

1. PCC = Portland Cement Concrete. ACC = Asphaltic Cement Concrete.
2. 4,000 psi at 28 days, 4-inch maximum slump and 5 to 7 percent air entrained, 6-sack min. mix. PCC pavements are recommended for trash container pads and in any other areas subjected to heavy wheel loads and/or turning traffic.
3. MoDOT Type 5 crushed limestone base material (CLBM)
4. The trash container pad should be large enough to support the trash container and the tipping axle of the collection truck.

4.11.4 Pavement Maintenance

The pavement sections provided in this report represent minimum recommended thicknesses and, as such, periodic maintenance should be anticipated. Preventive maintenance should be planned and provided for through an on-going pavement management program. Even with periodic maintenance, some movements and related cracking may still occur and repairs may be required.

4.11.5 Pavement Drainage

Pavement performance is affected by its surroundings. In addition to providing preventive maintenance, the civil engineer should consider the following recommendations in the design and layout of pavements:

- Final grade adjacent to paved areas should slope down from pavement edges at a minimum grade of 2%;
- The subgrade and the pavement surface should be adequately sloped to promote proper surface drainage;
- Install pavement drainage in areas anticipated to be frequently wetted (e.g. landscape islands, garden centers, wash racks);
- Install joint sealant and seal cracks immediately;
- Seal all landscaped areas in, or adjacent to pavements to reduce moisture migration to subgrade soils; and
- Place compacted, low permeability backfill against the exterior side of curb and gutter.

4.12 Special Inspection Requirements

The following items require special inspections in accordance with Chapter 17 of the International Building Code:

Schedule of Special Inspection Services [1]			
Material/Activity	Service	Applicable to this Project	
		Y/N	Extent
1705.6 Soil		Y	
• Verify materials below shallow foundations are adequate to achieve the design bearing capacity.	Field Inspection	Y	Periodic
• Verify excavations are extended to proper depth and have reached proper material	Field Inspection	Y	Periodic
• Perform classification and testing of controlled fill materials.	Field Inspection	Y	Periodic

Schedule of Special Inspection Services [1]			
• Verify use of proper material, densities, and lift thicknesses during placement and compaction of controlled fill.	Field Inspection	Y	Continuous
• Prior to placement of controlled fill, observe subgrade and verify site has been prepared properly.	Field Inspection	Y	Periodic
1705.7 Driven Deep Foundations		N	
1705.8 Cast-In-Place Deep Foundations		N	
1705.9 Helical Pile Foundations		N	
1. Testing and inspections services shall be performed by an approved agency in general accordance with section 1703 of the International Building Code. 2. This section references 2015 IBC. Other code years may have a differing section number for concrete elements			

The contractor shall request special inspection of the items listed above prior to those items becoming inaccessible and unobservable due to the progression of work.

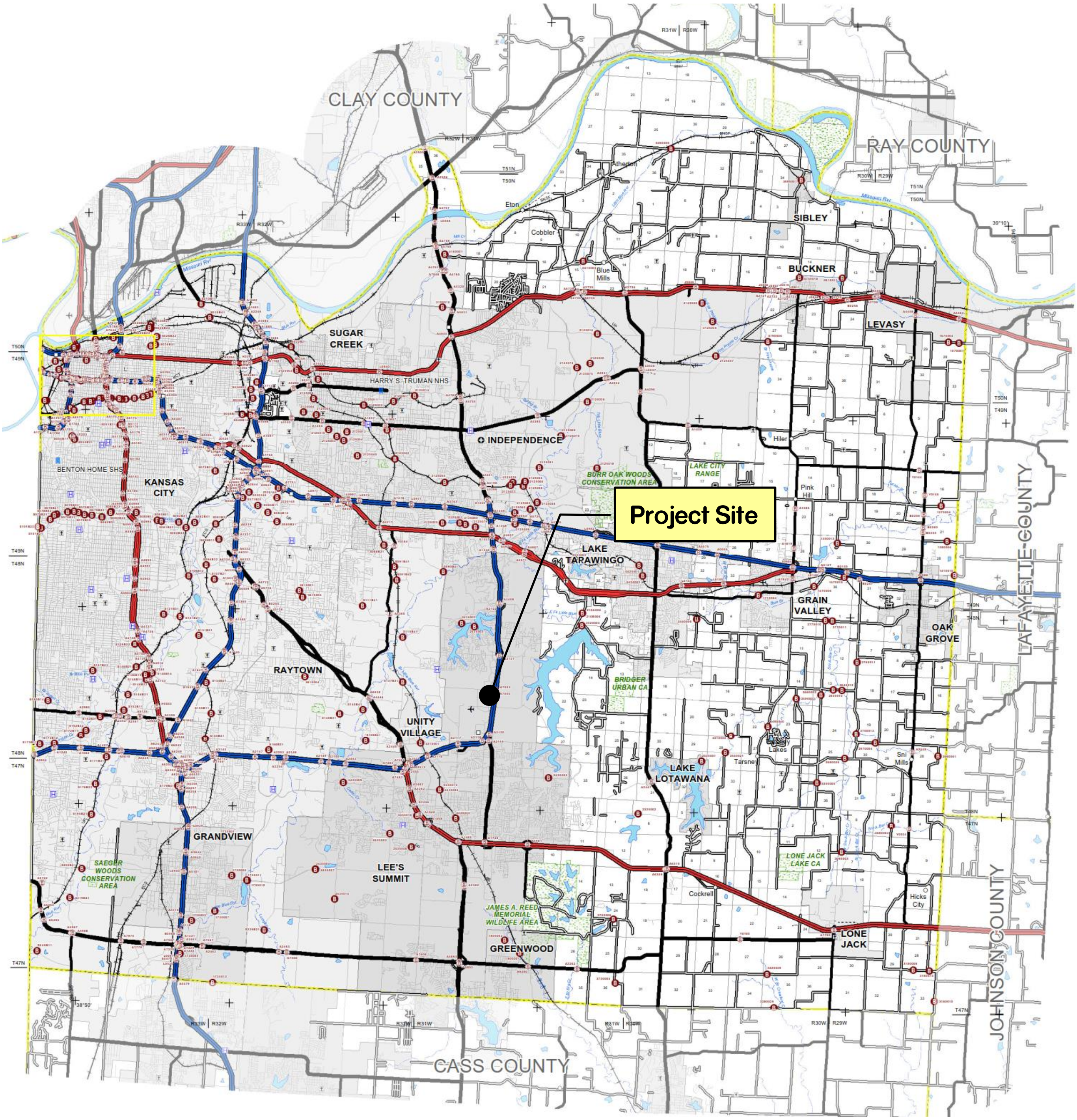
5 GENERAL COMMENTS

The recommendations provided herein are for the exclusive use of our client. Our recommendations are specific only to the project described herein and are not meant to supersede more stringent requirements of local ordinances or codes. The recommendations are based on subsurface information obtained at our boring locations, sample locations, our understanding of the project as described in this report, and geotechnical engineering practice consistent with the current standard of care. No warranty is expressed or implied. CGTL should be contacted if conditions encountered are not consistent with those described.

CGTL should be provided with a set of final plans and specifications once they are available to review whether our recommendations have been understood and applied correctly and to assess the need for additional exploration or analysis. Failure to provide these documents to CGTL may nullify some or all of the recommendations provide herein. In addition, any changes in the planned project or changes in site conditions may require revised or additional recommendations on our part.

The final part of our geotechnical service should consist of direct observation during construction to observe that conditions actually encountered are consistent with those described in this report and to assess the appropriateness of the analyses and recommendations contained herein. CGTL cannot assume liability or responsibility for the adequacy of recommendations without being retained to observe construction.

APPENDIX



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SITE LOCATION MAP

DENTAL OFFICE
LEE'S SUMMIT, MISSOURI

PROJECT NO.: G19422

Prepared By:
CROCKETT
GEOTECHNICAL - TESTING LAB
1000 W. Nifong Blvd, Building 1
Columbia, MO 65203
573-447-3981
www.CrockettGTL.com

BORING LOCATION PLAN

DENTAL OFFICE
LEE'S SUMMIT, MISSOURI

PROJECT NO.: G19422

Prepared By:
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GEOTECHNICAL - TESTING LAB
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Crockett GTL
1000 W Nifong Blvd. Bldg. #1
Columbia, MO 65203
Telephone: 573-447-0292

BORING NUMBER B-1

CLIENT Crockett Engineering Consultants
PROJECT NAME Dental Office
PROJECT NUMBER G19422
PROJECT LOCATION Lee's Summit, Missouri
DATE STARTED 6/3/19 **COMPLETED** 6/3/19
GROUND ELEVATION 991 ft MSL **HOLE SIZE** 4"
DRILLING CONTRACTOR IPES
GROUND WATER LEVELS:
DRILLING METHOD 4" SSA
AT TIME OF DRILLING --- Not Encountered
LOGGED BY Grimm **CHECKED BY** Lidholm
AT END OF DRILLING --- Not Encountered
NOTES Borehole backfilled upon completion
0.25hrs AFTER DRILLING --- Not Encountered

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION		SAMPLE TYPE NUMBER	RECOVERY LENGTH	BLOW COUNTS (N VALUE)	POCKET PEN. (psf)	UNC. COMP. (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS		
											LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0		TOPSOIL (7-inches)											
	0.6	FAT CLAY: Dark and light brown, trace rust stains, trace to with root hairs, with slickensides, very stiff	990.4										
1 - 3				ST 1	17		8000		104	21	52	22	30
	3.0	WEATHERED LIMESTONE: Hard	988.0										
	3.5		987.5										

Auger Refusal at 3.5 feet.
Bottom of borehole at 3.5 feet.

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CROCKETT GEOTECHNICAL - TESTING LAB

BORING NUMBER B-2

CLIENT Crockett Engineering Consultants
PROJECT NAME Dental Office
PROJECT NUMBER G19422
PROJECT LOCATION Lee's Summit, Missouri
DATE STARTED 6/3/19 **COMPLETED** 6/3/19
GROUND ELEVATION 991 ft MSL **HOLE SIZE** 4"
DRILLING CONTRACTOR IPES
GROUND WATER LEVELS:
DRILLING METHOD 4" SSA
AT TIME OF DRILLING --- Not Encountered
LOGGED BY Grimm **CHECKED BY** Lidholm
AT END OF DRILLING --- Not Encountered
NOTES Borehole backfilled upon completion
0.25hrs AFTER DRILLING --- Not Encountered

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	Elev.	SAMPLE TYPE NUMBER	RECOVERY LENGTH	BLOW COUNTS (N VALUE)	POCKET PEN. (psf)	UNC. COMP. (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0 – 0.7		TOPSOIL (8-inches)	990.3										
0.7 – 2.0		FAT CLAY: Brown, trace rust stains, trace root hairs, with slickensides, medium to stiff	989.0										
1 – 3				ST 1	24		2500	1765	86	31			
2.0 – 4.1		SHALEY FAT CLAY: Light gray, trace rust stains, trace sand and silt, with slickensides, medium to stiff	986.9										
3.25 – 4.1				SPT 2	7	11-50/1"	7000			26			
4.1 – 4.5		WEATHERED LIMESTONE: Hard	986.5										

Split Spoon Sampler Refusal at 4.1 feet.
Auger Refusal at 4.5 feet.
Bottom of borehole at 4.5 feet.

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CROCKETT
GEOTECHNICAL - TESTING LAB

BORING NUMBER B-3

CLIENT Crockett Engineering Consultants
PROJECT NAME Dental Office
PROJECT NUMBER G19422
PROJECT LOCATION Lee's Summit, Missouri
DATE STARTED 6/3/19 **COMPLETED** 6/3/19
GROUND ELEVATION 991 ft MSL **HOLE SIZE** 4"
DRILLING CONTRACTOR IPES
GROUND WATER LEVELS:
DRILLING METHOD 4" SSA
AT TIME OF DRILLING --- Not Encountered
LOGGED BY Grimm **CHECKED BY** Lidholm
AT END OF DRILLING --- Not Encountered
NOTES Borehole backfilled upon completion
0.25hrs AFTER DRILLING --- Not Encountered

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	Elev.	SAMPLE TYPE NUMBER	RECOVERY LENGTH	BLOW COUNTS (N VALUE)	POCKET PEN. (psf)	UNC. COMP. (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0 – 0.5		GRAVELLY TOPSOIL (6-inches)	990.5										
0.5 – 3.0		SHALEY FAT CLAY: Light gray, trace light brown, trace rust stains, with slickensides, medium to stiff	988.0	ST 1	20		3500	1665	95	29	70	28	42
3.0 – 3.5		WEATHERED LIMESTONE: Hard	987.5										

Auger Refusal at 3.5 feet.
Bottom of borehole at 3.5 feet.

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CROCKETT GEOTECHNICAL - TESTING LAB

BORING NUMBER B-4

CLIENT Crockett Engineering Consultants
PROJECT NAME Dental Office
PROJECT NUMBER G19422
PROJECT LOCATION Lee's Summit, Missouri
DATE STARTED 6/3/19 **COMPLETED** 6/3/19
GROUND ELEVATION 991 ft MSL **HOLE SIZE** 4"
DRILLING CONTRACTOR IPES
GROUND WATER LEVELS:
DRILLING METHOD 4" SSA
AT TIME OF DRILLING --- Not Encountered
LOGGED BY Grimm **CHECKED BY** Lidholm
AT END OF DRILLING --- Not Encountered
NOTES Borehole backfilled upon completion
0.25hrs AFTER DRILLING --- Not Encountered

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY LENGTH	BLOW COUNTS (N VALUE)	POCKET PEN. (psf)	UNC. COMP. (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0 – 0.7		TOPSOIL (8-inches) (0.7 / 990.3)										
0.7 – 3.0		FAT CLAY: Dark and light brown, trace rust stains, trace to with root hairs, with slickensides, medium to stiff (3.0 / 988.0)	ST 1	16		4000	1650	104	21			
3.0 – 3.5		WEATHERED LIMESTONE: Hard (3.5 / 987.5)										

Auger Refusal at 3.5 feet.
Bottom of borehole at 3.5 feet.

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CROCKETT GEOTECHNICAL - TESTING LAB

BORING NUMBER B-5

CLIENT Crockett Engineering Consultants
PROJECT NAME Dental Office
PROJECT NUMBER G19422
PROJECT LOCATION Lee's Summit, Missouri
DATE STARTED 6/3/19 **COMPLETED** 6/3/19
GROUND ELEVATION 990 ft MSL **HOLE SIZE** 4"
DRILLING CONTRACTOR IPES
GROUND WATER LEVELS:
DRILLING METHOD 4" SSA
AT TIME OF DRILLING --- Not Encountered
LOGGED BY Grimm **CHECKED BY** Lidholm
AT END OF DRILLING --- Not Encountered
NOTES Borehole backfilled upon completion
0.25hrs AFTER DRILLING --- Not Encountered

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	Elevation	SAMPLE TYPE NUMBER	RECOVERY LENGTH	BLOW COUNTS (N VALUE)	POCKET PEN. (psf)	UNC. COMP. (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX
0 – 0.5		TOPSOIL (6-inches)	989.5										
0.5 – 2.2		FAT CLAY: Dark and light brown, trace rust stains, trace to with root hairs, with slickensides, stiff	987.8	ST 1	26		4000	2015	103	21			
2.2 – 2.7		WEATHERED LIMESTONE: Hard	987.3										

Auger Refusal at 2.7 feet.
Bottom of borehole at 2.7 feet.

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CROCKETT GEOTECHNICAL - TESTING LAB

BORING NUMBER B-6

CLIENT Crockett Engineering Consultants
PROJECT NAME Dental Office
PROJECT NUMBER G19422
PROJECT LOCATION Lee's Summit, Missouri
DATE STARTED 6/3/19 **COMPLETED** 6/3/19
GROUND ELEVATION 990 ft MSL **HOLE SIZE** 4"
DRILLING CONTRACTOR IPES
GROUND WATER LEVELS:
DRILLING METHOD 4" SSA
AT TIME OF DRILLING --- Not Encountered
LOGGED BY Grimm **CHECKED BY** Lidholm
AT END OF DRILLING --- Not Encountered
NOTES Borehole backfilled upon completion
0.25hrs AFTER DRILLING --- Not Encountered

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY LENGTH	BLOW COUNTS (N VALUE)	POCKET PEN. (psf)	UNC. COMP. (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0		TOPSOIL (6-inches)										
0.5		FAT CLAY: Light gray, trace rust stains, with slickensides, stiff (989.5)										
1			ST 1	10		3000		96	27			
1.5		WEATHERED LIMESTONE: Hard (988.5)										
2.0		(988.0)										

Auger Refusal at 2.0 feet.
Bottom of borehole at 2.0 feet.

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CROCKETT GEOTECHNICAL - TESTING LAB

BORING NUMBER B-7

CLIENT Crockett Engineering Consultants
PROJECT NAME Dental Office
PROJECT NUMBER G19422
PROJECT LOCATION Lee's Summit, Missouri
DATE STARTED 6/3/19 **COMPLETED** 6/3/19
GROUND ELEVATION 990 ft MSL **HOLE SIZE** 4"
DRILLING CONTRACTOR IPES
GROUND WATER LEVELS:
DRILLING METHOD 4" SSA
AT TIME OF DRILLING --- Not Encountered
LOGGED BY Grimm **CHECKED BY** Lidholm
AT END OF DRILLING --- Not Encountered
NOTES Borehole backfilled upon completion
0.25hrs AFTER DRILLING --- Not Encountered

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION		SAMPLE TYPE NUMBER	RECOVERY LENGTH	BLOW COUNTS (N VALUE)	POCKET PEN. (psf)	UNC. COMP. (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0		TOPSOIL (6-inches)											
0.5		LEAN TO FAT CLAY: Brown and dark brown, trace rust stains, trace sand, possible undocumented fill, very stiff	989.5										
1				ST 1	8		6000		106	21			
1.7		WEATHERED LIMESTONE: Hard	988.3										
2.2			987.8										

Auger Refusal at 2.2 feet.
Bottom of borehole at 2.2 feet.

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CROCKETT GEOTECHNICAL - TESTING LAB

BORING NUMBER B-8

CLIENT Crockett Engineering Consultants
PROJECT NAME Dental Office
PROJECT NUMBER G19422
PROJECT LOCATION Lee's Summit, Missouri
DATE STARTED 6/3/19 **COMPLETED** 6/3/19
GROUND ELEVATION 991 ft MSL **HOLE SIZE** 4"
DRILLING CONTRACTOR IPES
GROUND WATER LEVELS:
DRILLING METHOD 4" SSA
AT TIME OF DRILLING --- Not Encountered
LOGGED BY Grimm **CHECKED BY** Lidholm
AT END OF DRILLING --- Not Encountered
NOTES Borehole backfilled upon completion
0.25hrs AFTER DRILLING --- Not Encountered

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	Elev.	SAMPLE TYPE NUMBER	RECOVERY LENGTH	BLOW COUNTS (N VALUE)	POCKET PEN. (psf)	UNC. COMP. (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0		TOPSOIL (7-inches)											
0.6		FAT CLAY: Reddish brown, trace rust stains, trace to with root hairs, with slickensides, medium to very stiff	990.4										
1				ST 1U	16		5500	1110	83	42			
2.3		SHALEY FAT CLAY: Light gray, trace rust stains, trace sand and silt, with slickensides, stiff to very stiff	988.7	ST 1L	8		7000	2950	102	26			
3.5		WEATHERED LIMESTONE: Hard	987.5	SPT 2	0	50/0"							
4.0			987.0										

Split Spoon Sampler Refusal at 3.5 feet.
Auger Refusal at 4.0 feet.
Bottom of borehole at 4.0 feet.

BORING LOG LEGEND AND NOMENCLATURE

Sample Type	Description
AU	Auger sample, disturbed, obtained from auger cuttings
NR	No recovery or lost sample
RC	Rock core, diamond core bit, nominal 2-inch diameter rock sample (ASTM D 2113)
ST	Thin walled (Shelby) tube sample, relatively undisturbed (ASTM D 1587)
SPT	Split spoon sample, disturbed (ASTM D 1586)
VA	Shear vane (ASTM D 2753)

Grain Size Terminology	
Boulders	Larger than 12-inches
Cobbles	3-inches to 12-inches
Gravel	Retained on #4 sieve to 3-inches
Sand	Retained on #200 sieve but passes #4 sieve
Silt or Clay	Passes #200 sieve

Descriptor	Relative Proportion of Sand and Gravel	Relative Proportion of Fines
Trace	Less than 15% by dry weight	Less than 5% by dry weight
With	15% to 30% by dry weight	5% to 12% by dry weight
Modifier	More than 30% by dry weight	More than 12% by dry weight

Relative Density of Coarse grained Soils	
Descriptive Term	SPT N-Value, Blows/Foot
Very Loose	0 - 3
Loose	4 - 9
Medium Dense	10 - 29
Dense	30 - 49
Very Dense	50+

Consistency of Fine Grained Soils		
Descriptive Term	SPT N-Value, Blows/Foot	Unconfined Compressive Strength, psf
Very Soft	0 – 1	0 – 500
Soft	2 – 3	501 – 1,000
Medium	4 – 9	1,001 – 2,000
Stiff	10 – 29	2,001 – 4,000
Very Stiff	30 – 49	4,001 – 8,000
Hard	50+	> 8,000

USCS Soil Classification System				
Major Divisions			Group Symbol	Group Name
coarse grained soils more than 50% retained on #200 sieve	gravel >50% of coarse fraction retained on #4 (4.75 mm) sieve	clean gravel <5% small than #200 sieve	GW	well-graded gravel, fine to coarse gravel
			GP	poorly graded gravel
		gravel with >12% fines	GM	silty gravel
			GC	clayey gravel
	sand >50% of coarse fraction passes #4 (4.75 mm) sieve	clean sand	SW	well-graded sand, fine to coarse sand
			SP	poorly graded sand
		sand with >12% fines	SM	silty sand
			SC	clayey sand
fine grained soils more than 50% passes #200 sieve	silt and clay liquid limit < 50	inorganic	ML	silt
			CL	clay
		organic	OL	organic silt, organic clay
	silt and clay liquid limit ≥ 50	inorganic	MH	silt of high plasticity, elastic silt
			CH	clay of high plasticity, fat clay
		organic	OH	organic clay, organic silt
highly organic soils			PT	peat

Weathering	Description of Rock Properties
Fresh	No discoloration. Not oxidized.
Slightly weathered	Discoloration or oxidation of most surfaces but or short distance from fractures
Moderately weathered	Discoloration or oxidation extends from fractures, usually throughout. All fractured surfaces are oxidized or discolored.
Severely weathered	Discoloration or oxidation throughout. All fractured surfaces are oxidized or discolored. Surfaces are friable.
Decomposed	Resembles a soil. Partial or complete remnant rock structure may be present.

Rock Quality Designator (RQD)	
RQD, %	Rock Quality
90 – 100	Excellent
75 – 90	Good
50 – 75	Fair
25 – 50	Poor
0 - 25	Very poor

Joint, Bedding, and Foliation Spacing in Rock		
Spacing	Joints	Bedding/Foliation
< 2-inches	Very close	Very thin
2-inches – 1-foot	Close	Thin
1-foot – 3-feet	Moderately Close	Medium
3-feet – 10-feet	Wide	Thick
>10-feet	Very Wide	Very thick