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Addendum No. 1
Bid Date: October 8, 2020
to the
Plans, Specifications and Contract Documents
for
Columbia-Adair County Economic Development Authority
Contract 2: Green River Commerce Park -
Access Road Extension Grading and Drainage
Columbia, Kentucky

Issued October 5, 2020

The following additions, deletions, changes or revisions are issued herewith and become a part of the Project Documents.

Item 1: **Bid Item 16.** Delete the "18 inch" reference in the description. Bid items 16A, 16B and 16C as shown.

Item 2: **Bid Item 29.** DGA. The Bidder may use DGA or crushed stone base for either or both items 19A and 19B. Payment will be based on quantity actually installed (weigh ticket verification required).

For Item 19A change the 4" reference to 6" as shown in the plans.

Item 3: **Specifications Section 00800 - Agreement.** Days to complete the project should be 90 days. It is the Owner's desire to complete the project this calendar year. However, if unsuitable weather prevents this, the completion time will be extended.

Item 4: Attached is a full geotechnical report for an alternate road route. This route could not be constructed at this time because of conflicts with an interstate gas pipeline. The route was changed to the one being bid. However, this full report may contain descriptive soils information of use to the bidder. Refer to the borings report in the project manual for site specific boring information.

End of Addendum No. 1

Report of Geotechnical Exploration

for

Green River Commerce Park - Access Road

Columbia, Kentucky

October 2, 2019

Prepared for

Columbia-Adair County Economic Development Authority, Inc.

Columbia, Kentucky

CSI Project Number LX190143

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Consulting Services Incorporated
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Geotechnical & Materials Engineering | IBC Special Inspection | Material Testing

October 2, 2019

Columbia-Adair County Economic Development Authority, Inc.
℅ MSE of Kentucky, Inc.
624 Wellington Way
Lexington, Kentucky 40503

Attention: Mr. Glen Ross, PE

Subject: **Report of Geotechnical Exploration**
Green River Commerce Park Access Road
Columbia, Kentucky
CSI Project No. LX190143

Dear Mr. Ross:

Consulting Services Incorporated of Kentucky (CSI) is pleased to present our report for the geotechnical services completed for the proposed Green River Commerce Park Access Road in Columbia, Kentucky. We provided our services in general accordance with CSI's proposal number 6362, dated August 28, 2019.

Our report represents information provided to us, readily available published data relevant to the site and site area, our observations and subsurface conditions encountered and our opinion of primary geotechnical conditions (discussion and recommendations) affecting design, construction and performance of the proposed earth supported portions of the project.

We appreciate the opportunity to provide our geotechnical services to you and the design team. Please do not hesitate to contact us for questions or comments about the information contained herein.

Cordially,

STATE OF KENTUCKY CHARLES YORK LITTLE 30169 LICENSED PROFESSIONAL ENGINEER
10/2/19

York Little, PE
Project Engineer
Licensed KY 30,169

Joseph S. Cooke, PE
Principal

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INTRODUCTION

1 SCOPE OF THE GEOTECHNICAL EXPLORATION

As proposed, we conducted geotechnical services which are summarized in the following report. Our services included a review of the project information provided, conducting a subsurface exploration that used soil borings and soundings to obtain samples for modeling the soil conditions at the subject site, an analysis of the data and information obtained, and providing recommendations for the earth supported portions of the site as listed in our proposal.

2 PROVIDED INFORMATION

Project information was provided to us via e-mail and telephone conversations with Mr. Glen Ross, PE and others with MSE. We reviewed the e-mails, the provided Google map image which shows the proposed access road alignment along with the approximate locations of both borings and soundings (borings without sampling), and a *Site Master Plan* drawing showing the proposed access road alignment with existing elevation contours and adjacent proposed building lots, dated June 1999. No proposed topographic information or grading information was supplied to us for this geotechnical report. Please note, the provided *Site Master Plan* included multiple proposed roadways. However, this geotechnical report is limited to the approximately 2,800 feet of access road generally extending northwest to southeast.

The project site is located to the southeast of the intersection of Cundiff Road and Campbellsville Road (Route 55) in Columbia, Kentucky. See the *Site Location Plan* in the Appendix for more details. Based on recent aerial images, the project site is undeveloped, with clusters of trees, tree lines, and grass fields.

We understand that the Owner wishes to construct an access road that is approximately 2,800 feet in length extending south and southeast from the existing Cundiff Road. CSI was not provided with any traffic loading for this access road. Based on our conversations with Mr. Glen Ross, PE with MSE, we understand this proposed access road will provide access for three proposed building lots. At this time, the usage of these lots are unknown. Based on our experience with similar type industrial parks, we have estimated the types and volume of the anticipated daily traffic for this access road. Additionally, CSI was not provided with grading plan for the project site. We have assumed maximum cuts and fill will not exceed 10 feet to achieve desired grades. We have listed our estimated daily traffic and grading assumptions in *Table 1*.

Table 1: Project Information (Assumed)

Site Grading	
Maximum anticipated cut	< 10 feet
Maximum anticipated fill	< 10 feet
Anticipated Traffic loading	
Daily Average Traffic	
Access Road	300 passenger vehicles
	Up to 6 Tractor trailers
	Up to 6 Delivery Trucks
	3 Garbage Trucks (per week)

Additionally, we understand asphalt paving may not occur immediately following the place of the dense graded aggregate (DGA) subbase. Rather, the DGA may be exposed for an extended period of time before asphalt is placed. We will address concerns with this construction sequencing later in the report. If any of the aforementioned information is in error or if the information changes during the course of the project, please contact our office so that we can re-evaluate the new information with respect to our proposed scope of work.

3 AREA/SITE INFORMATION

3A AREA TOPOGRAPHY/PHYSIOGRAPHY

The site is located in the Pennyrile physiographic region of Kentucky. The region consists of a limestone plain characterized by tens of thousands of sinkholes, sinking streams, streamless valleys, springs, and caverns. The bedrock in the eastern and southern parts of the region is dominated by thick deposits of Mississippian-age limestones. Published mapping indicates elevations in the site vicinity range from 860 feet to 900 feet. *Figure 1* shows the location of the site with respect to the regional physiography.

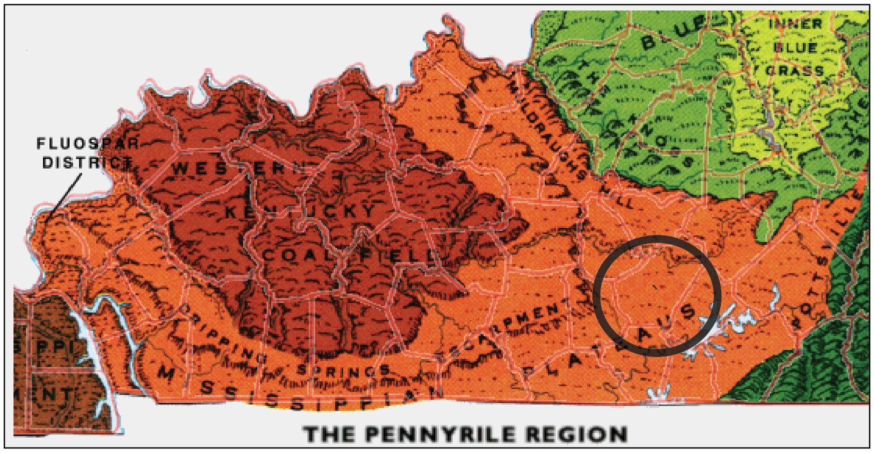


Figure 1. Kentucky Physiographic Map (site vicinity shown in the circle)

3B SITE GEOLOGY

A review of the *USGS Cane Valley Geologic Quadrangle Map, dated 1964* indicates the project site is underlain by Lower Mississippian aged rock deposits. Specifically, the project site is underlain by limestone portion of the Fort Payne Formation.

The Fort Payne Formation is composed of limestone, siltstone, and claystone. The limestone is described as yellowish gray to medium and light bluish gray, medium to very coarse grained, locally crossbedded, and weathers to red and yellow clay soil.

The siltstone is described as light to dark greenish gray and olive gray, dolomitic, cherty, and thin to massive bedded. Typically the siltstone weathers to reddish or yellow gray silty soil with irregular fragments of siltstone.

The claystone is described as greenish gray. The upper portions may contain few small lenses of calcareous shale, limestone, and sandstone. The clay stone is typically fine grained, and evenly bedded. *Figure 2* depicts the site geology of the project area.

Figure 2. Site Geology USGS Geologic Map of the Cane Valley Quadrangle, dated 1964
(site vicinity indicated by marker)

As with most of the geology of this portion of Kentucky, Karst (sinkholes, weathered bedrock, caverns, erratic bedrock, etc.) is associated with the site geology. Closed depressions are mapped at the project site and on adjacent sites in the immediate vicinity of the project site. Portions of the surrounding areas of the site have been developed and may have been regraded, thus obvious signs of additional sinkhole activity may have been filled or otherwise occluded.

The Karst Potential Map published by the Kentucky Geological Survey (KGS) indicates that the project site is in an area with very high karst potential. The KGS sinkhole map indicates one mapped sinkhole on the north side of the project site. Additionally, numerous sinkholes are mapped approximately one-half mile to the south, west, and east of the project site. *Figure 3* indicates the likelihood of Karst occurrence.

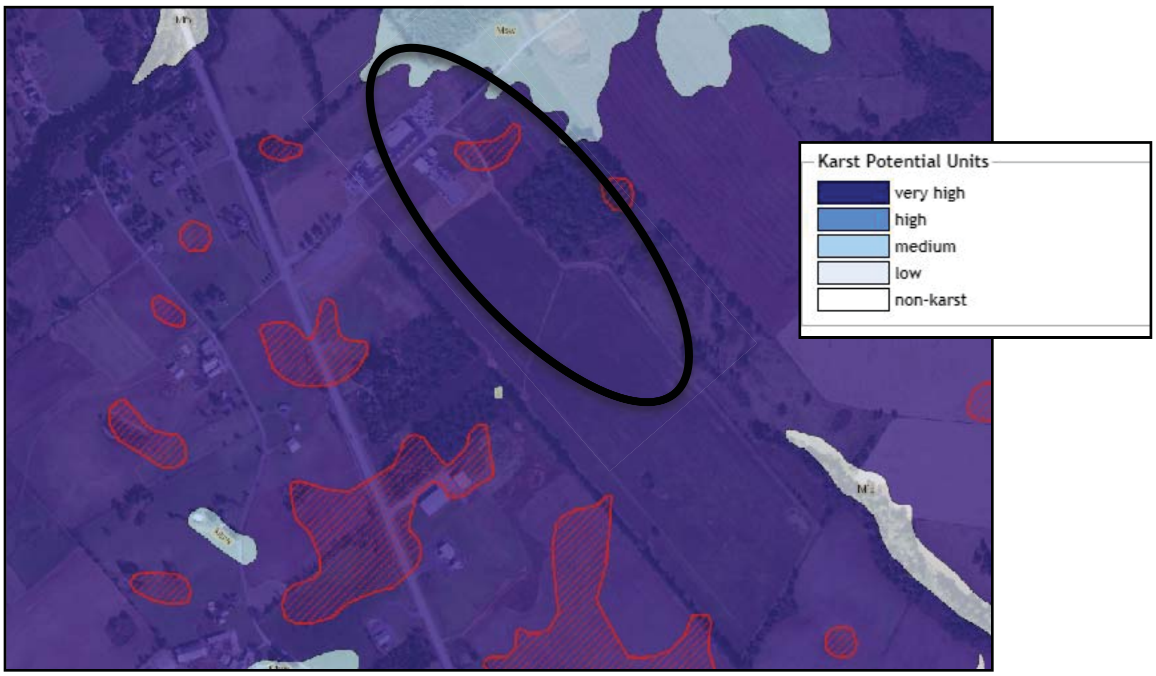


Figure 3. KGS Karst Areas Map
(site vicinity shown within oval)

3C PUBLISHED SITE SOIL CONDITIONS

According to the USDA Soil Survey of Adair County (NRCS website), the soils underlying the project site vicinity consist of the following series:

- Frederick silt loam (FrB2), 2 to 6 percent slopes, eroded
- Frederick silt loam (FrC2), 6 to 12 percent slopes, eroded
- Frederick silt loam (FrD2), 12 to 20 percent slopes, eroded
- Frederick-Caneyville complex (FvE), 20 to 40 percent slopes, rocky

The following are issues listed as characteristics of these series, which we believe could be of interest to the project:

- All four listed soil series (FrB2, FrC2, FrD2, and FvE) are listed as being well drained.
- All soil series are generally listed as having a depth to water table at least 80 inches.
- Depth to restrictive feature (i.e. - lithic bedrock) for all the soil series FrB2, FrC2, FrD2, and FvE are listed as greater than 80 inches.
- All soil series are also very limited to the construction of local roads and streets. Particular issues affecting construction include low strength, shrink-swell, frost action, soluble bedrock, and depth to hard bedrock.

We have considered these issues with respect to the proposed project improvements and have incorporated recommendations to address the issues in later sections of the report.

Due to the development of the site vicinity, the soil survey information listed above may no longer be useful since the site soils may have been altered. Thus, the soils described above may be on-site but not in their natural condition. *Figure 3* is the soils map from the USDA website.

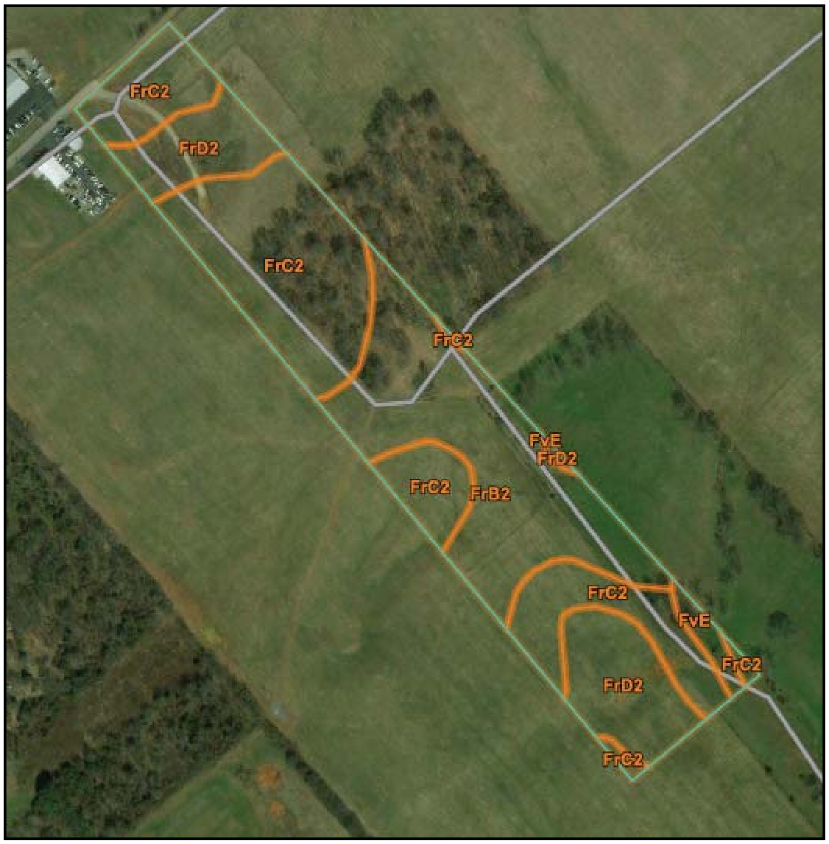


Figure 4: USDA Soil Survey Map of Project Site (site bordered in green and orange)

3D OTHER PUBLISHED SITE INFORMATION

We have reviewed several available aerial photographs, dated as far back as April 1993. The aerial photographs indicate only a few changes in the vicinity over the years. The project site appears to be mostly grass and crop covered with clumps of trees. The grassy fields appear to be separated by tree and/or fence rows. The reviewed aerial photographs do not indicate any obvious significant changes to the project site. The June 2003 aerial photograph appeared to show a small development adjacent to the project site and on the south side of Cundiff Road and the July 2006 aerial photograph appears to show the existing Cundiff Road in relatively the same layout as it is presently. The May 2011 aerial photograph appears to show new development on adjacent sites to the northwest of the project site on the north and south sides of Cundiff Road. Please note, the reviewed aerial photographs were taken at different times of the year. Obvious visual indicators of karst activity including the curve (assumed to avoid the existing sinkhole) in the existing access road at Cundiff Road on the north side of the site, a "square shaped" area of trees on the east side of the site, and some darker vegetation near the existing depression on the north side of the site were observed . Please reference the following aerial images for further details.

Figure 5: Aerial photograph, dated April 1993 from Google Earth
(site vicinity in oval)

Figure 6: Aerial photograph, dated June 2003 from Google Earth (site vicinity in oval)

Figure 7: Aerial photograph, dated May 2011 from Google Earth (site vicinity in oval)

Figure 8: Aerial photograph, dated June 2018 from Google Earth (site vicinity in oval)

FINDINGS

4 SITE SURFACE OBSERVATIONS

Mr. York Little, PE of CSI conducted a site visit, performed a field reconnaissance, logged soil borings and soundings, and directed field operations within the proposed project area on September 11, 2019.

The project site is located to the southeast of intersection of Campbellsville Road (KY Route 55) and Cundiff Road in Columbia, Kentucky. The project site consists of rolling terrain with crop and grass covered fields. Clumps of mature trees are located on the east side of the site. Two developed properties are located to the north of the project site. The existing asphalt paved Cundiff Road extends from Campbellsville Road into the commerce park and makes a slight curve to the east before the asphalt pavement ends at the north side of the project site. The existing asphalt paved roadway appears to be performing adequately with no obvious signs of pavement failure or large scale cracking. The north side of the project site consists of grass covered areas with some trees and a narrow existing gravel/dirt access road. The south side of the project is mostly an existing corn field. At the time of our drilling, the corn had not been harvested and the stalks were about six feet tall or taller.

As mentioned in our karst research section, a depression is located on the north side of the project site near the end of the asphalt paved roadway that ends shortly after entering the site. The bottom of the depression consisted of tall weeds and thick brush with few trees. No other obvious depressions were observed on the project site. Please note, the majority of the site's surface is covered by tall grasses and corn crops. Thus, obvious signs of surface depressions were difficult to observe during our site visit.

Existing municipal underground gas lines were marked on the north side of the project site and a gas transmission easement extends across the site perpendicularly from northeast to southwest. Three approximately 30-inch diameter gas transmission lines are located within this utility easement. The following photos depict the site conditions as they existed at the time of our geotechnical exploration.

Photo 1. View of the north side of the site with the existing asphalt paved road and surface depression (facing southeast)

Photo 2. View of the north end of the project site (facing south)

Photo 3. View of the existing roadway leading into the commerce park (facing southwest)

Photo 4. View of the rolling terrain and corn field on the south side of the site

Photo 5. View of the existing corn field

Photo 6. View of the surface depression with the bottom covered with grass and few trees

5 SUBSURFACE CONDITIONS

The subsurface conditions encountered at each of our soil boring and sounding locations are shown on the Boring and Sounding Logs in the Appendix. It should be noted that our soil borings were sampled according to the procedures presented in the Appendix. The Boring and Sounding Logs represent our interpretations of the subsurface conditions based on field logs, visual examination of field samples, and tests of the samples collected. The letters in parentheses following the soil descriptions are the soil classifications in accordance with the Unified Soil Classification System. It should be noted that the stratification lines shown on the soil boring logs represent approximate transitions between material types. In-situ stratum changes could occur gradually or at slightly different depths. Water levels shown on the Boring and Sounding Logs represent the conditions only at the time of our exploration.

5A SOIL CONDITIONS

During our field exploration, we completed 3 soil test borings and 8 soundings (borings without sampling) to explore the subsurface condition for the proposed access road. The three soil borings (labeled B-101 through B-103) and 8 soundings (labeled S-201 through S-208) were performed along the alignment of the proposed access road. MSE provided CSI with an aerial image of the site with approximate boring and sounding locations. Some of the borings and soundings were moved due to the transmission gas line easement near the middle of the project site. During our site reconnaissance, a R.M. Johnson Engineering, Inc. surveyor was on-site surveying and staking the center line of the proposed roadway. CSI located our boring and sounding locations based on these center line stakes. Please note, the center line stakes were positioned approximately every 50 feet of the new access road. Please note, sounding S-204 advanced near the center line stake at Sta 12+00 was not located in the field due to obstructions. Thus, sounding S-204 was located on our *Boring Location Plan* at Sta 12+00 and the elevation of the center line stake at Sta 12+00 was used for elevation of sounding S-204 in our sounding logs. Please reference the *Boring Location Plan* in the Appendix for further details.

As proposed, our soil borings were advanced to 10.5 feet and our soundings were advanced to 15 feet. Please note, all of our soundings and borings were advanced to their pre-determined termination depths without encountering bedrock. Standard penetration testing (SPT) and soil sampling was not performed at our sounding locations. However, the soil at these locations were logged in the field by observing the auger cuttings.

In general, at our soil borings and soundings we encountered the following: a layer of topsoil, overlying a layer of "till zone", overlying residual soils.

Topsoil was encountered at all of our borings and sounding locations with thicknesses ranging from 3 inches to 8 inches. The encountered topsoil consisted of dark brown silty soil with fine roots. Based on the agricultural use of the majority of the project site, the surface has likely been tilled in the past. Thus, till zone material was encountered at all of our soil borings below the surficial topsoil layer with thicknesses ranging from 4 to 5 inches. The till zone consisted of dark brown silty soil.

Below the surficial topsoil and till zone layers, residual soil was encountered at all of our soil borings and soundings. The residual soil consisted of tan, orangish tan, and reddish brown clay. The residual soil was generally sampled as damp to wet. While most of our soil samples were moist, typically damp soil was encountered near the surface and the wet soil was encountered deeper near the termination depths. Two Atterberg limits tests were performed on samples of the residual soils which indicated the more shallow sample (approximately 1 foot to 5 feet below the existing surface) was lean clay (CL) while the other (deeper) sample was fat clay (CH). On average, at our boring and sounding locations lean clay appeared to transition to fat clay at about 5 to 6 feet. The thickness of the residual soil was at least 9 feet to 14 feet. The residual soil was generally stiff to very stiff. Our borings and soundings were advanced to their pre-determined termination depths of 10.5 feet and 15 feet without encountering weathered bedrock or bedrock. Thus, total thicknesses of residual soil was not obtained.

5B GROUNDWATER CONDITIONS

Water was not observed at our soil borings and sounding locations upon completion of soil augering. Borings and soundings were immediately backfilled after the completion of soil augering.

PLEASE NOTE: the karst geology at this site and our experience suggests potential "spring" conditions exist at this site. Especially in deeper cut areas, springs may be encountered. Springs could saturate the subgrade and weaken the soils beneath the proposed roadway. If a spring is encountered during access road construction, CSI should be contracted to provide additional recommendations. Water issues are also dependent upon recent rainfall activity and surface and subsurface drainage patterns in the area.

6 LABORATORY TESTING

Laboratory tests were performed on selected recovered samples from our borings. Detailed descriptions of these tests and the results of our testing are included in the Appendix. Tests performed included:

- Natural moisture contents
- Atterberg limits
- Percent fines analysis
- Standard Proctors
- California Bearing Ratio (CBR) tests

GEOTECHNICAL DISCUSSION AND RECOMMENDATIONS

7 DISCUSSION-GEOTECHNICAL ISSUES

Based on our experience with similar projects and the conditions observed during our subsurface exploration, we believe that this site can be adapted for the proposed development. The primary geotechnical concerns are:

- High Plasticity (Fat) Clay
- Karst Geology
- Site Clearing and Cultivated Areas

The following sections discuss each issue. However, recommendations to address the issues are contained in later sections of the report.

7A HIGH PLASTICITY (FAT) CLAY

Two Atterberg limits tests were performed on samples of the residual soils which indicated the more shallow sample (collected from soundings S-206 and S-207 from approximately 1 foot to 5 feet below the existing surface) was lean clay (CL) while the other (deeper) sample was fat clay (CH). The fat clay sample was a combined bulk sample of similar material from boring B-101 and S-202 from approximately 5 feet to 10 feet. The Atterberg limits testing on the fat clay (CH) sample indicated Plasticity Indices (PI) of 35 percent, which falls within the moderate susceptibility range. Soils with a PI above 30 percent can have a tendency to shrink/swell with changes in moisture content. Soils with a PI greater than 50 are generally highly susceptible to volume change. Soils with a PI between these limits have moderate volume change potential.

Shrinking and swelling of bearing soils are generally not as severe in this Kentucky area as in other areas because long periods of excessively wet or dry weather do not normally occur. However, if site grading takes place during the dry summer or fall months, significant drying of the exposed subgrade soils may occur. If these soils re-saturate after completion of construction, structural distress may be experienced.

In new pavement areas, methods to control the adverse effects of these soils include soil modification methods (i.e.- careful moisture control, undercut/replace, lime stabilization, etc.), providing efficient drainage around proposed pavements and implementing more stringent fill specifications for new fill placement. Please reference the later sections of this report for specific recommendations pertaining to these fat clay soils.

7B KARST GEOLOGY

The site is located in an area with high potential for karst development. KGS mapping indicated a sinkhole located on the north side of the project site as well as on surrounding properties. Refer to *Figure 3* for more details. While on-site, CSI observed a depression that is located on the north side of the project site near the end of the asphalt paved roadway that ends shortly after entering the site. The bottom of the depression consisted of tall weeds and thick brush with few trees.

The available geologic data suggests that sinkholes are commonly associated with the limestone formation underlying the site. Karst features such as sinkholes, dropouts, weathered bedrock, caverns, erratic bedrock, etc. are typically exposed during grading activities and foundation and/or utility construction. Karst topography consists of limestone or dolomite that is weathered which results in sinkholes (i.e. – closed depressions), irregular top of rock profiles, pinnacled bedrock, slots or troughs in the bedrock, internal drainage systems, and open voids in either the bedrock itself or in the soil overburden (typically at the soil/rock interface). Additionally, soft/wet soils are commonly encountered at the soil/rock interface and in slots or troughs in the bedrock. Irregular depths to bedrock and deeper than normal soft soil conditions are common in areas of high karst potential. Please note, our borings and soundings were terminated prior to encountering bedrock.

An in-depth karst study was beyond the scope of this exploration. Procedures for construction in karst areas are contained in later sections of the report. Regardless of methods used, they should be treated on a case-by-case basis and should involve a CSI geotechnical engineer. Based on our knowledge of the area geology, sinkholes could be exposed during grading activities and underground utility construction. Detailed site proofrolling are frequently utilized in an attempt to locate incipient soil dropouts. Sinkholes must be evaluated and treated on an individual basis. A CSI geotechnical engineer should be retained for remediation recommendations if a sinkhole is exposed during construction. Treatment of depressions will likely involve monitoring by a CSI geotechnical engineer during earthwork operations to observe indications of sinkhole throats and conduits after stripping of topsoil and soil cutting activities are complete. Procedures for repairing sinkholes or other karst features should be done on a case-by-case basis and should involve a CSI geotechnical engineer.

7C SITE CLEARING AND CULTIVATED AREAS

Clearing of existing trees, brush, and crops will be necessary for this project. Larger trees are scattered throughout the proposed site. These trees may be within the proposed access road footprint. Expect that removal of large root masses will be required during site clearing. The voids left when the root masses are removed will need to be backfilled with structural fill.

In the cultivated areas, our borings indicated only a few inches of till zone. However, thicker areas of till zone are likely throughout the site. CSI engineering personnel should be on-site during stripping operations to ensure that adequate (and not excessive) topsoil stripping is performed (due to the presence of the till zone). Some of the till zone may be left in-place if it deemed adequate during a proofroll by a CSI geotechnical engineer.

8 EARTHWORK

We have not been provided with a proposed grading plan. Thus, we do not know the expected elevations of the new access road and anticipated cut and fill depths. Deep cuts should be avoided for two main reasons; reduce the risk of activating a latent karst feature and reduce the likelihood of risk of constructing the new roadway on fat clay in cut areas and on newly placed fill containing fat clay generated from deeper cut areas.

Additionally, due to the karst prone area, heavy proofrolls must be performed during construction in an effort to identify any hidden sinkholes or "drop outs". These proofrolls should be performed at the direction and in the presence of CSI.

Historically, more change orders (in total number and costs) occur during the earthwork portion of construction than in almost any other part of the project. Further, the site preparation phase of construction always affects the future performance of project pavements. Add into this, the fact that earthwork is the portion of work most influenced by wet weather and unknown conditions and time-wise, this section of the report could be the most important to prevent and minimize delays and costs during construction and for the life of the project.

Please review the concerns listed in section 7 prior to reading the following recommendations. If problems occur that the recommendations do not address or do not adequately remedy, please contact CSI as soon as possible.

8A SITE PREPARATION (WORK PRIOR TO FILLING)

- When ready to commence construction, remove/relocate all underground/overhead utilities as required by the construction plans. Please note, the depth of any cuts and fills could be limited in the area of the transmission gas line easement located near the middle of the site;

- All topsoil and organic materials should be removed (stripped) from the construction area and all structural fill areas. Roots larger than ½ inch in diameter should be removed (grubbed) from the proposed construction areas and all structural fill areas. These materials should be wasted from the site or stockpiled for use as topsoil in landscape areas;

- CSI engineering personnel should be on-site during stripping operations to ensure that adequate (and not excessive) topsoil stripping is performed (due to the presence of the till zone). Some of the till zone may be left in-place if it holds up well to a heavy proofroll (depending upon grades);

- Any remnants of old structures or utilities (not expected) must be removed to at least 5 feet outside of the new pavement areas. Any surficial fill (old construction debris, wood, etc.) and <u>tree stumps</u> must also be removed from within the pavement areas;
- Areas ready to receive new fill should be proofrolled with a loaded dump truck (as determined by a CSI geotechnical engineer) or similar equipment judged acceptable by the geotechnical engineer;

- Please refer to the Karst Region Construction recommendation section (Section 9);

- The level of proofroll should be determined by a CSI geotechnical engineer on a case-by-case basis;

- Perform the proofrolling after a suitable period of dry weather to avoid degrading the subgrade;

- Areas which pump, rut, or wave during proofrolling may require undercutting, depending on the location of the area and relation to subgrade, so, again CSI should be contacted for guidance. Thus, your budget should contain a contingency for undercutting and replacing;

- Backfill undercut areas should be performed in accordance with sections 8B and 8C;

- Retain CSI to observe the proofrolling operations and make recommendations for any unstable or unsuitable conditions encountered. This can save time on the construction schedule and save unnecessary undercutting.

<u>We recommend that site grading should take place between about late April to early November. Earthwork taking place outside this time period will likely encounter wet conditions and weather conditions that will provide little to no assistance with drying the soils.</u>

8B NEW FILL OPERATIONS

As previously stated, Atterberg limits test was performed on 2 representative soil samples from the site. One of the samples classified as fat clay (CH) with a maximum Plasticity Index (PI) of 35 percent. Soils with a PI above 30 percent can have a tendency to shrink/swell with changes in moisture content.

The on-site soils are likely suitable for earthwork operations. **<u>Strict placement criteria</u>** is required for new structural fill due to the presence of fat clays. If off-site fill material is imported to the project site, representative samples should be obtained of the proposed fill material to determine the moisture-density relationship and overall classification of the material. Off-site fill soils must have a plasticity index less than **<u>25</u>** percent.

After the exposed subgrade has been approved to receive new fill, the fill may commence with the following procedures and guidelines recommended:

- Place fill in maximum 8-inch thick loose lifts.

- Fill lifts should be compacted to at least 98 percent of the soil's maximum dry density (ASTM D698) and maintain the moisture content of compacted fill within optimum moisture content to up to 3 percent above optimum moisture;

- Fill compaction requirements should extend to at least 5 feet outside the proposed pavement areas;

- Maximum particle size of the soil should be limited to 4 inches in any dimension with no large concentrations of large fragments;

- Density testing should be performed as a means to verify percent compaction and moisture content of the material as it is being placed and compacted;

- Observations of fill "stability" is also critical, so it is recommended to observe the operation of the filling equipment traversing over the new fill to document movement (similar to proofrolling);

- Prior to the placement of DGA, we recommend checking the moisture content of the subgrade soils to ensure moisture contents are at or above optimum moisture. If drier than optimum soils are encountered, scarifying, watering, and recompacting the surface of the subgrade may be required;
- Off-site fill soils with a plasticity index (PI) of greater than 25 should not be used as new fill;
- Retain a representative of CSI to observe and document fill placement and compaction operations.

8C BACKFILL OPERATIONS (UTILITIES, ETC.)

These materials are placed in more confined areas than mass earthwork materials or pavement materials and therefore cannot be placed in full compliance with section 8B. The following are general recommendations for backfill areas:

- Fill lift thicknesses will vary dependent on compaction equipment available and material types, but in no case should exceed 8 inches;
- The maximum particle size should not exceed 4 inches;
- For crushed stone/aggregate backfills in trenches and when using smaller compaction equipment (such as a plate compactor, trench compactor, or similar) the lift thickness should not exceed 4 inches;
- CSI should be retained to provide additional recommendations for backfill (if necessary).

8E GENERAL NOTES

- For all earthwork operations, positive surface drainage is prudent to keep water from ponding on the surface and to assist in maintaining surface stability.
- The surface should be sealed prior to expected wet weather. This can usually be accomplished with rubber-tired construction equipment or a steel-drum roller.
- If any fill placement problems occur, CSI should be retained to provide additional recommendations, as needed.

9 KARST AREA CONSTRUCTION

CSI recommends to orientate the alignment of the new access road away from the known sinkhole on the north side of the site. Depending on the extent of the sinkhole, this section of access road may require remedial work. If a karst feature (sinkhole, dropout, or mud-filled slot/trough in the bedrock) is encountered, then a CSI geotechnical engineer should be contacted immediately.

Typically, repairs of Karst features consist of two primary alternatives – an inverted rock filter, or a concrete plug. Both of these alternatives are described briefly in the following sections; however, Karst features can vary greatly in size, width, depth and complexity of repair. The width of sinkholes are usually equal to or greater than two-thirds of the native overburden thickness. We did not encounter bedrock at our borings or soundings. Thus, the width of on-site sinkholes could be greater than 15 feet at this site. Their repair will depend entirely upon the specific conditions encountered and the proposed construction for that area. Therefore, remediation of Karst features should only be performed at the direction of, and under the supervision of, a CSI geotechnical engineer.

Inverted Rock Filter – In most instances, an inverted rock filter is the preferred remediation technique for repairing Karst features. An inverted rock filter allows the infiltration/ transmission of water while preventing erosion of the adjoining soil into the underlying Karst openings and/or conduits.

Construction of an inverted filter usually begins with excavating the Karst feature down to bedrock on all sides. An extended boom backhoe with a narrow bucket is typically the preferred excavation equipment for small to moderate size Karst features. For larger Karst features, a trackhoe is commonly used. Soil and/or mud are removed from the sidewalls of the Karst feature so that rock is exposed on all sides. Hand tools are sometimes required to clean the sidewalls since mud-filled crevices are common. In some instances, a bedrock "bottom" is not encountered. However, it is important that the excavation be extended to a point where the rock sidewalls narrow or converge.

Once the Karst feature has been excavated to the satisfaction of the CSI geotechnical engineer, heavy-duty, non-woven filter fabric is used to line the excavation. The filter fabric allows water to flow through the rock within the filter, but will not allow soil fines to be washed away. Large rock is then placed in the bottom of the excavation. The size of the large rock fragments will depend entirely upon the size and depth of the excavation. It is imperative that the size of rock fragments used in the bottom layer be considerably larger than the solution channel opening in the bedrock. Thus, large rock boulders would be used for a large excavation, while rip rap would be used for a smaller excavation. Layers of smaller rock fragments would then be placed on top of the larger rock fragments until the desired grade is obtained. For large/deep excavations, the rock fragments would typically consist of layers of boulders, rip rap, No. 2 stone, capped with No. 57 stone. For smaller/shallow excavations, the rock fragments would typically consist of layers of No. 2 stone capped with No. 57 stone. The thickness of each layer of rock should be determined in the field by the CSI geotechnical engineer.

Once the final layer of No. 57 crushed stone is placed, it should be leveled by raking. Once leveled, the filter fabric should be lapped over the No. 57 crushed stone so that no stone is exposed. The filter fabric should totally encapsulate the rock filter with no gaps between pieces of filter fabric. A minimum overlap of 2 feet is typically recommended for filter fabric used in inverted rock filters. From this elevation, compacted soil or crushed stone can be used to obtain the desired final grade. Please reference the the following diagram.

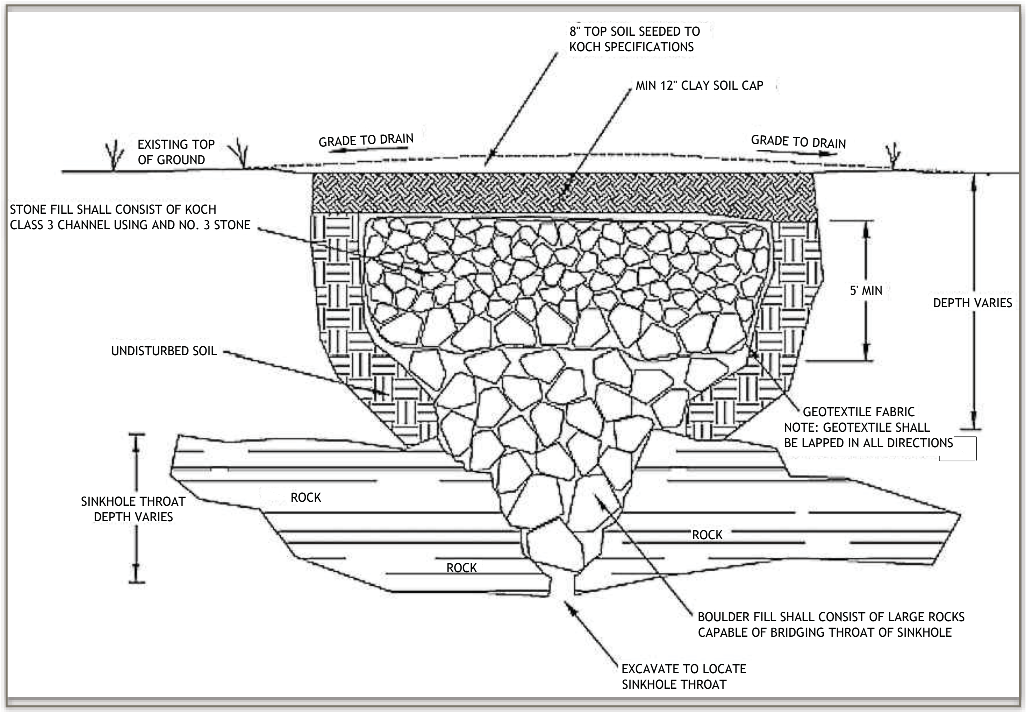


Figure 9: Example of Inverted Rock Filter Cross Section (For Reference Only)

Concrete Plug - In some instances, a concrete plug will be a more viable option to remediate a Karst feature. Typically, a concrete plug is used when the opening in the bedrock is at, or near, the proposed final grade and an inverted rock filter cannot be used effectively. Concrete plugs are primarily used for small, shallow Karst features. Concrete plugs should never be used when water flow is expected in the immediate area since the concrete plug will stop any water from flowing into, or through, the conduit system in the bedrock.

Construction of a concrete plug requires excavating the Karst feature down to bedrock on all sides. An extended boom backhoe with a narrow bucket is typically the preferred excavation equipment for small to moderate size Karst features. Soil and/or mud are removed from the sidewalls of the Karst feature so that rock is exposed on all sides. Hand tools are sometimes required to clean the sidewalls since mud-filled crevices are common. In some instances, a bedrock “bottom” is not encountered. However, it is important that the excavation be extended to a point where the rock sidewalls narrow or converge. In some instances, a bale of hay may be required to "choke off" the bottom of the opening so that concrete can be poured. Lean concrete (2,000 psi minimum) or excess concrete from the project can be used to construct the concrete plug. If rock is exposed in the bottom of the excavation, then the concrete can typically be poured in one pour. However, care must be exercised since the weight of the fluid concrete can "blow out" soil within the openings in the bedrock. Concrete can be poured in two or more pours to allow the initially placed concrete time to partially cure before additional concrete is poured. Concrete should be poured to at least the elevation of the highest exposed bedrock within the excavation. Concrete can be poured to the adjoining grade if it will not interfere with future construction activities. If the top of the concrete plug is left below the adjoining grade, it is imperative that the area be backfilled with compacted soil, compacted dense graded crushed stone, or flowable fill to the surrounding grade. The use of an open graded crushed stone (such as No. 57 stone) is not recommended since it will allow the free flow of water into the subsurface.

Levels of risk associated with Karst are difficult to assess. So the Owner must assume that there is always a level of risk of sinkholes or soil dropouts which could cause damage to completed pavements in any limestone Karst area. The use of suitable precautionary measures can reduce this risk. Some of these measures include:

- Typically the risk of sinkhole drop-out formation is reduced in filled areas and increased in cut areas. Designing the site layout so the new access road is constructed away form known sinkholes is recommended.

- Water flow considerations (both surface and subsurface) are a key factor to try to reduce Karst associated risks when planning. CSI should be retained to assess civil plans of water flow to provide guidance with regards to potential increases to Karst risks.

- A simple way to assess near surface potential dropouts is to conduct a strict proofroll of all construction areas (see the Earthwork section of the report) after clearing and topsoil removal. Cut areas should be re-proofrolled after planned subgrade is reached. If possible, this second proofroll should be performed after several cycles of rainy and fair weather. CSI should be retained to direct such proofrolls.

- Specific procedure used to repair drop-outs will depend on the specific condition encountered. The project geotechnical engineer should be contacted if drop-outs form or suspect old drop-outs are encountered.

10 SITE DRAINAGE

During construction, water should not be allowed to pond in excavations or undercutting will likely be required. Additionally, allowing water to pond in excavations greatly increases the risk for activating latent Karst features. During the life of the project, slope the subgrade and other site features so that surface water flows away from the site features. Diversion ditches should be used at the toe of all slopes to keep surface water from accumulating at or near site features. All storm drainage and surface runoff must be piped to a storm sewer system. Proper storm water drainage is critical to avoid increasing risk of sinkhole development. CSI should be allowed to review the final site civil drawings to ascertain any elevated risk associated with civil designs.

For excavations during construction, most free water could likely be removed via sump pumps and open channel flow (ditches) at or near the source of seepage. Wet weather springs may be encountered during construction of the new access road. As such, the contractor should be prepared to provide temporary sumps and sump pumps when these are encountered. If normal dewatering measures prove insufficient (not expected), CSI should be retained to provide recommendations on the issue.

Wet conditions are possible in excavations on-site during site construction. If pumping is required for dewatering purposes, pumping with long-flexible hoses day-lighted hundreds of feet away for the new access road is required.

11 PAVEMENT RECOMMENDATIONS

We were not provided with expected traffic loading for the new access road. However, based on the anticipated industrial usage of the new roadway, we expect the proposed access road will consist of heavy-duty asphalt pavement. Estimated traffic expected for this new access road will include passenger vehicles, some two-axle support trucks, tractor and trailer trucks, and an occasional garbage truck. We assume about 300 passenger vehicles, up to 6 two-axle support trucks and tractor trailers per day are expected with up to 3 garbage trucks per week.

Adequate soil/subgrade support is critical for any pavement area. Please refer to the recommendations contained in the Earthwork section of this report for subgrade preparation. We anticipate the new access road's subgrade will consist of on-site clays. Heavy proofrolling will be required in an effort to identify soft areas or karst features.

In areas of poor drainage areas or at the bottom of swales, partial undercutting and replacing with drier soil or DGA are viable options. Another option would be to replace with geo-grid and crushed. CSI should be retained to provide location specific stabilization recommendations at the time of construction.

Adequate drainage and slope of the pavement subgrade and pavement section should be provided to promote adequate drainage. Edges of the pavement should be provided a means of water outlet by extending the aggregate base course through to side ditches or providing drain pipes and weep holes at catch basin walls.

These recommendations are based on the assumption that the soil subgrade will be compacted and/or remediated according to the recommendations contained in this report.

11A ASPHALT PAVEMENT

California Bearing Ratio (CBR) tests were performed on two representative soils samples collected at this site. The recovered bulk samples indicated CBR values of 8.2 and 7.8 percent. These CBR values may have been inflated due to the inclusion chert fragments. Thus, we used a CBR value of at 6 percent for the pavement design which should be checked during construction. This design CBR value was selected based on our previous project experience in this area with similar soil types.

We recommend the proposed access road consist of a heavy duty pavement section. Our recommendations are based on the subgrade being prepared as per our recommendations. The generalized pavement design for heavy duty pavement is given below.

Table 2. Heavy Duty Asphalt Pavement Section

Pavement Section Component	Thickness (in)
Bituminous Surface Course	1.5
Bituminous Binder Course	4.5
Dense Graded Aggregate (DGA)*	8.0

*DGA to be placed in 6 inch thick maximum, compacted lifts

The dense graded aggregate (DGA) should be placed and compacted in accordance with Kentucky Department of Highways Standard Specifications, latest edition. The asphalt should be mixed, placed, and compacted in accordance with Kentucky Department of Highways Standard Specifications, latest edition. It is common practice to place the base stone and binder course prior to completion of construction without placing the surface course. It should be noted that repeated passes of heavily loaded construction traffic on the binder course will likely decrease the service life of your pavement.

We understand the DGA may be placed and left exposed before the asphalt pavement is placed. If the DGA is left exposed, water may wash away the fines and leave only larger sized gravel at the surface. The DGA thickness should be checked prior to asphalt placement by a CSI representative. If the DGA does not meet the required thickness or the surface of the DGA is lacking sufficient fine material, the surface may need to be reworked and/or additional DGA may need to be added.

12 NOTES ON THE REPORT AND RECOMMENDATIONS

We recommend that this complete report be provided to the various design team members, the contractors and the project Owner. Potential contractors should be informed of this report in the "Instructions to Bidders" section of the bid documents. A geotechnical exploration, such as the one we performed, uses widely spaced borings and soundings to attempt to model the subsurface conditions at the site. Because no exploration contains complete data or a complete model, there is always a possibility that conditions between borings and soundings will be different from those at specific boring/sounding locations. Thus, it is possible that some subsurface conditions will not be as anticipated by the project team or contractor. If this report is included or referenced in the actual contract documents, **it shall be explicitly understood that this report is for informational purposes only**. CSI shall not be responsible for the opinions of, or conclusions drawn by, others.

It has been our experience that the construction process often disturbs soil conditions and this process, no matter how much experience we use to anticipate construction methodology, is not completely predictable. Therefore, changes or modifications to our recommendations are likely needed due to these possible variances. Experienced CSI geotechnical personnel should be used to observe and document the construction procedures and the conditions encountered. Unanticipated conditions and inadequate procedures should be reported to the design team along with timely recommendations to solve the problems created. We recommend that the Owner retain CSI to provide this service based upon our familiarity with the project, the subsurface conditions and the intent of our recommendations.

This report is based on the supplied project information, the subsurface conditions observed at the time of the report, and our experience with similar conditions. As such, it cannot be applied to other project sites, types, or combinations thereof. If the Project Information section in this report contains incorrect information or if additional information is available, you should convey the correct or additional information to us and retain us to review our recommendations. Our recommendations may then require modification.

No section or portion of this report (including Appendix information) can be used as a stand alone article to make distinct changes or assumptions. The entire report and Appendix should be used together as one resource.

While this report deals with samples of subsurface materials and some comments on water conditions at the site, no assessment of site environmental conditions or the presence of contaminants were performed.

We wish to remind you that our exploration services include storing the soil and rock core samples collected and making them available for inspection for 30 days. The samples are then discarded unless you request otherwise. Please inform us if you wish to keep any of the obtained samples.

APPENDIX

Site Location Plan

Boring / Sounding Location Plan

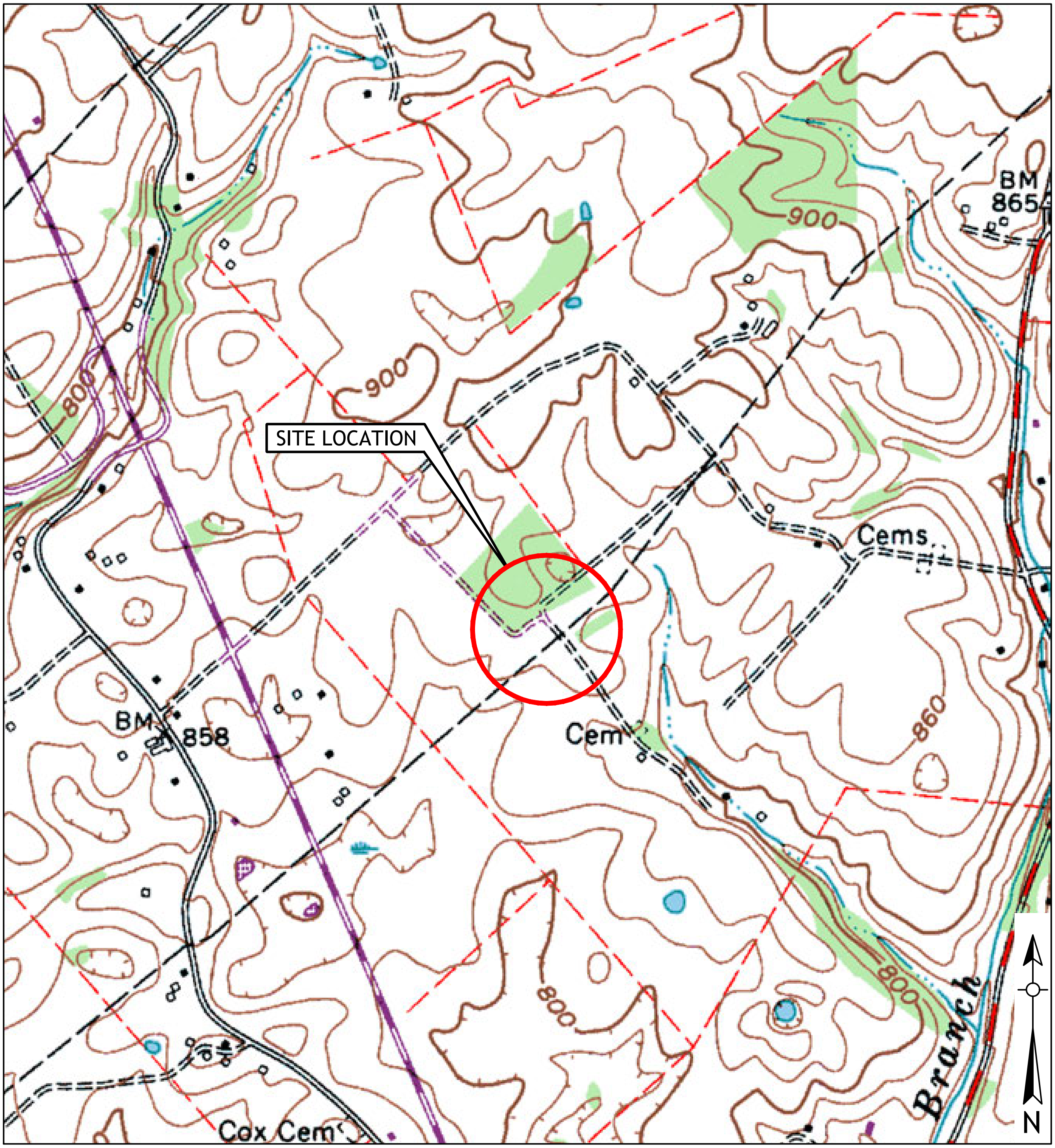
Key to Symbols and Descriptions

Boring / Sounding Logs

Field Testing Procedures

Summary of Lab Testing Table(s) and Lab Testing Sheets

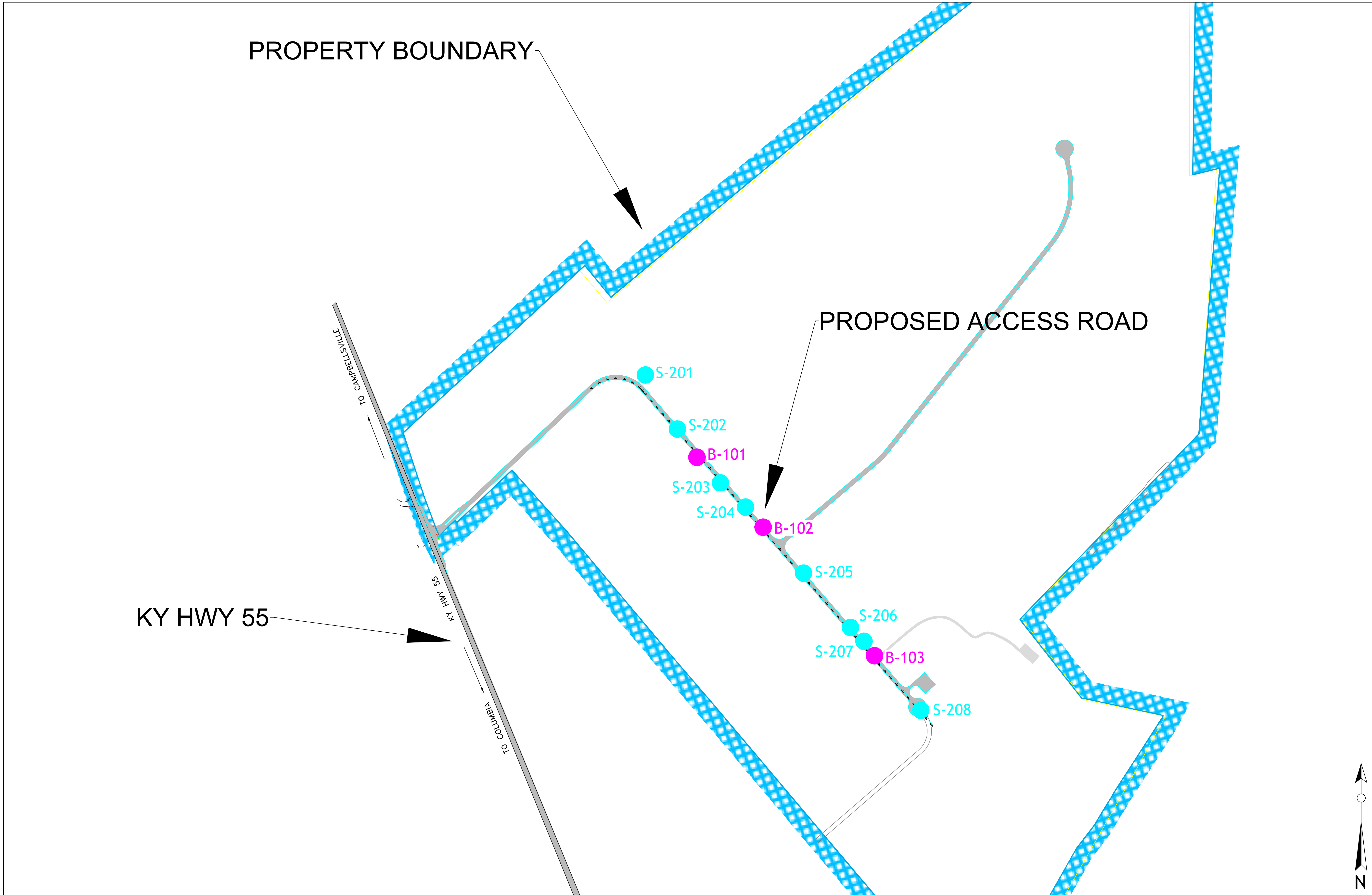
Laboratory Testing Procedures



Site Location Plan adapted from USGS Cane Valley, Kentucky Topographic Quadrangle map dated 1979, with further adaptation by CSI personnel.

FOR ILLUSTRATION PURPOSES ONLY

Consulting Services Incorporated of Kentucky 858 Contract Street Lexington, Kentucky 40505 859.309.6021 Office|888.792.3121 Fax www.csikentucky.com	SITE LOCATION PLAN	Project No: LX190143	Drawn By: RE
	Green River Commerce Park Access Road Columbia, Kentucky	Date: 10/01/2019	Checked By: YL
		Scale: Not To Scale	Drawing No: SLP - 1



Boring Location Plan adapted from provided Site Master Plan dated July, 26, 1999, with further adaptation by CSI personnel.
Elevations were supplied to CSI by others.

FOR ILLUSTRATION PURPOSES ONLY

LEGEND
S-XXX SOUNDING LOCATIONS
B-XXX BORING LOCATIONS

Drawn By: CG
Checked By: YL
Drawing No: BLP - 1
Project No: LX190143
Date: 10/2/2019
Scale: Not To Scale

BORING AND SOUNDING LOCATION PLAN
Green River Commerce Park Access Road
Columbia, Kentucky

Consulting Services Incorporated of Kentucky
858 Contract Street
Lexington, Kentucky 40505
859.309.6021 Office | 888.792.3121 Fax
www.csikentucky.com

Consulting Services Incorporated

LEXINGTON | LOUISVILLE | CINCINNATI

Geotechnical Boring Information Sheet

Sample Type Symbols

- Splitspoon (SPT)
- Shelby Tube
- Grab
- Rock Core
- Auger Cuttings

Surface Symbols

- Topsoil
- Asphalt
- Concrete
- Lean Clay
- Fat Clay
- Glacial Till
- Sandy Clay
- Silt
- Elastic Silt
- Lean Clay to Fat Clay
- Gravelly Clay
- Sandy Silt
- Gravelly Silt
- Sand
- Gravel
- Fill
- Limestone
- Sandstone
- Shale/Siltstone
- Weathered Rock

Samples Strength Descriptors

Cohesive Soils:	**N**
Very Soft	0-1
Soft	2-4
Firm	5-8
Stiff	9-15
Very Stiff	16-30
Hard	31+
Non-cohesive Soils:	
Very Loose	0-4
Loose	5-10
Firm	11-20
Very Firm	21-30
Dense	30-50
Very Dense	51+

Definitions

SPT-"Splitspoon" or standard penetration test. Blow counts are number of drops required for a 140 lb hammer dropping 30 inches to drive the sampler 6 inches.

N-value is the addition of the last two intervals of the 18-inch sample.

Shelby tubes are often called "undisturbed samples". They are directly pushed into the ground, twisted, allowed to rest for a small period of time and then pulled out of the ground. Tops and bottoms are cleaned and then sealed.

Sample classification is done in general accordance with ASTM D2487 and 2488 using the Unified Soil Classification System (USCS) as a general guide.

Soil moisture descriptions are based on the recovered sample observations. The descriptors are dry, slightly moist, moist, very moist and wet. These are typically based on relative estimates of the moisture condition of a visual estimation of the soils optimum moisture content (EOMC). Dry is almost in a "dusty" condition usually 6 or more percent below EOMC. Slightly moist is from about 6 to 2 percent below EOMC at a point at which the soil color does not readily change with the addition of water. Moist is usually 2 percent below to 2 percent above EOMC and the point at which the soil will tend to begin forming "balls" under some pressure in the hand. Very moist is usually from about 2 percent to 6 percent above EOMC and also the point at which it's often considered "muddy". Wet soil is usually 6 or more percent above EOMC and often contains free water or the soil is in a saturated state.

Silt or Clay is defined at material finer than a standard #200 US sieve (<0.075mm) Sand is defined as material between the size of #200 sieve up to #4 sieve. Gravel is from #4 size sieve material to 3". Cobbles are from 3" to 12". Boulders are over 12".

Rock hardness is classified as follows:

Very Soft:	Easily broken by hand pressure
Soft:	Ends can be broken by hand pressure; easily broken with hammer
Medium:	Ends easily broken with hammer; middle requires moderate blow
Hard:	Ends require moderate hammer blow; middle requires several blows
Very Hard:	Many blows with a hammer required to break core

Rock Quality Designation (RQD) is defined as total combined length of 4" or longer pieces of core divided by the total core run length; defined in percentage.

Water or cave-in observed in borings is at completion of drilling each boring unless otherwise noted.

Strata lengths shown on borings represents a rough estimate. Transition may be more abrupt or gradual. Soil borings are representative of that estimated location at that time and are based on recovered samples. Conditions may be different between borings and between sample intervals. Boring information is not to be considered stand alone but should be taken in context with comments and information in the geotechnical report and the means by which the borings are logged, sampled and drilled.

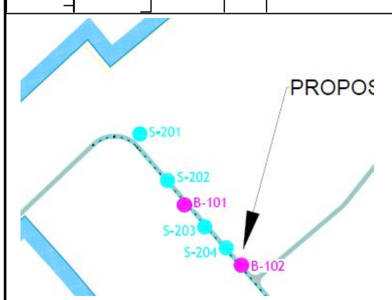
BORING LOG

Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

BORING: **B-101**

Project Number: LX190143 Name: Green River Commerce Park Access Road Client: Columbia - Adair County Economic Development Authority Location: Columbia, Kentucky Logged By: Y. Little, P.E.	Weather: Clear, 90s Elevation (ft): 864.4 Date Started: 9/11/19 Date Completed: 9/11/19 Checked By: J. Cooke, P.E.	Contractor: Mathes Drilling Drill Rig: Mobile B-53 Method: SFA Hole Size (in): 4

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
864			TOPSOIL - mixed with gravel - 4 inches				Dry upon completion of soil augering
			TILL ZONE - brown, silty clay with fine roots	4-6-8 (14)	11		
862	2	CL	LEAN CLAY (CL) - with sand, STIFF, tan, with some chert fragments, moist	5-5-6 (11)	15		
860	4			4-6-7 (13)	18		
858	6	CH	FAT CLAY (CH) - with sand, STIFF, reddish-brown with tan, with zones of chert fragments, moist to wet	5-6-7 (13)	18		
856	8						
854	10			3-4-5 (9)	18		
			Boring Terminated at 10.5 feet				
852	12						
850	14						
848	16						
846	18						



*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

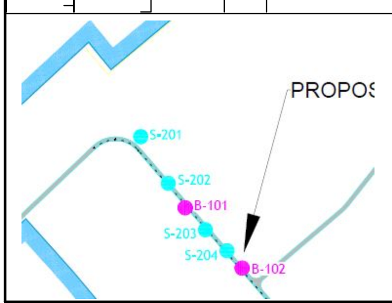
BORING LOG

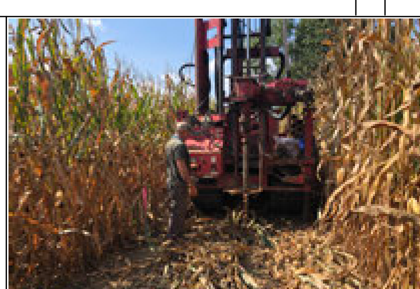
BORING: B-102

Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

Project Number: LX190143	Weather: Clear, 90s	Contractor: Mathes Drilling
Name: Green River Commerce Park Access Road	Elevation (ft): 871.9	Drill Rig: Mobile B-53
Client: Columbia - Adair County Economic Development Authority	Date Started: 9/11/19	Method: SFA
Location: Columbia, Kentucky	Date Completed: 9/11/19	Hole Size (in): 4
Logged By: Y. Little, P.E.	Checked By: J. Cooke, P.E.	

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
			TOPSOIL - 3 inches				Dry upon completion of soil augering
			TILL ZONE - brown, silty clay	3-4-5 (9)	16		
870	2	CL	LEAN CLAY (CL) - with sand, STIFF, tan to orangish-tan, damp to moist	4-6-6 (12)	18		
868	4	CH	FAT CLAY (CH) - with sand, STIFF, orangish-tan with red and tan mottling, with few chert fragments, moist	5-6-8 (14)	18		
866	6						
864	8	CH	FAT CLAY (CH) - with sand, STIFF to VERY STIFF, reddish-brown with tan mottling, with chert fragments, wet to moist	4-5-6 (11)	18		
862	10			7-8-9 (17)	18		
			Boring Terminated at 10.5 feet				
860	12						
858	14						
856	16						
854	18						





*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

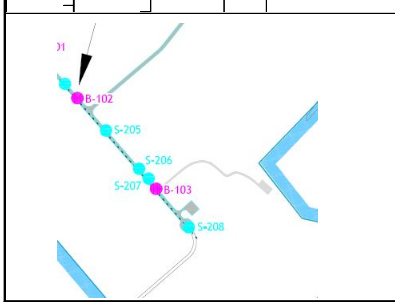
BORING LOG

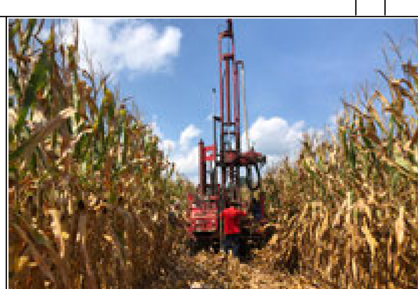
Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

BORING: B-103

Project Number: LX190143	Weather: Clear, 90s	Contractor: Mathes Drilling
Name: Green River Commerce Park Access Road	Elevation (ft): 834.9	Drill Rig: Mobile B-53
Client: Columbia - Adair County Economic Development Authority	Date Started: 9/11/19	Method: SFA
Location: Columbia, Kentucky	Date Completed: 9/11/19	Hole Size (in): 4
Logged By: Y. Little, P.E.	Checked By: J. Cooke, P.E.	

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
	0		TOPSOIL - mixed with gravel - 5 inches				Dry upon completion of soil augering
			TILL ZONE - brown, silty clay				
834	0–6	CL	LEAN CLAY (CL) - with sand, STIFF, tan, with chert fragments, damp to moist	3-5-7 (12)	8		
832				4-5-5 (10)	11		
830				6-7-5 (12)	13		
828	6–9.5	CH	FAT CLAY (CH) - with sand, STIFF, orangish-tan, with gray mottling, with few chert fragments, moist	6-6-4 (10)	15		
826	9.5–10.5	CH	FAT CLAY (CH) - with sand, STIFF, orangish-tan, with red and gray mottling, with chert fragments, moist	7-6-6 (12)	18		
824	10.5		Boring Terminated at 10.5 feet				





*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

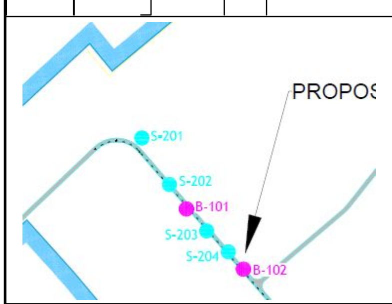
BORING LOG

Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

BORING: **S-201**

Project Number: LX190143	Weather: Clear, 90s	Contractor: Mathes Drilling
Name: Green River Commerce Park Access Road	Elevation (ft): 866.6	Drill Rig: Mobile B-53
Client: Columbia - Adair County Economic Development Authority	Date Started: 9/11/19	Method: SFA
Location: Columbia, Kentucky	Date Completed: 9/11/19	Hole Size (in): 4
Logged By: Y. Little, P.E.	Checked By: J. Cooke, P.E.	

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
866	0		TOPSOIL - 6 inches				Dry upon completion of soil augering
		CL	LEAN CLAY (CL) - tan with some chert fragments, moist				
864	2	CL	LEAN CLAY (CL) - reddish brown, moist				Note: Descriptions based only on auger cuttings. No SPT sampling was performed
862	4						
860	6	CH	FAT CLAY (CH) - reddish brown and tan with some chert fragments, moist				
858	8						
856	10						
854	12						
852	14						
850	16		Sounding Terminated at 15.0 feet				
848	18						



*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location

Right Photo: Photo of Boring

BORING LOG

Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

BORING: S-202

Project Number: LX190143	Weather: Clear, 90s	Contractor: Mathes Drilling
Name: Green River Commerce Park Access Road	Elevation (ft): 859.2	Drill Rig: Mobile B-53
Client: Columbia - Adair County Economic Development Authority	Date Started: 9/11/19	Method: SFA
Location: Columbia, Kentucky	Date Completed: 9/11/19	Hole Size (in): 4
Logged By: Y. Little, P.E.	Checked By: J. Cooke, P.E.	

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
			TOPSOIL - 5 inches				Dry upon completion of soil augering Note: Descriptions based only on auger cuttings. No SPT sampling was performed
		CL	LEAN CLAY (CL) - tan, moist				
	6	CH	FAT CLAY (CH) - reddish brown and tan, with few chert fragments, moist				
	12	CH	FAT CLAY (CH) - reddish brown, with chert fragments, moist				
			Sounding Terminated at 15.0 feet				

Elevation scale (ft): 858, 856, 854, 852, 850, 848, 846, 844, 842, 840
Depth scale (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18

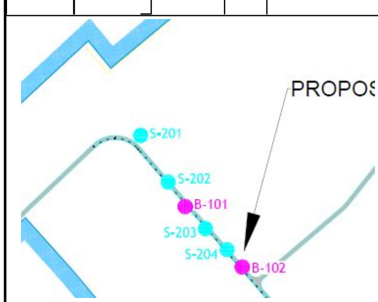


Photo Not Available

*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

BORING LOG

Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

BORING: **S-203**

Project Number: LX190143	Weather: Clear, 90s	Contractor: Mathes Drilling
Name: Green River Commerce Park Access Road	Elevation (ft): 860.3	Drill Rig: Mobile B-53
Client: Columbia - Adair County Economic Development Authority	Date Started: 9/11/19	Method: SFA
Location: Columbia, Kentucky	Date Completed: 9/11/19	Hole Size (in): 4
Logged By: Y. Little, P.E.	Checked By: J. Cooke, P.E.	

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
860	0		TOPSOIL - 6 inches				Dry upon completion of soil augering
		CL	LEAN CLAY (CL) - brown, moist				Note: Descriptions based only on auger cuttings. No SPT sampling was performed
856	4	CH	FAT CLAY (CH) - tan with zones of chert fragments, moist				
	15		Sounding Terminated at 15.0 feet				

Elevation scale (ft): 860, 858, 856, 854, 852, 850, 848, 846, 844, 842
Depth scale (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18

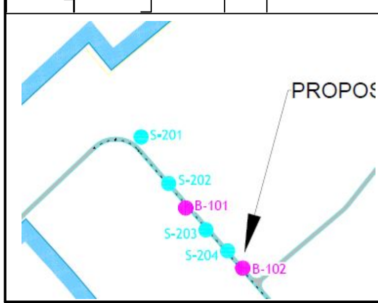


Photo Not Available

*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

BORING LOG

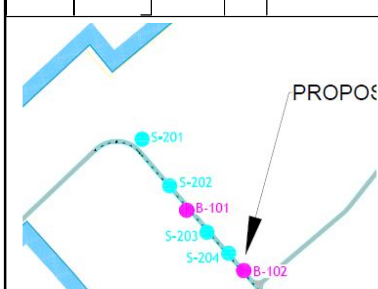
Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

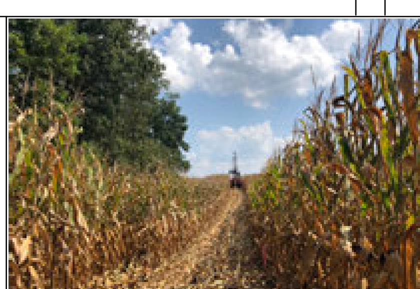
BORING: **S-204**

Project Number: LX190143 Name: Green River Commerce Park Access Road Client: Columbia - Adair County Economic Development Authority Location: Columbia, Kentucky Logged By: Y. Little, P.E.	Weather: Clear, 90s Elevation (ft): 861.5 Date Started: 9/11/19 Date Completed: 9/11/19 Checked By: J. Cooke, P.E.	Contractor: Mathes Drilling Drill Rig: Mobile B-53 Method: SFA Hole Size (in): 4

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
	0–0.5		TOPSOIL - 6 inches				Dry upon completion of soil augering Note: Descriptions based only on auger cuttings. No SPT sampling was performed
	0.5–6	CL	LEAN CLAY (CL) - brown, moist				
	6–8	CH	FAT CLAY (CH) - reddish tan, moist				
	8–15	CH	FAT CLAY (CH) - reddish brown and tan, with chert fragments, moist				
	15		Sounding Terminated at 15.0 feet				

Depth scale (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18





*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

BORING LOG

Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

BORING: S-205

Project Number: LX190143	Weather: Clear, 90s	Contractor: Mathes Drilling
Name: Green River Commerce Park Access Road	Elevation (ft): 855.8	Drill Rig: Mobile B-53
Client: Columbia - Adair County Economic Development Authority	Date Started: 9/11/19	Method: SFA
Location: Columbia, Kentucky	Date Completed: 9/11/19	Hole Size (in): 4
Logged By: Y. Little, P.E.	Checked By: J. Cooke, P.E.	

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
			TOPSOIL - 6 inches				Dry upon completion of soil augering Note: Descriptions based only on auger cuttings. No SPT sampling was performed
854, 852, 850	2, 4, 6	CL	LEAN CLAY (CL) - reddish brown, with chert fragments, moist				
848, 846, 844, 842	8, 10, 12, 14	CH	FAT CLAY (CH) - reddish brown and tan, moist				
840, 838, 836	16, 18		Sounding Terminated at 15.0 feet				

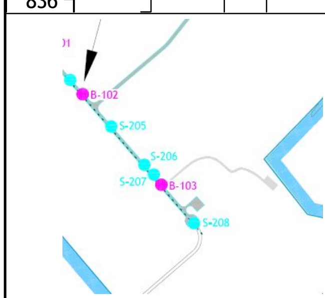


Photo Not Available

*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

BORING LOG

Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
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Fax: 888.792.3121

BORING: S-206

Project Number: LX190143	Weather: Clear, 90s	Contractor: Mathes Drilling
Name: Green River Commerce Park Access Road	Elevation (ft): 847.5	Drill Rig: Mobile B-53
Client: Columbia - Adair County Economic Development Authority	Date Started: 9/11/19	Method: SFA
Location: Columbia, Kentucky	Date Completed: 9/11/19	Hole Size (in): 4
Logged By: Y. Little, P.E.	Checked By: J. Cooke, P.E.	

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
847.5	0		TOPSOIL - 5 inches				Dry upon completion of soil augering
		CL	LEAN CLAY (CL) - tan with chert fragments, moist				Note: Descriptions based only on auger cuttings. No SPT sampling was performed
		CH	FAT CLAY (CH) - reddish brown and tan, with chert fragments, moist				
	15.0		Sounding Terminated at 15.0 feet				

Elevation scale (ft): 846, 844, 842, 840, 838, 836, 834, 832, 830, 828
Depth scale (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18

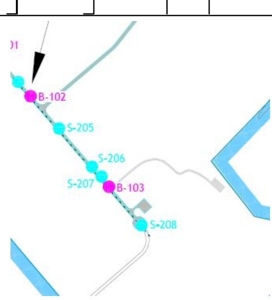

Photo Not Available

*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

BORING LOG

Consulting Services Incorporated
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

BORING: S-207

Project Number: LX190143 Name: Green River Commerce Park Access Road Client: Columbia - Adair County Economic Development Authority Location: Columbia, Kentucky Logged By: Y. Little, P.E.	Weather: Clear, 90s Elevation (ft): 839.4 Date Started: 9/11/19 Date Completed: 9/11/19 Checked By: J. Cooke, P.E.	Contractor: Mathes Drilling Drill Rig: Mobile B-53 Method: SFA Hole Size (in): 4

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
			TOPSOIL - 8 inches				Dry upon completion of soil augering Note: Descriptions based only on auger cuttings. No SPT sampling was performed
838, 836, 834	2, 4, 6	CL	LEAN CLAY (CL) - tan, with few chert fragments, moist				
832, 830, 828, 826	8, 10, 12, 14	CH	FAT CLAY (CH) - reddish brown and tan, with chert fragments, moist				
824, 822, 820	16, 18		Sounding Terminated at 15.0 feet				

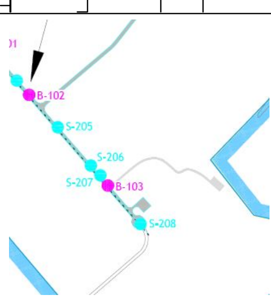

Photo Not Available

*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

BORING LOG

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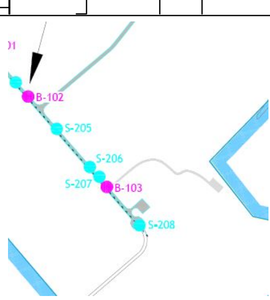
858 Contract Street
Lexington, Kentucky 40505
Phone: 859.309.6021
Fax: 888.792.3121

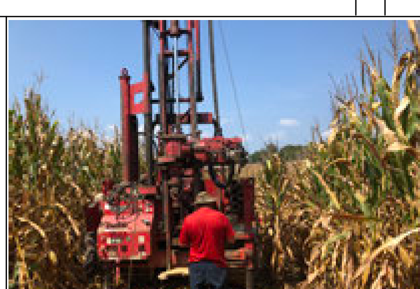
BORING: S-208

Project Number: LX190143	Weather: Clear, 90s	Contractor: Mathes Drilling
Name: Green River Commerce Park Access Road	Elevation (ft): 838.9	Drill Rig: Mobile B-53
Client: Columbia - Adair County Economic Development Authority	Date Started: 9/11/19	Method: SFA
Location: Columbia, Kentucky	Date Completed: 9/11/19	Hole Size (in): 4
Logged By: Y. Little, P.E.	Checked By: J. Cooke, P.E.	

Elev. (ft)	Depth (ft)	Symbol	Description	Blow Counts (N Value)	Recov. (in)	Water Level	Remarks
838.9–838.2	0–0.7		TOPSOIL - 8 inches				Dry upon completion of soil augering Note: Descriptions based only on auger cuttings. No SPT sampling was performed
838.2–832.9	0.7–6	CL	LEAN CLAY (CL) - reddish brown, with chert fragments, moist				
832.9–823.9	6–15	CH	FAT CLAY (CH) - reddish brown and tan, moist				
823.9	15		Sounding Terminated at 15.0 feet				

Elevation scale (ft): 838, 836, 834, 832, 830, 828, 826, 824, 822, 820
Depth scale (ft): 2, 4, 6, 8, 10, 12, 14, 16, 18





*Elevations were detemined in the field by others.

Left Photo: Photo of Boring Location
Right Photo: Photo of Boring

FIELD TESTING PROCEDURES

Field Operations: The general field procedures employed by CSI are summarized in ASTM D 420 which is entitled "Investigating and Sampling Soils and Rocks for Engineering Purposes." This recommended practice lists recognized methods for determining soil and rock distribution and ground water conditions. These methods include geophysical and in situ methods as well as borings.

Borings are drilled to obtain subsurface samples using one of several alternate techniques depending upon the subsurface conditions. These techniques are:

a. Continuous 2-1/2 or 3-1/4 inch I.D. hollow stem augers;

b. Wash borings using roller cone or drag bits (mud or water);

c. Continuous flight augers (ASTM D 1425).

These drilling methods are not capable of penetrating through material designated as "refusal materials." Refusal, thus indicated, may result from hard cemented soil, soft weathered rock, coarse gravel or boulders, thin rock seams, or the upper surface of sound continuous rock. Core drilling procedures are required to determine the character and continuity of refusal materials.

The subsurface conditions encountered during drilling are reported on a field test boring record by the chief driller. The record contains information concerning the boring method, samples attempted and recovered, indications of the presence of various materials such as coarse gravel, cobbles, etc., and observations between samples. Therefore, these boring records contain both factual and interpretive information. The field boring records are on file in our office.

The soil and rock samples plus the field boring records are reviewed by a geotechnical engineer. The engineer classifies the soils in general accordance with the procedures outlined in ASTM D 2488 and prepares the final boring records, which are the basis for all evaluations and recommendations.

The final boring records represent our interpretation of the contents of the field records based on the results of the engineering examinations and tests of the field samples. These records depict subsurface conditions at the specific locations and at the particular time when drilled. Soil conditions at other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the subsurface soil and ground water conditions at these boring locations. The lines designating the interface between soil or refusal materials on the records and on profiles represent approximate boundaries. The transition between materials may be gradual. The final boring records are included with this report.

The detailed data collection methods using during this study are discussed on the following pages.

Soil Test Borings: Soil test borings were made at the site at locations shown on the attached Boring Plan. Soil sampling and penetration testing were performed in accordance with ASTM D 1586.

The borings were made by mechanically twisting a hollow stem steel auger into the soil. At regular intervals, the drilling tools were removed and soil samples obtained with a standard 1.4 inch I.D., 2 inch O.D., split tube sampler. The sampler was first seated 6 inches to penetrate any loose cuttings, then driven an additional foot with blows of a 140-pound hammer falling 30 inches. The number of hammer blows required to drive the sampler the final foot was recorded and is designated the "penetration resistance". The penetration resistance, when properly evaluated, is an index to the soil strength and foundation supporting capability.

Representative portions of the soil samples, thus obtained, were placed in glass jars and transported to the laboratory. In the laboratory, the samples were examined to verify the driller's field classifications. Test Boring Records are attached which graphically show the soil descriptions and penetration resistances.

Core Drilling: Refusal materials are materials that cannot be penetrated with the soil drilling methods employed. Refusal, thus indicated, may result from hard cemented soil, soft weathered rock, coarse gravel or boulders, thin rock seams or the upper surface of sound continuous rock. Core drilling procedures are required to determine the character and continuity of refusal materials.

Prior to coring, casing is set in the drilled hole through the overburden soils, if necessary, to keep the hole from caving. Refusal materials are then cored according to ASTM D 2113 using a diamond-studded bit fastened to the end of a hollow double tube core barrel. This device is rotated at high speeds, and the cuttings are brought to the surface by circulating water. Core samples of the material penetrated are protected and retained in the swivel-mounted inner tube. Upon completion of each drill run, the core barrel is brought to the surface, the core recovered is measured, the samples are removed and the core is placed in boxes for storage.

The core samples are returned to our laboratory where the refusal material is identified and the percent core recovery and rock quality designation is determined by a soils engineer or geologist. The percent core recovery is the ratio of the sample length obtained to the depth drilled, expressed as a percent. The rock quality designation (RQD) is obtained by summing up the length of core recovered, including only the pieces of core which are four inches or longer, and dividing by the total length drilled. The percent core recovery and RQD are related to soundness and continuity of the refusal material. Refusal material descriptions, recoveries, and RQDs are shown on the "Test Boring Records".

Hand Auger Borings and Dynamic Cone Penetration Testing: Hand auger borings are performed manually by CSI field personnel. This consists of manually twisting hand auger tools into the subsurface and extracting “grab” or baggie samples at intervals determined by the project engineer. At the sample intervals, dynamic cone penetration (DCP) testing is performed. This testing involves the manual raising and dropping of a 20-pound hammer, 18 inches. This “driver” head drives a solid-13⁄4 inch diameter cone into the ground. DCP “counts” are the number of drops it takes for the hammer to drive three 13⁄4 inch increments, recorded as X-Y-Z values.

Test Pits: Test pits are excavated by the equipment available, often a backhoe or trackhoe. The dimensions of the test pits are based on the equipment used and the power capacity of the equipment. Samples are taken from the spoils of typical buckets of the excavator and sealed in jars or “Ziploc” baggies. Dynamic Cone Penetration or hand probe testing is often performed in the upper few feet as OSHA standards allow. Refusal is deemed as the lack of advancement of the equipment with reasonable to full machine effort.

Water Level Readings: Water table readings are normally taken in conjunction with borings and are recorded on the "Test Boring Records". These readings indicate the approximate location of the hydrostatic water table at the time of our field investigation. Where impervious soils are encountered (clayey soils) the amount of water seepage into the boring is small, and it is generally not possible to establish the location of the hydrostatic water table through water level readings. The ground water table may also be dependent upon the amount of precipitation at the site during a particular period of time. Fluctuations in the water table should be expected with variations in precipitation, surface run-off, evaporation and other factors.

The time of boring water level reported on the boring records is determined by field crews as the drilling tools are advanced. The time of boring water level is detected by changes in the drilling rate, soil samples obtained, etc. Additional water table readings are generally obtained at least 24 hours after the borings are completed. The time lag of at least 24 hours is used to permit stabilization of the ground water table, which has been disrupted by the drilling operations. The readings are taken by dropping a weighted line down the boring or using an electrical probe to detect the water level surface.

Occasionally the borings will cave-in, preventing water level readings from being obtained or trapping drilling water above the caved-in zone. The cave-in depth is also measured and recorded on the boring records.

Summary of Laboratory Results

Sheet 1 of 1

Borehole	Depth	Sample Type	Liquid Limit	Plastic Limit	Plasticity Index	Class-ification	Water Content (%)	Unconfined Compressive Strength (ksf)	Dry Density (pcf)	Wet Density (pcf)	Max. Dry Density (pcf)	Opt. Water Content (%)	CBR	Swell (%)	RQD	Percent Recovery	k (cm/sec)	% Finer #200
B-101	0.0	SS					21.2											
B-101	1.5	SS					24.6											
B-101	4.0	SS					26.6											
B-101	6.5	SS					27.4											
B-101	9.0	SS					33.3											
B-102	0.0	SS					11.4											
B-102	1.5	SS					21.7											
B-102	4.0	SS					17.8											
B-102	6.5	SS					32.1											
B-102	9.0	SS					24.2											
B-103	0.0	SS					15.6											
B-103	1.5	SS					13.6											
B-103	4.0	SS					19.8											
B-103	6.5	SS					21.4											
B-103	9.0	SS					18.8											
Bulk-1	0.0	GRAB	40	23	17	CL	19.9				104.9	19.4	7.8					79.5
Bulk-2	0.0	GRAB	66	31	35	CH	29.3				96.4	23.9	8.2					82.4

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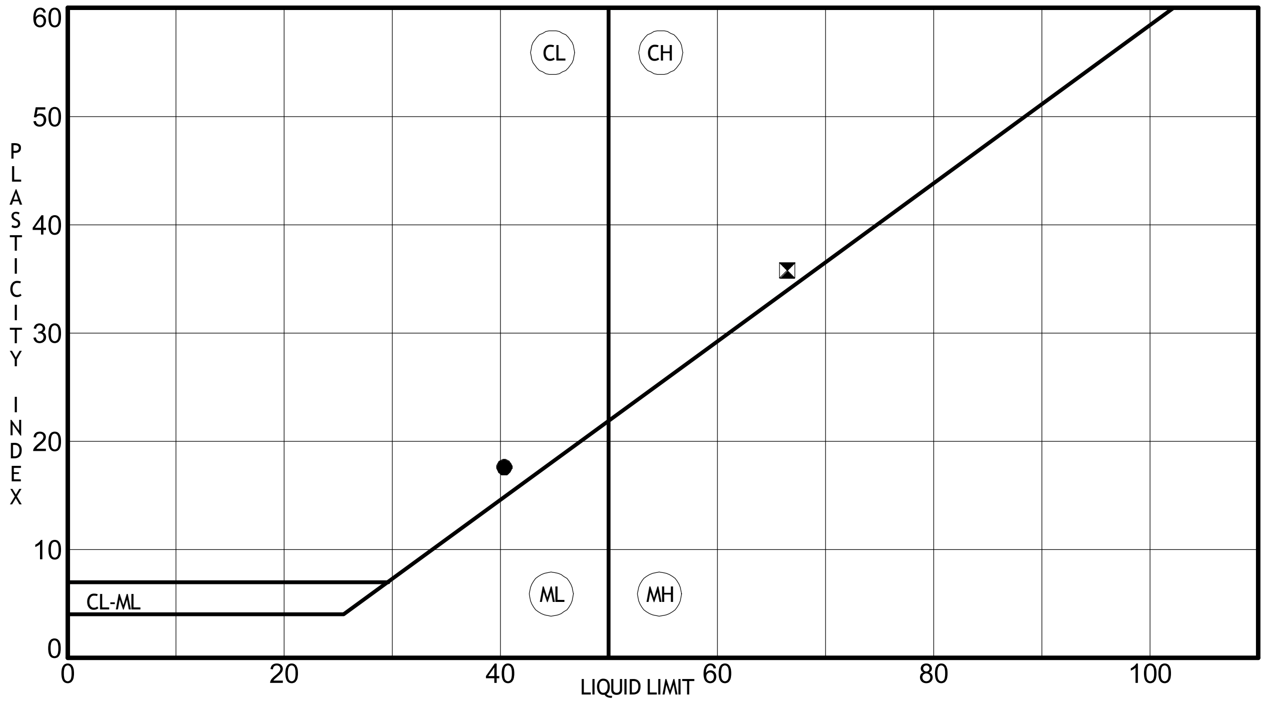
SS - Split Spoon Sample
GRAB - Bulk Grab Sample
k - Coefficient of Permeability
- See Attached test Results

PROJECT INFORMATION

Client: Columbia-Adair County Economic Development Authority
Project Name: Green River Commerce Park Access Road
Project Number: LX190143
Project Location: Columbia, Kentucky

Liquid and Plastic Limits Test Report



	Boring	Depth (ft)	LL	PL	PI	Water Content	% < #40	% < #200	USCS	Description
●	Bulk-1	1.0-5.0	40	23	17	19.9		79.5	CL	tan LEAN CLAY with SAND and chert fragments
⧗	Bulk-2	6.0-10.0	66	31	35	29.3		82.4	CH	reddish-brown and tan FAT CLAY with SAND and chert fragments

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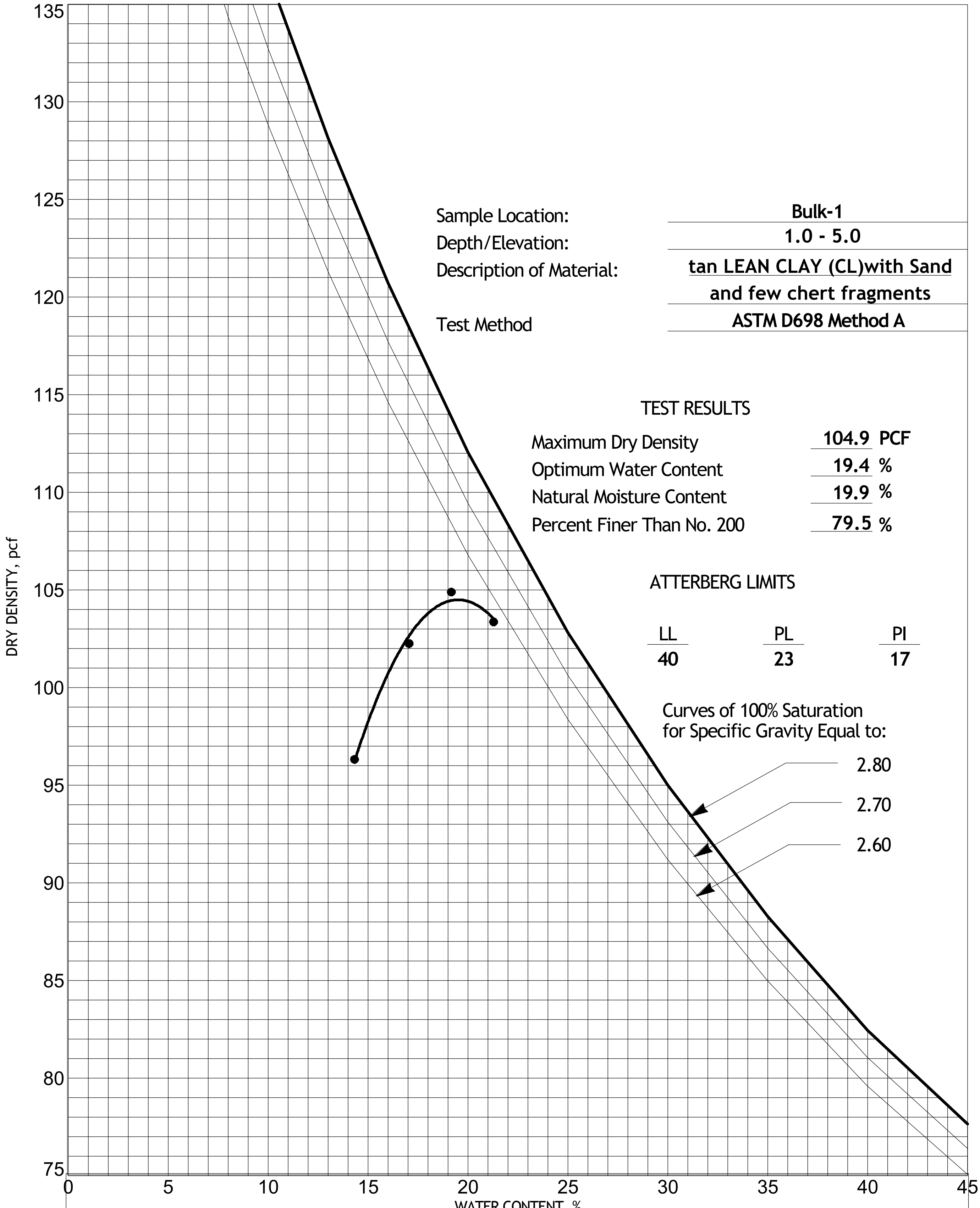
Fax: 888.792.3121

PROJECT INFORMATION

Client: Columbia-Adair County Economic Development Authority
Project Name: Green River Commerce Park Access Road
Project Number: LX190143
Project Location: Columbia, Kentucky

MOISTURE-DENSITY RELATIONSHIP



Sample Location:	Bulk-1
Depth/Elevation:	1.0 - 5.0
Description of Material:	tan LEAN CLAY (CL)with Sand and few chert fragments
Test Method	ASTM D698 Method A

TEST RESULTS

Maximum Dry Density	104.9	PCF
Optimum Water Content	19.4	%
Natural Moisture Content	19.9	%
Percent Finer Than No. 200	79.5	%

ATTERBERG LIMITS

LL	PL	PI
40	23	17

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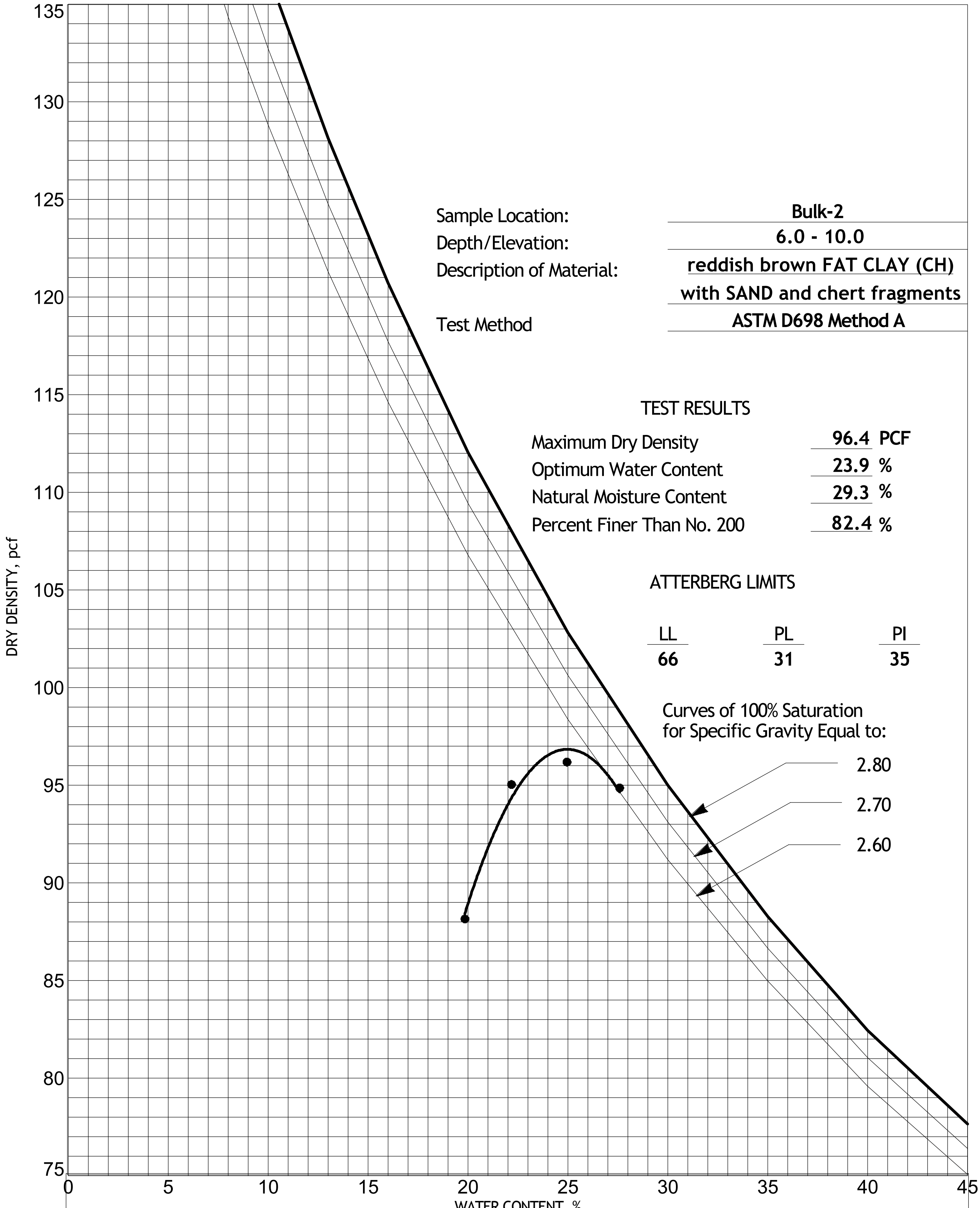
PROJECT INFORMATION

Client: Columbia-Adair County Economic Development Authority
Project Name: Green River Commerce Park Access Road
Project Number: LX190143
Project Location: Columbia, Kentucky

MOISTURE-DENSITY RELATIONSHIP



Sample Location: **Bulk-2**

Depth/Elevation: **6.0 - 10.0**

Description of Material: **reddish brown FAT CLAY (CH) with SAND and chert fragments**

Test Method **ASTM D698 Method A**

TEST RESULTS

Maximum Dry Density	**96.4**	PCF
Optimum Water Content	**23.9**	%
Natural Moisture Content	**29.3**	%
Percent Finer Than No. 200	**82.4**	%

ATTERBERG LIMITS

LL	PL	PI
66	**31**	**35**

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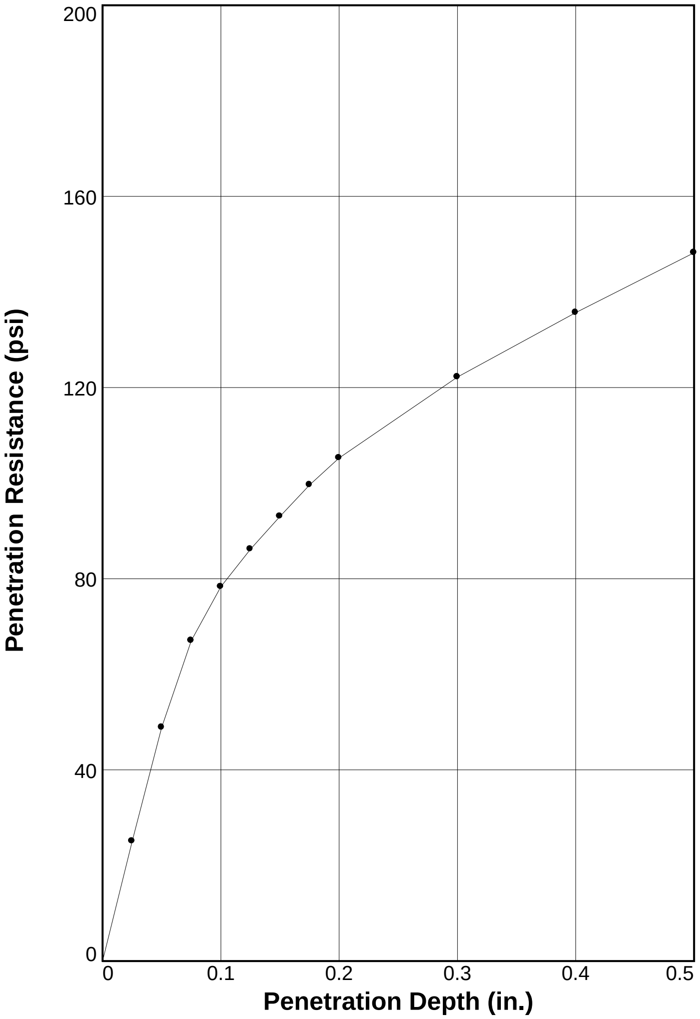
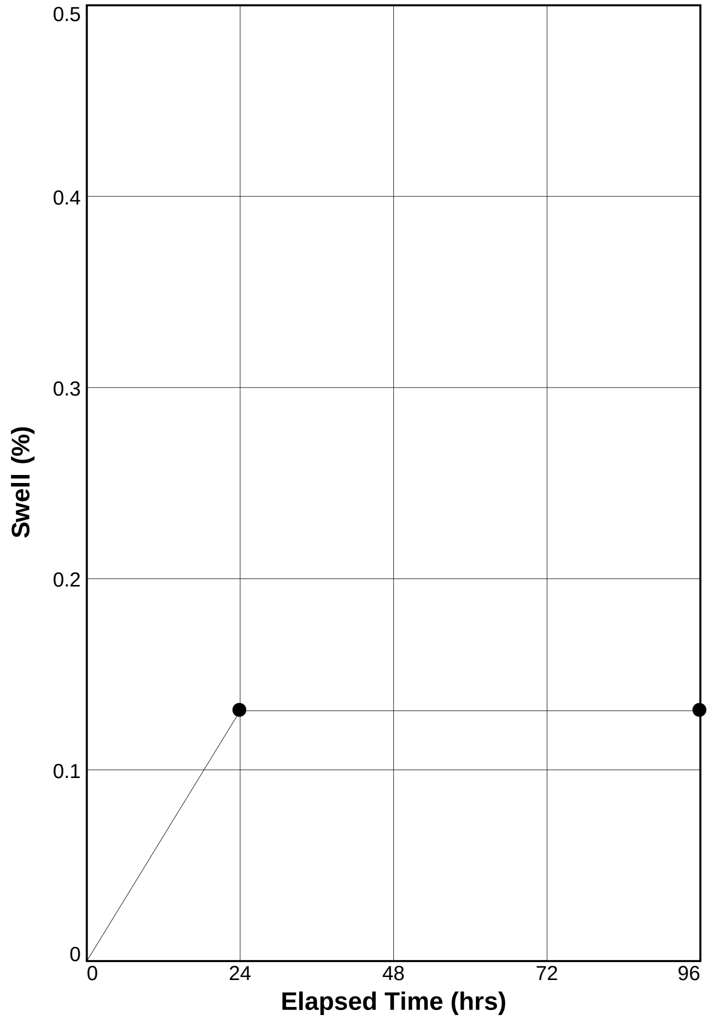
PROJECT INFORMATION

Client: Columbia-Adair County Economic Development Authority
Project Name: Green River Commerce Park Access Road
Project Number: LX190143
Project Location: Columbia, Kentucky

BEARING RATIO TEST REPORT
ASTM D1883-16





	Molded			Soaked			CBR (%)		Linearity Correction (in.)	Surcharge (lbs.)	Max. Swell (%)
	Density (pcf)	Percent of Max. Dens.	Moisture (%)	Density (pcf)	Percent of Max. Dens.	Moisture (%)	0.10 in.	0.20 in.			
1 ○	100.8	96.1	21.0	100.6	95.9	21.7	7.8	7.0	0.000	15	0.1
2 △											
3 □											

Material Description	USCS	Max. Dens. (pcf)	Optimum Moisture (%)	LL	PI
tan LEAN CLAY with SAND and few chert fragments	CL	104.9	19.4	40	17

Project No: LX190143

Project: Green River Commerce Park Access Road - Columbia, Kentucky

Source of Sample: Bulk **Depth (ft):** 1.0 - 5.0

Sample Number: Bulk - 1 (Combined sample from S-206 and S-207)

Date:

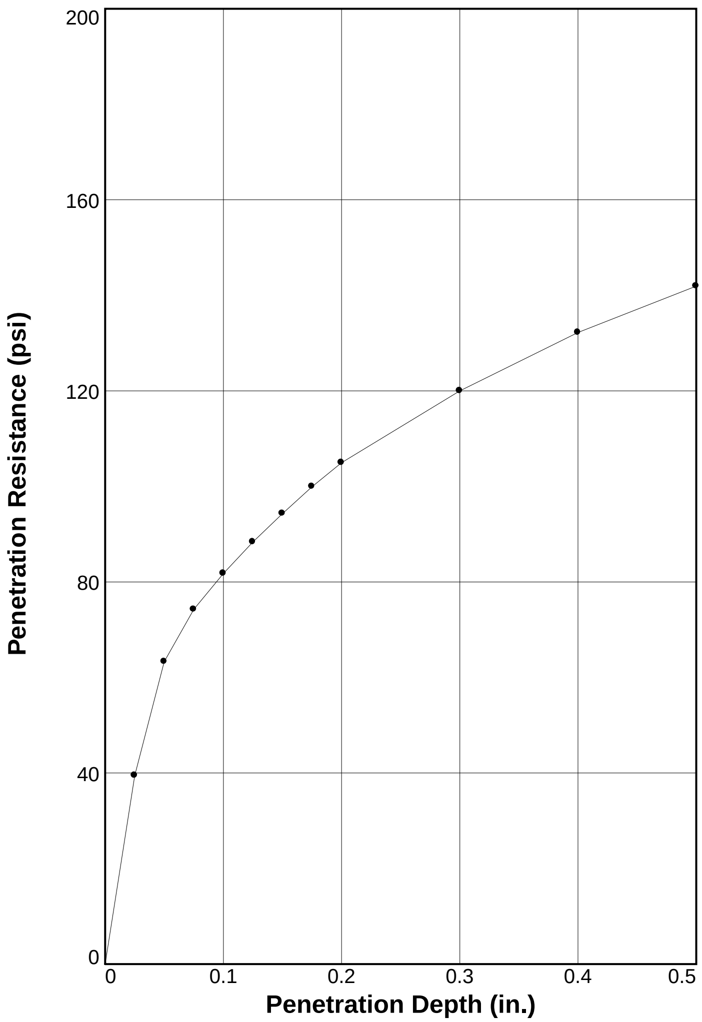
BEARING RATIO TEST REPORT

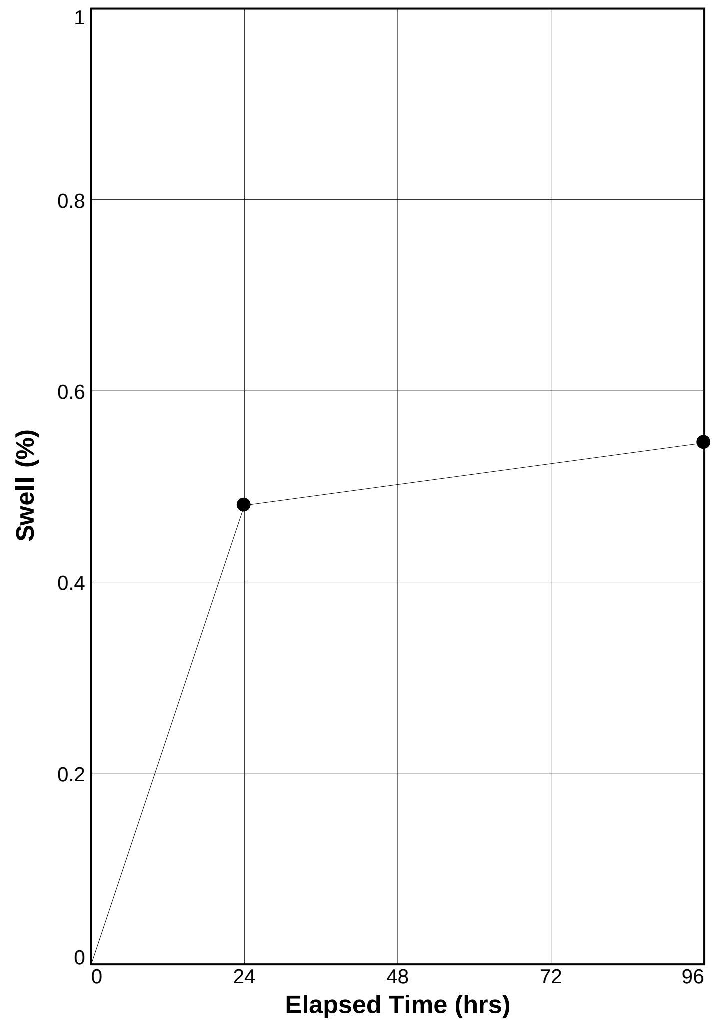
CSI of Kentucky

Test Description/Remarks:

Figure ________

BEARING RATIO TEST REPORT
ASTM D1883-16





	Molded			Soaked			CBR (%)		Linearity Correction (in.)	Surcharge (lbs.)	Max. Swell (%)
	Density (pcf)	Percent of Max. Dens.	Moisture (%)	Density (pcf)	Percent of Max. Dens.	Moisture (%)	0.10 in.	0.20 in.			
1 ○	94.1	97.6	25.7	93.6	97.1	26.8	8.2	7.0	0.000	15	0.5
2 △											
3 □											

Material Description	USCS	Max. Dens. (pcf)	Optimum Moisture (%)	LL	PI
reddish brown and tan FAT CLAY with SAND and few chert fragments	CH	96.4	23.9	66	35

Project No: LX190143

Project: Green River Commerce Park Access Road - Columbia, Kentucky

Source of Sample: Bulk **Depth (ft):** 6.0-10.0

Sample Number: Bulk - 2 (Combined sample from B-101 and S-202)

Date:

BEARING RATIO TEST REPORT

CSI of Kentucky

Test Description/Remarks:

Figure ________

LABORATORY TESTING PROCEDURES

Soil Classification: Soil classifications provide a general guide to the engineering properties of various soil types and enable the engineer to apply past experience to current problems. In our investigations, samples obtained during drilling operations are examined in our laboratory and visually classified by an engineer. The soils are classified according to consistency (based on number of blows from standard penetration tests), color and texture. These classification descriptions are included on our "Test Boring Records."

The classification system discussed above is primarily qualitative and for detailed soil classification two laboratory tests are necessary: grain size tests and plasticity tests. Using these test results the soil can be classified according to the AASHTO or Unified Classification Systems (ASTM D 2487). Each of these classification systems and the in-place physical soil properties provides an index for estimating the soil's behavior. The soil classification and physical properties obtained are presented in this report.

Rock Classification: Rock classifications provide a general guide to the engineering properties of various rock types and enable the engineer to apply past experience to current situations. In our explorations, rock core samples obtained during drilling operations are examined in our laboratory and visually classified by an engineer. The rock cores are classified according to relative hardness and RQD (see Guide to Rock Classification Terminology), color, and texture. These classification descriptions are included on our Test Boring Records.

Atterberg Limits: Portions of the samples are taken for Atterberg Limits testing to determine the plasticity characteristics of the soil. The plasticity index (PI) is the range of moisture content over which the soil deforms as a plastic material. It is bracketed by the liquid limit (LL) and the plastic limit (PL). The liquid limit is the moisture content at which the soil becomes sufficiently "wet" to flow as a heavy viscous fluid. The plastic limit is the lowest moisture content at which the soil is sufficiently plastic to be manually rolled into tiny threads. The liquid limit and plastic limit are determined in accordance with ASTM D 4318.

Moisture Content: The Moisture Content is determined according to ASTM D 2216.

Percent Finer Than 200 Sieve: Selected samples of soils are washed through a number 200 sieve to determine the percentage of material less than 0.074 mm in diameter.

Rock Strength Tests: To obtain strength data for rock materials encountered, unconfined compression tests are performed on selected samples. In the unconfined compression test, a cylindrical portion of the rock core is subjected to increasing axial load until it fails. The pressure required to produce failure is recorded, corrected for the length to diameter ratio of the core and reported.

Compaction Tests: Compaction tests are run on representative soil samples to determine the dry density obtained by a uniform compactive effort at varying moisture contents. The results of the test are used to determine the moisture content and unit weight desired in the field for similar soils. Proper field compaction is necessary to decrease future settlements, increase the shear strength of the soil and decrease the permeability of the soil.

The two most commonly used compaction tests are the Standard Proctor test and the Modified Proctor test. They are performed in accordance with ASTM D 698 and D 1557, respectively. Generally, the Standard Proctor compaction test is run on samples from building or parking areas where small compaction equipment is anticipated. The Modified compaction test is generally performed for heavy structures, highways, and other areas where large compaction equipment is expected. In both tests a representative soil sample is placed in a mold and compacted with a compaction hammer. Both tests have three alternate methods.

Test	Metho d	Hammer Wt./ Fall	Mold Diam.	Run on Material Finer Than	No. of Layer s	No. of Blows/ Layer
Standard D 698	A	5.5 lb./12”	4”	No. 4 sieve	3	25
	B	5.5 lb./12”	4”	3/8” sieve	3	25
	C	5.5 lb./12”	6”	3/4” sieve	3	56

Test	Metho d	Hammer Wt./ Fall	Mold Diam.	Run on Material Finer Than	No. of Layer s	No. of Blows/ Layer
Modified D 15557	A	10 lb./18”	4”	No. 4 sieve	5	25
	B	10 lb./18”	4”	3/8” sieve	5	25
	C	10 lb./18”	6”	3/4” sieve	5	56

The moisture content and unit weight of each compacted sample is determined. Usually 4 to 5 such tests are run at different moisture contents. Test results are presented in the form of a dry unit weight versus moisture content curve. The compaction method used and any deviations from the recommended procedures are noted in this report.

Laboratory California Bearing Ratio Tests: The California Bearing Ratio, generally abbreviated to CBR, is a punching shear test and is a comparative measure of the shearing resistance of a soil. It provides data that is a semi-empirical index of the strength and deflection characteristics of a soil. The CBR is used with empirical curves to design pavement structures.

A laboratory CBR test is performed according to ASTM D 1883. The results of the compaction tests are utilized in compacting the test sample to the desired density and moisture content for the laboratory California Bearing Ratio test. A representative sample is compacted to a specified density at a specified moisture content. The test is performed on a 6-inch diameter, 4.58-inch-thick disc of compacted soil that is confined in a cylindrical steel mold. The sample is compacted in accordance with Method C of ASTM D 698 or D 1557.

CBR tests may be run on the compacted samples in either soaked or unsoaked conditions. During testing, a piston approximately 2 inches in diameter is forced into the soil sample at the rate of 0.05 inch per minute to a depth of 0.5 inch to determine the resistance to penetration. The CBR is the percentage of the load it takes to penetrate the soil to a 0.1 inch depth compared to the load it takes to penetrate a standard crushed stone to the same depth. Test results are typically shown graphically.

Consolidation Tests: Consolidation tests are conducted on representative soil samples to determine the change in height of the sample with increasing load. The results of these tests are used to estimate the settlement and time rate of settlement of structures constructed on similar soils. A consolidation test is performed according to ASTM D2435 on a single section of an undisturbed sample extruded from a sample tube. The sample is trimmed into a disc 2.5 inches in diameter and 0.75 inch thick. The disc is confined in a stainless steel ring and sandwiched between porous plates. It is then subjected to incrementally increasing vertical loads, and the resulting deformations are measured with a micrometer dial gauge. Void ratio are then calculated from these deformation readings. The test results are typically provided in tabular form or in the form of plots of void ratio versus applied stress (e-log p curves).

Organic Content: The Organic Content is determined according to ASTM D2974. The moisture content is first determined by drying portions of the sample at 105 degrees Celsius. The ash content is then determined by igniting the oven-dried sample from the moisture content determination in a muffle furnace at 440 degrees Celsius. The substance remaining after ignition is the ash. The organic content is expressed as a percentage by subtracting the percent ash from one hundred.

Direct Shear Tests: Direct shear tests are performed according to ASTM D3080 to determine the shear strength parameters of the soil. The specimen of soil is placed in a rigid box that is divided horizontally into two frames. The specimen is then confined under a vertical or normal stress and horizontal force is applied to fail the specimen along a horizontal plane at its mid-height.

Because drainage of the soil specimen cannot be easily controlled, undrained tests (i.e., UU and CU tests) are possible only on impervious soils and pore pressure measurements cannot be made. Drained tests (i.e., CD tests), however, are possible on all soil types. Since the drainage paths through the specimen are short and pore water pressures are dissipated fairly rapidly, the direct shear test is well suited to the CD test.

A minimum of three test specimens are required to establish the strength envelope of a soil. The soil parameters obtained are the cohesion and angle of internal friction.

Unconfined Compression Tests: The unconfined compression test is an unconsolidated-undrained triaxial shear test with no lateral confining pressure. This test is used to determine the shear strength of clayey soils. An unconfined compression test is performed according to ASTM D2166 on a single section of an undisturbed sample extruded from a sampling tube. The sample is trimmed to a length-to-diameter ratio of about 2 and placed in the testing device. Incrementally increasing vertical loads are applied until the sample fails. Test results are provided in the form of a stress-strain curve or a value representing the unconfined compressive strength of the sample.

Grain Size Tests: Grain Size Tests are performed to determine the soil classification and the grain size distribution. The soil samples are prepared for testing according to ASTM D421 (dry preparation) or ASTM D2217 (wet preparation). The grain size distribution of soils coarser than a number 200 sieve (0.074 mm opening) is determined by passing the samples through a standard set of nested sieves. Materials passing the number 200 sieve are suspended in water and the grain size distribution calculated from the measured settlement rate. These tests are conducted in accordance with ASTM D422.

Triaxial Shear Tests: Triaxial shear tests are used to determine the strength characteristics and friction angle of a given soil sample. Triaxial tests are also used to determine the elastic properties of the soil specimen. Triaxial shear tests are performed on several sections of a relatively undisturbed sample extruded from the sampling tube. The samples are trimmed into cylinders 1.4 to 2.8 inches in diameter and encased in rubber membranes. Each is then placed in a compression chamber and confined by all around water pressure. Samples are then subjected to additional axial and/or lateral loads, depending on the soil and the field conditions to be simulated. The test results are typically presented in tabular form or in the form of stress-strain curves and Mohr envelopes or p-q plots.

Three types of triaxial tests are normally performed. The most suitable type of triaxial test is determined by the loading conditions imposed on the soil in the field and the soil characteristics.

1. Consolidated-Undrained (designated as a CU or R Test).

2. Consolidated-Drained (designated as a CD or S Test).

3. Unconsolidated-Undrained (designated as a UU or Q Test).