APPENDIX G – GEOTECHNICAL OVERVIEW

Report of Abbreviated Geotechnical Overview

US 68X and US231X Planning Study
Bowling Green, Warren County, Kentucky
P-004-2017

Prepared By:
Stantec Consulting Services Inc.
Lexington, Kentucky

Prepared for:
Kentucky Transportation Cabinet
Frankfort, Kentucky

October 26, 2017

Stantec Consulting Services Inc.
3052 Beaumont Centre Circle, Lexington KY 40513-1703

October 26, 2017
File: rpt_002_let_178556010

Attention: Mr. Bart Asher, PE
Kentucky Department of Highways
Division of Structural Design
Geotechnical Branch
1236 Wilkinson Boulevard
Frankfort, Kentucky 40601

Reference: Report of Abbreviated
US 68X and US 231 Planning Study
Warren County, Kentucky
P-004-2017

Dear Mr. Asher,

Enclosed is the abbreviated geotechnical overview for the proposed Planning Study overview for referenced project. The overview is based upon research of available published data and preliminary data for the study area. The scope of work performed and results of the overview are presented in the accompanying attachment.

Regards,

STANTEC CONSULTING SERVICES INC.

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/rnm

Attachment: Attachment A USGS Geologic Map

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1.0 PROJECT DESCRIPTION

The Kentucky Transportation Cabinet (KYTC) – Division of Planning is conducting a planning study to evaluate improvements at/near US 68 and US 231. This portion of Kentucky is well known for its rolling terrain, red clay soils and the karst behavior of the underlying bedrock (karst features may include sinkholes, caves and solution features in the bedrock). Therefore, the project team will need to be aware and cautious in relation to karst.

The purpose of US 68X and US 231X Planning Study is to evaluate operational and safety improvements at the Russellville Road (US 68X) intersections with Morgantown Road (US 231X) and University Boulevard (junction and disjunction of US 68X and US 231X) in Bowling Green, Kentucky. The study will also investigate and evaluate options to widen the railroad underpass on Russellville Road to better accommodate bicycle and pedestrian facilities. The study area is presented on the drawing provided in Appendix A.

2.0 SCOPE OF WORK

The scope of work for this study consists of performing an abbreviated geotechnical overview for the proposed study area based upon research of available published data, and Stantec's experience with highway design and construction within the region. A site visit was not part of Stantec's scope, therefore, this report is based soley on available published data. General geotechnical and geologic characteristics of the study area have been identified and are discussed in this report. Stantec personnel, using a variety of sources, performed a literature search that included reviews of the following sources:

- Available topographic and geologic mapping of the project area published by the United States Geological Survey (USGS) and the Kentucky Geological Survey (KGS);
- The Geologic Map of Kentucky, published by the USGS and the KGS;
- Kentucky Geologic Map Information Service http://kgs.uky.edu/kgsmap/kgsgeoserver/viewer.asp;
- KYTC Geotechnical Data, published by the KGS and KYTC, http://kgs.uky.edu/kgsmap/kytcLinks.asp;
- Prior Projects Nearby:

Report Number	County	Route	Item Number
R-008-1986	Warren	US 68	03-0247.05
R-003-1987	Warren	KY 880	03.0970.00
R-004-2003	Warren	US 31W	03.0312.00
R-041-2012	Warren	US 31W	03-0131.00
S-017-1987	Warren	KY 880	03-0970.01
S-038-1987	Warren	KY 880	03-0970.01
S-039-1995	Warren	US 231	03-0052.00

- United States Department of Agriculture, Soil Conservation Service (SCS) Soil Survey Publications for affected counties;
- Physiographic Regions, published by KGS, http://kgs.uky.edu/kgsweb;
- American Engineers, Inc., Report of Geotechnical Exploration, Western Kentucky University, Parking Structure 3, April 2016;
- Map of the Lost River Cave Group, Bowling Green, Kentucky, Center for Cave and Karst Studies, WKU and the Green River Grotto of the National Speleological Society.
- Site Drainage Plan, University Boulevard and Creasom Drive, DDS Engineering, PLLC

3.0 PHYSIOGRAPHIC AND STRATIGRAPHIC SETTING

3.1 TOPOGRAPHY AND DRAINAGE

The project study area is located on the Geology of the Bowling Green South Quadrangle, Kentucky. Subsurface conditions are characteristic of Upper Mississippian age bedrock, which in this area consists of limestone. Generally, this area is known for its karst landscape; characterized by gently rolling hills, red clay soils and numerous sinkholes and depressions. The limestone bedrock, which lies below the ground surface in the study area, is highly soluble and prone to dissolution and the resulting development of karst features such as sinkholes, caves, springs and disappearing streams.

Surface drainage in the area is directed towards urban drainage structures. Drainage structures are located in the parking lot just north of the Softball Field that allows surface runoff to be directed to the underlying karst system. Underground drainage is a function of surface and groundwater flows that are controlled by the nature of these rocks and the associated surface features. Slopes generally control the runoff from precipitation and stream drainage, with ridgelines forming drainage boundaries. Underground water in most watersheds and drainage basins tend to follow the topography of the area. In areas containing soluble limestone or karst regions, the underground drainage may differ from the boundary of its surface watershed.

3.2 STRATIGRAPHY

Review of available geologic mapping for the area indicates the site is underlain by the Ste. Genevieve Limestone. Based on USGS mapping, the underlying bedrock can be described as limestone, gray to white, predominantly oolitic, fine to medium crystalline, and thin to thick bedded.

Structure contours presented on the USGS geologic map indicates the bedrock to have a regional dip towards the west- northwest. A portion of the geologic mapping of the area is presented in Appendix A.

3.3 FAULTING IN THE AREA

An unnamed fault is depicted on the adjacent Bowling Green North Quadrangle approximately 8.5 miles to the north. The fault is not expected to have a detrimental effect on the project.

3.4 SOILS AND UNCONSOLIDATED MATERIALS

Soils within the area of the roadway have derived in-place from a weathering process of the parent limestone formation. These soils generally consist of clays and silty clays. Soil descriptions contained herein are based upon SCS soil surveys and on Stantec's knowledge of the study area.

3.5 REGIONAL SEISMICITY

Seismicity within the Commonwealth of Kentucky varies widely depending on location. The western portion of the state is dominated by the New Madrid and Wabash Valley source zones. In general, these zones are fairly active with many documented historical seismic events. Central and eastern portions of the state experience less frequent earthquakes because the source zones are quite distant from these areas.

The seismic hazard along a roadway and its structures shall be characterized by the acceleration response spectrum for the site and the site factors for the relevant site class. A comprehensive geotechnical investigation will be required to determine the site class. However, based on anticipated depths to bedrock at/near stream locations, Site Class B or C can be expected. The 2014 AASHTO LRFD Bridge Design specifications provide guidelines for selecting a seismic performance category and a soil profile type for bridge sites. This information establishes the elastic seismic response coefficient and spectrum for use in further structural design and analyses. Refer to Section 3.10.2 of the AASHTO guidelines for specifications. The corridor alignment will likely be affected by seismic activity from the New Madrid and Wabash Valley source zones.

4.0 GEOTECHNICAL CONSIDERATIONS

4.1 GENERAL

Based on the project study area and Stantec's roadway experience, it is anticipated that the new alignment/reconstruction will generally follow the existing alignments of streets and roads. Therefore, it is anticipated that much of the improvements will consist more of widening and not have many new cuts or fills required along the existing highway. For portions where the existing roadway may be widened, it appears that intersections and structures will need to be reworked/realigned along the reconstructed roadways. The revisions to the interchanges will include: providing necessary clear zones, addressing geometric deficiencies in the roadway and adjusting the alignment. As the interchanges are reworked, the Project Team should keep in mind the geotechnical considerations that are included in Section 4 as they pertain to existing utilities, cut slopes, embankments and widened structures.

4.2 CUT SLOPE CONSIDERATIONS

Cut slope configurations in rock are generally controlled by bedrock lithology, bedrock quality, results of Slake Durability Index (SDI) tests in shales and siltstones, and by the presence of any fractures and/or joints. In general, if joint/fracture angles are high (as measured from horizontal), steeper cut slopes can be constructed and an acceptable level of stability can be maintained. If discontinuities exhibit low angles and steep cut slopes are utilized, large block failures may occur along the open cut face.

Slope configurations for rock cuts in durable or Type I non-durable rock generally range from 1H:4V to 1H:2V pre-split slopes, on approximate 30-foot intervals of vertical height, with 18 to 20-foot intermediate benches. These types of cuts could be anticipated within this alignment with rock cut slopes of 1H:2V being likely most common. Rock cuts in the area can be problematic due to the karst nature of the bedrock. Solution features can cause the bedrock surface to be erratic. Cuts in nondurable shales and shallow cuts in bedrock may be best handled on 2H:1V slopes.

Slope configurations for soil cuts are generally constructed on a 2H:1V or flatter.

4.3 EMBANKMENT CONSIDERATIONS

The anticipated excavated rock materials should be suitable for use in project embankments. Select rock types for use as rock embankment, rock road bed, channel lining, etc., would be limestone. Based on the existing grade and existing cuts, sufficient quantities of durable rock may not be generated during construction and the use of off-site sources should be considered. Foundation soils are likely to be clays. Based on the anticipated clay soils present, soil stabilization for pavement subgrade should be anticipated.

Embankments constructed of durable rock materials generally exhibit adequate stability at 2H:1V slope configurations. However, flatter embankment slopes may be required for tall embankments constructed from nondurable shales and clay soils, or in areas where embankments are founded on alluvial materials.

4.4 STRUCTURES

It is anticipated that existing structures will need to be widened and or replaced to meet horizontal clearances with the new highway. At this time, it is unknown as to whether the proposed roadway improvements would require new and/or widened substructure elements. Based on Stantec's knowledge of the area, it can be anticipated that the majority of the bridges within the project corridor are likely supported by rock bearing foundation systems, which could be a spread footing or deep foundations to bedrock. Culverts along the proposed alignment may be replaced or widened. It can be anticipated the culverts within the project corridor are likely supported by either a non-yielding or yielding foundation system depending upon the location along the proposed alignment. A detailed geotechnical investigation will be required to determine the foundation support system.

4.5 KARST CONDITIONS

The project site is underlain by limestone bedrock that is susceptible to solutioning and karst activity. The solutioning process typically begins along fissures, joints or bedding planes and creates channel systems within the bedrock. Generally, groundwater flows through these rock channels and removes soil located immediately above the rockline. As internal erosion continues, the upper portion of the soil overburden collapses to form sinkholes and regolith zones (zones of unconsolidated soil and rock fragments). Refer to Figure 1 for a graphical depiction of karst activity typical of areas underlain by limestone bedrock.

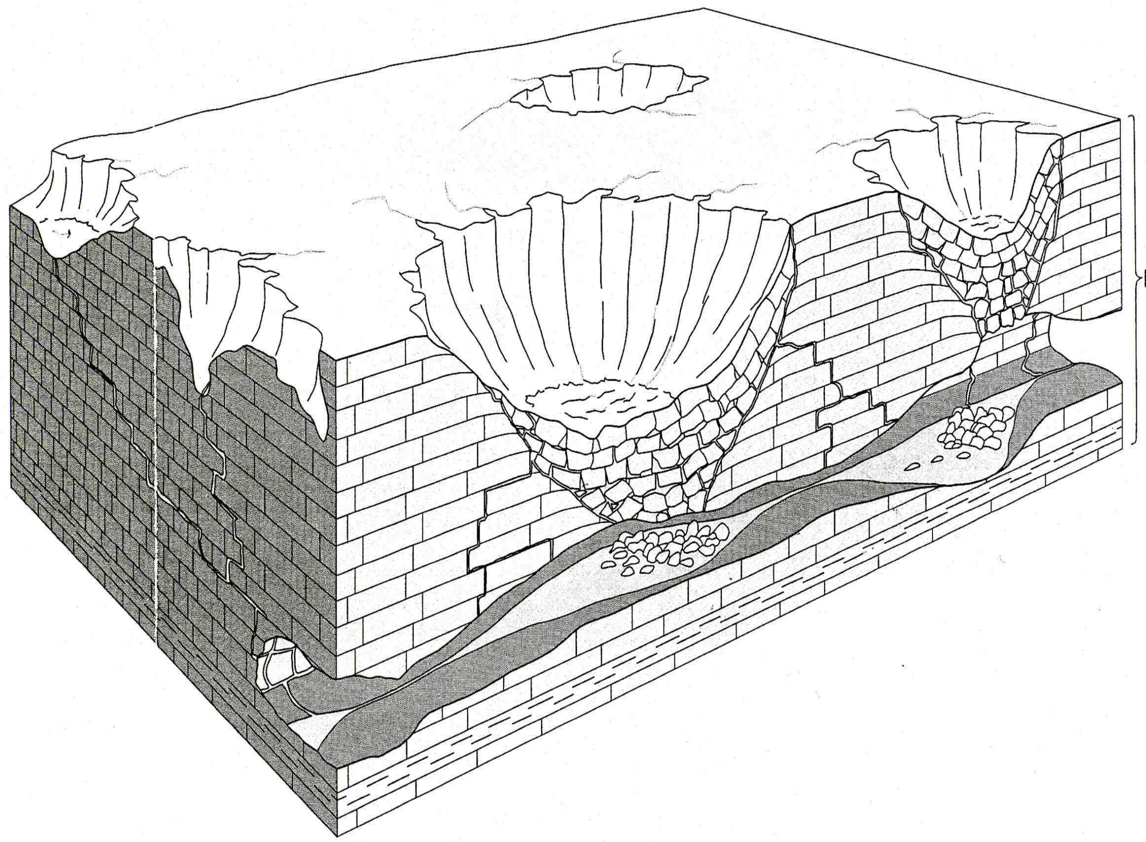


Figure 1. Graphical Depiction of Karst Activity Typical of Areas Underlain by Limestone Bedrock

(From United States Geological Survey, Geologic Map of the Somerset Quadrangle, Pulaski County, Kentucky, 1974.)

As mentioned previously, karst conditions exist within the study area. Any open sinkholes or solution cavities identified within the construction limits that are not utilized for drainage purposes should be filled and/or capped in accordance with Section 215 of the current edition of the Standard Specifications for Road and Bridge Construction.

Sinkholes are noted on the mapping presented in Appendix A within the study area. Any sinkholes utilized for drainage purposes for new roadway construction should incorporate adequate measures to minimize water infiltration into the subgrade and erosion control measures to minimize siltation of open sinkholes.

Adequate drainage will be of primary concern with any new design or new construction in the area to minimize environmental impacts by surface runoff into the underlying karst network.

Proper management of surface water will also lessen the occurrence of sinkhole dropouts during construction. Mitigation of surface runoff should be performed by silt checks, silt traps, sediment basins and lined ditches where appropriate. Siltation of sinkholes should be avoided, especially those to remain open after construction. Western Kentucky University (WKU) has drainage basins which allows surface water runoff from their parking lot drain into the underlying Karst system. A map provided by WKU depicting the location of these drainage basins along with partial limits of a cave are provided as Appendix B. These drainage features along with approximate limits of a cave are also shown on the mapping in Appendix A.

Two caves are known to exist beneath the study area, Robinson Cave and Creason Cave. According to an email from Christopher Groves, Director of the Crawford Hydrology Lab, these caves were discovered in the mid 1980's using geophysical techniques. Robinson Cave is the larger of the two and is generally located beneath the railroad and Robinson Avenue. Creason Cave is located about 30 feet beneath Creason Street and parallel with Marylan Avenue. Neither cave has a natural entrance. The map presented in Appendix A shows their approximate locations.

American Engineers, Inc (AEI) performed a geotechnical exploration for a new parking structure at Western Kentucky University. As a part of AEI's geotechnical exploration for Parking Structure 3 (now under construction), Mundell Consulting Professionals conducted a geophysical exploration in the area of the parking structure. Based on that study, a competent limestone "cap rock" was indicated to exist beneath most of the parking structure site. Limestone of moderate to severe weathering was noted beneath the competent limestone, with two areas potentially being air-filled voids.

Sinkhole failures can occur without any to little warning. Two notable failures have occurred in the Bowling Green area in the past 15 years. The Dishman Lane failure which occurred in 2002. This failure occurred in the State Trooper Cave System approximately 2 miles south of the project study area. The second is the Corvette Museum in 2014 which gained national attention. The Corvette museum is located about 5.25 miles northeast of the project area.

5.0 CONCLUSIONS

5.1. The purpose of this abbreviated overview was to provide a general summary of the bedrock, soil and geomorphic features likely to be encountered within the proposed alignment; and to identify geotechnical features that may have an adverse impact on the project alignment.

5.2. Karst topography/sinkholes and basins are located within the study area. Sinkholes or solution cavities identified within the construction limits that are not accepting drainage should be filled and/or capped in accordance with Section 215 of the current edition of the Standard Specifications for Road and Bridge Construction.

Any sinkholes utilized for drainage purposes for the new roadway construction should incorporate adequate measures to minimize water infiltration into the subgrade and erosion control measures to minimize siltation of open sinkholes. The Design Team should inventory the sinkholes and other karst features, such as caves, along the proposed alignment. The inventory should note whether or not the sinkhole accepts drainage.

Reportedly the drainage basins in WKU's parking area have reduced flooding in the immediate area. Any improvements in the area should avoid these drainage features.

Karst terrain in the study area will likely be the most detrimental factor to any new construction in the area. Rock cuts in the area can be problematic due to the karst topography. Solution features can cause the bedrock surface to be erratic.

Two known caves (Robinson and Creason Caves) are present beneath the study area. New route alignments and widenings should be positioned outside the limits of the caves. If this is not possible, any new alignments should cross the cave system(s) in a perpendicular manner. In no case should new construction cross a large room within the cave system(s). Geotechnical drilling may need to be supplemented with geophysical techniques in immediate areas of known sinkholes/karst activity.

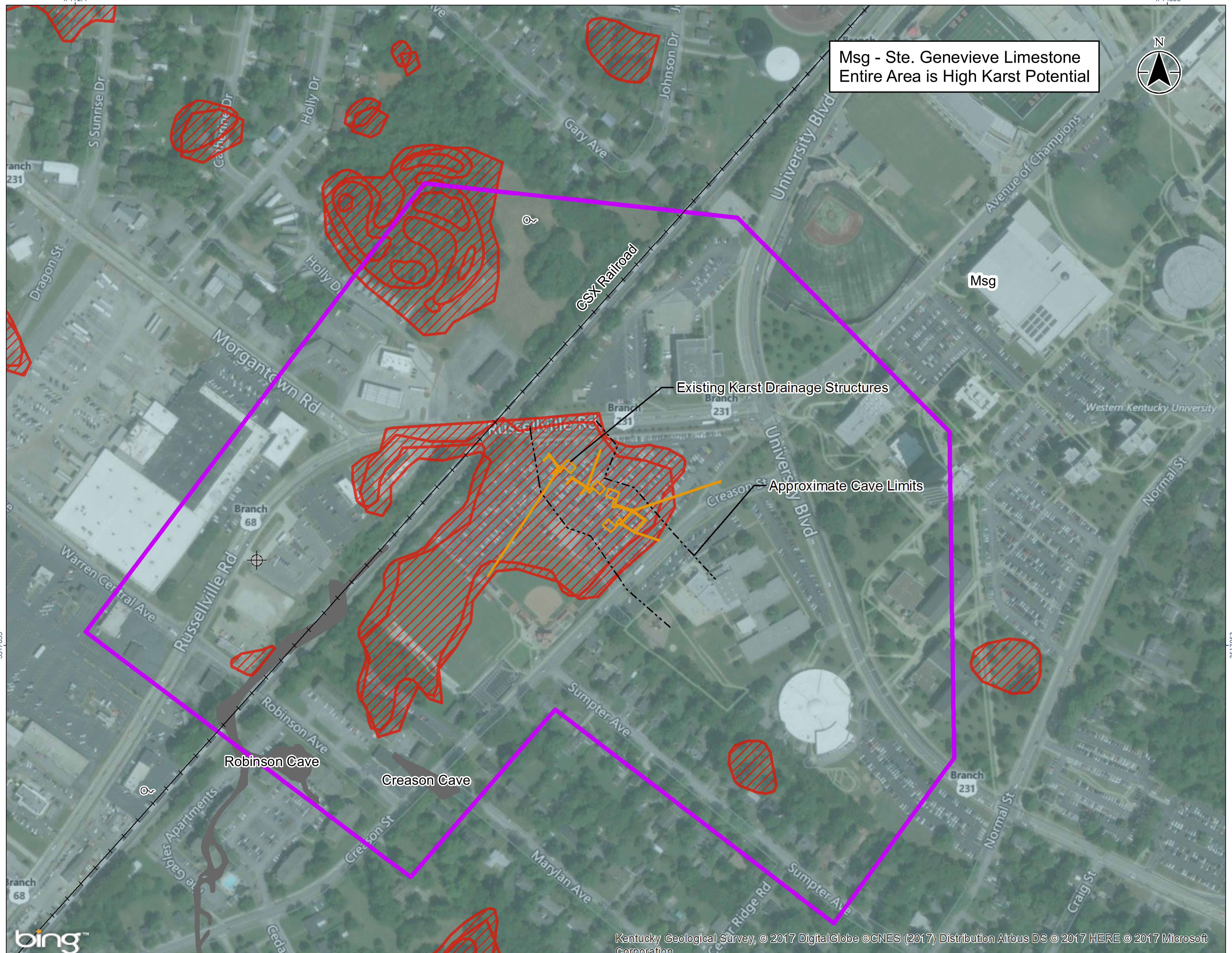
5.3. Geotechnical drilling will be critical in this region for new, replacement or widened culverts, bridges, retaining walls, and design due to the karst potential. It is anticipated that conventional spread footing and/or pile foundation systems can be utilized for structures. However, if voids/caves are present, additional costs associated with karst mitigation should be anticipated.

5.4. Because portions of projects may be widening projects, information on pavement structure should be obtained to assist the team on pavement structure and California Bearing Ratio (CBR) information. Other projects in the vicinity have utilized mechanical or chemical stabilization and generally yielded CBR values of approximately 6 or less.

5.5. Once alignment and sections are identified, then open faced logging of exposed cuts and/or drilling should be performed. Sampling of foundation soils should be performed for embankment situations of sufficient height to evaluate stability.

5.6. The information presented in this overview should be reviewed in the general nature in which it was intended. A thorough geotechnical exploration of the proposed alignments and grades will be required to properly anticipate and plan for special requirements necessary for the design and construction of the proposed projects within the study area.

APPENDIX A
USGS GEOLOGIC MAP



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KENTUCKY TRANSPORTATION CABINET

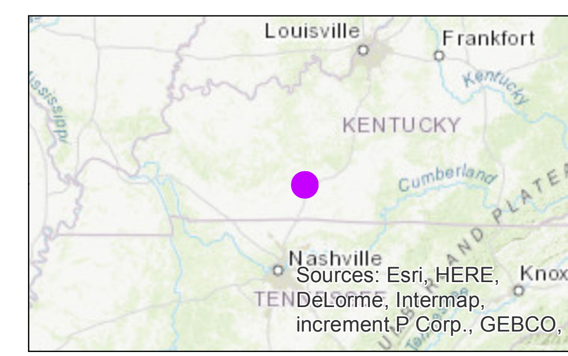
- Spring
- Water Well
- Study Area
- Cave
- Sinkhole
- Approximate Cave Limits
- Existing Karst Drainage Structures

0 300 600 Feet

1:3,600 (At original document size of 11x17)

Notes

1. Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet
2. Robinson & Creason Cave information taken from a map of the Lost River Cave Group, Bowling Green, Kentucky. Explored and surveyed by the Center for Cave and Karst Studies, Western Kentucky University and the Green River Grotto of the National Speleological Society.
3. Approximate Cave Limits and drainage features taken from a drawwing supplied by Western Kentucky University (WKU) dated 7/11/2002.



Project Location

Barren County, KY

178556010
Prepared by MDB on 2017-10-23
Technical Review by DB on 2017-10-23
Independent Review by DC on 2017-10-23

Client/Project

KYTC
Bowling Green Study Area

Exhibit
1

Title
US68 and US231 Planning Study