M E M O R A N D U M

TO: **Stephen De Witte, PE**
Project Management Coordinator
Division of Planning

FROM: **Michael Carpenter, PE**
Geotechnical Branch Manager
Division of Structural Design

BY: **Sean House, PG**
Geotechnical Branch

DATE: **October 27, 2020**

SUBJECT: **Boyle/Garrard Counties**
FD52 011 052 000-005P
FD52 040 052 000-004P
Evaluate options for improving safety on KY 52
Between Danville and Lancaster
Item # 7-104.00
Mars # 1207801P (Boyle)
Mars # 1207802P (Garrard)
Geotechnical Overview Report

1.0 Project Description

The Kentucky Transportation Cabinet (KYTC) is conducting a study to identify and evaluate possible site improvements on KY 52 in Boyle and Garrard County. The scope of the study will begin at US 150 in Danville (KY 52 MP 0.0), travel approximately 9.3 miles East, and end at KY 1150 on the western edge of Lancaster (KY 52 MP 4.2). The goal of this study is to help identify any geotechnical concerns that may affect small alignment changes and/or spot improvements made to enhance safety on the KY 52 corridor. The project location and corridor are presented on the map provided (Appendix A).

2.0 Scope of Work

The scope of work for this study consists of performing a geotechnical overview for the proposed study area base upon research of available published data and the Geotechnical Branch's experience with highway design and construction within the region. General geotechnical and geologic characteristics of the study area have been identified and are discussed in this report. The following sources were used to perform a literature search:

- USGS Professional Paper 1151-H: The Geology of Kentucky: Physiography;
- USGS Professional Paper 1151-H: The Geology of Kentucky: Ordovician System;
- Geologic Map of the Danville Quadrangle (GQ# 985), by E.R. Cressman, published by the USGS, 1972;
- Geologic Map of the Bryantsville Quadrangle (GQ # 945), by Don E. Wolcott and Earle R. Cressman, published by the USGS, 1971;

- Geologic Map of the Buckeye Quadrangle (GQ # 843), by Don E. Wolcott, published by the USGS, 1970;
- Geologic Map of the Lancaster Quadrangle (GQ # 888), by Gordon W. Weir, published by the USGS, 1971;
- USDA Web Soil Survey, https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm;
- Available KYTC Arcmap Datasets and Layers
- KYTC Projects Nearby (KYTC Geotechnical Report Number):
  - CR 5016, Bridge over Clark's Run (S-053-1985)
  - CR 5338, Bridge over Boone Creek (S-034-1996)
  - KY 34, Boyle MP 17-18 & Garrard MP 0-1 (R-001-1988)
  - KY 34 over Herrington Lake (S-031-1986)
  - Danville Bypass (R-011-2002)

2.1 Topography and Drainage

The project study area is located within two physiographic regions identified by the USGS. The western portion, Danville to the eastern side of the Dix River, is located in the Inner Bluegrass Region which is characterized with very low relief and thick residual soils. The Dix River is the main tributary that crosses the study area along with two tributaries, Clarks Run and Hanging Fork Creek. The river flows through meanders entrenched 100 to 200 feet below the plains and low hills. The river bottom is narrow, sinuous, and confined by limestone cliffs and steep, wooded slopes covered with colluvium.

Figure 1. Dix River north of KY 52 river crossing

On the eastern side of the Dix River there is a transition zone between the previously discussed Inner Bluegrass Region and the Outer Bluegrass Region. The transition zone is underlain by the Clays Ferry Formation and is known as the Eden Shale belt. This area is characterized of rounded hills and ridges of moderate relief. Soils are thin, but bedrock, mostly shale, is poorly exposed.

The eastern portion of the project study area, east side of the Dix River to Lancaster, is located in the Outer Bluegrass Region. This region can be characterized with low to moderate relief and soils that range from thick, over limestone, to thin, over shales.

2.2 Geologic Structures

There are two prominent structural features located within the study area with the first being the Jessamine dome located in the western portion of the study area. The Jessamine dome occupies most of central Kentucky, as indicated by the outcrop area of the oldest rocks exposed in the state, the High Bridge Group of Middle Ordovician age and the Lexington Limestone of Middle and Late Ordovician age.

The central part of the project, where the High Bridge Group and Lexington Limestone are at ground level, marks the edge of the Jessamine Dome and lies relatively flat structurally. The southern edge of the Jessamine dome is just south of KY 52 and its eastern edge is east of the Dix River at the Kentucky River Fault Zone. Structural contours begins to dip away from the edges radiating out from the Jessamine dome exposing younger rock strata.

The second geologic structure that was mentioned earlier is the Kentucky River Fault Zone located just east of the Dix River (Appendix B). The Kentucky River Fault Zone is a major northeast-southwest-trending normal fault system that consists of closely spaced grabens and horsts. The fault zone in the study area is approximately 2,100 feet in width, is bookended by two normal faults, and contains the youngest rock formations in the study area due to the downward movement of the fault block.

There are several smaller scale east-west and northwest-southeast-trending faults located on the east and west side of the Kentucky River Fault Zone. These are also normal faults but with much less stratigraphic displacement.

2.3 Stratigraphy

The existing KY 52 extends across three geologic quadrangles, from west to east, Danville (GQ # 985), Bryantsville (GQ # 945), and Buckeye (GQ # 843). From the south western corner of the Buckeye Quadrangle KY 52 trends south into the Lancaster Quadrangle (GQ# 888).

The western portion of the study area, Danville and Bryantsville Geologic Quadrangles, indicate to be underlined by Middle Ordovician aged bedrock formations. In descending order, they are the Lexington Limestone Formation and the Tyrone Limestone Formation. The Lexington Limestone consists mostly of very fossiliferous and fossil-fragmental calcarenite with thin to thick, regular and modular bedding.

Figure 2. Lexington Limestone on KY 52 west of Dix River crossing

The Tyrone Limestone Formation is the upper part of the High Bridge Group which is the oldest stratigraphic units exposed in Kentucky. Exposures can be found in the lower part of the Dix River and Hanging Fork Creek's gorges. The Tyrone Limestone consists primarily of sparingly fossiliferous micrite and dolomite.

At the Kentucky River Fault Zone, eastern Bryantsville Geologic Quadrangle, geologic mapping indicates a sharp change in stratigraphy. From the eastern edge of the Bryantsville Geologic Quadrangle through the Buckeye and Lancaster Geologic Quadrangles the surface is underlined with Upper Ordovician aged bedrock formations. In descending order, they are the Ashlock Formation, Calloway Creek Limestone, Garrard Siltstone, and the Clays Ferry Formation.

The Ashlock Formation consists of several members. These members range is thickness and are most commonly composed of (1) sparsely fossiliferous or nonfossiliferous laminated dolomite and dolomitic limestone, (2) nonlaminated dolomitic mudstone, and (3) very fossiliferous nodular-bedded limestone and a lesser amount of interbedded fossiliferous shale.

The Calloway Creek Limestone is composed of limestone, shale, and minor siltstone. It is mostly fossiliferous limestone which occurs in even and nodular beds that are commonly 1 to 4 inches thick. Limestone makes up 70 percent or more of the Calloway Creek. Shale occurs as partings and thin beds. Siltstone occurs almost exclusively in the lower one-third of the formation.

The Garrard Siltstone is composed of interbedded siltstone, shale, and limestone. Shale accounts for less than 20 percent, and limestone less than 10 percent. The siltstone is in even beds a few inches to several feet thick which are locally contorted into ball-and-pillow structures.

The Clays Ferry Formation is made up of interbedded limestone, shale, and minor siltstone. The limestone and shale occur in about equal amounts, while the siltstone accounts for only a small percentage and is more abundant near the top. The limestone is mostly very fossiliferous and occurs in even beds commonly 2 to 6 inches thick. The shale is commonly sparsely fossiliferous and also generally occurs in beds 2 to 6 inches thick. The shale beds commonly have sharp contacts with the limestone beds.

2.3 Soils and Unconsolidated Materials

Residual soils are the predominant soil type found within this area. They are derived in-place from a weathering process of the parent limestone, dolomitic limestone, and shale. The project, as previously discussed, is underlain by two different stratigraphic groups which results in slightly different soil materials and their landform settings.

In the western portion of the study area, underlain by the Middle Ordovician aged bedrock formations, the USDA Websoil Survey has a majority of the soils classified as silt loams. These soils tend to occur on gentle slopes and ridge tops and are typically 2.5-5.0 feet in depth. They are a clayey residuum derived from phosphatic limestone that are well drained and ideal for farmland.

The Kentucky River Fault Zone, east of the Dix River, exposes the Upper Ordovician aged bedrock and changes the parent material of the soils and the landform settings that they encompass. The USDA Websoil Survey classifies the majority of the soils as silty clay loam. They range in depth from 0.5-4.0 feet in depth on gentle to steep slopes and often contain cobbles, stones, or boulders from the thin limestone beds of the Upper Ordovician bedrock formations. These soils tend to contain more clay, due to the weathering of shale, and are not prime farmland material.

Tertiary or Quaternary fluvial deposits are also found in pockets in proximity to the Dix River. These deposits contain gravel, sand, and silt where the surface is littered with gravel composed of chiefly quartz geodes, with minor chert and conglomerate pebbles.

2.4 Karst

Karst topography from the weathering of carbonate rocks typifies the Inner Bluegrass region. According to the KYTC Arcmap Karst Potential Map (Appendix C) the western portion of the project is in a high to very high risk karst potential area. Several sinkholes have been identified and noted on Appendix B.

On the eastern portion of the study area, Outer Bluegrass Physiographic Region/Upper Ordovician aged bedrock formations, karst potential decreases due to the larger presence of shale. The KYTC Arcmap Kart Potential Map (Appendix C) designates this portion of the study area as having a low to medium karst potential.

Figure 3. Water filled sinkhole south side of KY 52 in Boyle Co.

2.5 Mines and Quarries

There are two (2) active surface mines located within the study area that are highlighted in Appendix D. There are as follows:

1. Dix River Underground
   4963 Danville Road, Lancaster, KY 40444
   (859) 792-2171
   The Allen Co. Inc.

2. Danville Mine & Mill
   1648 Stanford Road, Danville, KY 40422
   (859) 236-6829
   Caldwell Stone Co. Inc.

The two (2) quarries mine material from the Lexington Limestone and Tyrone Limestone formations. They harvest limestone to produce aggregate for concrete use, Aglime for soil stabilization, and construction aggregate for roads, buildings, bridges, and asphalt.

Figure 4. Danville Mine & Mill

3.0 Geotechnical Considerations

The goal of this study is to help identify any geotechnical concerns that may affect small alignment changes and/or spot improvements made to enhance safety on the KY 52 corridor. Large scale alignment changes are not anticipated at this time with possible construction being performed at or around the current alignment. A site investigation was performed on October 7th, 2020 to help identify any current geotechnical deficiencies with the current alignment. Based on the available resources combined with a site investigation small geotechnical concerns and considerations will be presented below.

3.1 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. Slope configurations for rock cuts in durable bedrock can generally be 1H:2V presplit slopes on approximate 30-foot intervals of vertical height with 18 to 20-feet intermediate benches or 15-foot overburden benches. Slope configurations for non-durable bedrock (SDI < 95) are generally constructed on 2H:1V slopes or flatter.

Cuts located in the Upper Ordovician aged bedrock formations, east of the Dix River, contained interbedded limestone and shale. These cuts displayed differential weathering that resulted in large pieces of limestone filling the ditches. Cuts widened or created can be anticipated to be constructed on 2H:1V slopes with adequate ditches to catch debris.

Figure 5. Rock cut east of the Dix River

3.2 Embankment Considerations

Most of the anticipated excavated materials should be suitable for use in project embankments constructed on 2H:1V slope configurations or flatter up to 20-feet tall. Foundation soils are likely to be shallow and consist of low plasticity clays. Any embankments built 20-feet or taller will require stability analysis and may require flatter slopes.

There are locations on the eastern portion of the study area where embankment failure mitigations, rails/lagging and additional asphalt, have been used. The failures could be a result of poor construction techniques, poor embankment material, poor foundation material, or sharp cut/fill transitions on the steeper slopes in the area. Special shale compaction construction, flatter side slopes, partial rock embankment, and constructed embankment platforms are some of the techniques used to reduce these issues.

Figure 6. Rails and lagging mitigation on embankment east of the Dix River

3.3 Saturated, Soft, or Unstable Soils

Low plasticity clays with high silt contents may be present on the project where lanes are being added to the roadway. These types of soil can be very moisture sensitive and create subgrade problems where the roadway template is in a shallow fill or in cut conditions. They can also result in problems during embankment construction. In these areas a working platform consisting of Kentucky Coarse Aggregate #2's, 3's, or 23's wrapped with Geotextile Fabric may be required.

Based on available mapping and observations in the field, ponds exist within the project study area. Depending on the project alignment, these ponds will require treatment if they are located within the construction limits.

3.4 Gas Wells

Based on the available mapping, there are gas wells in the vicinity of the project study area. These wells are depicted on the mapping in Appendix D. Any gas wells within the proposed right-of-way limits, shall be treated in accordance with Mines and Mineral Specifications.

3.5 Water Wells and Springs

Based on available mapping (Appendix D), water wells and springs are common within/near the proposed study area. These locations should be inventoried to verify their locations. If impacted during construction, special construction will be required to close the wells. Spring boxes and/or granular material may be required in the vicinity of springs.

3.6 Karst Conditions

Geologic mapping and field observations indicate the presence of sinkholes (Appendix D). Any open sinkhole and/or solution cavities within the limits of construction, whether shown on the plans or not, that are not used for drainage purposes, shall be filled and/or capped in accordance with the current edition of Section 215 of the Standard Specifications for Road and Bridge Construction.

Any sinkholes utilized for drainage purposed for new roadway construction should incorporate adequate measures to minimize water infiltration into the subgrade and erosion control measures to minimize situation 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 lesson 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. Situation sinkholes should be avoided, especially those to remain open after construction.

Karst conditions also create varying rocklines that can effect slope stability, ultimate slope configuration, and disturbed limits. In cut situations extra Right-of-Way may be recommended to allow for slope remediation during construction. Deeper than anticipated rocklines can also reduce the amount of constructible excavated material. Select rock quantities may have to be adjusted and borrowed material may be necessary for construction purposes.

3.7 Structures

At this time, it is unknown as to whether the proposed roadway would require new and/or widened substructure elements. It can be anticipated that most of the bridges within the project study area are likely supported by rock bearing foundation systems. Culverts along the proposed alignments may be replaced or widened. The culverts within the study area are likely supported by either non-yielding or yielding foundation systems depending upon the location along the proposed alignment. A detailed geotechnical investigation will be required to determine the foundation support systems.

3.8 Faulting

As described above, the Kentucky River Fault Zone crosses the study area east of the Dix River with a northeast-southwest bearing. The fault zone may present dipping, fractured, or extremely weathered bedrock that can present problems during/after construction. Any new roadway alignments should cross the fault zone perpendicular to the strike plane to limit the amount of exposure of the fault.

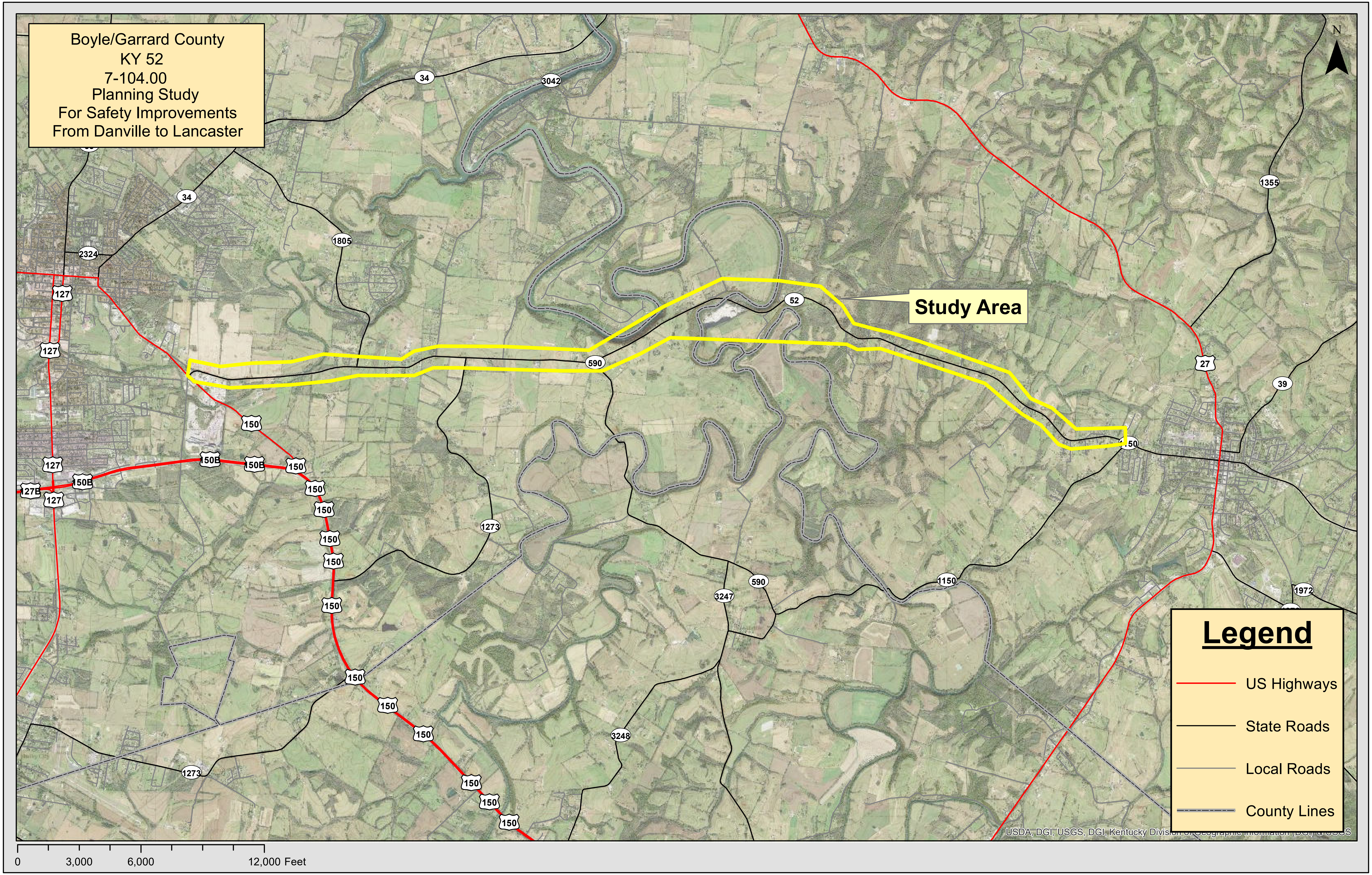
4.0 Conclusions

The purpose of this 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.

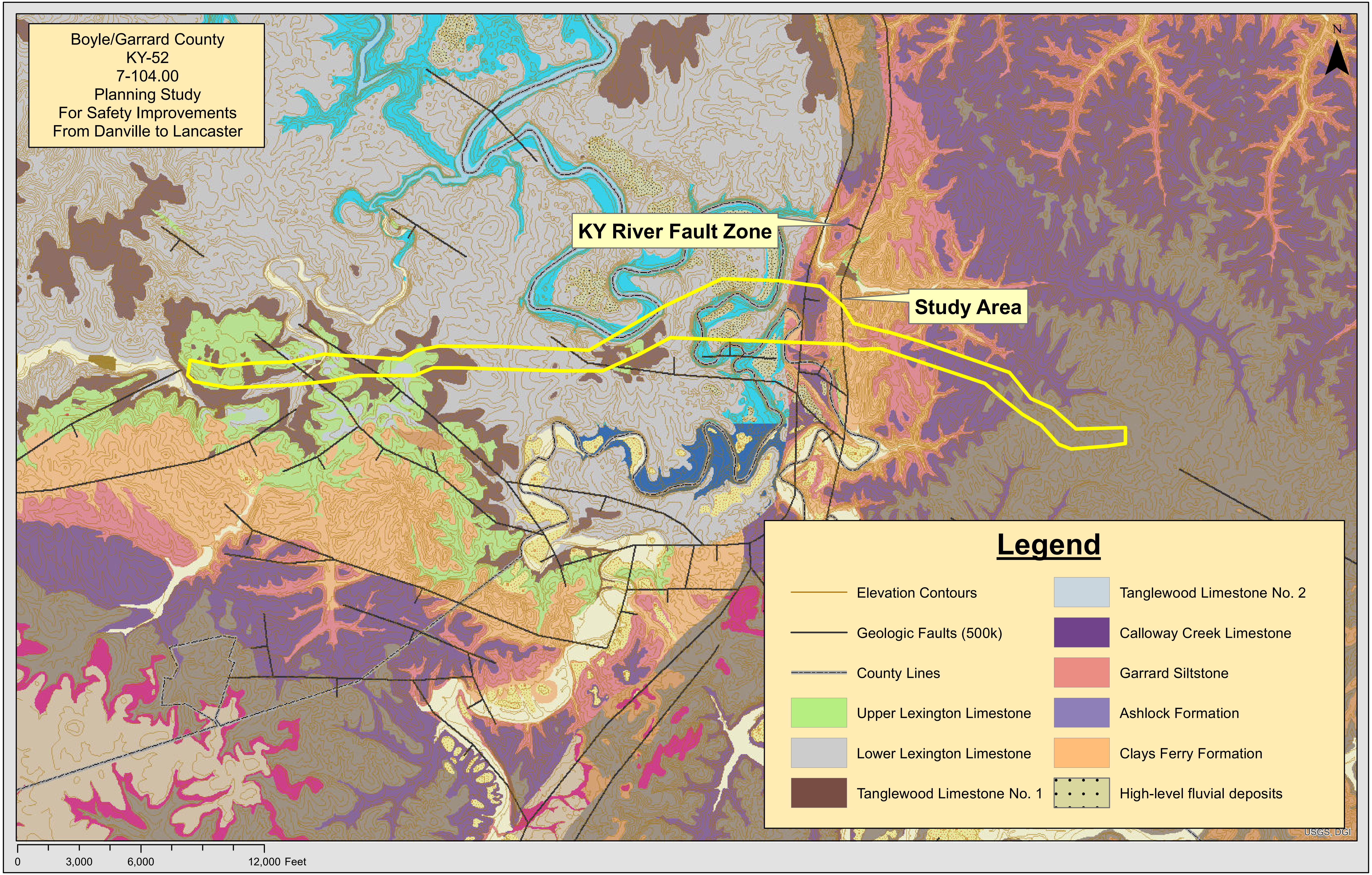
Geotechnical drilling will be needed for roadway cut/fills and structures. Because a portion of this project will impact the current alignment, information on pavement structure should be obtained to assist the team in pavement design. Sampling of foundation soils should be performed for embankment situations.

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 alignment and grade will be required to properly anticipate and plan for special requirements necessary for the design and construction of the proposed alignment.

Appendix A
Study Area Corridor

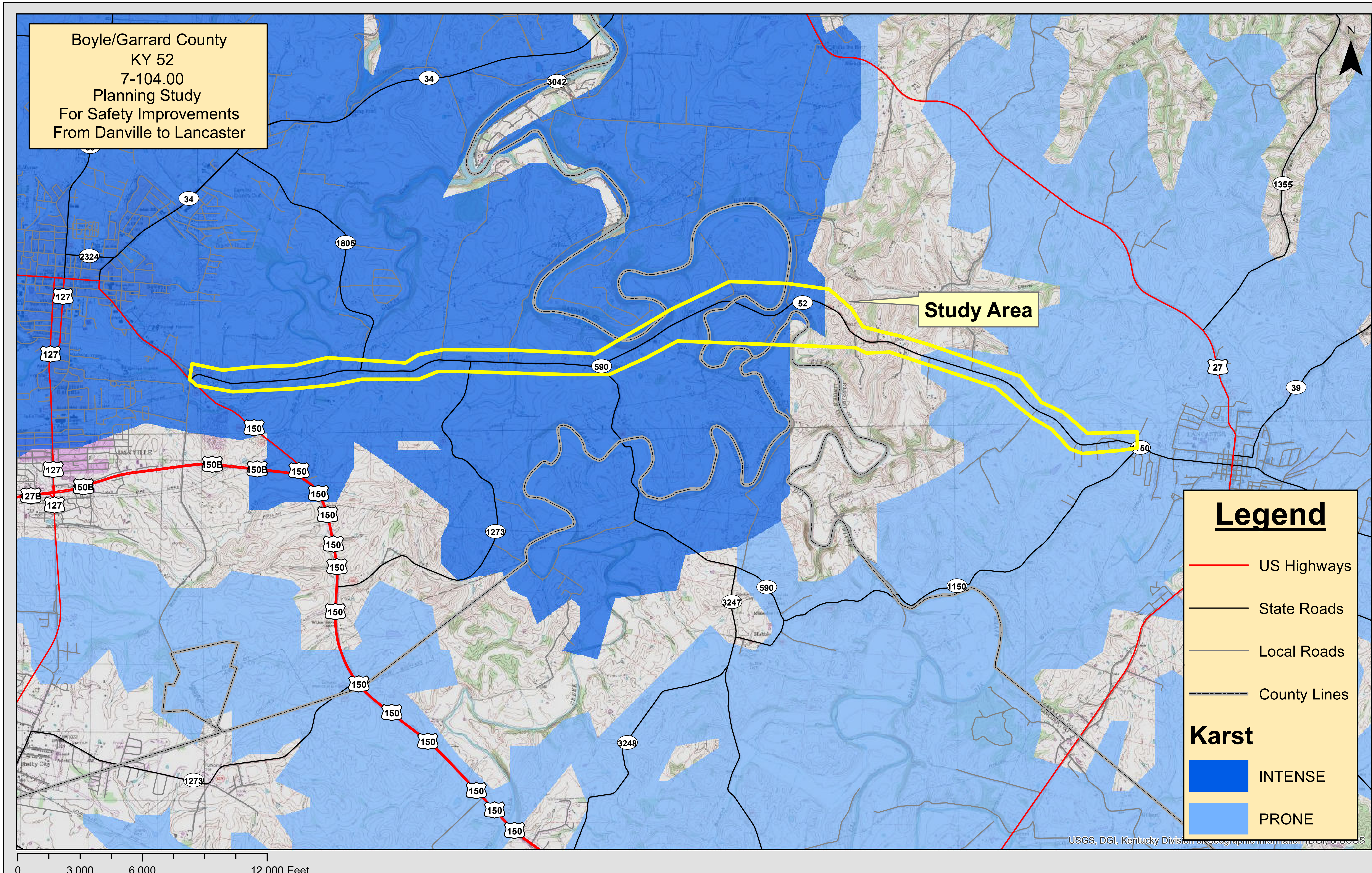

Boyle/Garrard County
KY 52
7-104.00
Planning Study
For Safety Improvements
From Danville to Lancaster
N
Study Area
52
590
150
150B
127
127B
34
3042
1805
2324
1273
3247
3248
1150
1355
27
39
1972
Legend
US Highways
State Roads
Local Roads
County Lines
0
3,000
6,000
12,000 Feet

Appendix B
Geologic Map

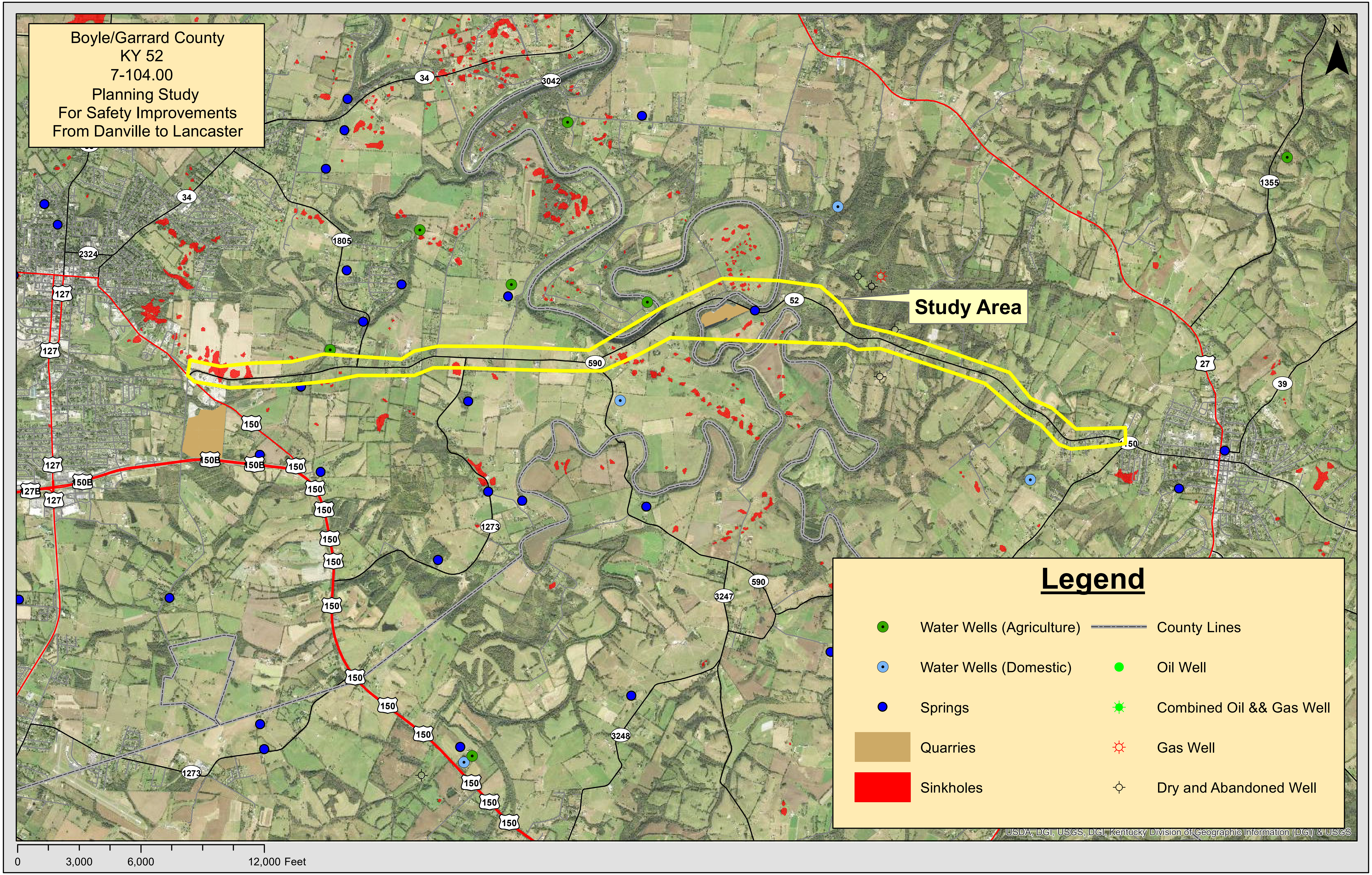


Boyle/Garrard County
KY-52
7-104.00
Planning Study
For Safety Improvements
From Danville to Lancaster
KY River Fault Zone
Study Area
N
Legend
Elevation Contours
Geologic Faults (500k)
County Lines
Upper Lexington Limestone
Lower Lexington Limestone
Tanglewood Limestone No. 1
Tanglewood Limestone No. 2
Calloway Creek Limestone
Garrard Siltstone
Ashlock Formation
Clays Ferry Formation
High-level fluvial deposits
USGS, DGI
0
3,000
6,000
12,000 Feet

Appendix C
Karst Potential Map


Boyle/Garrard County
KY 52
7-104.00
Planning Study
For Safety Improvements
From Danville to Lancaster
Study Area
Legend
US Highways
State Roads
Local Roads
County Lines
Karst
INTENSE
PRONE
0
3,000
6,000
12,000 Feet
N

Appendix D
Springs/Sinkholes/Quarries/Wells



Boyle/Garrard County
KY 52
7-104.00
Planning Study
For Safety Improvements
From Danville to Lancaster
Study Area
Legend
Water Wells (Agriculture)
Water Wells (Domestic)
Springs
Quarries
Sinkholes
County Lines
Oil Well
Combined Oil && Gas Well
Gas Well
Dry and Abandoned Well
0
3,000
6,000
12,000 Feet
USDA, DGI, USGS, DGI, Kentucky Division of Geographic Information (DGI) & USGS