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**SUBJECT:** Pendleton County  
FD04 096 0177 005-010 P  
KY 177 Improvements  
Item No. 6-80258.00  
Mars No. 1632901P  
Geotechnical Overview

### **1.0 Project Description**

The Kentucky Transportation Cabinet (KYTC) is conducting a study along KY 177 through and around the city of Butler in Pendleton County. The limits of the study extend approximately from KY 177-mile points 5.8 to 9.2. The goal of this study is to evaluate and improve mobility and accessibility along the KY 177 corridor. This overview will be utilized to identify geologic and geotechnical considerations within the project limits. The study's location and extent are presented on the drawing provided (Appendix A).

### **2.0 Scope of Work**

The scope of work for this study consists of performing a geotechnical overview for the proposed project location based upon research of available published data, and the Geotechnical Office's experience with highway design and construction within the region. A site visit was also performed to evaluate existing conditions within the study area and note additional findings that were not addressed through the literature search. The general geotechnical and geologic characteristics of the study are presented below.

### **3.0 Topography and Drainage**

The project study area is located within the Outer Bluegrass Physiographic Region of Kentucky. The topography throughout most of the project site is characterized by a wide meandering flood plain along the Licking River surrounded by rolling terrain consisting of broad ridge tops and relatively narrow valleys. Typical vertical relief is in the magnitude of 300 feet.



Licking River floodplain along KY 177, North of Butler.

Surface drainage flows in a dendritic pattern, believed to be the result of underlying bedrock with uniform resistance to erosion, directed towards the Licking River. The Licking River trends North-South and ultimately empties into the Ohio River at Newport, KY. In general, groundwater above the Licking River valley is insignificant but hillside seeps and springs are common as groundwater can travel between bedrock strata and joints.

#### **4.0 Geology**

The study area falls between the De Mossville and Butler 7.5-minute quadrangle maps of Kentucky. Published geologic mapping indicates the project area to be underlain by Quaternary deposits and Ordovician aged bedrock. The deposits and bedrock have been grouped based on similar geologic characteristics and displayed as formations on the geologic maps (Appendix B). In descending order, the geologic formations are Alluvium, Terrace deposits, Fairview Formation, Kope Formation, and Point Pleasant Formation.

#### **4.1 Lithology**

The Quaternary aged Alluvium and Terrace deposits are thick accumulations of unconsolidated sediment deposited above the bedrock by water movement within the valley along the Licking River approximately below elevation 540 to 560. The unconsolidated sediment consists predominantly of clay and silt with an abundant

amount of gravel and sand. The Terrace deposits mapped generally sit above the alluvium within the study area and are less than 20 feet thick. The Alluvium is reported to be as much as 50 feet thick along the floodplain. Past geotechnical borings found on KYTC's archived plans for the KY 177 bridge over the Licking River record the total thickness of unconsolidated deposits to be anywhere from 3.2 to 37.9 feet thick.

The Fairview Formation consists of interbedded shale and limestone. Over half the formation consists of thinly bedded shale (50%-65%). The shale is medium gray to bluish-gray, clayey to silty, calcareous, and contains few fossils. The shale within the Fairview Formation will degrade and weather once exposed to the elements classifying the material as non-durable. The limestone (35%-50% of the formation) is medium to light medium gray, coarse to fine grained, thinly bedded in irregular to even layers, and with few fossils. The Fairview Formation can be sparsely found at the highest elevations capping ridges.



Fairview Formation exposure on KY 177 at mile point 5.75.

The Kope Formation, the predominant strata within the project limits and up to 230 feet thick, consists of interbedded shale and limestone. Shale comprises 75%-80% of the formation. The shale is gray, silty, calcareous, and typically exhibits a very low resistance to weathering. While fresh, the unweathered shale appears to be competent material, but upon exposure to the elements will deteriorate rapidly into highly plastic clays and silts with low shear strength. The limestone (20%-25%) consists of two types: (1) medium gray, fine to coarse crystalline, thin even to irregular beds, fossil fragmental; and (2) medium to dark gray, fine grained to micrograined, argillaceous and silty, even to irregular beds, and few fossils.

The Point Pleasant Formation is located beneath the Kope Formation and the unconsolidated material of the Alluvium and Terrace deposits. This formation is exposed near the base of hillsides below elevation 590 on the North side of the project and elevation 630 on the South side. The formation consists of 50%-70% limestone and 30%-50% shale. The limestone within this formation varies and has been grouped into three major types. It can vary from medium gray to medium light gray, coarse grained to micrograined, lenticular to tabular beds in irregular to even layers, bioclastic, argillaceous, laminated to crossbedded, with fossils. Shale is medium-dark-gray to medium-light-gray, laminated, with calcareous and silty zones, often found as thin layers and partings. The Point Pleasant Formation typically weathers to rubble due to the breakdown of exposed poor-quality shale separating the thin limestone layers.

## **4.2 Surficial Soils**

Surficial soils within the study area are anticipated to be shallow outside of the floodplain. The ridgetops consist of residual soils. Residual soils are derived in-place from a weathering process of the parent bedrock material. The web soil survey produced by the National Cooperative Soil Survey identifies these soils to be silty clay. Soils in these areas are typically five (5) feet or less in depth.

The hillsides can consist of colluvium. Colluvium is a locally derived residuum that has accumulated and/or migrated downslope due to gravity and erosion. Hillside soils depths can range approximately from five (5) to ten (10) feet. These soils consist of brown clays with gravel and limestone slabs and are subject to slumping.

Located at the base of the hillsides, wedge shaped deposits with a hummocky topography have accumulated. These deposits are an accumulation of the gravity driven residuum that were located on the hillsides. They consist of poorly sorted clay, silty, gravel and boulders (limestone and shale) and soil horizons are not distinguishable.

## **4.3 Geologic Structures and Hazards**

According to the Geologic Maps of the Butler Quadrangle (GQ #982) and of the De Mossville Quadrangle (GQ #862) the structural contours drawn on the base of the Fairview Formation, indicate bedrock is flat lying with a dip of less than one percent per mile. No faults or other significant structural features are noted in the study area.

The Fairview Formation is known to develop or have karst features such as solutioned cavities, sinkholes and springs. These features are not noted in the study area but may be encountered or exposed if constructing within this formation. Other than the Fairview Formation, the rest of the project lies within bedrock that is not in a karst risk location (Appendix D).

The entirety of the project area is notorious for cut and fill slope stability failures. The driving force behind these instabilities can be attributed to groundwater movement, poor rock mass quality, deep colluvium accumulations, primary and secondary structures of the river valley deposits, and the proximity to the Licking River and potential high water levels.



Slide repair on KY 177 mile point 4.45.



Slide repair on KY 177 mile point 6.55.

KYTC's geotechnical database identified multiple landslide reports within Pendleton County. Two of these reports are for existing KY 177, and adjacent to the study limits. The first slide report (L-011-2000) completed in the year 2000 is at mile point 3.14, and the second report (L-106-2019) from 2019 is located at mile point 4.52. Both nearby slides were the result of embankment failures with a geotechnical recommendation of installing recycled railroad rails and lagging for mitigation. Additional landslides areas derived from LiDAR are outlined on the Kentucky Geological Survey's landslide mapping service to the Northeast of Butler, KY. These outlined landslide areas appear to have originated in the Kope Formation along steep hillsides and the banks of the Licking River. Slide repairs were also noted from the site visit along KY 177 and are displayed on the landslide map (Appendix E). The repairs ranged from installing rail and lagging, shotcrete and drains, polybags, to concrete and stone masonry retaining walls.

## 5.0 Geotechnical Considerations

Based on the available resources significant geotechnical concerns should be considered when evaluating the project area. This includes any large-scale alignment changes or small-scale spot improvements that involve disturbing the current earthwork. A site investigation was performed on December 8, 2023 to help identify any current geotechnical deficiencies with the current alignment.

The Ordovician age bedrock formations within the study consists of marine shales and limestone. These shales are commonly of poor quality and tend to weather deeply directly below the interface with the overlying soils. Due to the weathering characteristics of the shale and the percentage of shale in each formation, the bedrock within the study area is considered non-durable. Durable rock and/or limestone from excavation will not be available for construction purposes.

### 5.1 Cut Slopes

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-foot intermediate benches or 15-foot overburden benches. Slope configurations for non-durable bedrock or soils are generally constructed on 2H:1V slopes or flatter.

The Kope Formation is the dominant rock formation in the project corridor. Highway projects that intersect the Kope Formation have typically experienced slope stability and maintenance issues associated with the deep Rock Disintegration Zones (RDZ) and the rapid slaking of the newly exposed bedrock. The disintegration mainly occurs in the shale component (60-80%) of the formation. Slope configurations of 2H:1V or flatter should be anticipated. As the shale in the Kope Formation erodes large blocks of limestone beds can slide and potentially reach the road.

Cut slopes on ridge flanks where deep deposits of colluvium have accrued should be avoided. These areas have been subjected to groundwater seepage, erosion, creep displacement, and expansion/contraction of the shales and residual soils. The removal of toe support can accelerate the rate of creep or cause outright slope failures.

## **5.2 Embankments**

The project area is notorious for unstable fill slopes. As mentioned above a host of factors contribute to the instability of fill slopes: ground water movement, poor fill construction material, weak poorly sorted colluvium material, compressible and relatively weak terrace deposits, secondary structures consisting of desiccation cracks and slickensides, and proximity to the Licking River and its flooding hazard.

To help mitigate groundwater conditions adequate sub drainage facilities are often used. A system of longitudinal underdrains and lateral outlets increase stability factors both during and following construction.

Material excavated from the project would most likely consist of non-durable shales. Embankments principally of non-durable shale (SDI less than 95 according to KM 64-513) should be constructed using special shale compaction methods. If this construction method is not followed the shale can break down in a few years causing settlement and potential failures. Side slopes may still be 2:1 depending on embankment height.

The terrace and alluvium deposits of the Licking River Valley are considered weak and compressible. Embankments constructed in the valley would most likely require a staged construction method. This method would help control groundwater conditions, restrict buildup of excess pore water pressure, provide slopes long-term stability, and confirm or amend predicted time versus settlement relationships. Settlement platforms and piezometers would be installed to monitor excess water pore pressures and ground movement from settlement due to new embankments at bridge end bents. Proximity to the Licking River should be avoided as the existing riverbank is unstable following rapid draw down.

## **5.3 Saturated, Soft, or Unstable Soils in Subgrade**

Based on review it appears durable rock from roadway excavation will not be sufficient to construct a roadbed for the project. Therefore, other methods of improving the subgrade can be considered. Chemical stabilization is the preferred method of subgrade improvement. In areas where lanes are being added or chemical stabilization is not feasible (such as cross-overs, tie-ins, etc.) the subgrade can be constructed with Kentucky Coarse Aggregate No. 2, No. 3, or No. 23 sized stone with geotextile fabric.

Natural streams, drains, and alluvium may be encountered within the project limits along with possible springs. Any saturated or unstable areas encountered within embankment foundation limits may need to be stabilized and the stream channel may need to be redirected or have pipes installed.

#### **5.4 Water Wells and Springs**

As previously noted, the uplands area contributes most or all the ground water recharge to the Licking River Valley. An adequate subsurface drainage system may be required to help control artesian conditions and increase stability factors both during and following construction.

Springs may be present within the proposed study area. These locations should be inventoried to verify their locations. Spring boxes and/or granular material may be required in the vicinity of springs. All water wells and/or cisterns within the limits of construction, whether shown on the plans or not, shall be plugged in accordance with Section 708 of the current Standard Specifications for Road and Bridge Construction.

#### **5.5 Gas and Oil Well**

Based on the available mapping, there are no oil and gas wells in the vicinity of the project study area. Any gas wells within the proposed right-of-way limits, shall be treated in accordance with Mines and Mineral Specifications.

#### **5.6 Mines and Quarries**

Multiple quarries can be found scattered throughout the Outer Bluegrass Region. An active open pit limestone quarry exists approximately 1.4 miles northeast of Butler off KY 177. The quarry is currently operated by Hilltop Stone, LLC and is extracting limestone aggregate from the Lexington Limestone Formation. Other than the limestone, coal seams and other minable resources are not present around or within the study area. As a result, mines will not be present.

#### **5.7 Karst Conditions**

Geologic mapping and field observations does not 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.

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.

#### **5.8 Structures**

At this time, it is unknown as to whether the proposed roadway would require new and/or widened substructure elements. Based on a review of KYTC geotechnical reports conducted for existing structures in the area, it is evident that most of the bridges across the region are supported by rock bearing foundation systems, such as spread footing or steel H-piles driven to bedrock. This includes both the KY 177 bridge (MP 4.913) and nearby US 27 bridge (MP 16.912) over the Licking River that utilize a spread footing foundations embedded into bedrock.



Bedrock exposed in stream bottom at KY 3185 bridge at mile point 2.3.

The existing 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 appropriate foundation support systems.

## 6.0 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. If a portion of this project will be a widening project, information on existing pavement structure should be obtained to assist the team in pavement design. Due to the high volume of traffic chemical modification may not be feasible so a granular subgrade could be utilized. Sampling of foundation soils should be performed for embankment situations.

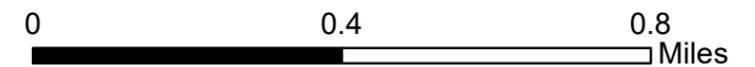
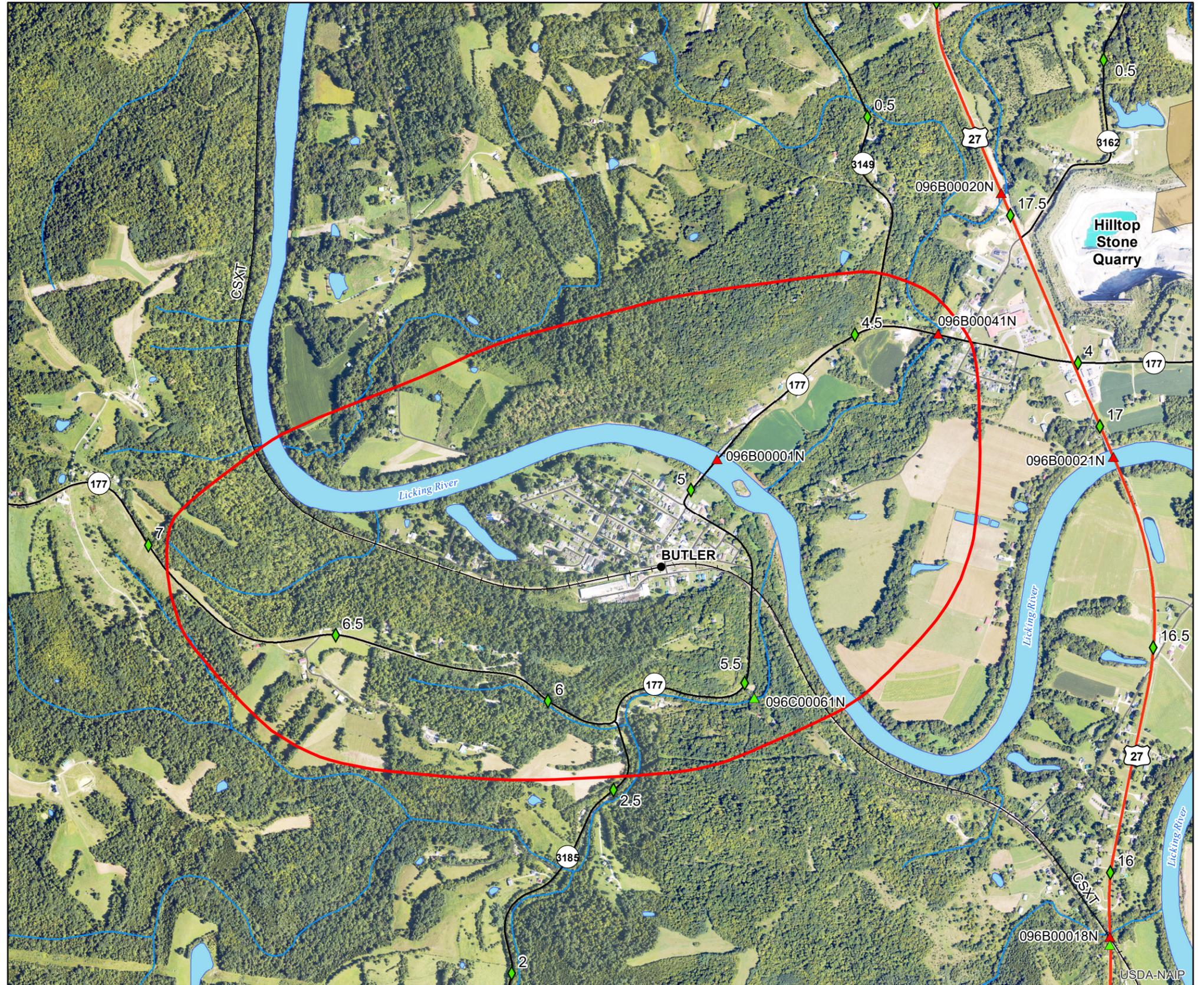
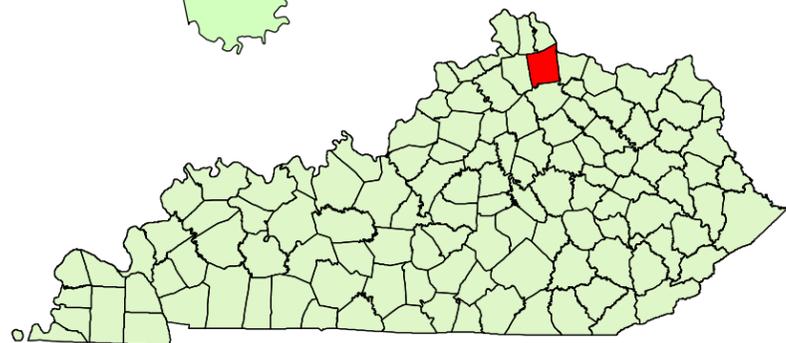
The information presented in this overview should be reviewed in the general nature in which it was intended. A thorough geotechnical exploration of the proposed alignment and grade will be required to properly anticipate and plan for special requirements necessary for the design and construction of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

# **Appendix Study Area Corridor**

# Pendleton P-007-2023 - Site Map

## Legend

- Cities
  - ▲ State Maintained Structures
  - ▲ County Maintained Structures
  - Elevation Contour
  - Structure contour
  - Waterbodies
  - Rivers and Streams
  - Project Area
- Roads & Rails**
- US 27
  - State Roads
  - Local Roads
  - Active Rail
  - ◆ Milepoint (0.5 Mile-Increments)



USDA-NAIP

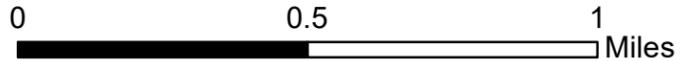
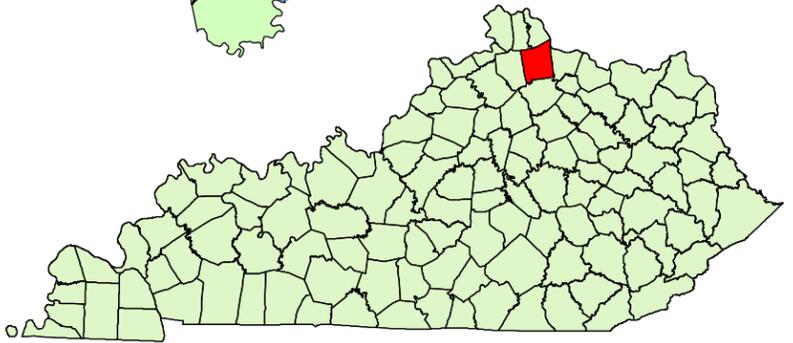
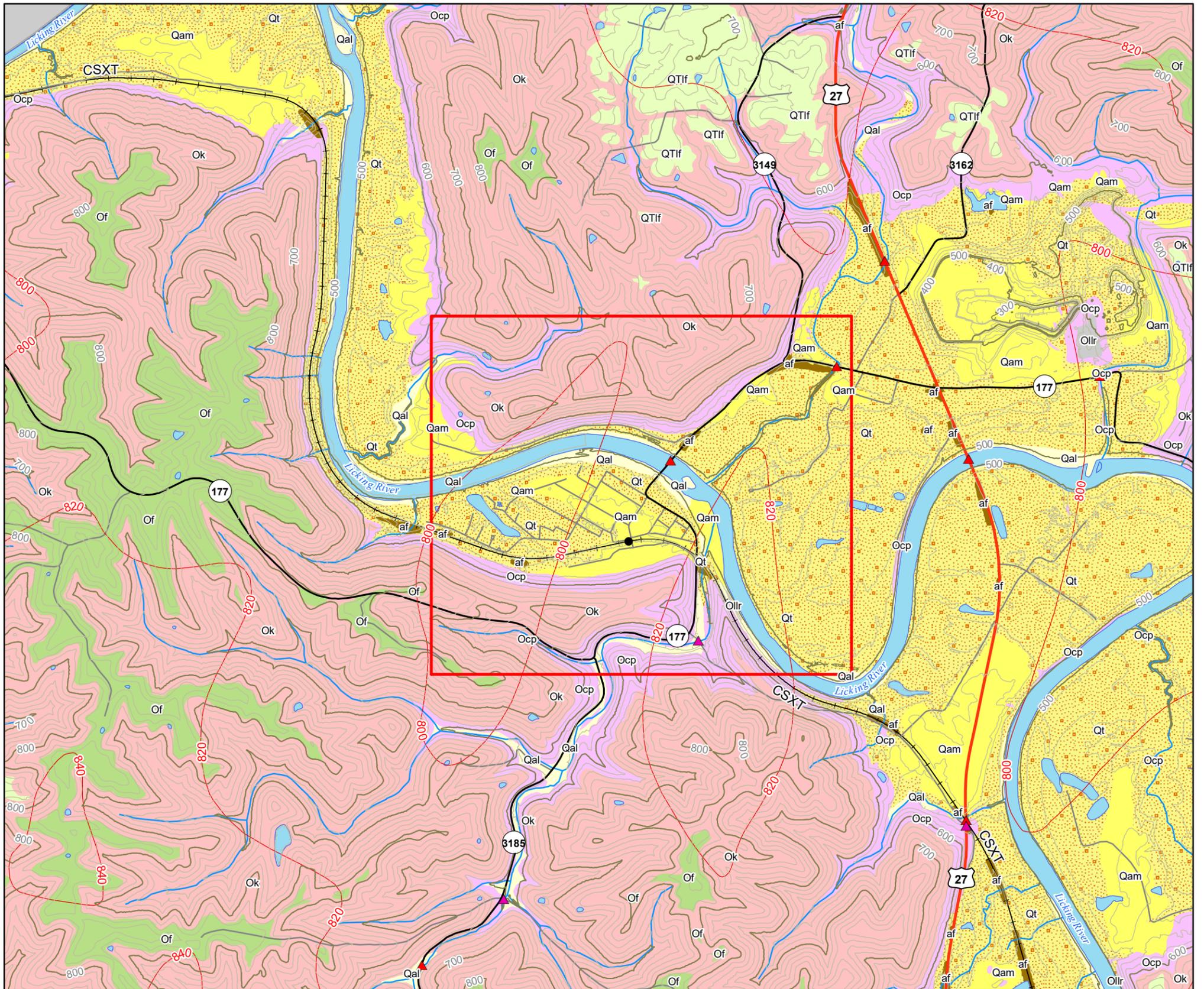
# Pendleton P-007-2023 - Geologic Map

## Legend

- Cities
  - ▲ State Maintained Structures
  - Elevation Contour
  - Structure contour
  - Waterbodies
  - Rivers and Streams
  - Project Area
- ### Roads & Rails
- US 27
  - State Roads
  - Local Roads
  - Active Rail

### Geologic Formations

<b>Qal</b>	Alluvium
<b>af</b>	Artificial fill
<b>Qam</b>	Alluvium of valley sides, meander cores, cut-off meanders, and abandoned channels
<b>Qt</b>	Terrace deposits
<b>QTif</b>	Lacustrine and fluvial deposits (pre-Illinoian)
<b>Of</b>	Fairview Formation
<b>Ok</b>	Kope Formation
<b>Ocp</b>	Point Pleasant Tongue of Clays Ferry Formation
<b>Ollr</b>	Lower part of Lexington Limestone



# Pendleton P-007-2023 - Soils Map

## Legend

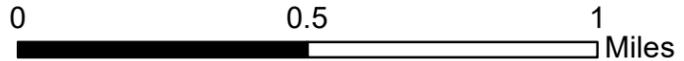
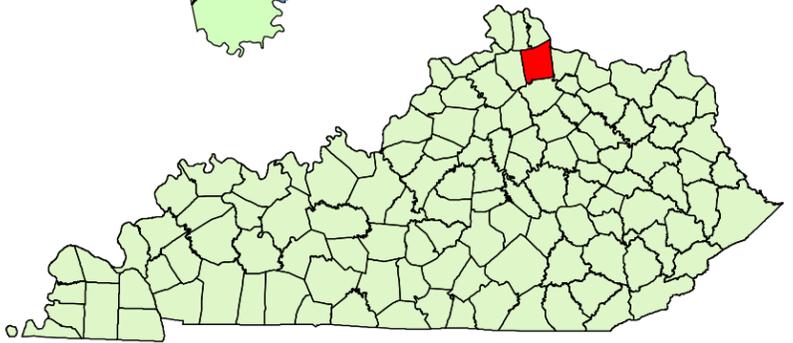
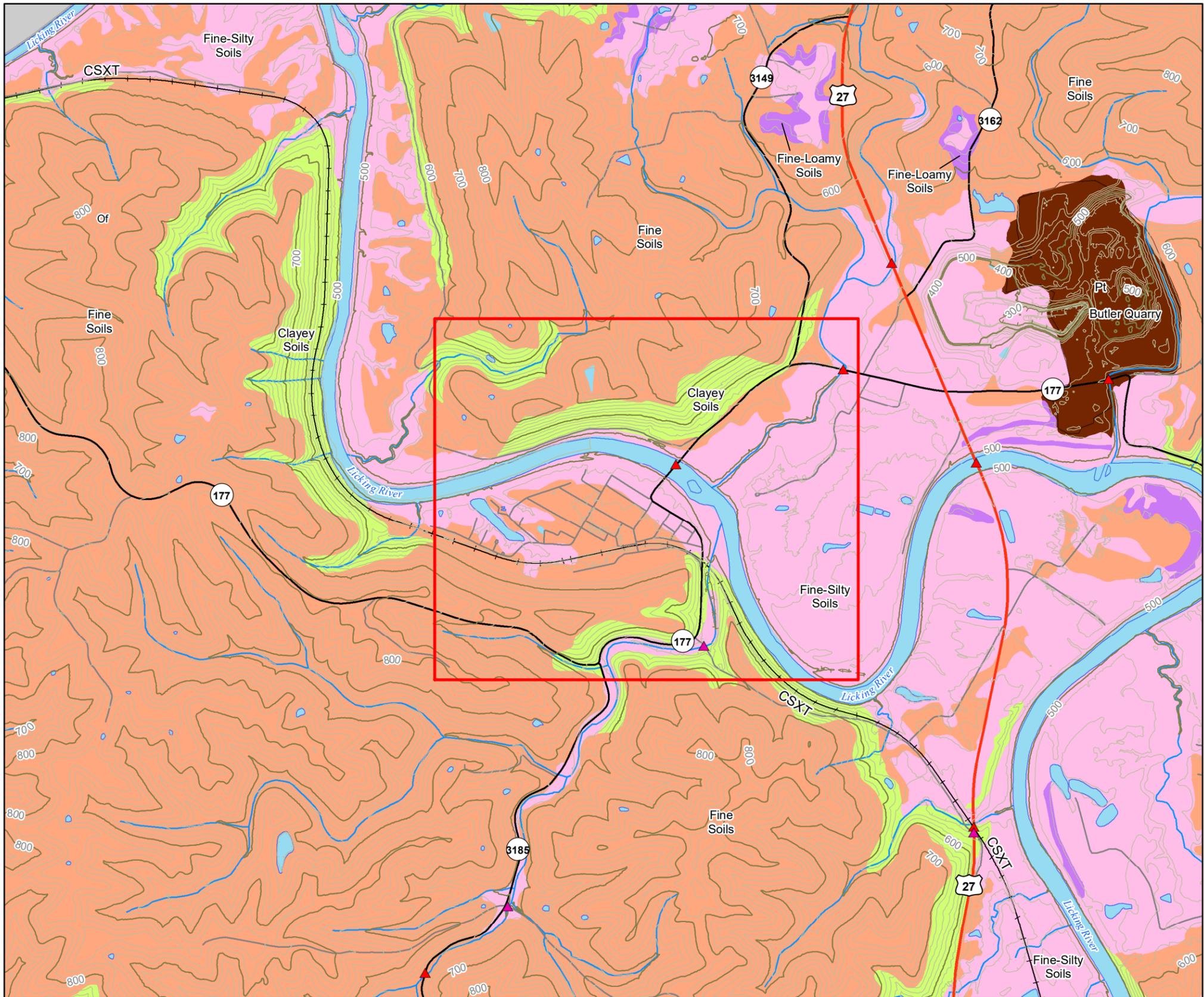
- Cities
- ▲ State Maintained Structures
- Elevation Contour
- Structure contour
- Waterbodies
- Rivers and Streams
- Project Area

### Soil Types (by particle size)

- Pits-Dumps Complex
- Clayey Soils
- Fine Soils
- Fine-Silty Soils
- Fine-Loamy Soils

### Roads & Rails

- US 27
- State Roads
- Local Roads
- Active Rail



# Pendleton P-007-2023 - Karst Potential

## Legend

● Cities

▲ State Maintained Structures

— Elevation Contour

Waterbodies

Rivers and Streams

Project Area

### Karst Potential

INTENSE

PRONE

NONE

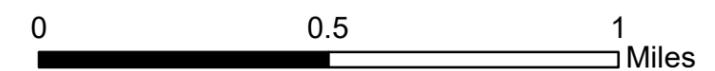
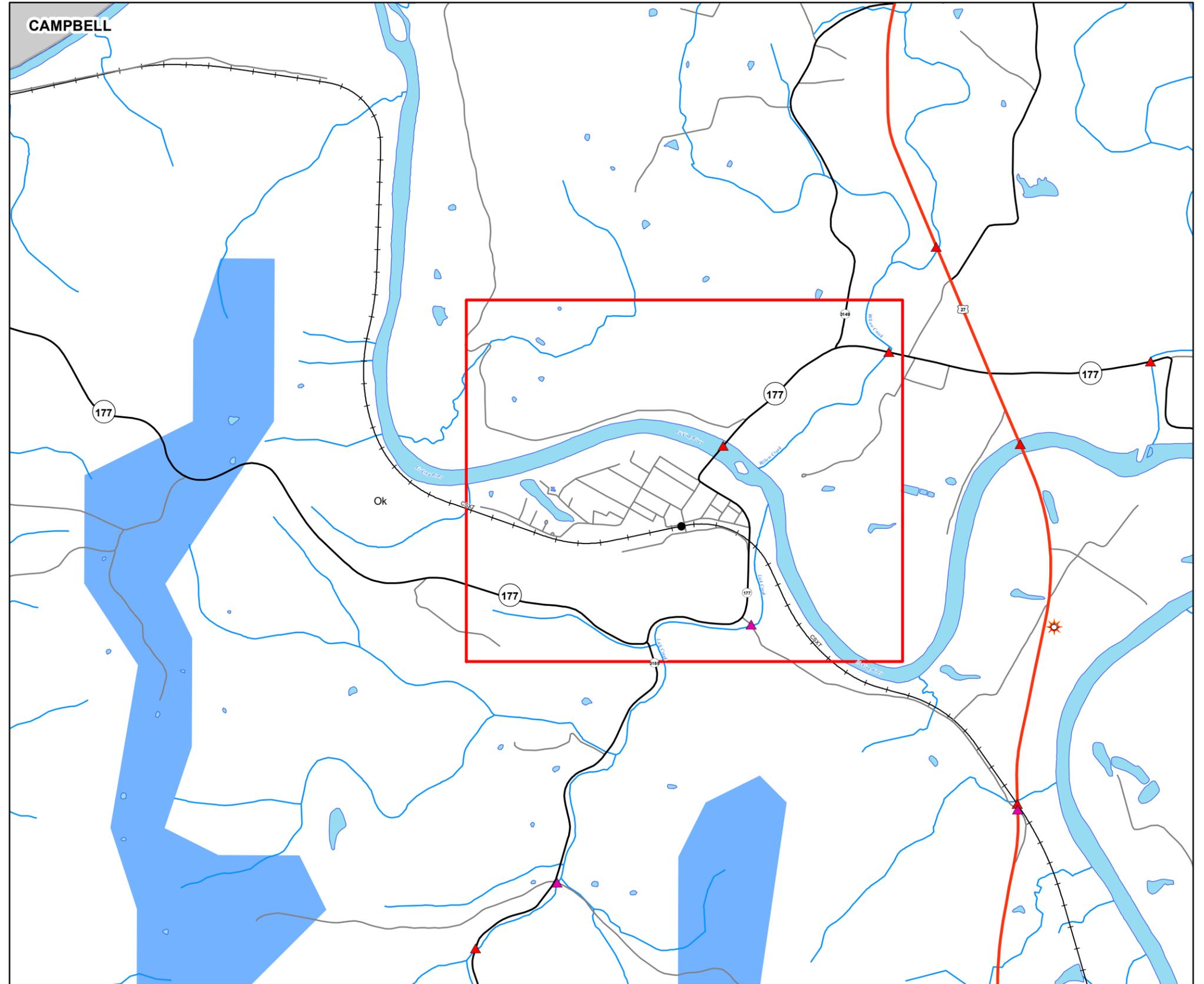
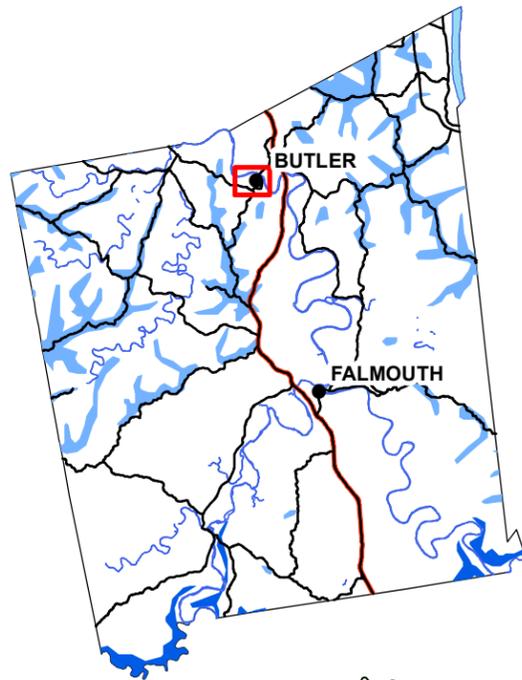
### Roads & Rails

US 27

State Roads

Local Roads

Active Rail



# Pendleton P-007-2023 - Hillshade and Landslide Map

## Legend

- Cities
  - ▲ State Maintained Structures
  - Elevation Contour
  - Structure contour
  - Waterbodies
  - Rivers and Streams
  - Project Area
- Hillshade Relief**
- Higher Elevation
  - Lower Elevation
- Landslides Information**
- Issued Landslide Reports
  - Observed Landslide Repairs
  - Extent of Landslide Repair
  - Landslide Areas
- Roads & Rails**
- US 27
  - State Roads
  - Local Roads
  - Active Rail

