Appendix D

Geotechnical Overview

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Geotechnical Overview Summary

I-65 New Interchange Feasibility Study
Item No. 03-402
Warren County, Kentucky

Prepared for:
Kentucky Transportation Cabinet

Prepared by:
Michael Baker International, Inc.

June 2020

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I-65 New Interchange Feasibility Study
Warren County, Kentucky

Geotechnical Overview Report

1 Project Location and Purpose

The project involves a feasibility study for a new interchange that will be located along the I-65 Corridor in Warren County, Kentucky. The northern limits of the study area are I-165/Natcher Parkway, and the southern limits are the Warren County line. The western limits are defined by US 31W, and Plano Road is the eastern limits. Three new interchange areas were targeted for this study which include Carter Sims Road, KY 240, and KY 242. Refer to Figure 1 Project Location Map – I-65 New Interchange Feasibility Study and Appendix A for Study Area Overview.
This new Interchange Feasibility Study is being conducted to:

- Determine the need and preferred location of a new interchange along I-65 in the southern portion of Warren County, Kentucky, and;
- Provide connectivity to main arterial routes (US 31W, Three Springs Road, and Plano Road).

The primary focus of this Geotechnical Overview study is to identify, document and describe geotechnical features of concern within the study area that can serve to differentiate and compare alternatives and support the recommendation of a preferred interchange location.

1.1 Scope

Geotechnical involvement at this point in the project involves an abbreviated Geotechnical Overview of the Project. This Geotechnical Overview includes results of geotechnical literature and database review, physiographic and stratigraphic setting, karst potential and sinkholes mapping, descriptions of the regional geology, geologic and topographic maps, geotechnical considerations, and conclusions on the geotechnical features identified.

2 GEOTECHNICAL CONSIDERATIONS AND CONCLUSIONS

2.1 General

As the interchange alternatives are further considered, the Project Team should review the highlighted geotechnical considerations that are included in this section related to karst potential and sinkholes, water wells and springs, oil and gas wells, cut slopes, embankments and subgrade, new structures or widening of existing structures. No specific data was reviewed related to existing utilities in the study area. Based on our review of available information, the geotechnical and geological conditions within the study area and the three target new interchanges are considered similar.

2.2 Karst Conditions

The karst conditions are considered similar for either of the three interchanges since all three interchanges are in an area of high karst potential with CK-EHMP Karst/sinkhole Hazard Score of severe for the study area and mapped sinkholes. The dominate lithology in the area is karst conducive limestone. The subsurface bedrock conditions within the study area has a high karst potential. The Carter Sims Road interchange area appears to have 14 mapped sinkholes, KY 242 interchange area appears to have 3 mapped sinkholes, and KY 240 interchange area appears to have 1 mapped sinkhole. Sinkhole treatments and associated costs will need to be considered for construction. The sinkhole treatment should be performed in accordance with Section 215 Treatment of Open Sinkholes of the current edition of the KYTC Standard Specifications for Road and Bridge

Construction.

2.3 Water Wells, Springs and Streams

The water wells, springs, and streams are considered similar for either of the three interchanges. Approximately 62 domestic water and other wells and 26 springs have been identified in the study area. Two springs and a water well are identified near Carter Sims Road Interchange area, two water wells and a spring are identified west of I-65 near KY 242 interchange area, and one water well is identified west of I-65 near KY 240 interchange area. Seasonally high-water tables, flooding, shallow groundwater and springs are associated with karst terrain within the study area. If impacted during construction, special construction will be required to close the wells, and spring boxes and/or granular material may be required in the vicinity of springs for drainage.

2.4 Gas and Oil Wells

Approximately 78 oil and gas well types have been identified in the study area. No specific gas, oil wells or other types of wells were identified within the Carter Sims Road or KY 240 interchange areas, therefore the gas and oil wells are considered similar for either of these two interchanges. One gas, oil wells or other types of wells was identified within the KY 242 interchange area.

2.5 Cut Slope Considerations

Cut slope considerations are similar for either new interchange. The low topographic relief indicates that cut slopes are likely to be shallow. Cut slopes in soil should be 2H;1V or flatter. Cut slopes in limestone can consider a steeper slope of 0.5H:1v, provided this steeper slope is supported by subsurface information. Geotechnical test boring program and analysis would be required to determine final cut and embankment slopes base on subsurface conditions encountered. Depending on the depth to bedrock, roadway excavations may not produce enough quantities of select durable rock for treating subgrade stability issues and embankment foundation material. Roadway profile borings and rockline soundings will be required to better define on-site select rock quantities from roadway excavations and/or recommended rock borrow quantity.

2.6 Embankment and Subgrade Considerations

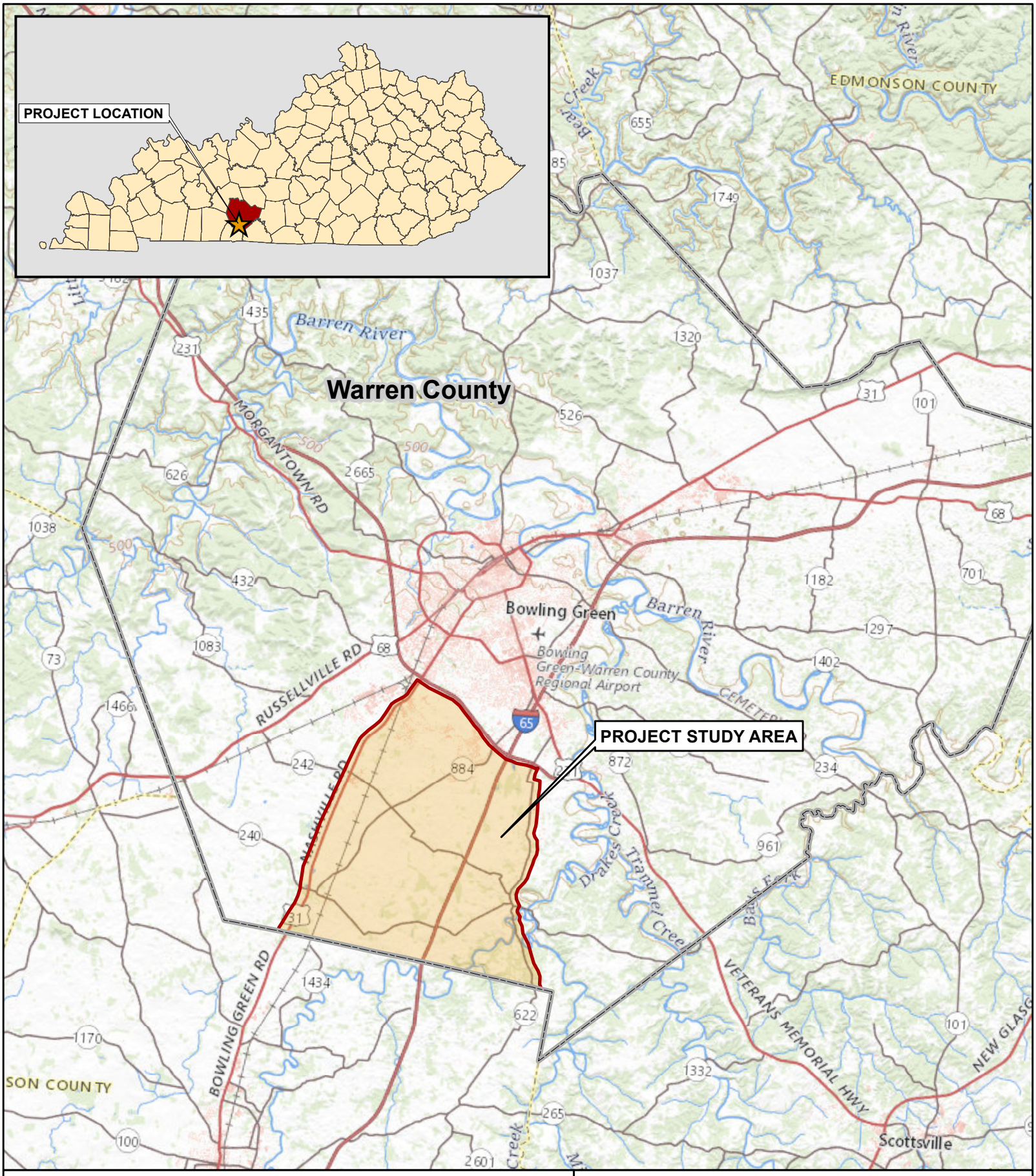
Embankment and subgrade considerations are similar for either new interchange. New embankment construction may only be required at locations where approach embankments need to be enlarged to accommodate the wider structures, and at possible new interchange locations. Embankments constructed of durable rock materials generally exhibit adequate stability at 2H:1V slope ratios. Flatter embankment slopes may be required for higher embankments constructed from nondurable shales or in areas where embankments are founded on alluvial materials. Alluvial soils can be expected along major drainage courses such as the West Drake Creek. Low shear strengths and high settlement potentials are generally associated with alluvial deposits that may require controlled placement of embankment. Consolidation settlements and short-term embankment stability problems are common for roadway embankments in alluvial floodplains. Any saturated, soft, or unstable areas encountered within new embankment foundation or pavement subgrade limits should be drained and stabilized utilizing non-erodible granular embankment or durable limestone from roadway excavation or select rock borrow. Rock may be required to stabilize soft soils and to maintain positive drainage due to the clay soils. Subgrade problems for both pavements and embankment foundations may occur where existing pavement is removed, or embankment foundation construction is performed on the low to medium plastic clays and highly plastic fat clays. The extent of this subgrade stability issues will depend on the time of construction and the seasonal water table fluctuations, therefore, coarse aggregate working platforms and/or geotextiles or other treatment with positive drainage may be needed in some areas during construction.

2.7 Structures

Structures considerations are similar for either of the new interchanges. Bridges and other drainage structures will be required for the new interchange. Reinforced concrete box culverts along the proposed alignment may also need to be replaced or extended. It can be anticipated the culverts within the project corridor are likely supported by either a non-yielding or yielding foundation system. Soil corrosivity testing should be conducted for any new structure. Review of KYTC geotechnical reports

conducted for existing structures indicates that the bridges are supported by rock bearing foundation systems, which include spread footings or steel H-piles driven to bedrock. A detailed geotechnical investigation will be required to determine the foundation support systems for new or widened structures.

Figures



PROJECT STUDY AREA

N

Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.

FIGURE 1:
PROJECT LOCATION MAP
KYTC I-65 NEW INTERCHANGE FEASIBILITY STUDY
WARREN CO., KENTUCKY

0 2 4 6 8 10 Miles

Date: 5/19/2020

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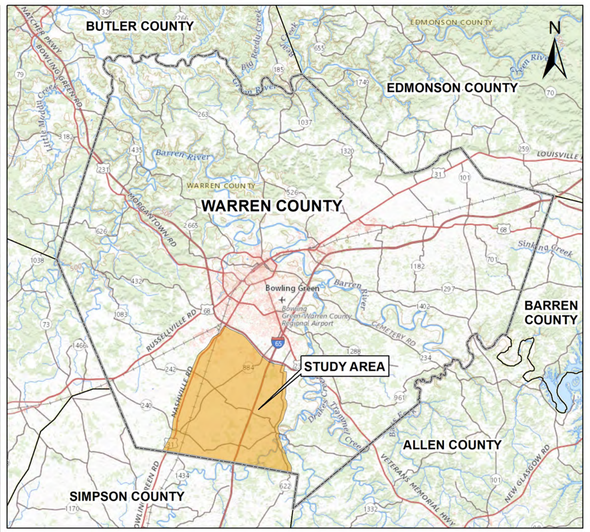
Appendix A
Study Area Overview



Legend - Source

- Study Area Limits
- Incorporated Area

Study Area Target Interchanges

- Carter Sims Road
- KY 242
- KY 240

Notes:

Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.

Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet

KYTC I-65
New Interchange Feasibility Study
Warren Co., Kentucky

APPENDIX A
STUDY AREA OVERVIEW

0 1 2 Miles

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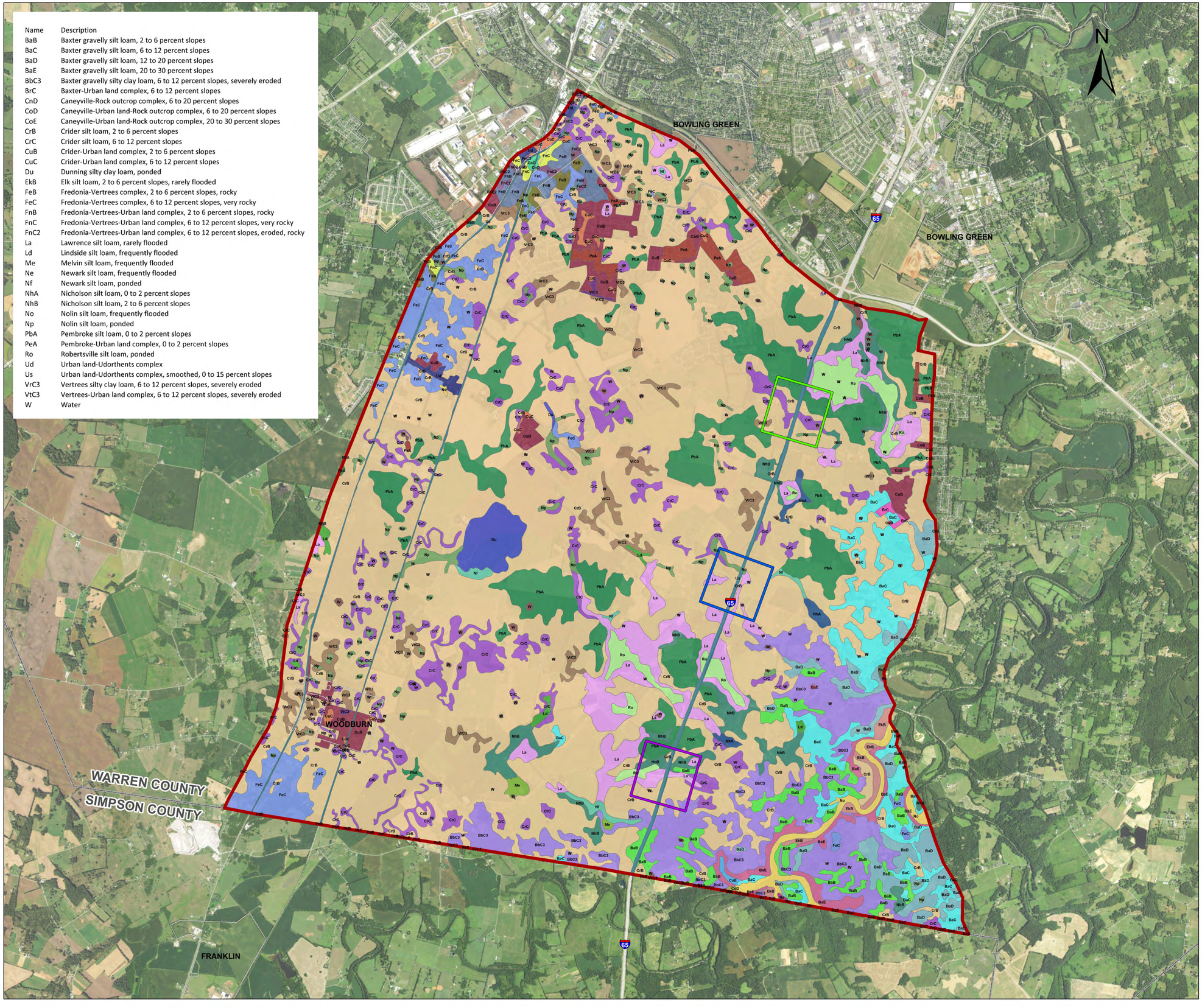
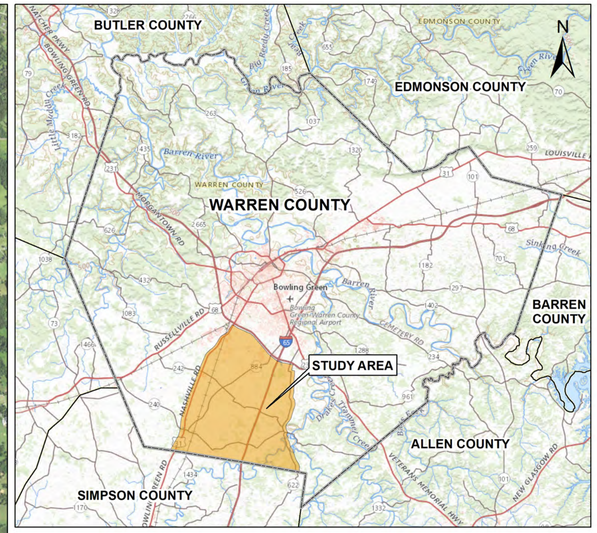
Appendix B
NRCS Soils Overview

Name	Description
BaB	Baxter gravelly silt loam, 2 to 6 percent slopes
BaC	Baxter gravelly silt loam, 6 to 12 percent slopes
BaD	Baxter gravelly silt loam, 12 to 20 percent slopes
BaE	Baxter gravelly silt loam, 20 to 30 percent slopes
BbC3	Baxter gravelly silty clay loam, 6 to 12 percent slopes, severely eroded
BrC	Baxter-Urban land complex, 6 to 12 percent slopes
CnD	Caneyville-Rock outcrop complex, 6 to 20 percent slopes
CoD	Caneyville-Urban land-Rock outcrop complex, 6 to 20 percent slopes
CoE	Caneyville-Urban land-Rock outcrop complex, 20 to 30 percent slopes
CrB	Crider silt loam, 2 to 6 percent slopes
CrC	Crider silt loam, 6 to 12 percent slopes
CuB	Crider-Urban land complex, 2 to 6 percent slopes
CuC	Crider-Urban land complex, 6 to 12 percent slopes
Du	Dunning silty clay loam, ponded
EkB	Elk silt loam, 2 to 6 percent slopes, rarely flooded
FeB	Fredonia-Vertrees complex, 2 to 6 percent slopes, rocky
FeC	Fredonia-Vertrees complex, 6 to 12 percent slopes, very rocky
FnB	Fredonia-Vertrees-Urban land complex, 2 to 6 percent slopes, rocky
FnC	Fredonia-Vertrees-Urban land complex, 6 to 12 percent slopes, very rocky
FnC2	Fredonia-Vertrees-Urban land complex, 6 to 12 percent slopes, eroded, rocky
La	Lawrence silt loam, rarely flooded
Ld	Lindside silt loam, frequently flooded
Me	Melvin silt loam, frequently flooded
Ne	Newark silt loam, frequently flooded
Nf	Newark silt loam, ponded
NhA	Nicholson silt loam, 0 to 2 percent slopes
NhB	Nicholson silt loam, 2 to 6 percent slopes
No	Nolin silt loam, frequently flooded
Np	Nolin silt loam, ponded
PbA	Pembroke silt loam, 0 to 2 percent slopes
PeA	Pembroke-Urban land complex, 0 to 2 percent slopes
Ro	Robertsville silt loam, ponded
Ud	Urban land-Udorthents complex
Us	Urban land-Udorthents complex, smoothed, 0 to 15 percent slopes
VrC3	Vertrees silty clay loam, 6 to 12 percent slopes, severely eroded
VtC3	Vertrees-Urban land complex, 6 to 12 percent slopes, severely eroded
W	Water





Legend - Source

- Study Area Limits
- Incorporated Area

Study Area Target Interchanges

- Carter Sims Road
- KY 242
- KY 240

NRCS Soils

BaB	CoE	FeC	Nf	Ud
BaC	CrB	FnB	NhA	Us
BaD	CrC	FnC	NhB	VrC3
BaE	CuB	FnC2	No	VtC3
BbC3	CuC	La	Np	W
BrC	Du	Ld	PbA	
CnD	EkB	Me	PeA	
CoD	FeB	Ne	Ro	

Notes:

Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.

Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet

KYTC I-65
New Interchange Feasibility Study
Warren Co., Kentucky

APPENDIX B
NRCS SOILS OVERVIEW

0 1 2 Miles

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Appendix C
Geologic Overview

Mgb
BIG CLIFTY SANDSTONE MEMBER

Mg
GIRKIN FORMATION

Msg
Ste. GENEVIEVE LIMESTONE

Qal
ALLUVIUM

Msl
Ste. LOUIS LIMESTONE

Msw
SALEM and WARSAW LIMESTONE

BOWLING GREEN

WOODBURN

FRANKLIN

WARREN COUNTY

SIMPSON COUNTY

FAULT LINE

Limits of
Structure Contouring on Chattanooga Shale

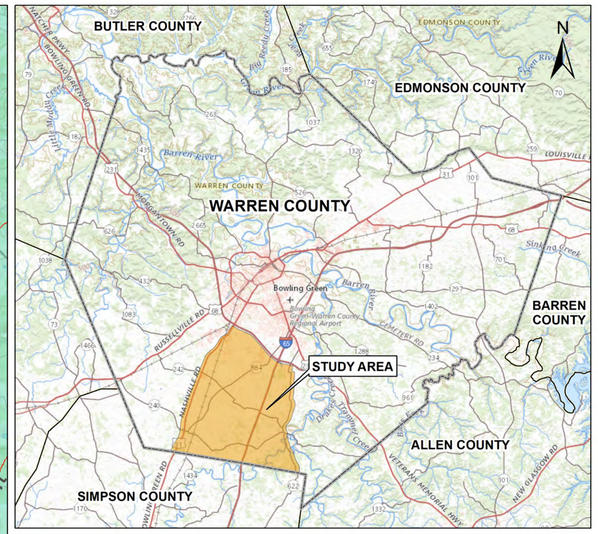
-360 ft
-340 ft
-320 ft
-300 ft
-280 ft
-260 ft
-260 ft
-240 ft
-220 ft
-200 ft
-180 ft
-160 ft
-140 ft
-120 ft
-80 ft
-60 ft
-40 ft
-20 ft
20 ft
40 ft
60 ft
80 ft
100 ft
120 ft
140 ft
160 ft
180 ft
200 ft
220 ft
240 ft
260 ft
280 ft

200 ft TOP Chattanooga Shale

160 ft TOP Chattanooga Shale

0 ft TOP Chattanooga Shale

TOP 100 ft Chattanooga Shale



Legend - Source

- Study Area Limits
- Incorporated Area

Study Area Target Interchanges

Layer

- Carter Sims Road
- KY 242
- KY 240

Geologic Formation Data - Kentucky Geologic Survey

- Boundary
  Limits of Structure Contouring on Chattanooga Shale
- 40 ft — Contour
  Structure Contouring on Top of Chattanooga Shale

Notes:

Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.
Kentucky Geological Survey

Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet

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New Interchange Feasibility Study
Warren Co., Kentucky

APPENDIX C
GEOLOGIC OVERVIEW

0 1 2 Miles

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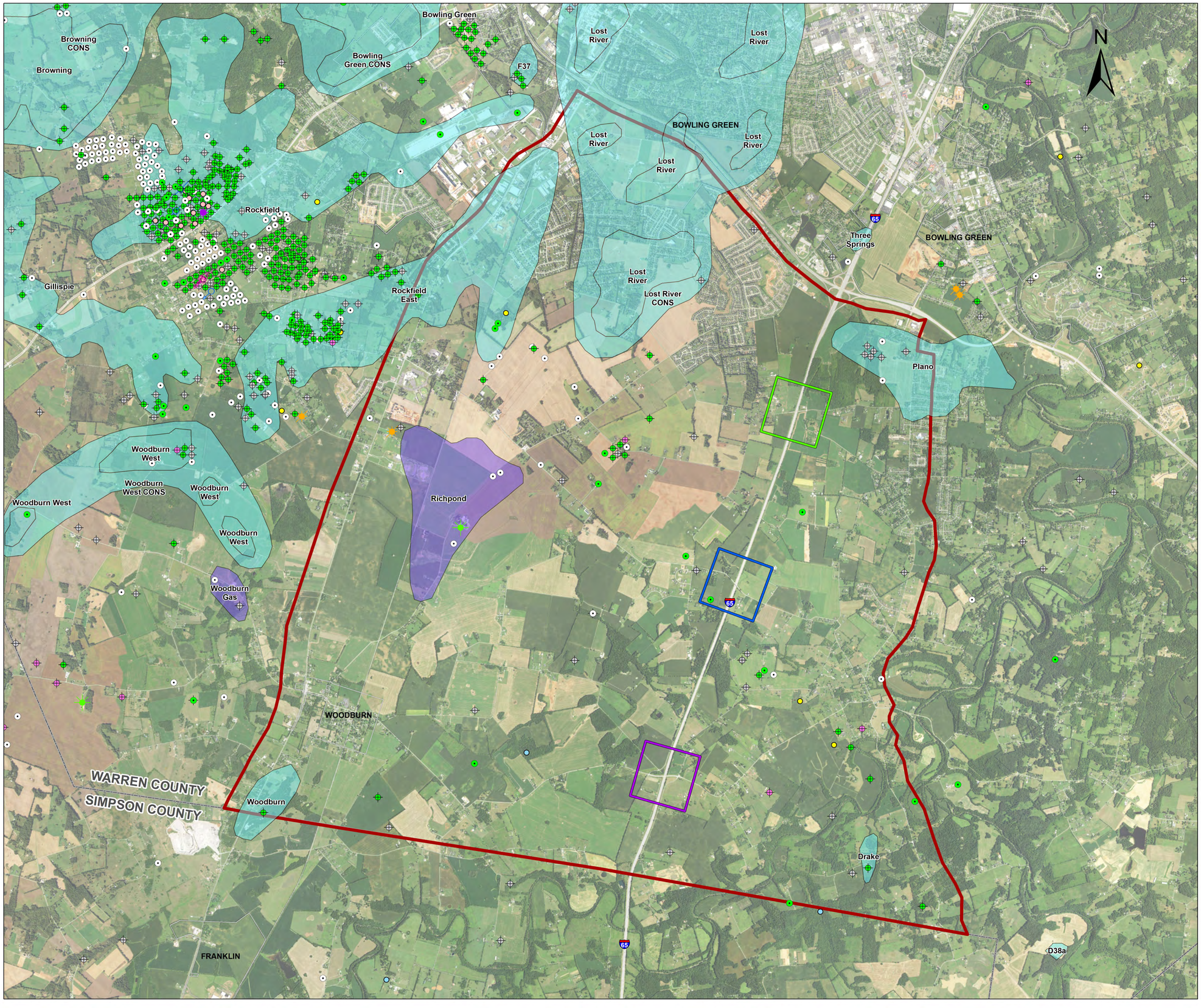
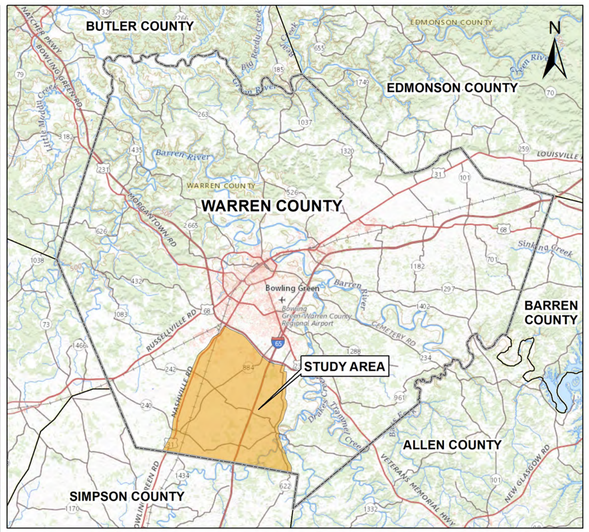
Appendix D
Oil and Gas Well Overview





Legend - Source

- Study Area Limits
- Incorporated Area

Oil and Gas Fields

- Gas
- Oil

Study Area Target Interchanges

- Carter Sims Road
- KY 242
- KY 240

Oil & Gas Wells - Kentucky Geological Survey

No Data	DG	IA	OB
AI	GAS	LOC	OIL
D&A	GI	O&G	SRI
			TRM

AI: Air Injection
D&A: Dry & abandoned
DG: Domestic gas
GAS: Gas producer
GI: Gas injection
IA: Improperly abandoned
LOC: Location (new permit issued or insufficient data)
O&G: Combined oil & gas producer
OB: Observation
OIL: Oil producer
SRI: Secondary recovery injection (Class II)
TRM: Terminated (permit expired or cancelled)

Notes:

Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.

Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet

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New Interchange Feasibility Study
Warren Co., Kentucky

APPENDIX D
OIL and GAS WELL OVERVIEW

0 1 2 Miles

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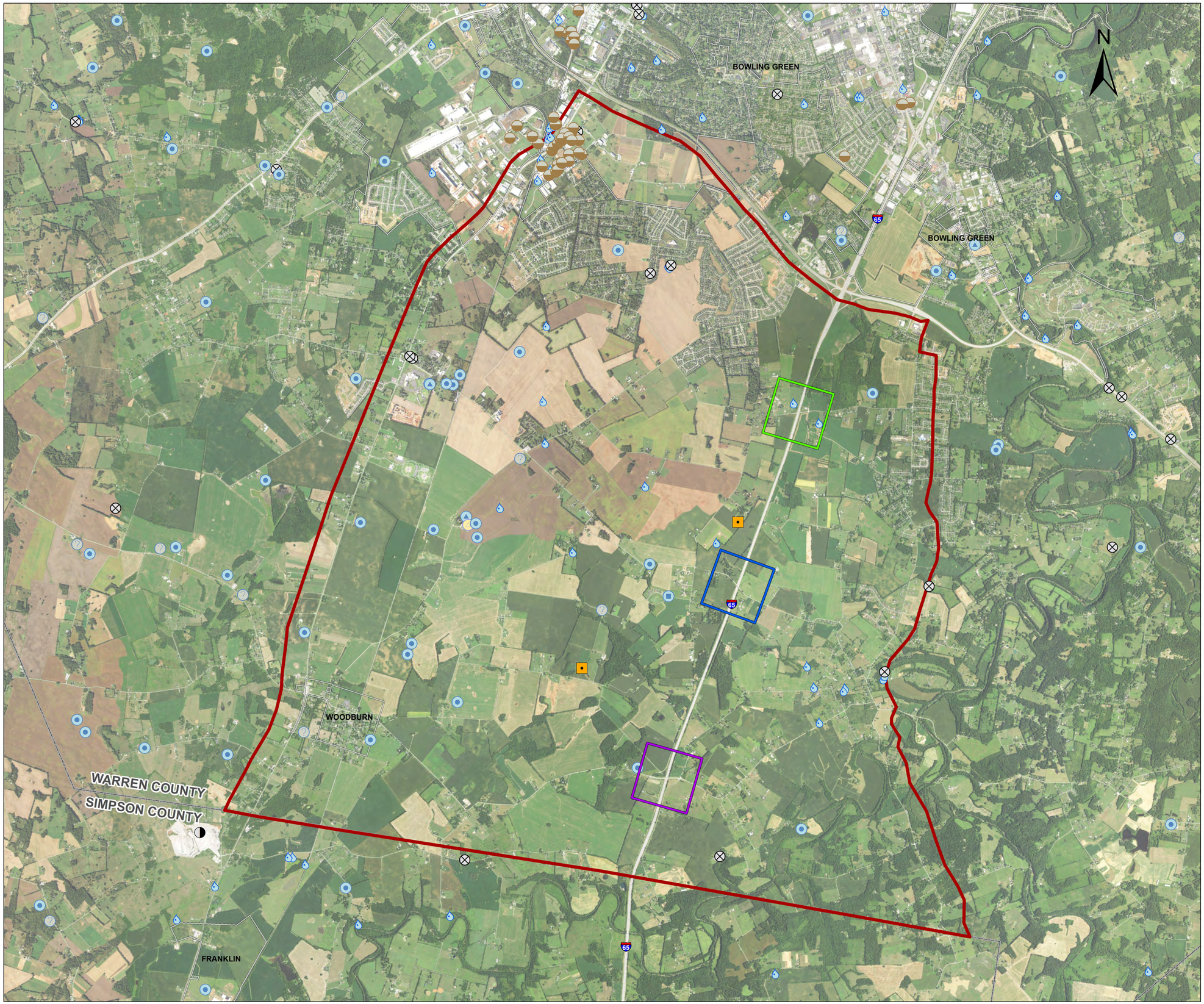
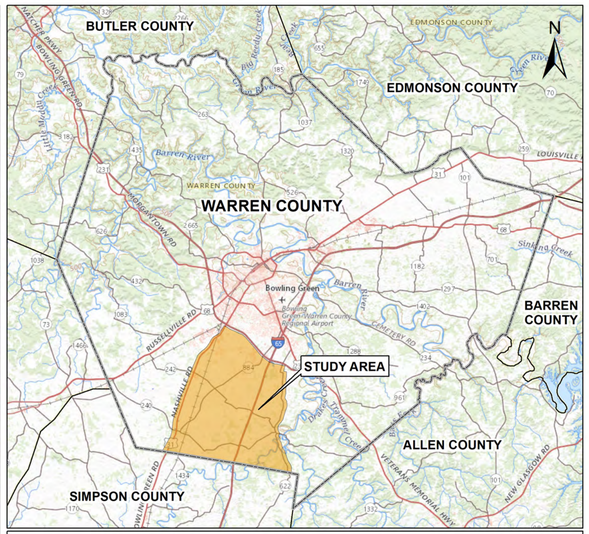
Appendix E
Water Wells and Springs Overview





Legend - Source

- Study Area Limits
- Incorporated Area

Study Area Target Interchanges

- Carter Sims Road
- KY 242
- KY 240

KENTUCKY GEOLOGICAL SURVEY DATA

Waterwells Primary Use

- NO DATA
- AGRICULTURE - ANIMAL AQUACULTURE
- AGRICULTURE - GENERAL
- AGRICULTURE - IRRIGATION
- DOMESTIC - SINGLE HOUSEHOLD
- MINING
- MONITORING WELL - AMBIENT MONITORING
- MONITORING WELL - WATER LEVEL MONITORING ONLY
- UNKNOWN
- UNUSED
- GROUNDWATER SPRINGS

Notes:
Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.

Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet

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Warren Co., Kentucky

APPENDIX E
WATERWELLS AND SPRINGS OVERVIEW

0 1 2 Miles

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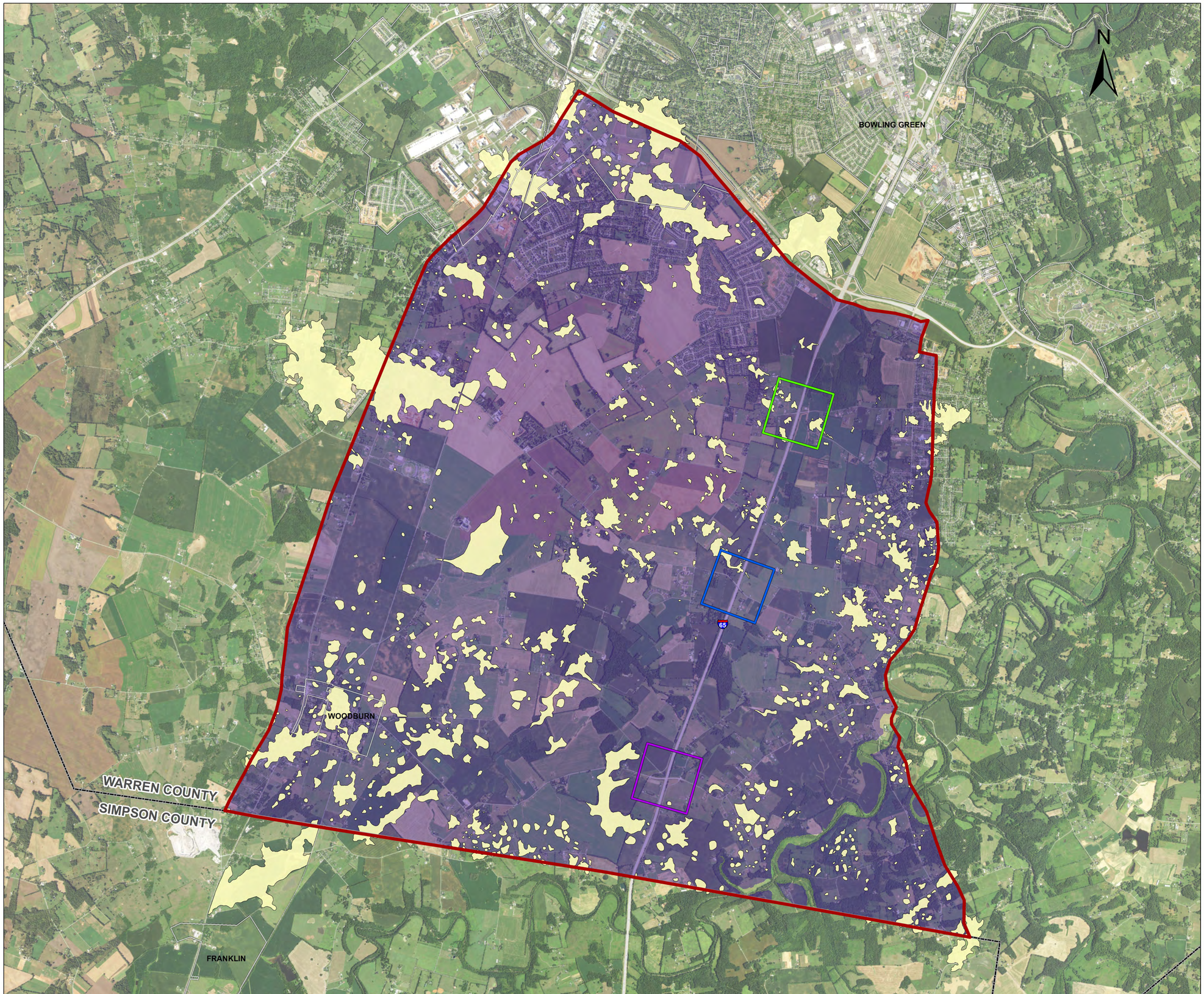
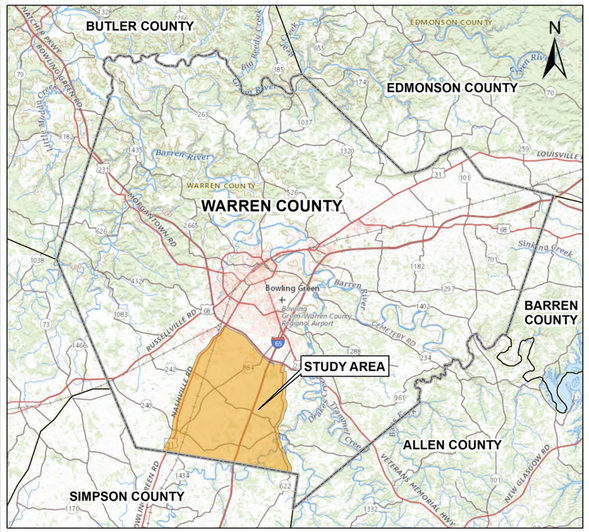
Appendix F
Karst Potential and Sinkholes





Legend - Source

- Study Area Limits
- Incorporated Area
- Identified Sinkholes - Kentucky Geological Survey

Study Area Target Interchanges

- Carter Sims Road
- KY 242
- KY 240
- Karst Potential Very High - Kentucky Geological Survey

Data Clipped at Study Area Limits

Notes:

Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.
Kentucky Geological Survey

Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet

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New Interchange Feasibility Study
Warren Co., Kentucky

APPENDIX F
KARST POTENTIAL and SINKHOLES

0 1 2 Miles

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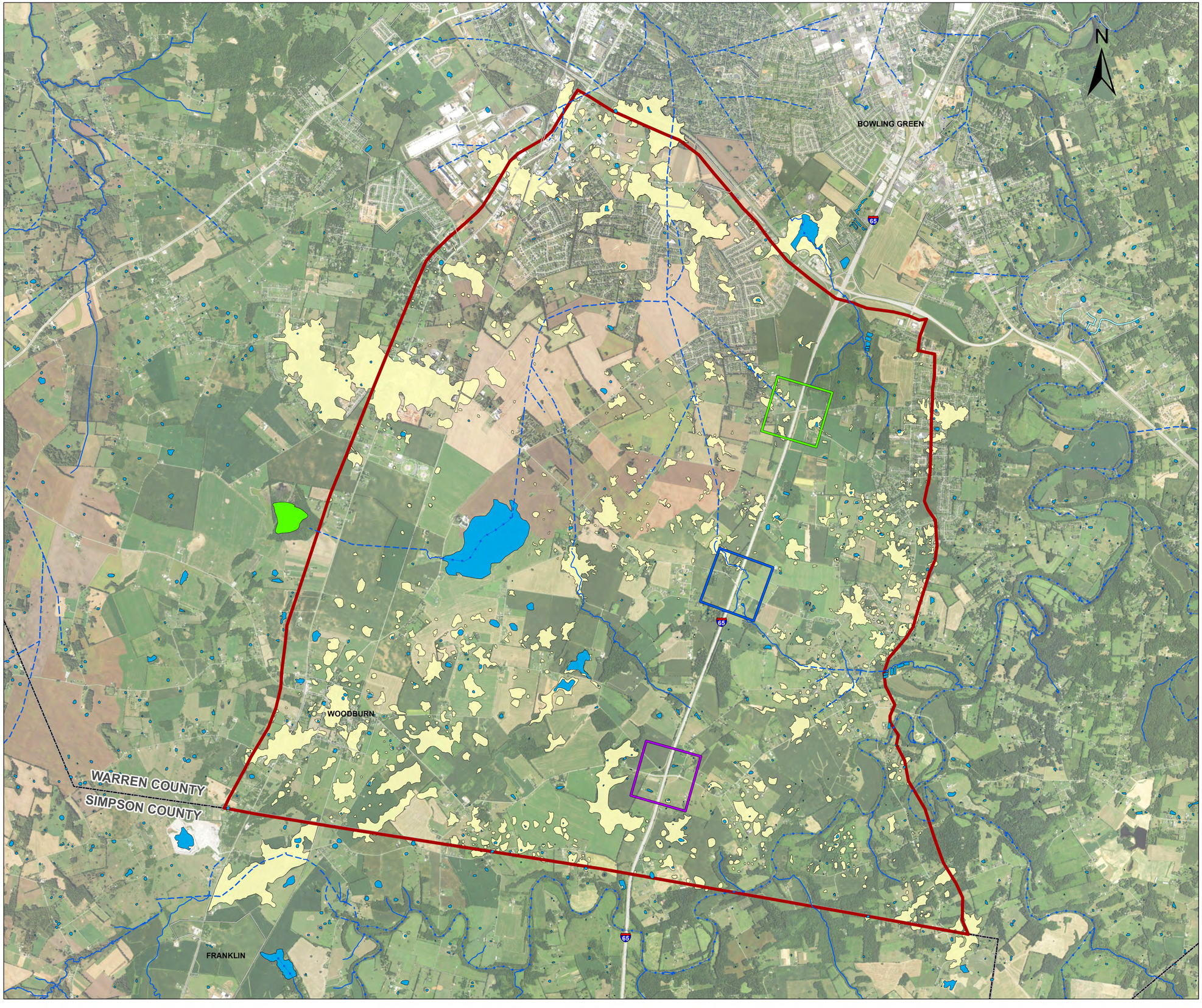
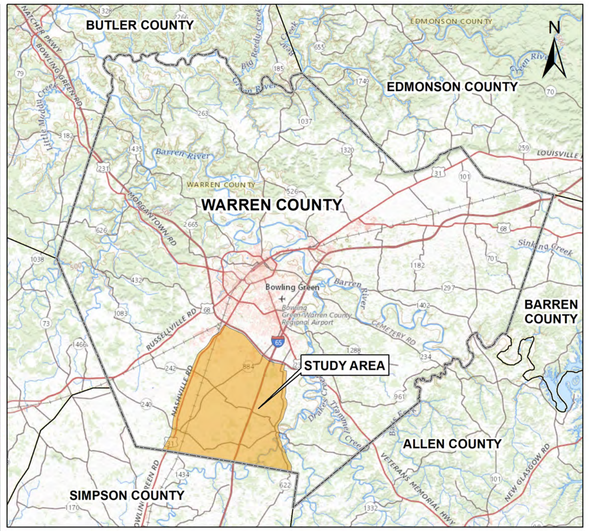
Appendix G
Lakes Streams and Ponds Overview





Legend - Source

- Study Area Limits
- Incorporated Area
- Identified Sinkholes - Kentucky Geological Survey

Study Area Target Interchanges

- Carter Sims Road
- KY 242
- KY 240

Data Clipped at Study Area Limits

NHD Resource - USGS

- Lake - Pond
- Swamp Marsh
- Artificial Path
- Pipeline
- Stream - River
- Underground Conduit

Notes:

Service Layer Credits: USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.

Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet

KYTC I-65
New Interchange Feasibility Study
Warren Co., Kentucky

APPENDIX G
STREAMS - LAKES - PONDS OVERVIEW

0 1 2 Miles

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Appendix H

Generalized Geologic Map

Mgb
BIG CLIFTY SANDSTONE MEMBER

Mg
GIRKIN FORMATION

Msg
Ste. GENEVIEVE LIMESTONE

Qal
ALLUVIUM

Msl
Ste. LOUIS LIMESTONE

Msw
SALEM and WARSAW LIMESTONE

BOWLING GREEN

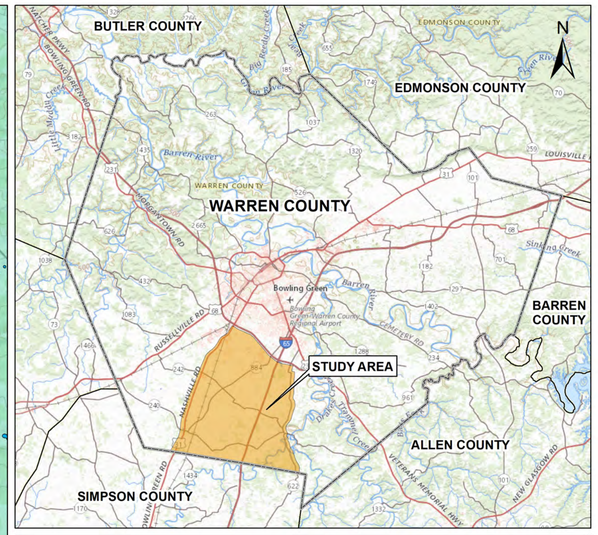
WOODBURN

FRANKLIN

WARREN COUNTY

SIMPSON COUNTY

N



Legend - Source

- Incorporated Area
- Study Area Limits
- Identified Sinkholes - Kentucky Geological Survey
- Sinkhole Drainage Areas - Kentucky Geologic Survey
- Dye Trace Input and RecoveryPoints
- Inferred or Mapped Groundwater Flow Routes

Study Area Target Interchanges

- Carter Sims Road
- KY 242
- KY 240

NHD Resource - USGS

- Artificial Path
- Pipeline
- Stream - River
- Underground Conduit
- Lake - Pond
- Swamp Marsh

Notes:
Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
USGS The National Map: National Boundaries Dataset, 3DEP Elevation Program, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; USGS Global Ecosystems; U.S. Census Bureau TIGER/Line data; USFS Road Data; Natural Earth Data; U.S. Department of State Humanitarian Information Unit; and NOAA National Centers for Environmental Information, U.S. Coastal Relief Model. Data refreshed August, 2019.
Kentucky Geological Survey

Coordinate System: NAD 1983 StatePlane Kentucky FIPS 1600 Feet

KYTC I-65
New Interchange Feasibility Study
Warren Co., Kentucky

APPENDIX H
GENERALIZED GEOLOGIC MAP

0 1 2 Miles

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Date: 5/19/2020

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Appendix I

KGS Generalized Geologic Map for Land-Use Planning:

Warren County, Kentucky

Kentucky Geological Survey
James C. Cobb, State Geologist and Director
UNIVERSITY OF KENTUCKY, LEXINGTON

Generalized Geologic Map for Land-Use Planning: Warren County, Kentucky

E. Glynn Beck, David A. Williams, and Daniel I. Carey

KGS
MAP AND CHART 59
Series XII, 2007

Warren County Courthouse at Bowling Green

Warren County, 545 square miles in the Pennyrile and Western Kentucky Coal Field, was formed in 1797. The slightly rolling karst sinkhole plain in the south has few surface streams and hundreds of sinkholes. Sandstone-capped hills lie to the northwest. The two areas are separated by the Dripping Springs Escarpment, which rises 200 feet above the karst plain, traversing the county from northeast to southwest. The highest point in the county, 955 feet, is Pilot Knob, 2 miles southeast of Smiths Grove. The lowest elevation, 395 feet, is at the confluence of the Barren and Green Rivers. The 2006 population of 99,525, was 7.6 percent greater than that of 2000. Photo by Dan Carey, Kentucky Geological Survey.

Karst Plain

Seen from the sandstone-capped hills of the Dripping Springs Escarpment, the fertile farmland of the limestone (unit 2) karst plain stretches to the south. Photo by Dan Carey, Kentucky Geological Survey.

Oil and Gas

Oil and gas have contributed to the local economy. From 1980 through 2005, 3.4 million barrels of oil and 1.7 billion cubic feet of gas were produced. Photo by Dan Carey, Kentucky Geological Survey.

Mineral Resources

Rinker Materials produces construction aggregate and agricultural lime from the St. Genevieve limestone at this quarry (left) on Barren River Road and another quarry south of Girkin. Aerial photo (2004) by the U.S. Department of Agriculture, Farm Services Administration, National Agricultural Imagery Program.

Water Resources

Warren County is blessed with an abundance of water. The Barren River (left) is one of many streams that provide fishing, boating, and swimming. Photo by Dan Carey, Kentucky Geological Survey.

Groundwater

In karst areas such as Warren County, stormwater runoff can flow underground through large solution channels. This groundwater flow does not follow the topography of the surface, and water from one watershed may flow underground and reappear in an adjacent watershed. A knowledge of the groundwater flow, gained through dye-trace studies, is required to manage storm water and to protect water quality and drinking-water sources. For more information about dye tracing in the area, see Ray and Currens (1998, 2000).

In the upland regions of Warren County more than three-quarters of the drilled wells are adequate for a domestic supply. Yields as high as 50 gallons per minute have been reported from wells penetrating large solution channels. In the northwest corner of the county and in low-lying areas near the Barren River and its main tributaries most wells are inadequate for domestic use, unless the well intercepts a major solution opening in the limestone; in this case, the yield could be very large. Springs with flows ranging from a few gallons per minute to 2,000 gallons per minute are found in the county. Minimum flows generally occur in early fall, maximum flows in late winter.

For more about the groundwater resources of the county, see Carey and Stickney (2004).

Tar-Sands in Western Kentucky

Investigations by the Kentucky Geological Survey have confirmed that major tar-sand resources are present in western Kentucky (Noger, 1999). In-place resources are calculated to be in excess of 3 billion barrels. The principal formations that contain tar-sand deposits (also referred to as asphaltic sandstones, heavy-oil deposits, or bitumen-impregnated sandstones) are the Kyrock, Bee Springs, Tar Springs, Hardinsburg, and Big Clifty Sandstones. Some of these may occur in Logan, Warren, Butler, Edmonson, Hart, Grayson, Breckinridge, and Hardin counties. In Warren County, tar-sands may be present in unit 4. Photo by Randy Bruner.

For more information information on tar-sands, go to kgsweb.uky.edu/PubsSearching/PubsSimpleSearch.asp, keyword= tar sands.

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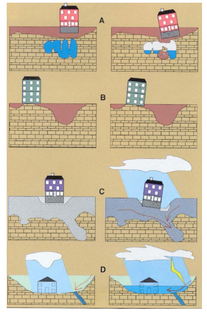
Sandstone (Unit 4) and Shale (Unit 6)

Sandstone (unit 4) overlying shale (unit 6) is exposed along the Natchez Parkway near Butler County. The erosion-resistant sandstone caps the hills (below) north of the Dripping Springs Escarpment. Photos by Dan Carey, Kentucky Geological Survey.

Construction on Karst



Limestone terrain can be subject to subsidence hazards, which usually can be overcome by prior planning and site evaluation. "A" shows construction above an open cavern, which later collapses. This is one of the most difficult situations to detect, and the possibility of this situation beneath a structure warrants insurance protection for homes built on karst terrain. In "B," a heavy structure presumed to lie above solid bedrock actually is partially supported on soft, residual clay soils that subside gradually, resulting in damage to the structure. This occurs where inadequate site evaluation can be traced to lack of geophysical studies and inadequate core sampling. "C" and "D" show the close relationship between hydrology and subsidence hazards in limestone terrain. In "C," the house is situated on porous fill (light shading) at a site where surface- and groundwater drainage move supporting soil (darker shading) into voids in limestone (blocks) below. The natural process is then accelerated by infiltration through fill around the home. "D" shows a karst site where normal rainfall is absorbed by subsurface conduits, but water from infrequent heavy storms cannot be carried away quickly enough to prevent flooding of low-lying areas. Adapted from AIPG (1993).

Limestone (Unit 3)

White, and gray bands of limestone in the 340-million-year-old Mississippian Age Girkin Formation can be seen (right) along the Natcher Parkway. This rock is difficult to excavate. Photo by Dan Carey, Kentucky Geological Survey.

Karst Geology

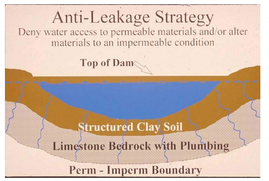
Karst areas (unit 2) are indicated by sinkholes. The term "karst" refers to a landscape characterized by sinkholes, springs, sinking streams (streams that disappear underground), and underground drainage through solution-enlarged conduits or caves. Karst landscapes form when slightly acidic water from rain and snowmelt seeps through soil cover into fractured and soluble bedrock (usually limestone, dolomite, or gypsum). Sinkholes are depressions on the land surface into which water drains underground. Usually circular and often funnel-shaped, they range in size from a few feet to hundreds of feet in diameter. Springs occur when water emerges from underground to become surface water. Caves are solution-enlarged fractures or conduits large enough for a person to enter.

Limestone (Unit 2)

Limestone (unit 2) is exposed along the Natcher Parkway. Water seeps into cracks and crevices, dissolving the limestone and creating underground flow paths, sinkholes, and caves. Photo by Dan Carey, Kentucky Geological Survey.

Major Construction

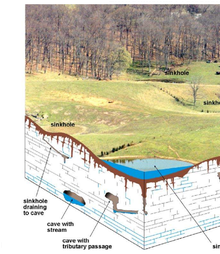
Following geologist's recommendations can help prevent costly construction failures. (Photos above and below courtesy of Richard McGehee, Inspector, Field Operations Branch, Kentucky Division of Water.)



Pond Construction

Successful pond construction must prevent water from seeping through structured soils into limestone solution channels below. A compacted clay liner (left) or artificial liner may prevent pond failure. Getting the basin filled with water as soon as possible after construction prevents drying and cracking, and possible leakage, of the clayey soil liner. Ponds constructed in dry weather are more apt to leak than ponds constructed in wet weather. A geotechnical engineer or geologist should be consulted regarding the requirements of a specific site. Other leakage prevention measures include synthetic liners, bentonite, and asphaltic emulsions. The U.S. Department of Agriculture–Natural Resources Conservation Service can provide guidance on the application of these liners to new construction, and for treatment of existing leaking ponds. Dams should be constructed of compacted clayey soils at slopes flatter than 3 units horizontal to 1 unit vertical. Ponds with dam heights exceeding 25 feet, or pond volumes exceeding 50 acre-feet, require permits. Contact the Kentucky Division of Water, 14 Reilly Rd., Frankfort, KY 40601, telephone: 502.564.3410. Illustration by Paul Howell, U.S.Department of Agriculture–Natural Resources Conservation Service.

Environmental Protection



- Never use sinkholes as dumps. All waste, but especially pesticides, paints, household chemicals, automobile batteries, and used motor oil, should be taken to an appropriate recycling center or landfill.
- Make sure runoff from parking lots, streets, and other urban areas is routed through a detention basin and sediment trap to filter it before it flows into a sinkhole.
- Make sure your home septic system is working properly and that it's not discharging sewage into a crevice or sinkhole.
- Keep cattle and other livestock out of sinkholes and sinking streams. There are other methods of providing water to livestock.
- See to it that sinkholes near or in crop fields are bordered with trees, shrubs, or grass buffer strips. This will filter runoff flowing into sinkholes and also keep tilled areas away from sinkholes.
- Construct waste-holding lagoons in karst areas carefully, to prevent the bottom of the lagoon from collapsing, which would result in a catastrophic emptying of waste into the groundwater.
- If required, develop a groundwater protection plan (410KAR5:037) or an agricultural water-quality plan (KRS224.71) for your land use.

(From Currens, 2001)

Radon

Ventilation system removes radon from the basement area of this home. Photo by Dan Carey, Kentucky Geological Survey.

Radon gas can be a local problem, although it is not widely distributed in Kentucky in amounts above the U.S. Environmental Protection Agency's maximum recommended limit of 4 picocuries per liter. Some areas of Unit 2 may contain high levels of uranium or radium, parent materials for radon gas. Several limestones in the state contain apatite, a phosphate mineral. Uranium is sometimes part of the apatite crystal structure, and when the limestone weathers away the phosphates containing uranium can become concentrated in the soil and ultimately give rise to high levels of radon. A few areas of moderately high radon concentrations are known in the Warren County sinkhole plain. About 60 percent of measured radon values in Unit 2 exceeded EPA limits, ranging from 4 to less than 32 picocuries per liter. Homes in these areas should be tested for radon, but the homeowner should keep in mind that the threat to health results from relatively high levels of exposure over long periods of time, and the remedy may simply be additional ventilation of the home.

Radon Risk If You've Never Smoked

Radon level	If 1,000 people who never smoked were exposed to this level over a lifetime*...	The risk of cancer from radon exposure compares to**...	WHAT TO DO:
20 pCi/L	About 36 people could get lung cancer	35 times the risk of drowning	Fix your home
10 pCi/L	About 18 people could get lung cancer	20 times the risk of dying in a home fire	Fix your home
8 pCi/L	About 15 people could get lung cancer	4 times the risk of dying in a fall	Fix your home
4 pCi/L	About 7 people could get lung cancer	The risk of dying in a car crash	Fix your home
2 pCi/L	About 4 people could get lung cancer	The risk of dying from poison	Consider fixing between 2 and 4 pCi/L
1.3 pCi/L	About 2 people could get lung cancer	(Average indoor radon level)	(Reducing radon levels below 2 pCi/L is difficult.)
0.4 pCi/L		(Average outdoor radon level)	

Note: If you are a former smoker, your risk may be higher.
* Lifetime risk of lung cancer deaths from EPA Assessment of Risks from Radon in Homes (EPA 402-R-03-003).
** Comparison data calculated using the Centers for Disease Control and Prevention's 1999-2001 National Center for Injury Prevention and Control Reports.

The EPA recommends action be taken if indoor levels exceed 4 picocuries per liter, which is 10 times the average outdoor level. Some EPA representatives believe the action level should be lowered to 2 picocuries per liter; other scientists dissent and claim the risks estimated in this chart are already much too high for low levels of radon. The action level in European countries is set at 10 picocuries per liter. Note that this chart is only one estimate; it is not based upon any scientific result from a study of a large population meeting the listed criteria. (From the U.S. Environmental Protection Agency.)

Radon Ventilation

Ventilation system removes radon from the basement area of this home. Photo by Dan Carey, Kentucky Geological Survey.

Source-Water Protection Areas

Source-water protection areas are those in which activities are likely to affect the quality of the drinking-water source. For more information, see kgsweb.uky.edu/download/water/swapp/swapp.htm.

Acknowledgments

Bedrock mapping was adapted from Davidson (2002), Mullins (2002a-f), Thompson (2002a-h), and Toth (2002a-c). Sinkhole data from Paylor and others (2004). Thanks to Richard McGehee, Inspector, Field Operations Branch, Kentucky Division of Water; Paul Howell, U.S. Department of Agriculture-Natural Resources Conservation Service; and Jim Currens, Kentucky Geological Survey, for photographs and illustrations. Thanks to Richard Sergeant, Kentucky Geological Survey, for photo assistance.

Planning Guidance by Rock Unit Type

Rock Unit	Foundation and Excavation	Septic System	Residence with Basement	Highways and Streets	Access Roads	Light Industry and Malls	Intensive Recreation	Extensive Recreation	Reservoir Areas	Reservoir Embankments	Underground Utilities
1. Clay, silt, sand, and gravel (alluvium)	Fair foundation material; easy to excavate.	Severe limitations. Failed septic systems can contaminate groundwater. Refer to soil report (Barton and others, 1981).	Severe limitations. Water in alluvium may be in direct contact with basement. Refer to soil report (Barton and others, 1981).	Moderate to severe limitations. Seasonal high water table. Subject to flooding. Refer to soil report (Barton and others, 1981).	Severe limitations. Seasonal high water table. Subject to flooding. Refer to soil report (Barton and others, 1981).	Severe limitations. Seasonal high water table. Subject to flooding. Refer to soil report (Barton and others, 1981).	Subject to flooding. Poor drainage. Refer to soil report (Barton and others, 1981).	Subject to flooding. Refer to soil report (Barton and others, 1981).	Pervious material. Seasonal high water table. Subject to flooding. Refer to soil report (Barton and others, 1981).	Fair stability. Fair compaction characteristics. Piping hazard. Refer to soil report (Barton and others, 1981).	Moderate to severe limitations. Wetness, flooding. Refer to soil report (Barton and others, 1981).
2. Limestone	Excellent foundation material; difficult to excavate.	Severe limitations. Impermeable rock. Locally fast drainage through fractures and danger of groundwater contamination.	Severe to moderate limitations. Rock excavation; locally, upper few feet may be rippable. Sinks possible; drainage required.	Slight to moderate limitations. Rock excavation; locally, upper few feet may be rippable. Sinks possible; drainage required.	Slight limitations. Local drainage problems from seeps or springs; sinks possible.	Slight to moderate limitations, depending on topography. Rock excavation; locally, upper few feet may be rippable. Sinks possible; local drainage problems.	Severe to slight limitations, depending on activity and topography. Steep slopes.	Slight to moderate limitations, depending on activity and topography.	Severe limitations. Leaky reservoir; locally, conditions may be favorable. Sinks possible.	Severe limitations.	Severe limitations. Rock excavation.
3. Limestone, shale, sandstone, and siltstone	Fair to good foundation material; difficult to excavate.	Severe limitations. Impermeable rock. Thin soils.	Severe to moderate limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Severe limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Moderate limitations. Rock excavation. Steep slopes.	Severe limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Severe to slight limitations, depending on activity and topography. Steep slopes.	Slight to moderate limitations, depending on activity and topography.	Slight limitations. Reservoir may leak where rocks are fractured.	Severe limitations.	Moderate limitations. Highly variable amount of rock and earth excavation.
4. Sandstone	Fair to good foundation material; difficult to excavate.	Severe limitations. Thin soils.	Severe to moderate limitations. Rock excavation; locally, upper few feet may be rippable; steep slopes.	Moderate to severe limitations. Rock excavation; locally, upper few feet may be rippable; steep slopes.	Moderate limitations. Rock excavation. Steep slopes.	Moderate limitations. Rock excavation. Steep slopes.	Severe limitations. Steep slopes.	Slight to moderate limitations, depending on activity and topography.	Moderate limitations; permeable rock.	Severe limitations.	Moderate limitations. Highly variable amount of rock and earth excavation. Steep slopes.
5. Shale, siltstone, limestone, coal, underclay, and conglomerate	Fair to good foundation material; difficult to excavate.	Severe to moderate limitations. Rock excavation; locally, upper few feet may be rippable; steep slopes.	Severe limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Severe limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Moderate limitations. Rock excavation. Steep slopes.	Severe limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Severe limitations. Steep slopes.	Moderate to slight limitations, depending on activity and topography.	Slight limitations. Reservoir may leak where rocks are fractured.	Severe limitations.	Moderate limitations. Highly variable amount of rock and earth excavation.
6. Sandstone, siltstone, thin limestone, and shale	Fair to good foundation material; difficult to excavate.	Severe limitations. Thin soils and low permeability.	Severe to moderate limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Severe limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Moderate limitations. Rock excavation. Steep slopes.	Severe limitations. Rock excavation; locally, upper few feet may be rippable. Steep slopes.	Severe limitations. Steep slopes.	Slight to moderate limitations, depending on activity and topography.	Slight limitations. Reservoir may leak where rocks are fractured.	Severe limitations.	Moderate limitations. Highly variable amount of rock and earth excavation.
7. Rock fragments mixed with clay	Severe limitations. Unstable materials.	Severe limitations.	Severe limitations.	Severe limitations.	Severe limitations.	Severe limitations.	Severe limitations.	Severe limitations.	Severe limitations.	Severe limitations.	Moderate limitations. Unstable materials. Sparks when struck by heavy equipment; explosion hazard if natural gas present.

LAND-USE PLANNING TABLE DEFINITIONS

FOUNDATION AND EXCAVATION

The terms "earth" and "rock" excavation are used in the engineering sense; earth can be excavated by hand tools, whereas rock requires heavy equipment or blasting to remove.

LIMITATIONS

Slight—A slight limitation is one that commonly requires some corrective measure but can be overcome without a great deal of difficulty or expense.

Moderate—A moderate limitation is one that can normally be overcome but the difficulty and expense are great enough that completing the project is commonly a question of feasibility.

Severe—A severe limitation is one that is difficult to overcome and commonly is not feasible because of the expense involved.

LAND USES

Septic tank disposal system—A septic tank disposal system consists of a septic tank and a filter field. The filter field is a subsurface tile system laid in such a way that effluent from the septic tank is distributed with reasonable uniformity into the soil.

Residences—Ratings are made for residences with basements because the degree of limitation is dependent upon ease and required depth of excavation. For example, excavation in limestone has greater limitation than excavation in shale for a house with a basement.

Highways and streets—Refers to paved roads in which cuts and fills are made in hilly topography, and considerable work is done preparing subgrades and bases before the surface is applied.

Access roads—These are low-cost roads, driveways, etc., usually surfaced with crushed stone or a thin layer of blacktop. A minimum of cuts and fills are made, little work is done preparing a subgrade, and generally only a thin base is used. The degree of limitation is based on year-around use and would be less severe if not used during the winter and early spring. Some types of recreation areas would not be used during these seasons.

Light industry and malls—Ratings are based on developments having structures or equivalent load limit requirements of three stories or less, and large paved areas for parking lots. Structures with greater load limit requirements would normally need footings in solid rock, and the rock would need to be core drilled to determine the presence of caverns, cracks, etc.

Intensive recreation—Athletic fields, stadiums, etc.

Extensive recreation—Camp sites, picnic areas, parks, etc.

Reservoir areas—The floor of the area where the water is impounded. Ratings are based on the permeability of the rock.

Reservoir embankments—The rocks are rated on limitations for embankment material.

Underground utilities—Included in this group are sanitary sewers, storm sewers, water mains, and other pipes that require fairly deep trenches.

Karst Plain

Seen from the sandstone-capped hills of the Dripping Springs Escarpment, the fertile farmland of the limestone (unit 2) karst plain stretches to the south. Photo by Dan Carey, Kentucky Geological Survey.

APPROXIMATE STUDY AREA

7.5-Minute Quadrangle Map Index

Geology of Kentucky

Learn more about Kentucky geology at www.uky.edu/KGS/geoky/

Additional Resources

Listed below are Web sites for several agencies and organizations that may be of assistance with landuse planning issues in Warren County:

www.warrencountyky.com/—Warren County
www.bgky.org/—City of Bowling Green
ces.ca.uky.edu/warren/—University of Kentucky Cooperative Extension Service
www.bradd.org/—Barren River Area Development District
www.thinkkentucky.com/EDIS/cmnty/index.aspx?cw=067—Kentucky Economic Development Information System
www.uky.edu/KGS/gis/atlas/21227.html—Kentucky Atlas and Gazetteer
quickfacts.census.gov/qfd/states/21/21227.html—U.S. Census Data
kgsweb.uky.edu/download/kgsplanning.htm—Planning information from the Kentucky Geological Survey

Mapped Surface Faults

Faults are common geologic structures across Kentucky, and have been mapped in many of the Commonwealth's counties. The faults shown on this map are part of the Pennyrile Fault System, which is not considered to be active. Earthquake damage in Warren County is still a possibility, however. Soil creep, slumps, and landslides along steep slopes may occur from erosion or ground motion associated with a strong earthquake. Areas associated with alluvium (Unit 1) are subject to liquefaction during a strong earthquake. Faults may be associated with increased fracturing of bedrock in the immediately adjacent area. This fracturing may influence slope stability and ground-water flow in these limited areas.

Michael Baker
INTERNATIONAL

We Make a Difference

Appendix J
KGS Generalized Block Diagram
of
Western Pennyroyal Karst.

Kentucky Geological Survey
James C. Cobb, State Geologist and Director
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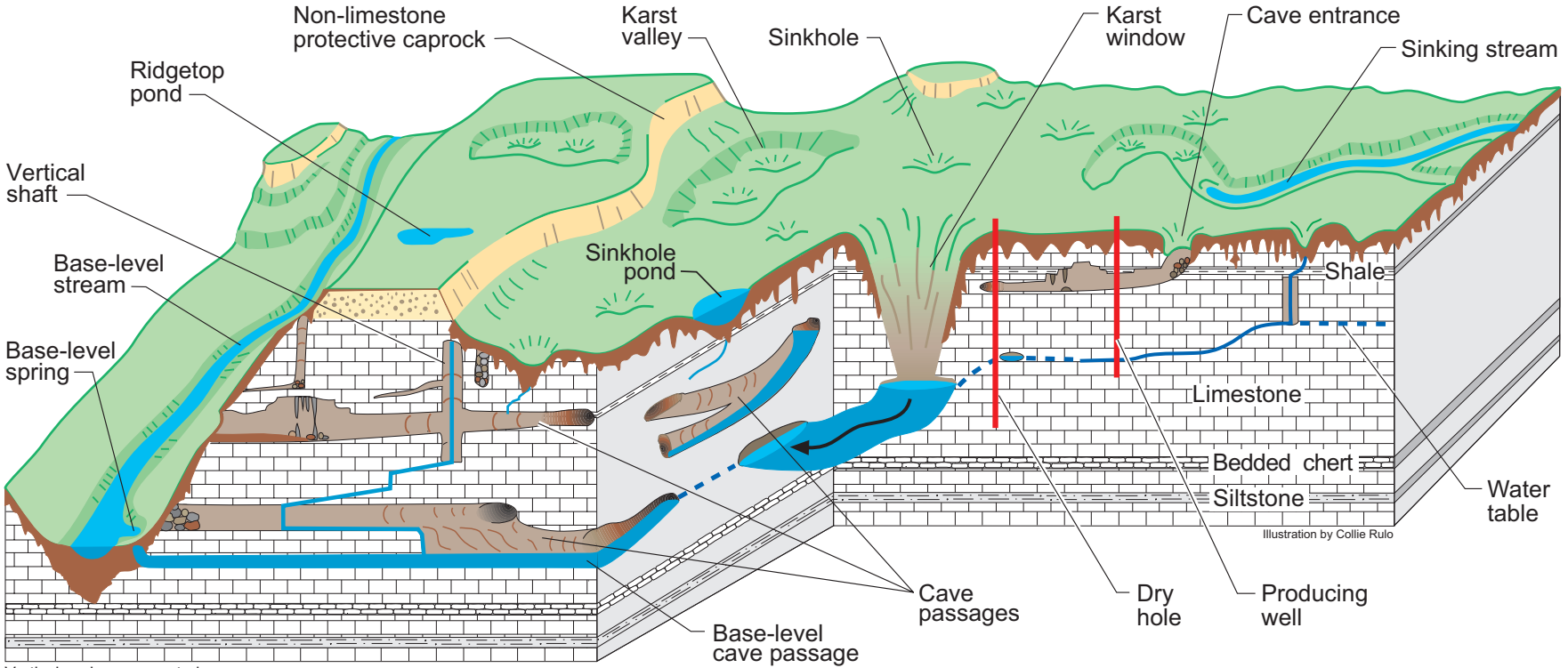
Generalized Block Diagram of the Western Pennyroyal Karst

James C. Currens

MAP AND CHART 16
Series XII, 2001



Western Pennyroyal karst:

Karst occurs where limestone or other soluble bedrock is near the earth's surface, and fractures in the rock become enlarged when the rock dissolves. Sinkholes and sinking streams are two surface features that indicate karst development. In karst areas most rainfall sinks underground, resulting in fewer streams flowing on the surface than in non-karst settings. Instead of flowing on the surface, the water flows underground through caves, sometimes reemerging at karst windows, then sinks again to eventually discharge at a base-level spring along a major stream or at the top of an impermeable strata. The development of karst features is influenced by the type of soluble rock and how it has been broken or folded by geologic forces. There are four major karst regions in Kentucky: the Inner Bluegrass, Western Pennyroyal, Eastern Pennyroyal, and Pine Mountain. This diagram depicts the Western Pennyroyal karst.

Many of the conditions needed for long cave systems occur in the Western Pennyroyal. These include a thick block of pure limestone, a high rainfall rate, higher elevation areas draining toward a major stream, rocks dipping toward the stream, and large areas of the limestone protected from erosion at the surface by overlying insoluble rocks. In the Mammoth Cave area, all of these conditions are found together, which resulted in Mammoth Cave, the longest known cave system in the world at 350 miles! As erosion on the surface continues over geologic time, the major stream draining a karst terrane cuts its channel deeper. In response, deeper conduits increase their flow to the major stream and new springs develop at lower elevations along the stream's banks. Older, higher flow routes are left as dry cave passages, some of which become sediment filled. To produce significant amounts of water, wells drilled into karst aquifers must intersect a set of enlarged fractures, a dissolution conduit, or a cave passage with an underground stream.

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Historic Architectural Overview

The objective of this historic architectural overview is to locate and document historic-age (50 years) above-ground properties (buildings, structures, districts, and objects) that may be eligible for listing in the National Register of Historic Places (NRHP) under Criterion C. Due to the limitations of this study and the vast number of resources within the Study Area, historical significance under Criteria A, B, and D was not evaluated.

Literature Review/ Previous Investigations

On May 1, 2020, an architectural historian from Michael Baker International, Inc. (Michael Baker) submitted a Project Review Form and online request for GIS/PDF report of previously identified above-ground, historic-age properties to the Kentucky Heritage Council (KHC). On May 7, 2020, KHC returned the results of the file search request including a PDF and shapefiles.

The search results listed **233** previously identified above-ground properties within the study area, including 112 coded properties (see **Appendix 3, Attachment A, Table 1**) and 121 inventoried properties (see **Appendix 3, Attachment A, Table 2**). Coded properties are those that were part of an informal survey effort (often decades old) and do not have a corresponding site form. *Official site numbers will need to be requested for these resources during future phases of the historic properties survey effort.* In 14 instances, a coded resource was also given an official site number, in which case a single property was counted twice (duplicate resources are listed in **Appendix 3, Attachment A, Table 3**). In sum, there is a total of 219 previously identified above-ground properties within the study area.

- 112 Coded Properties +
- 121 Inventoried Properties

= 233 Previously identified properties points (as per KHC file search)

= **219 TOTAL** (less duplicate resources)

Cemeteries: Ten cemeteries were identified within the previous survey results, several of which are associated with nearby churches, some are family plots on private properties, and at least one has been relocated. The previously identified cemeteries are listed in **Appendix 3, Attachment A, Table 4.**

- 10 Cemeteries

National Register Listed and Eligible Properties: The survey results indicated the presence of four NRHP-listed properties and one (1) NRHP-eligible property. Based on aerial photographs, it seems likely that at least one of the NRHP-listed properties has been demolished (WA 115, William P. Neale House). This assumption should be confirmed in the field. NRHP-listed and eligible properties are listed in **Appendix 3, Attachment A, Table 5.**

- 3 Extant NRHP-Listed Properties
- 1 Demolished NRHP-Listed Property
- 1 NRHP-Eligible Property

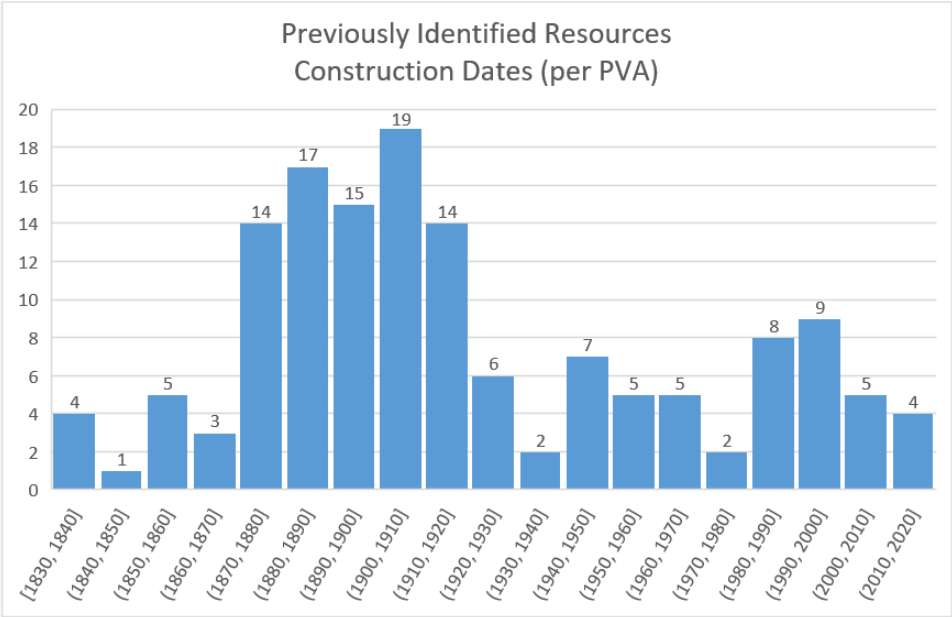
Demolished Properties: For each of the previously identified above-ground properties, the project architectural historian used assessment records provided through the Warren County, Kentucky, Property Valuation Administrator (PVA) (http://www.warrencountyky.gov/pva) to supplement existing survey information in terms of address, year of construction (if applicable), and photographs. In addition, the architectural historian referenced current and past aerial photographs and Google Street View images to affirm the status of each of the properties where possible. Photographs of each of the previously identified above-ground properties (as available) are provided in **Appendix 3, Attachment B.** As a result of this effort, previously identified above-ground properties that are no longer extant were notated as such and a documentary screenshot was captured, where available. 44 previously identified above-ground properties within the study area have been demolished since the time of initial survey (see **Appendix 3, Attachment A, Table 6** for demolished properties).

- 44 Demolished Properties

Modern Properties: Within the previously identified survey results from KHC, several of the buildings appear to be modern (constructed after 1970). It is possible the original surveyors documented resources despite their age, or more likely, the historic-age building was demolished and replaced with a new building. In some instances, the construction date on the PVA assessment is wrong, and the building is, in fact, historic age. Approximately 28 previously identified above-ground properties fall into this category. These are notated in **Appendix 3, Attachment A, Tables 1 and 2,** and demarked through a recent date in the "Year on Assessment" column.

- 28 Modern Properties

The previously identified above-ground properties were constructed between 1830 and 2016 (as per assessment records). As mentioned above, approximately 28 of these were built after 1970. The majority of the previously identified above-ground properties were constructed between 1870 and 1920, indicating that early survey efforts did not focus on Mid-Century buildings. It is also worth noting that the PVA assessment data does not provide accurate construction dates for all buildings. Many dates provided are likely estimated dates of construction.



Newly Identified Above-Ground Properties

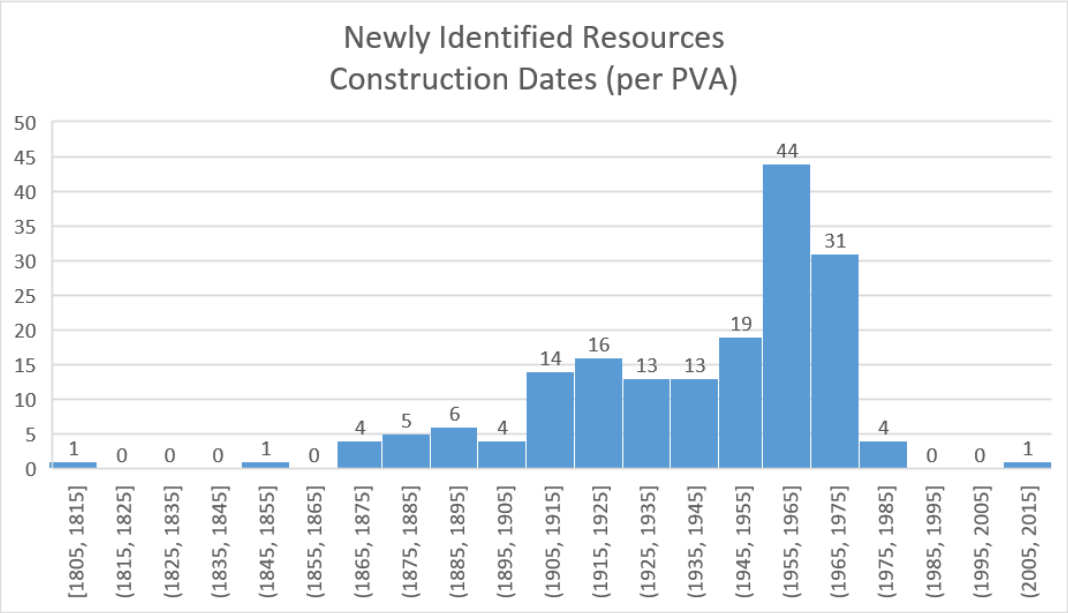
The objective of this project is to locate and document above-ground properties (buildings, structures, districts, and objects) that are 50 years old or older in the study area that may be eligible for listing in the NRHP under Criterion C. The following text summarizes the newly identified above-ground properties within the study area.

Methodology: The architectural historian utilized historic United States Geological Survey (USGS) topographic quadrangles overlaid with current aerial photographs to pinpoint buildings that likely meet the 50-year age threshold. In addition, assessment records provided through the Warren County, Kentucky PVA provided estimated construction dates for most of the buildings in the study area. A combination of these sources, coupled with historic aerial photography when needed, provided the basis for determining locations (and approximate ages) of historic-age, above-ground properties.

Newly Identified Above-Ground Properties: The desktop survey resulted in the identification of 224 additional above-ground properties within the study area (Appendix 3, Attachment A, Table 7). Photographs of each resource are provided in Appendix 3, Attachment C. These properties are primarily residential (161, or 72 percent), followed by those zoned as "Farms" (41, or 18 percent). Of course, many of the farms also have residences, so this number is somewhat misleading. The study area contains two newly identified religious properties (churches) and 14 cemeteries (Appendix 3, Attachment A, Table 8). While the cemeteries appear on the USGS topographic quadrangle maps, some were difficult to see on an aerial photograph. Therefore, all the cemetery locations should be field checked to confirm their existence.

The newly identified above-ground resources within the study area were constructed between 1805 and 2011 (as per assessment records). Six identified resources with post-1970 assessment dates appear to

have historic-age buildings, and were therefore included in this overview. Similarly, the 1805 date may be an outlier. Newly identified cemeteries were not assigned dates.



Summary and Recommendations

This desktop survey and overview report identified 219 previously identified above-ground properties and 224 newly identified above-ground properties totaling 443 above-ground properties. This includes 24 cemeteries. Based on preliminary review of photographs and probable construction dates, an intensive-level survey is not necessary for most of the properties. This includes any properties that have been demolished, any properties that are not 50-years of age (modern), any properties that do not appear to meet Criterion C of the NRHP, and/or those that do not retain sufficient historic integrity.

The following properties have the potential for NRHP-eligibility under Criterion C (or are already NRHP-listed). Therefore, an intensive-level survey is recommended for any of the following resources that may be affected by project activities.

1) NRHP-Listed Properties (4) -- Resurvey and document existing conditions, including any demolitions.

2) NRHP-Eligible Properties (1) -- Survey and evaluate NRHP criteria for eligibility, as resource was previously determined NRHP eligible.

3) Cemeteries (24) – Locate and document cemeteries according to KHC guidelines and survey requirements.

4) Bridges (1) – Locate and document historic bridges according to KHC guidelines and survey requirements. Only one bridge has been identified within the study area thus far (WAB 1047).

5) Resources with Criterion C Potential (21) – Conduct intensive-level survey where property is potentially affected by the proposed undertaking. See **Appendix 3, Attachment A, Table 9** for a list of these properties, and **Appendix 3, Attachment D** for an informative summary of each property.

6) Potential Historic Districts (1) – if the Woodburn community has the potential to be affected under any of the project alternatives, it should be evaluated for its historic district potential.

7) No Photo Resources – Any historic-age above-ground properties that have not been photographed should be visually inspected in the field, where they have the potential for effect under any of the project alternatives.

Potential Interchange Locations: Within the potential interchange locations, there are five previously identified historic resources, three newly identified historic-age resources, and one cemetery. The three newly identified historic resources are recommended for no further study (ID #s 061, 063, and 140). The newly identified cemetery (ID #062) should be surveyed prior to any construction activities. Of the previously identified resources, two are demolished (11400070 and 11400290), one is recommended for no further study (11400261), and two warrant additional study. The following two resources *may* be eligible for listing in the NRHP: (11400278, 5037 Richpond Road and WA 107, the Jesse R. Kirby House).

Summary:

- 112 Previously Identified (Coded Properties)
- 121 Previously Identified (KHC Inventoried Properties)
- 10 Previously Identified (Cemeteries)
- 4 Previously Identified (NRHP-Listed Properties)
- 1 Previously Identified (NRHP-Eligible Properties)
- 44 Previously Identified (Demolished Properties)
- 28 Previously Identified (Modern Properties)
- 224 Newly Identified (Total)
- 14 Newly Identified (Cemeteries Only)
- 21 Properties that Warrant Additional Research