2006

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

Daniel I. Carey
University of Kentucky, daniel.carey@uky.edu

Joseph Buckles
University of Kentucky

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

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

Daniel I. Carey
Kentucky Geological Survey
and
Joseph Buckles
University of Kentucky

https://doi.org/10.13023/kgs.mc137.12
MAP AND CHART 137
Series XII, 2006

Fleming County Courthouse at Flemingsburg

Fleming County, an area of 351 square miles in the Outer Bluegrass Region, was formed in 1798. Western Fleming County is characterized by gently rolling hills and mild local relief. East of a line between Hillsboro and Mount Carmel is an escarpment. Slopes are steep. The highest elevation in the county is over 1,420 feet, a knob on the Fleming/Rowan County line about 3 miles southeast of Plummers Landing. The lowest elevation is 590 feet where the Licking River leaves the county. The 2004 county population of 14,480 was 5 percent greater than the population in 2000. Photo by Dan Carey, Kentucky Geological Survey.

Rural Residential Development

A growing population is spreading across the county. This residential development is north of Flemingsburg off Ky. 11. Photo by Dan Carey, Kentucky Geological Survey.

Agriculture

Limestone-shale terrain (unit 3) provides soils for rich pasturelandand attractive sites for rural residential development. Thoughtful planning can minimize conflicting community interests. Photo by Dan Carey, Kentucky Geological Survey.

Covered Bridges

The Grange City covered bridge over Fox Creek is one of several such bridges in the county, survivors from a time of slower pace. Photo by Dan Carey, Kentucky Geological Survey.

For Planning Use Only

This map is not intended to be used for selecting individual sites. Its purpose is to inform land-use planners, government officials, and the public in a general way about geologic bedrock conditions that affect the selection of sites for various purposes. The properties of thick soils may supersede those of the underlying bedrock and should be considered on a site-to-site basis. At any site, it is important to understand the characteristics of both the soils and the underlying rock. For further assistance, contact the Kentucky Geological Survey, 859.257.5500. For more information, and to make custom maps of your area, visit the KGS Land-Use Planning Internet Mapping Web Site at kgsmap.uky.edu/website/lkyluplan/viewer.htm.

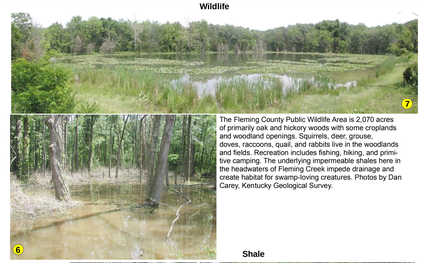
Acknowledgments

Geology adapted from Murphy (2005a-c), Murphy and Petersen (2005a, b), Nelson and Petersen (2005), Palmgreen (2005), Palmgreen and Murphy (2005), Petersen (2005, 2006), Toth (2006), and Zhang (2005a-c). Mapped sinkholes from Paylor and others (2004).

Mineral Resources

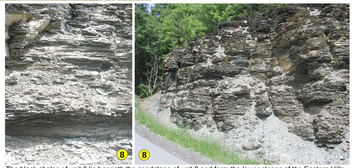
Hanson Aggregates Midwest Inc. operates the Flemingsburg Quarry near Fleming Creek south of Flemingsburg. Agricultural lime and construction aggregate are quarried from unit 4. Aerial photo (2004) by the U.S. Department of Agriculture, Farm Services Administration, National Agricultural Imagery Program.

Wildlife



The Fleming County Public Wildlife Area is 2,070 acres of primarily oak and hickory woods with some croplands and woodland openings. Squirrels, deer, grouse, doves, raccoons, quail, and rabbits live in the woodlands and fields. Recreation includes fishing, hiking, and primitive camping. The underlying impermeable shales here in the headwaters of Fleming Creek impede drainage and create habitat for swamp-loving creatures. Photos by Dan Carey, Kentucky Geological Survey.

Shale



The black shales of unit 6 lie beneath the sandstone of unit 8 and form the lower slopes of the Eastern Hills. These shales provide poor support and contain iron pyrite, which causes them to swell when wet and shrink when dry. Note the vertical fissures in the photo above. The extraction of shale oil from this formation may someday be economically viable. Photos by Dan Carey, Kentucky Geological Survey.

Slope Stability

Shales provide a poor foundation, particularly when drainage is not properly managed. Road slumps, such as this one on Ky. 559, can be an ongoing maintenance problem. Photo by Dan Carey, Kentucky Geological Survey.

Sandstone

This outcrop along Ky. 1013 shows the 300-million-year-old sandstone (unit 9) that provides the resistant caprock for the distinctive hills of eastern Fleming County. Photo by Dan Carey, Kentucky Geological Survey.

Eastern Hills

The Eastern Hills, composed of units 5, 7, and 8, loom on the horizon. Photo by Dan Carey, Kentucky Geological Survey.

Slope Failure

Mass movements or landslides of surficial materials are frequent and costly geologic hazards in the northeastern Kentucky area. Northern Kentucky has the greatest monetary loss per capita caused by landslides in the country. The failure of the slope may be rapid, but more commonly is a slow almost imperceptible movement, called creep, of a few inches per year. Whether rapid or slow, the end results and damage are similar and costly; broken plumbing, cracked walls and foundations, cracked streets and sidewalks, and commonly total loss of the structures.

Virtually all units containing shale on slopes are subject to landslides.

Clay shales of unit 7 become plastic when wet and present particularly difficult problems for excavations and foundations. An engineering geologist or a geotechnical engineer should be consulted when clay shales are present.

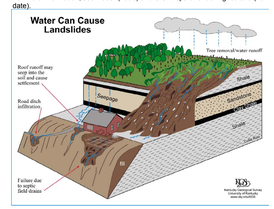
Gravity is the main driving force, but water nearly always plays a critical role by adding weight and lubricating the particles in the weathered shale. Cutting into or overloading a slope with structures and fill can also be major contributing factors.

Precautions include taking care of all surface-water runoff by making certain that all runoff from roofs, gutters, patios, sidewalks, and driveways is carried well away from and not toward the house; diverting drainage from areas sloping toward the house; cutting into natural slopes as little as possible and avoiding the use of fill; and trying to place the foundation of the structure on undisturbed bedrock.

When in doubt, consult an engineering geologist or a geotechnical engineer. Relict landslides can also be easily reactivated. Look for unusual bulges or cracks in the slope, tilted or curved trees, springs coming out onto the hillside, and tilted and cracked sidewalks, streets, and retaining walls.

For more information, see Potter (1996) and U.S. Department of Agriculture (no date).

Water Can Cause Landslides



What Are the Factors That Cause Landslides?

Many factors contribute to landslides. The most common are listed below:

1. Steep slopes: Avoid when choosing a building site.
2. Water: Slope stability decreases as water moves into the soil. Springs, seeps, roof runoff, gutter downspouts, septic systems, and site grading that cause ponding or runoff are sources of water that often contribute to landslides.
3. Changing the natural slope by creating a level area where none previously existed.
4. Poor site selection for roads and driveways.
5. Improper placement of fill material.
6. Removal of trees and other vegetation: Site construction often results in the elimination of trees and other vegetation. Plants, especially trees, help remove water and stabilize the soil with their extensive root systems.

What Are Some Ways to Prevent Landslides?

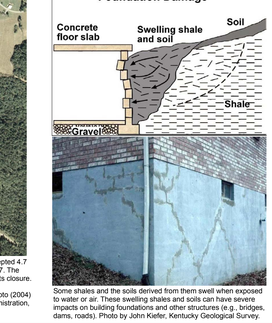
1. Seek professional assistance prior to construction.
2. Proper site selection: Some sloping areas are naturally prone to landslides. Inspect the site for springs, seeps, and other wet areas that might indicate water problems. Take note of unusual cracks or bulges at the soil surface. These are typical signs of soil movement that may lead to slope failure. Also be aware of geologically sensitive areas where landslides are more likely to occur.
3. Alter the natural slope of the building site as little as possible during construction. Never remove soil from the toe or bottom of the slope or add fill to the top of the slope. Landslides are less likely to occur on sites where disturbance has been minimized. Seek professional assistance before earth moving begins.
4. Remove as few trees and other vegetation as possible. Trees develop extensive root systems that are very useful in slope stabilization. Trees also remove large amounts of groundwater. Trees and other permanent vegetative covers should be established as rapidly as possible and maintained to reduce soil erosion and landslide potential.
5. Household water disposal system: Seek professional assistance in selecting the appropriate type and location of your septic system. Septic systems installed in fill material can saturate soil and contribute to landslides.
6. Proper water disposal: Allowing surface waters to saturate the sloping soil is perhaps the most common cause of landslides. Properly located diversion channels are helpful in redirecting runoff away from areas disturbed during construction. Runoff should be channeled and water from roofs and downspouts piped to stable areas at the bottom of the slope.

(From U.S. Department of Agriculture, Natural Resources Conservation Service, no date)

Swelling and Shrinking Shales

A problem of some concern in this area is the swelling of some of the clays and shales. Expanding shale can cause backfill to swell and concrete to crack and crumble. It can heave the foundation, the slab, and interior partitions resting on it, and damage upper floors and interior partitions. This phenomenon has been responsible for extensive damage to schools, homes, and businesses in Kentucky. During times of drought, these same shales may shrink, causing foundations to drop. Anyone planning construction on these shales should seek professional advice from a geologist or engineer familiar with the problem.

Swelling Shale and Foundation Damage



Some shales and the soils derived from them swell when exposed to water or air. These swelling shales and soils can have severe impacts on building foundations and other structures (e.g., bridges, dams, roads). Photo by John Kiefer, Kentucky Geological Survey.

Karst Hydrology

Karst areas in Fleming County 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. Springs form underground to become surface water. Caves are solution-enlarged fractures or conduits large enough for a person to enter.

Water Resources

This reservoir is a source of water for the Flemingsburg Utility System. A local resident reports that it also provides habitat for bluegill, crappie, small-mouth bass, and catfish. About 80 percent of Fleming County residents are served by public water and 30 percent are on public sewer. Photo by Dan Carey, Kentucky Geological Survey.

Groundwater

Some wells located in the Licking River Valley and the major creek valleys will produce enough water for a domestic supply except during dry weather. In the upland areas of Fleming County (70 percent of the county), most drilled wells will not produce enough water for a dependable domestic supply unless they are drilled along drainage lines, in which case they may produce enough water except during dry weather. Throughout the county groundwater is hard or very hard and may contain salt or hydrogen sulfide, especially at depths greater than 100 feet. For more information on groundwater in the county, see Carey and Stickney (2005).

Additional Resources

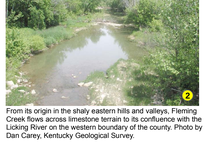
Listed below are Web sites for several agencies and organizations that may be of assistance with land-use planning issues in Fleming County:

ces.ca.uky.edu/fleming/ University of Kentucky Cooperative Extension Service
www.tvacd.com/ Buffalo Trace Area Development District
www.ithink.kentucky.com/edis/cimmty/ce0690/ Kentucky Economic Development Information System
www.uky.edu/KentuckyAtlas/21068.html#Fleming Kentucky Atlas and Gazetteer, Fleming County
quickfacts.census.gov/qfd/states/21/21069.html U.S. Census data
kgsweb.uky.edu/download/kgsplanning.htm Planning information from the Kentucky Geological Survey

Limestone Terrain

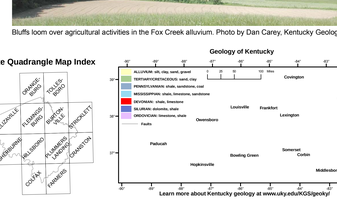
Limestone soils and terrain (unit 4) provide for a rich agriculture. Photo by Dan Carey, Kentucky Geological Survey.

Fleming Creek



From its origin in the shaly eastern hills and valleys, Fleming Creek flows across limestone terrain to its confluence with the Licking River on the western boundary of the county. Photo by Dan Carey, Kentucky Geological Survey.

Fox Creek Alluvium



Bluffs loom over agricultural activities in the Fox Creek alluvium. Photo by Dan Carey, Kentucky Geological Survey.

Maxey Flats

The 280-acre Maxey Flats commercial disposal facility accepted 4.7 million tons of low-level radioactive waste from 1963 to 1977. The Commonwealth of Kentucky has maintained the site since its closure. More information on the site is available at www.waste.ky.gov/programs/sf/Maxey+Flats.htm. Aerial photo (2004) by the U.S. Department of Agriculture, Farm Services Administration, National Agricultural Imagery Program.

Flood Protection

This 64-acre lake, created in 1988 by a 45-foot dam on the Brushy Fork of Fox Creek, is one of five such lakes in the basin that are part of the U.S. Department of Agriculture Fox Creek Watershed Project. The dam, Flood Retarding Structure No. 2, provides 1,433 acre-feet of storage for a 4,205-acre drainage area. Photo by Dan Carey, Kentucky Geological Survey.

9 Photo location

10 Photo location

*Flood information is available from the Kentucky Division of Water, Flood Plain Management Branch, www.water.ky.gov/floods/.

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.

Fox Creek Alluvium

Bluffs loom over agricultural activities in the Fox Creek alluvium. Photo by Dan Carey, Kentucky Geological Survey.

EXPLANATION

- School
- Water wells
  - Domestic
  - Monitoring
- Spring
- Sinkhole
- Wet area
- Rock outcrop
- Severely eroded area
- County line
- Railroad
- Watershed boundary
- Geologic fault
- Mapped sinkhole
- Wildlife management area
- Quarry
- Source water protection area (SWPA), zone 1
- Wetlands > 1 acre (U.S. Fish and Wildlife Service, 2003)
- Incorporated city boundaries
- Designated flood zone* (FEMA, 2004)
- 50-foot contour interval

7.5-Minute Quadrangle Map Index

Geology of Kentucky

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

For information on obtaining copies of this map and other Kentucky Geological Survey maps and publications call our Public Information Center at 859.257.3896 or 877.778.7827 (toll free)
View the KGS World Wide Web site at: www.uky.edu/kgs

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. Seasonal high water table. Subject to flooding. Refer to soil report (Jacobs, 1993).	Severe limitations. Seasonal high water table. Subject to flooding. Refer to soil report (Jacobs, 1993).	Severe limitations. Seasonal high water table. Subject to flooding. Refer to soil report (Jacobs, 1993).	Severe limitations. Seasonal high water table. Subject to flooding. Refer to soil report (Jacobs, 1993).	Severe limitations. Seasonal high water table. Subject to flooding. Refer to soil report (Jacobs, 1993).	Severe limitations. Seasonal high water table. Subject to flooding. Refer to soil report (Jacobs, 1993).	Slight to severe limitations, depending on type of activity and topography. Subject to flooding. Refer to soil report (Jacobs, 1993).	Slight to severe limitations, depending on type of activity and topography. Subject to flooding. Refer to soil report (Jacobs, 1993).	Pervious material. Seasonal high water table. Subject to flooding. Refer to soil report (Jacobs, 1993).	Fair stability. Fair compaction characteristics. Piping hazard. Refer to soil report (Jacobs, 1993).	Severe limitations in general, except for seasonal high water table. Subject to flooding. Refer to soil report (Jacobs, 1993).
2. Clay, silt, sand, and gravel (terrace deposits)	Fair foundation material; easy to excavate.	Severe to slight limitations, depending on amount of soil cover.	Moderate to slight limitations, depending on slope.	Slight limitations.	Slight limitations, depending on degree of slope.	Slight limitations, depending on degree of slope.	Moderate to slight limitations, depending on activity and topography. Possible wooded slopes.	Slight limitations, depending on activity and topography. Slight limitations for nature preserve.	Not recommended. Pervious material.	Severe to slight limitations. Unstable steep slopes.	Slight limitations.
3. Limestone, shale*	Good to excellent foundation material; difficult to excavate.	Moderate to severe limitations. Impermeable rock. Locally fast drainage through fractures and sinks. Danger of groundwater contamination.	Severe to moderate limitations. Rock excavation may be required.	Moderate to severe limitations. Rock excavation possible. Local drainage problems, especially on shale. Sinks possible. Avoid steep slopes.	Slight to moderate limitations, depending on topography. Rock excavation likely. Local drainage problems, especially on shale. Sinks possible.	Slight to moderate limitations, depending on topography. Rock excavation likely. Sinks common. Local drainage problems. Groundwater contamination possible.	Slight to moderate limitations. Rock excavation may be required.	Slight to moderate limitations, depending on activity and topography. Slight limitations for forest or nature preserve.	Moderate to slight limitations. Reservoir may leak where rocks are fractured. Sinks possible.	Moderate to slight limitations. Reservoir may leak where rocks are fractured. Sinks possible.	Moderate to severe limitations. Rock excavation likely.
4. Limestone	Good to excellent foundation material; difficult to excavate.	Moderate to severe limitations. Impermeable rock. Locally fast drainage through fractures and sinks. Danger of groundwater contamination.	Severe to moderate limitations. Rock excavation; locally, rock may have to be rippable. Sinks possible. Drainage required.	Slight to moderate limitations. Rock excavation; locally, rock may have to be rippable. Sinks possible. Drainage required.	Slight to moderate limitations, depending on topography. Rock excavation likely. Local drainage problems. Sinks possible.	Slight to moderate limitations, depending on topography. Rock excavation likely, especially; upper few feet may be rippable. Sinks possible. Local drainage problems.	Slight to moderate Rock excavation may be required.	Slight to moderate limitations, depending on activity and topography. Slight limitations for forest or nature preserve.	Severe limitations. Leaky reservoir rock. Locally, conditions may be favorable. Sinks possible.	Severe limitations. Leaky rock.	Severe limitations. Rock excavation.
5. Black shale*	Poor foundation material; easy to moderately difficult to excavate. Low strength and stability. May contain plastic clays.	Severe limitations. Thin soils and low permeability.	Severe limitations. Low strength, slumping, and seepage problems.	Severe limitations. Low strength, slumping, and seepage problems.	Severe limitations. Low strength, slumping, and seepage problems.	Severe limitations. Low strength, slumping, and seepage problems.	Moderate to severe limitations, depending on activity and topography.	Slight to severe limitations, depending on activity. Slight limitations for forest or nature preserve.	Slight limitations for small ponds.	Severe limitations. Poor strength and stability.	Moderate limitations. Poor strength. Wetness.
6. Shale*, limestone	Fair to good foundation material; difficult excavation. Slumps when wet. Avoid steep slopes.	Slight to severe limitations, depending on amount of soil cover and depth to impermeable rock.	Severe to moderate limitations. Rock excavation may be required. Slumps when wet. Avoid steep slopes. Possible shrinking and swelling shales.	Severe to moderate limitations. Rock excavation may be required. Slumps when wet. Avoid steep slopes.	Severe to moderate limitations. Rock excavation may be required. Slumps when wet. Avoid steep slopes.	Moderate to severe limitations, depending on topography. Rock excavation. Local drainage problems. Susceptible to landslides.	Slight to severe limitations, depending on activity and topography. Possible steep wooded slopes.	Slight to moderate limitations, depending on activity and topography. Possible steep wooded slopes. Slight limitations for forest or nature preserve.	Moderate to slight limitations. Reservoir may leak where rocks are fractured.	Slight to moderate limitations. Reservoir may leak where rocks are fractured.	Moderate to severe limitations. Rock excavation likely.
7. Shale*	Poor foundation material; easy to moderately difficult to excavate. Low strength and stability. May contain plastic clays.	Severe limitations. Low permeability.	Severe limitations. Low strength, slumping, and seepage problems.	Moderate to severe limitations, depending on slopes. Strength, slumping, and seepage problems.	Moderate to severe limitations, depending on slopes. Strength, slumping, and seepage problems.	Moderate to severe limitations, depending on slopes. Strength, slumping, and seepage problems.	Slight to severe limitations, depending on activity.	Slight to moderate limitations, depending on activity. Slight limitations for forest or nature preserve.	Slight limitations. Reservoir may leak where rocks are fractured. Most ponds on shale are successful.	Severe limitations. Poor strength and stability.	Moderate limitations. Poor strength. Wetness.
8. Siltstone, sandstone, shale	Good to excellent foundation material; difficult to excavate.	Severe limitations. Thin soils.	Severe limitations. Rock excavation. Steep slopes.	Severe limitations. Rock excavation. Steep slopes.	Severe limitations. Rock excavation. Steep slopes.	Severe limitations. Rock excavation. Steep slopes.	Severe limitations. Rock excavation. Steep slopes.	Slight to severe limitations, depending on activity. Slight limitations for forest or nature preserve.	Not applicable.	Not applicable.	Severe limitations. Rock excavation.

*Shales and clays in these units can shrink during dry periods, and swell during wet periods and cause cracking of foundations. On hillsides, especially where seeps and springs are present, they can also be susceptible to landslides.

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.

References Cited

Carey, D.I., and Stickney, J.F., 2005, Groundwater resources of Fleming County, Kentucky: Kentucky Geological Survey, ser. 12, County Report 35, www.uky.edu/KGS/water/library/gwatlas/Fleming/Fleming.htm [accessed 4/20/06].

Federal Emergency Management Agency, 2004, www.fema.gov [accessed 4/9/06].

Jacobs, S.E., 1993, Soil survey of Fleming County, Kentucky: U.S. Department of Agriculture, Soil Conservation Service, 207 p.

Murphy, M.L., 2005a, Spatial database of the Hillsboro quadrangle, Fleming and Bath Counties, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-876. Adapted from Mytton, J.W., and McDowell, R.C., 1970, Geologic map of the Hillsboro quadrangle, Fleming and Bath Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-876, scale 1:24,000.

Murphy, M.L., 2005b, Spatial database of the Plummers Landing quadrangle, Fleming and Rowan Counties, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-964. Adapted from McDowell, R.C., Peck, J.H., and Mytton, J.W., 1971, Geologic map of the Plummers Landing quadrangle, Fleming and Rowan Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-964, scale 1:24,000.

Murphy, M.L., 2005c, Spatial database of the Strickett quadrangle, northeastern Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-394. Adapted from Morris, R.H., 1965, Geologic map of the Strickett quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-394, scale 1:24,000.

Murphy, M.L., and Petersen, C., 2005a, Spatial database of the Cranston quadrangle, northeastern Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-1212. Adapted from Philley, J.C., Hybert, D.K., and Hoge, H.P., 1975, Geologic map of the Cranston quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1212, scale 1:24,000.

Murphy, M.L., and Petersen, C., 2005b, Spatial database of the Farmers quadrangle, east-central Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-1236. Adapted from McDowell, R.C., 1975, Geologic map of the Farmers quadrangle, east-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1236, scale 1:24,000.

Nelson, H.L., Jr., and Petersen, C., 2005, Spatial database of the Colfax quadrangle, east-central Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-1332. Adapted from McDowell, R.C., 1976, Geologic map of the Colfax quadrangle, east-central Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1332, scale 1:24,000.

Palmgreen, K.A., 2005, Spatial database of the Moorefield quadrangle, northeastern Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-1510. Adapted from Wigley, P.B., 1978, Geologic map of the Moorefield quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1510, scale 1:24,000.

Palmgreen, K.A., and Murphy, M.L., 2005, Spatial database of the Sherburne quadrangle, northeastern Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-854. Adapted from Outerbridge, W.F., 1973, Geologic map of the Sherburne quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-854, scale 1:24,000.

Paylor, R.L., Flores, L., Caudill, M., and Currens, J.C., 2004, A GIS coverage of karst sinkholes in Kentucky: Kentucky Geological Survey, ser. 12, Digital Publication 5, 1 CD-ROM.

Petersen, C., 2005, Spatial database of the Cowan quadrangle, northeastern Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-1466. Adapted from Blade, L.V., 1978, Geologic map of the Cowan quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-1466, scale 1:24,000.

Petersen, C., 2006, Spatial database of the Tollesboro quadrangle, Lewis and Fleming Counties, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-661. Adapted from Peck, J.H., 1967, Geologic map of the Tollesboro quadrangle, Lewis and Fleming Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-661, scale 1:24,000.

Potter, P.E., 1996, Exploring the geology of the Cincinnati/northern Kentucky region: Kentucky Geological Survey, ser. 12, Special Publication 22, 115 p.

Toth, K.S., 2006, Spatial database of the Orangeburg quadrangle, northeastern Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-588. Adapted from Schilling, F.A., Jr., and Peck, J.H., 1967, Geologic map of the Orangeburg quadrangle, northeastern Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-588, scale 1:24,000.

U.S. Department of Agriculture, Natural Resources Conservation Service, no date, Landslide prevention in eastern Kentucky.

U.S. Fish and Wildlife Service, 2003, National Wetlands Inventory, www.nwi.fws.gov [accessed 3/6/06].

Zhang, Q., 2005a, Spatial database of the Burtonville quadrangle, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-396. Adapted from Morris, R.H., 1965, Geology of the Burtonville quadrangle, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-396, scale 1:24,000.

Zhang, Q., 2005b, Spatial database of the Elizaville quadrangle, Fleming and Mason Counties, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-893. Adapted from McDowell, R.C., 1971, Geologic map of the Elizaville quadrangle, Fleming and Mason Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-893, scale 1:24,000.

Zhang, Q., 2005c, Spatial database of the Flemingsburg quadrangle, Fleming and Mason Counties, Kentucky: Kentucky Geological Survey, ser. 12, Digitally Vectorized Geologic Quadrangle Data DVQG-837. Adapted from Peck, J.H., 1969, Geologic map of the Flemingsburg quadrangle, Fleming and Mason Counties, Kentucky: U.S. Geological Survey Geologic Quadrangle Map GQ-837, scale 1:24,000.