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

MAP AND CHART 72
Series XII, 2004

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

Bart Davidson and Daniel I. Carey

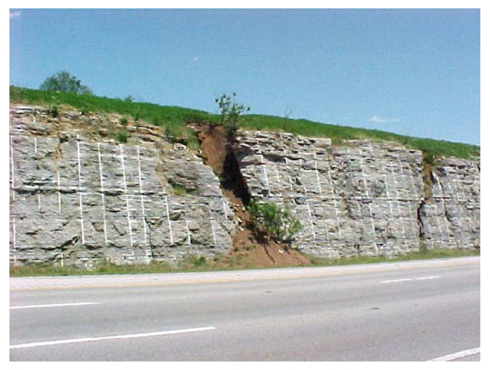
Landslides

Hillside construction can cause earth movements if not properly planned. Photos by Paul Howell, Natural Resources Conservation Service.

Heavy equipment is used to clean up a rockfall between Richmond and Irvine on Ky. 52. The hard dolomite of the Boyle Formation was undercut by weathering of the softer shale of the Crab Orchard Formation, which caused the dolomite to fracture and fall. Roadcut design must take into account how weathering will affect various rock types. Photo by Bart Davidson, Kentucky Geological Survey.

Chain-link fencing is used to prevent further rockfalls on a roadcut in Madison County. Photo by Bart Davidson, Kentucky Geological Survey.

Karst



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 snow-melt seeps through soil cover into fractured and soluble bedrock (usually limestone, dolomite, or gypsum).

Sinkholes are depressions on the land surface where 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 that are large enough for a person to enter.

Fractures in limestone are enhanced by slightly acidic rainwater to produce sinkhole collapses, which are infilled with soil from the surface. These fractures can also contribute to roadway failure. Photo by Bart Davidson, Kentucky Geological Survey.

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 natural soil.

Residences–Ratings are made for residences with and without 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–Refer 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 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.

Environmental Issues

A septic system is installed for a public facility near Berea. Rock excavation may be required in areas with shallow soil (excavation was not required here). Underlying shale may restrict percolation in some areas. In areas overlying limestone, septic systems can leak through fractures in the limestone, contaminating groundwater. Photo by Bart Davidson, Kentucky Geological Survey.

Madison County Courthouse

Madison County has two major townships–Richmond, the county seat and home of Eastern Kentucky University, and Berea, home of Berea College. The 2005 population of 72,408, was 25.9 percent greater than the population in 1990.

Madison County was founded in 1798 and named after James Madison, the fourth president of the United States. Most of the county lies in the Outer Bluegrass Region, but the extreme southern area includes the outer edge of the Eastern Coalfield.

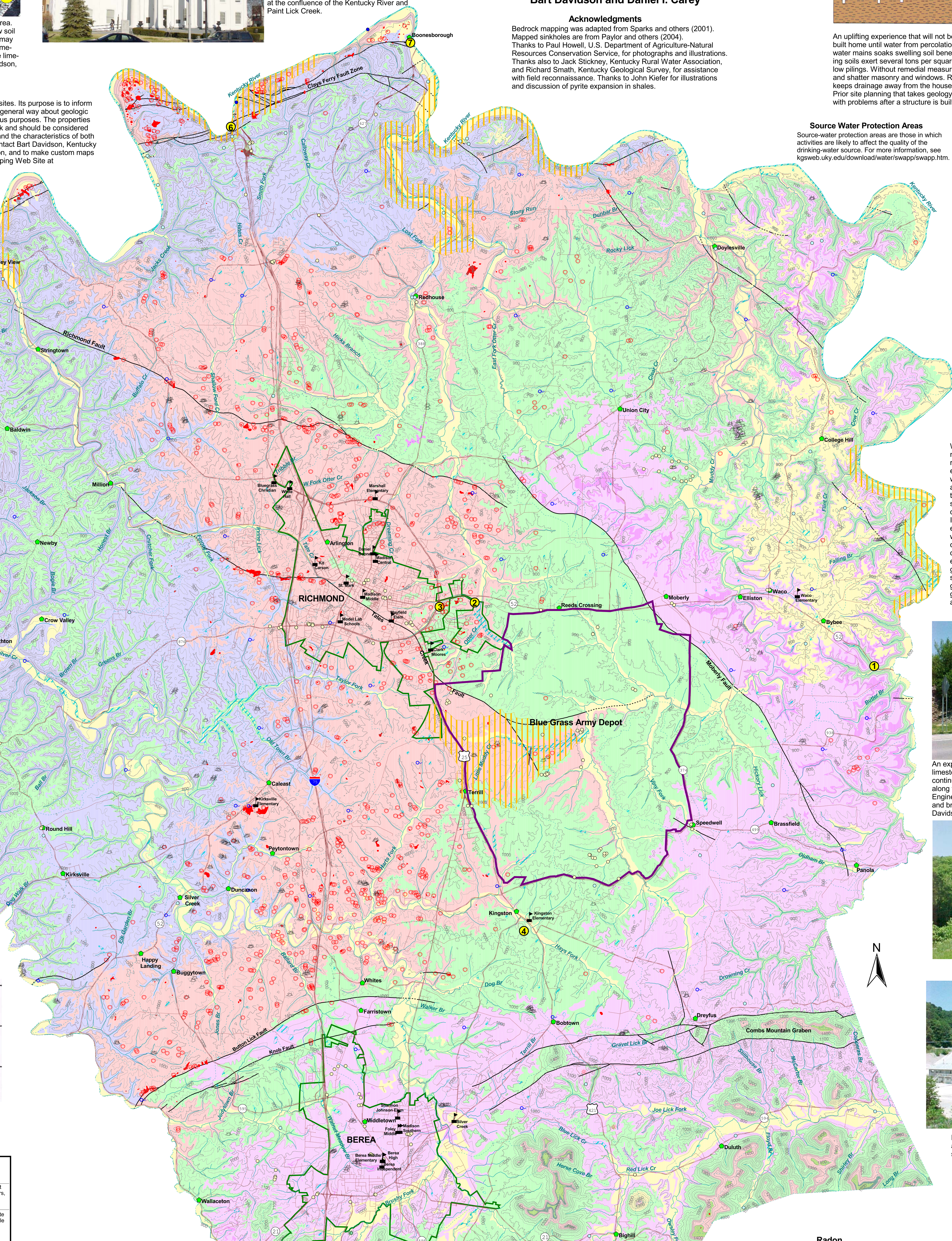
The highest elevation in the county, 1,660 feet, is on Bear Mountain, 3 miles southeast of Berea. The lowest elevation, 530 feet, is at the confluence of the Kentucky River and Paint Lick Creek.

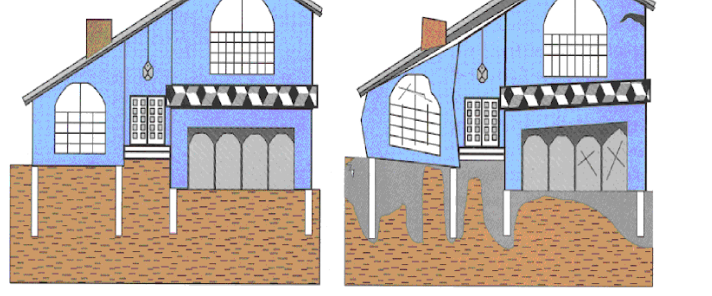
For Planning Use Only

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 supercede 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 information, contact Bart Davidson, Kentucky Geological Survey, 859.257.5500 x162. For more information, and to make custom maps of your local area, visit our Land-Use Planning Internet Mapping Web Site at kgsmap.uky.edu/website/kyluplan/viewer.htm.

Acknowledgments

Bedrock mapping was adapted from Sparks and others (2001). Mapped sinkholes are from Paylor and others (2004). Thanks to Paul Howell, U.S. Department of Agriculture-Natural Resources Conservation Service, for photographs and illustrations. Thanks also to Jack Stickney, Kentucky Rural Water Association, and Richard Smath, Kentucky Geological Survey, for assistance with field reconnaissance. Thanks to John Kiefer for illustrations and discussion of pyrite expansion in shales.





An uplifting experience that will not be appreciated! Left: All is well in this newly built home until water from percolation, drains, lawn sprinklers, leaking sewers, or water mains soaks swelling soil beneath the foundation. Right: With time, expanding soils exert several tons per square foot of pressure on the foundation and shallow pilings. Without remedial measures, the house will actually become deformed and shatter masonry and windows. Remedies vary from mere maintenance that keeps drainage away from the house to expensive reconstruction of foundations. Prior site planning that takes geology into account is always preferable to dealing with problems after a structure is built. From AIPG (1993).

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.

EXPLANATION

- School
- Soil Survey Observations
  - Rock outcrop
  - Sinkhole
- Water wells
  - Domestic
  - Monitoring
  - Public
  - Spring
  - Gas well
  - Oil well
- Blue Grass Army Depot boundary
- Source water protection areas--zone1
- Wetlands > 1 acre (U.S. Fish & Wildlife Service, 2003)
- Corporate limits
- Watershed boundary
- Concealed fault
- Fault
- Artificial fill
- Mapped sinkholes

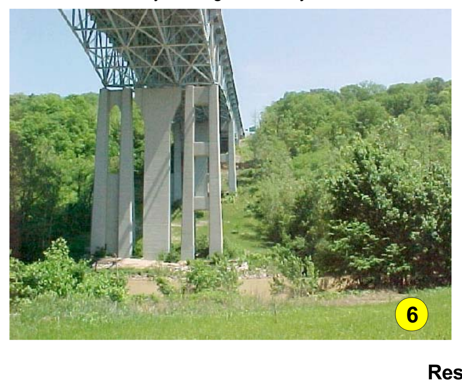
50-foot elevation contour interval

7 Photography location

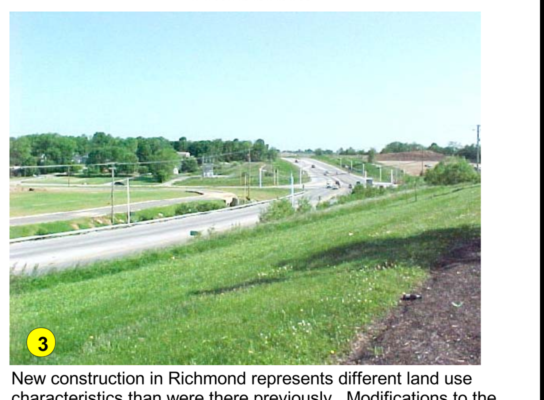
Groundwater Availability

Within the thin Kentucky River Valley along the northern edge of Madison County, and in the lower reaches of the valleys of the larger creeks that empty into the Kentucky River, most drilled wells will produce enough water for a domestic supply at depths of less than 100 feet. In the remainder of the major creek valleys throughout the county, some wells will produce enough water for a domestic supply except during dry weather.
In the upland areas of Madison County, which encompasses 70 percent of the county, most drilled wells will not produce enough water for a dependable domestic supply except along drainage lines that 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 the groundwater resources of the county, see Carey and Stickney (2001).

An expression (above) of the Kentucky River Fault in limestone north of the Clays Ferry bridge on I-75, which continues under the bridge itself (below). Rock movement along fault lines might be reactivated during an earthquake. Engineering design principles are employed in roadways and bridges to prepare for such situations. Photos by Bart Davidson, Kentucky Geological Survey.



Construction

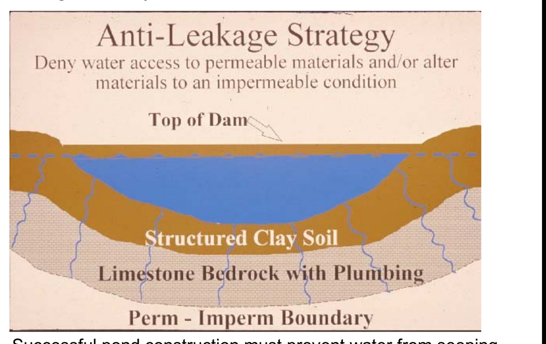


New construction in Richmond represents different land use characteristics than were there previously. Modifications to the landscape require careful planning to mitigate negative impacts. For example, less groundwater recharge and increased storm runoff occur because of increased pavement area. Photo by Bart Davidson, Kentucky Geological Survey.

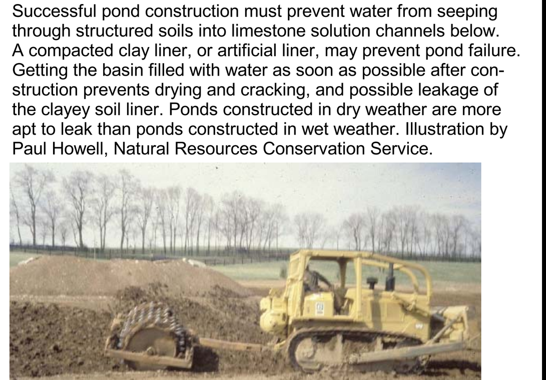
Natural gas piplines (30-inch mains) are laid across a new subdivision in Kingston. Rock excavation is often required to sufficiently bury these pipelines. Photo by Bart Davidson, Kentucky Geological Survey.

Ponds and Reservoirs

An earthen dam was constructed to contain Lake Reba in Richmond. Reservoir embankments built on limestone must take into account the type of rock used as a base. Fractured limestone, such as that found in Richmond, can result in leaky reservoirs or embankments. Photo by Bart Davidson, Kentucky Geological Survey.



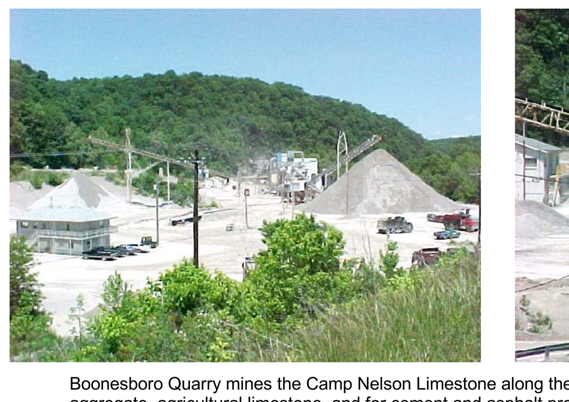
Successful pond construction must prevent water from seeping through structured soils into limestone solution channels below. A compacted clay liner, or artificial liner, may prevent pond failure. Getting the basin filled with water as soon as possible after construction prevents drying and cracking, and possible leakage of the clayey soil liner. Ponds constructed in dry weather are more apt to leak than ponds constructed in wet weather. Illustration by Paul Howell, Natural Resources Conservation Service.

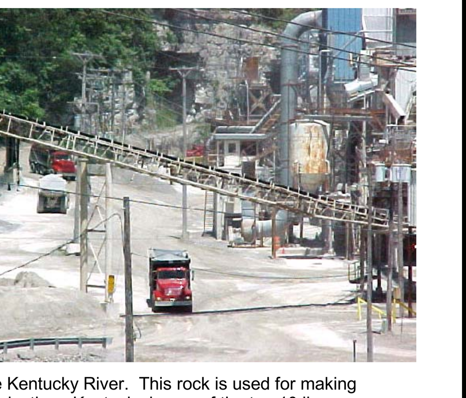


A clayey-soil pond liner is placed in loose, moist layers and compacted with a sheepsfoot roller. A geotechnical engineer or geologist should be consulted about the requirements of a specific site. Other leakage-prevention measures include synthetic liners, bentonite, and asphaltic emulsions. The U.S. 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. Photo by Paul Howell, Natural Resources Conservation Service.

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.

Resources



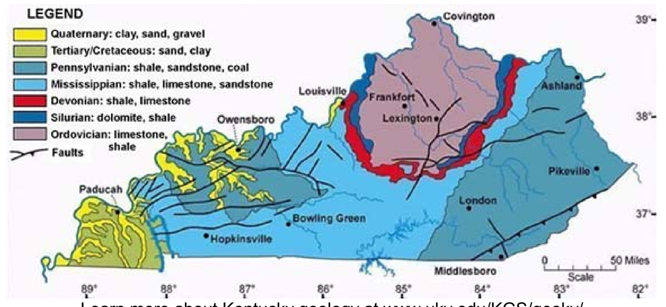


Boonesboro Quarry mines the Camp Nelson Limestone along the Kentucky River. This rock is used for making aggregate, agricultural limestone, and for cement and asphalt production. Kentucky is one of the top 10 limestone producers in the country. Photo by Bart Davidson, Kentucky Geological Survey.

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 represent seismic activity that occurred several million years ago at the latest. There has been no activity along these faults in recorded history. Seismic risk associated with these faults is very low. Faults may be associated with increased fracturing of bedrock in the immediately adjacent area. This fracturing may influence slope stability and groundwater flow in these limited areas.

Geology of Kentucky



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

Planning Guidance by Rock Unit Type

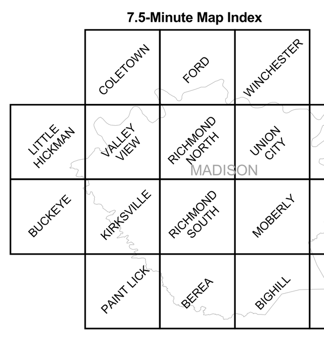
Rock Unit	Foundation and Excavation	Septic System	Residence with Basement	Highways and Streets	Access Roads	Light Industry and Malls	Intensive Recreation	Extensive Recreation	Reservoir Areas	Reservoir Embankments	Underground Utilities
1. Sand, gravel, silt, clay	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).	Refer to soil report (Newton and others, 1973).
2. Siltstone, limestone, and shale (See discussion of swelling shales.)	Fair to good foundation material; difficult to excavate. Pyrite expansion in shales possible. Easy to excavate, but poor foundation.	Severe limitations. Impermeable rock. Thin soils. Locally fast drainage through fractures and sinks to water table; possible groundwater contamination.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes. Potential for forest or nature preserve.	Slight limitations. Reservoir may leak where rocks are fractured. Most ponds in shale are successful.	Severe limitations. Reservoir may leak where rocks are fractured. Sinks possible. Most ponds in shale are successful.	Severe to moderate limitations. Possible rock excavation.
3. Limestone and shale (See discussion of swelling shales.)	Limestone--good to excellent foundation material; difficult to excavate. Possible pyrite expansion in shales. Easy to excavate, but poor foundation.	Severe limitations. Impermeable rock. Locally fast drainage through fractures and sinks to water table; possible groundwater contamination.	Severe limitations. Rock excavation may be required.	Severe limitations. Rock excavation. Steep slopes.	Moderate limitations. Rock excavation; possible steep slopes. Slight limitations with suitable topography.	Severe to slight limitations, depending on topography. Rock excavation. Local drainage problems. Sinks common. Groundwater contamination possible.	Severe to moderate limitations. Rock excavation may be required.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes. Potential for forest or nature preserve.	Slight limitations. Reservoir may leak where rocks are fractured. Most ponds in shale are successful.	Severe limitations. Reservoir may leak where rocks are fractured. Sinks possible. Most ponds in shale are successful.	Severe to moderate limitations. Possible rock excavation.
4. Shale and dolomite (See discussion of swelling shales.)	Dolomite--excellent foundation material; difficult to excavate. Possible pyrite expansion in shales; easy to excavate, but poor foundation.	Severe limitations. Impermeable rock. Locally fast drainage through fractures and sinks to water table; possible groundwater contamination.	Severe limitations. Rock excavation may be required.	Moderate limitations. Rock excavation. Local drainage problems. Sinks common.	Moderate limitations. Rock excavation. Local drainage problems. Sinks common.	Severe to moderate limitations. Rock excavation. Local drainage problems. Sinks common.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes. Potential for forest or nature preserves.	Severe to moderate limitations. Reservoir may leak where rocks are fractured. Sinks possible. Most ponds in shale are successful.	Severe to moderate limitations. Reservoir may leak where rocks are fractured. Sinks possible. Most ponds in shale are successful.	Severe limitations. Possible rock excavation.
5. Limestone, dolomite, and shale (See discussion of swelling shales.)	Fair to good foundation material; difficult to excavate. Possible expansive shales; easy to excavate, but poor foundation.	Severe limitations. Impermeable rock.Locally fast drainage through fractures and sinks to water table; possible groundwater contamination.	Severe limitations. Rock excavation may be required.	Moderate limitations. Rock excavation. Local drainage problems. Sinks common.	Moderate limitations. Rock excavation. Local drainage problems. Sinks common.	Severe to slight limitations, depending on topography. Rock excavation. Local drainage problems. Sinks common. Groundwater contamination possible.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes. Potential for forest or nature preserve.	Severe to moderate limitations. Reservoir may leak where rocks are fractured. Sinks possible. Most ponds in shale are successful.	Severe to moderate limitations. Reservoir may leak where rocks are fractured. Sinks possible. Most ponds in shale are successful.	Severe limitations. Possible rock excavation.
6. Dolomite	Excellent foundation material; difficult to excavate.	Severe limitations. Impermeable rock. Locally fast drainage through fractures and sinks to water table; possible groundwater contamination.	Severe limitations. Rock excavation may be required.	Severe limitations. Rock excavation. Possible steep slopes.	Severe to moderate limitations. Rock excavation. Possible steep slopes and narrow ravines.	Moderate to slight limitations, depending on topography. Rock excavation. Local drainage problems. Sinks common.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes. Potential 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.	Severe limitations. Rock excavation.
7. Shale, siltstone, and sandstone (See discussion of swelling shales.)	Fair to good foundation material; difficult to excavate. Possible pyrite expansion in shales, Easy to excavate, but poor foundation.	Severe limitations. Thin soils. Impermeable rock.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes. Potential for forest or nature preserve.	Slight limitations. Reservoir may leak where rocks are fractured. Most ponds in shale are successful.	Severe limitations. Reservoir may leak where rocks are fractured. Most ponds in shale are successful.	Severe to moderate limitations. Thin soils. Possible rock excavation.
8. Sandstone	Fair to good foundation material; difficult to excavate.	Severe limitations. Thin soils.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required. Possible steep slopes.	Severe to moderate limitations. Rock excavation may be required.	Severe to slight limitations, depending on activity and topography. Possible steep wooded slopes. Potential for forest or nature preserve.	Slight limitations. Reservoir may leak where rocks are fractured.	Severe limitations. Reservoir may leak where rocks are fractured.	Severe to moderate limitations. Thin soils. Possible rock excavation.

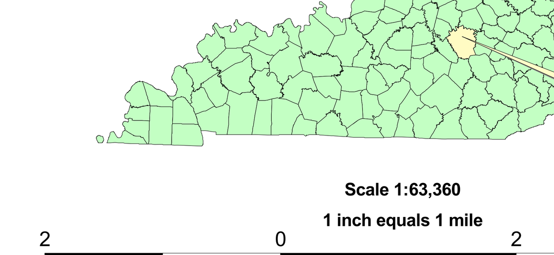
Additional Planning Information

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

ces.ca.uky.edu/madison/ University of Kentucky Cooperative Extension Service
www.bgadd.org/ Bluegrass Area Development District
www.thinkkentucky.com/edis/cmnty/cw001/ Richmond, Kentucky Economic Development Information System
www.thinkkentucky.com/edis/cmnty/cw002/ Berea, Kentucky Economic Development Information System
http://www.uky.edu/KentuckyAtlas/21151.html Kentucky Atlas and Gazetteer, Madison County
quickfacts.census.gov/qfd/states/21/21151.html U.S. census data
kgsweb.uky.edu/download/kgsplanning.htm County planning information from the Kentucky Geological Survey

7.5-Minute Map Index





Scale 1:63,360

1 inch equals 1 mile

2 0 2 4 Miles

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.

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Radon

Radon gas, although not widely distributed in Kentucky in amounts above the U.S. Environmental Protection Agency's maximum recommended limit of 4 picocuries per liter, can be a local problem. The black shales in unit 4 may have high levels of radon. Unit 5, the Tanglewood Limestone, may also contain high levels of uranium or radium, parent materials for radon gas. The Tanglewood and several other limestones in the state locally contain the phosphate mineral apatite. Uranium is sometimes part of the apatite structure, and when the limestone weathers away, the phosphates containing uranium become concentrated in the soil and ultimately can give rise to high levels of radon. Homes in these areas should be tested for radon, but the homeowner should keep in mind that the health threat results from relatively high levels of exposure over long periods of time, and the remedy may simply be additional ventilation of the home.

COMPARATIVE RISK CHART for RADON LEVELS

Radon Level pCi/L	Estimated Fatal Lung Cancers/1000	Comparable Exposure Levels	Comparable Risk Estimate
200	440 - 770	1,000 times average outdoor level	More than 60 times non-smoker risk
100	270 - 630	100 times average outdoor level	Four pack/day smoker or 20,000 chest X-rays/yr
40	120 - 380	100 times average outdoor level	Two-pack/day smoker
20	60 - 210		
10	30 - 120	10 times average indoor level	One pack/day smoker
4	13 - 50	10 times average outdoor level	Five times non-smoker risk
2	7 - 30		
1	3 - 13	Average indoor level	Non-smoker risk of fatal lung cancer
0.2	1 - 3	Average outdoor level	20 chest X-rays/yr

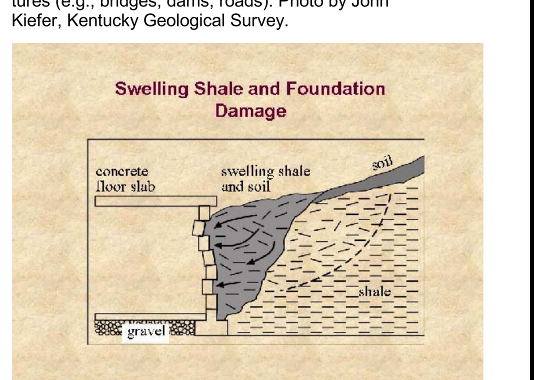
EPA recommends action be taken if indoor levels exceed 4 pCi/L, which is 10 times the average outdoor level. Some EPA representatives believe the action level should be lowered to 2 pCi/L; other scientists dissent and claim the risks estimated in this chart are already much too high for low levels of radon. The action level in European countries is set at 10 pCi/L. 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)

Swelling Shales and Soils

A problem of considerable concern in this area is the swelling of some of the clay minerals in shales such as the Crab Orchard (unit 4) and the Borden (unit 2) formations. This process is exacerbated when the shale contains the mineral pyrite (fool's gold), such as is the case in the Devonian New Albany (unit 4) black shale. Pyrite is a common mineral and can be found distributed throughout the black shale, although it is not always present and may be discontinuous both laterally and horizontally. In the presence of moisture and oxygen, pyrite oxidizes and produces sulfuric acid. The acid reacts with calcium carbonates found in water, the rock itself, crushed limestone, and concrete. This chemical reaction produces sulfate and can form the mineral gypsum, whose crystallization can cause layers of shale to expand and burst, backfill to swell, and concrete to crack and crumble. It can heave the foundation, the slab and interior partitions resting on it, and can even damage upper floors and interior partitions. This phenomenon has been responsible for extensive damage to schools, homes, and businesses in Kentucky.

We strongly suggest that anyone planning construction on these shales seek professional advice from a geologist or engineer familiar with the problem.

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.



Swelling shales should never be used for backfill. Illustration by John Kiefer, Kentucky Geological Survey.