Kentucky Geological Survey
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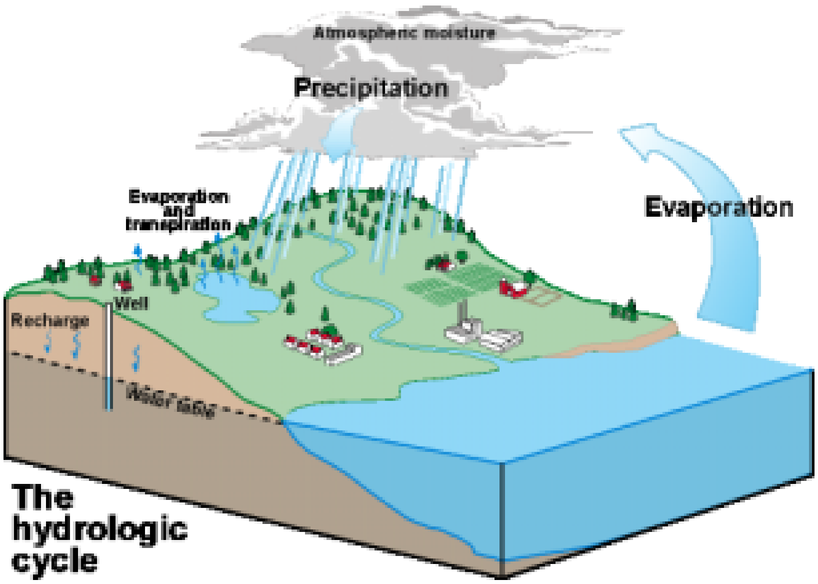
GROUND-WATER RESOURCES

OF

MADISON COUNTY, KENTUCKY



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Contents

Foreword

This report on the ground-water resources of the county was prepared for the Water Resource Development Commission by the Kentucky Geological Survey. Reports were prepared for each of Kentucky's 120 counties. These reports complement other county planning reports of the Commission, including Strategic Water Development Plans and Strategic Wastewater Treatment Plans, and the Division of Water's County Water Supply Plans.

Each ground-water resource report is a compilation of information on hydrology, geology, topography, water supply and water quality taken from maps, reports, and data collected from 1940 to 2000. The primary mode of access to the information is via links from the report to the internet--for example, by linking to the KGS internet library of ground-water research. The digital form of the report, and its ability to link to data anywhere on the internet, makes it at dynamic tool for gathering information.

The current compilation is by no mains exhaustive: no doubt valuable data have been overlooked. As new or more-detailed information becomes available, it can be easily linked into this report.

While this report may be of value to planners and geologists for strategic planning and feasibility-level studies, it cannot replace field investigation for the development or assessment of site-specific ground-water resources.

DISCLAIMER STATEMENT

The Kentucky Geological Survey (KGS) is constantly gathering data from multiple sources, interpreting the data it gathers, and reflecting its interpretations on maps such as those in this report. Reasonable efforts have been made by KGS to verify that these maps and the digital data provided thereon accurately interpret the source data used in its preparation; however, these maps may contain omissions and errors in scale, resolution, rectification, positional accuracy, development methodology, interpretations of source data, and other circumstances. As additional data becomes available to KGS, and as verification of source data continues, these maps may be re-interpreted or updated by KGS. These maps are designed at a designated scale and should not be enlarged. Further, these maps should not be used for navigation, engineering, legal or any other site-specific use. Nothing contained herein shall be deemed an expressed or implied waiver of the sovereign immunity of the Commonwealth or its duly authorized representatives, agents, or employees.

Introduction

This report is intended to provide both a basic understanding of ground-water resources in the county and links to more in-depth sources of information, maps, and data. Links are highlighted in blue. Most of the links are to document files or maps in Adobe PDF files. The PDF may be viewed with the free Acrobat Reader. Some of the files are large and, depending on your system, you may prefer to download the files to your system overnight. A few maps may be in MrSid file format. These files are viewable with the free MrSid Viewer, with ESRI GIS software, and with any other MrSid-compatible software.

Acknowledgments

Many individuals and several agencies provided information and assistance in the preparation of this atlas. The GIS students at the Federal Prison Camp, Lexington, Ky., prepared index maps and created spatial data from historical well maps. Staff members of the Kentucky Natural Resources Information System provided technical and programming assistance. Reports from the Kentucky Division of Water, the U.S. Geological Survey, the Kentucky Geological Survey, the Water Resource Development Commission, the U.S. Census Bureau, and other agencies were used. And finally, the atlas would not have been completed at this time if the Water Resource Development Commission had not promoted the project and provided both financial and technical support.

Overview

About 4,800 residents of Madison County rely on private domestic water supplies: about 1,000 use wells, and 3,800 use other sources. 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 upland areas, 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 ground water is hard or very hard and may contain salt or hydrogen sulfide, especially at depths greater than 100 feet.

Water Use

Madison County had an estimated population of 60,543 (24,869 households) in 1999; projected population is 72,809 (33,067 households) in 2020. Public water is provided to about 92 percent of the county's residents. In areas not served by public water, about 20 percent of the households use wells and 80 percent use other sources. About 460 customers will be added to public water service through new line extensions from 2000 to 2020. If all proposed water line extensions are made, about 7 percent of the county will still rely on private water supplies in the year 2020.

The Water Resource Development Commission has prepared a report on water supply infrastructure in the county.

It is estimated that there are over 200,000 water wells in Kentucky. The Ground-Water Data Repository, maintained by the Kentucky Geological Survey, has information on over 50,000 of these wells. The locations of wells and springs in the county for which data is available is shown on the map of wells and springs in the county. A map of certified well drillers in Kentucky has been prepared by the Kentucky Division of Water.

Topography of the County

Discussion from McGrain and Currens (1978)

Most of Madison County lies in the Outer Blue Grass region of central Kentucky, but the extreme southern area includes the outer edge of the Eastern Kentucky coal field. Various parts of the county are gently rolling, hilly, and mountainous. The most striking topographic features are the deeply entrenched valley of the Kentucky River which marks the northern boundary of the county and the Cumberland escarpment in the southern area.

View elevation map

Ridgetops in the northern half of the county are commonly 900 to 1,000 feet, some 350 to 450 feet above the Kentucky River. The area is hilly and few flat areas occur. The lowest elevation in the county, approximately 530 feet, is at the confluence of the Kentucky River and Paint Lick Creek at the northeastern corner of the county.

North and northeast of Berea, in the south-central part of the county, the topography is more subdued. Although the elevations are around 1,000 feet, the relief is the lowest in the county. The principal areas of flat land in the county are found here.

The highest elevations and the greatest local reliefs are found in the area south of a line between Berea and Panola. The Cumberland escarpment and the hills resulting from the erosion of the Eastern Kentucky coal field front are striking topographic features. Peaks and ridges rise 600 to 700 feet or more above the valley floors. Pilot Knob at 1,411 feet and Indian Fort Mountain at 1,552 feet, both near the community of Bighill, are examples of such erosion remnants. Bear Mountain, 3 miles southeast of Berea, has the highest elevation in Madison County at 1,660 feet.

The elevation of Richmond, at the courthouse, is 950 feet. Other elevations are Berea, 1,034 feet; Bighill, 813 feet; Bybee, 910 feet; Fort Boonesboro State Park, 585 feet; Kingston, 928 feet; Kirksville, 994 feet; Moberly, 877 feet; Panola, 791 feet; Valley View, 568 feet; and Waco, 827 feet. The spillway elevation of Lake Reba is 857 feet, and at Taylor Fork Lake the spillway is at 825 feet.

The 7.5-minute topographic quadrangle maps that cover the county are shown, by name and by index code (Kentucky Natural Resources and Environmental Protection Cabinet) on the index map.

Geology of the County

In Madison County, water is obtained from consolidated sedimentary rocks ranging in age from Ordovician, Silurian, Devonian, Mississippian, to Pennsylvanian and from unconsolidated sediments of Quaternary age. The oldest rocks exposed on the surface in Madison County were deposited in shallow seas 490 million years ago during Ordovician. Above the Ordovician rocks are Devonian rocks, which includes the New Albany shale. The New Albany shale, also called the black shale, is 400 million years old. The black shale was formed when the deep sea floor became covered with an organic black muck. The muck is now hard black shale (an oil shale) which is one of the most distinctive of all geologic formations in Kentucky. The Mississippian sandstones and siltstones are the result of a great influx of mud, silts, and sands brought in by rivers and streams from uplands many miles to the northeast and deposited as a great delta. The Mississippian limestones found in Madison County were deposited 350 million years ago in the bottom of a warm, shallow sea. At the end of the Mississippian, 320 million years ago, the seas receded and sediments of the Pennsylvanian were deposited. The warm climate of the Pennsylvanian grew extensive forests and great coastal swamps at the edges of water bodies. Marine waters advanced and receded many times, which produced many layers of sandstone, shale, and coal. Vegetation of all sorts fell into the water and was buried under blankets of sediments, which over long geologic time were compressed into coal. The non-vegetative sediments such as sand, clay and silt were compressed into sandstone and shale. Over the last one million years unconsolidated Quaternary sediments have been deposited along the larger streams and rivers.

Geologic Formations in the County

Unconsolidated deposits

ALLUVIUM (Qa)
HIGH-LEVEL FLUVIAL DEPOSITS (QTf)

Limestones

BORDEN FORMATION (Mbf)
SLADE FORMATION (in southeastern corner) (Mpn),(Mn)
UPPER PART OF LEXINGTON LIMESTONE (Tanglewood Limestone, Millersburg, Strodes Creek, Devils Hollow, Sulfur Well, Brannon and Perryville Members) (Ol)
LOWER PART OF LEXINGTON LIMESTONE (Grier, Logana and Curdsville Members) (Ol)
HIGH BRIDGE GROUP (Tyrone Limestone, Oregon Formation, Camp Nelson Limestone) (Ohb)

Dolomites

KNOX GROUP (Okx)

Sandstones

CORBIN SANDSTONE MEMBER, GRUNDY and BEE ROCK FORMATIONS(contains Lee type sandstone of the former Lee Formation) (Plc)

Interbedded clay shales, siltstones, and sandstones

BORDEN FORMATION (MDbb)
GARRARD SILTSTONE (Okc)

Coals, sandstones, and shales

BREATHITT GROUP (Pikeville Formation) (Pbl)

Fractured shales

NEW ALBANY SHALE (MDnb)
BOYLE DOLOMITE (MDnb)

Clay shales

PARAGON FORMATION (Mpk)
CRAB ORCHARD FORMATION AND BRASSFIELD DOLOMITE (Scb)

Interbedded limestones and shales

DRAKES FORMATION (Od)
ASHLOCK FORMATION and CALLOWAY CREEK LIMESTONE (Oaf)
CLAYS FERRY FORMATION and KOPE FORMATION (Okc)

For more information, see the definitions of geologic terms and rock descriptions, a geologic map of the county, a summary of the geology of Kentucky, and a discussion of fossils and prehistoric life in Kentucky.

Ground Water Availability

Alluvium (Qa)

Topography

The alluvium forms narrow flood plains and small terraces along the Kentucky River and larger tributaries.

Hydrology

The alluvium yields 100 to 500 gal/day (gallons per day) to wells in thick deposits along the Kentucky River; elsewhere, the alluvium is too thin and fine-grained to yield much water. Water is hard.

High Level Fluvial Deposits (QTf)

Topography

These deposits blanket localized areas of uplands and hilltops having no distinct surface expression.

Hydrology

These deposits yield 100 to 500 gal/day to wells in thick deposits, otherwise, they are too thin and scattered to be important as an aquifer. The do yield water to small springs and dug wells. Water is soft.

Breathitt Group (Pikeville Formation) (Pbl)

Topography

The Breathitt Group underlies the valleys and forms the hills of the southeastern corner of the county. Tops of hills and ridges commonly are capped by sandstone. Shales form wide valleys and moderate or gentle slopes on hills.

Hydrology

The Breathitt yields more than 500 gal/day to almost half of the wells drilled in valley bottoms and more than 100 gal/day to about half the wells drilled on hillsides and on ridges. Sandstones yield water to most wells. Shales also yield water to many wells, and coal yields water to a few. Near-vertical joints and openings along bedding plains yield most of the water to wells. Waters are highly variable in chemical character

Corbin Sandstone Member, Grundy and Bee Rock Formations (contains Lee type sandstone of the former Lee Formation) (Plc)

Topography

These rocks form the tops of steep-sided ridges and knobs, steep bluffs and cliffs. Some sandstone paleochannels have been cut through shales of the Paragon Formation into limestone units of Late Mississippian.

Hydrology

These rocks yield 100 to 500 gal/day to drilled wells on broad ridges, but almost no water to wells on narrow ridges or hilltops. They do yield water to small springs. Water is soft.

Paragon Formation (Mpk)

Topography

The Paragon is too thin and limited in extent to have distinct surface expression.

Hydrology

The Paragon yields almost no water. Impermeable shale may hold water in overlying sandstone and conglomerate.

Slade Formation (in southeastern corner) (Mpn),(Mn)

Topography

In the southeastern corner of the county these limestone beds form steep hillsides and prominent bluffs in sides of ridges and knobs that are capped by Pennsylvanian rocks.

Hydrology

The Slade yields 100 to 500 gal/day to drilled wells in the few places where it occurs below stream level. It yields almost no water to wells on narrow ridgetops or hillsides, but does yield water to small springs on hillsides, particularly at the heads of streams. Springs have large winter and small summer flows. Water is hard to very hard.

Borden Formation (MDbb), (Mbf)

Topography

The Borden forms the main part of Mississippian escarpment, ridges, and knobs. Shale forms dissected slopes, massive siltstone forms cliffs, and limestone forms ledges on shale slopes.

Hydrology

The Borden yields 100 to 500 gal/day to wells in valley bottoms. It may yield more than 500 gal/day to drilled wells in broad valley bottoms from fractured sandy rocks near streams. It yields almost no water to wells on hills. Water from wells drilled below stream level may contain salt, sulfate or iron less than 100 feet below the level of the principal valley bottoms. Water from dug wells and small springs is soft and has a low dissolved-solids content Water from shale is soft; from the siltstone, hard; and from the limestone, very hard. Because much of this formation is soft and silty, it has been well suited to the construction of dug wells in the past.

New Albany Shale (MDnb)

Topography
The New Albany forms broad, flat valleys and flat uplands. It forms steep, dissected hillsides and bluffs along streams.

Hydrology
The New Albany yields 100 to 500 gal/day to drilled wells in valley bottoms and on uplands, usually at depths of less than 50 feet; water from greater depths is highly mineralized. The shale yield water to small springs. Water may be soft or highly mineralized. Salt, hydrogen sulfide, and iron are the usual objectionable constituents.

Boyle Dolomite (MDnb)

Topography
The Boyle forms resistant ledges on valley sides between shale slopes above and below.

Hydrology
The Boyle yields almost no water to drilled wells. It does yield water to many small perennial springs. Water is hard but otherwise of good quality.

Crab Orchard Formation and Brassfield Dolomite (Scb)

Topography
The shale forms steep, dissected hillsides and broad, flat valley bottoms. The shale erodes readily below more resistant overlying limestone, forming notches and recesses. Dolomite beds form discontinuous ledges along hillsides.

Hydrology
The shale yields almost no water to wells or springs, but may yield small amounts of water to wells in valley bottoms. Water is highly mineralized. Dolomite beds yield hard water to small springs.

Drakes Formation (Od)

Topography
The Drakes forms dissected upland areas, with slopes moderately steep where underlain by shale, and moderately undulating to gently rolling where underlain by limestone. The Drakes forms steep and cliffy slopes along large streams, littered with limestone slabs left as shale beds weather and wash away.

Hydrology

The Drakes yields 100 to 500 gal/day to drilled wells in broad valleys and along streams in upland, but almost no water to drilled wells on hillsides or ridgetops. It does yield water to small springs. Water is hard and in valley bottoms may contain salt or hydrogen sulfide. Shale limits amount of water that has access to thick limestone beds, and therefore restricts number of openings in these beds enlarged by solution. As a result, the limestone beds yield little water.

Ashlock Formation and Calloway Creek Limestone (Oaf)

Topography

These rocks form gently to moderately rolling uplands away from major streams. The formation is highly dissected where shale content increases, with small sinkholes, minor underground drainage, and broad, flat valleys where limestone predominates.

Hydrology

These formations yield 100 to 500 gal/day to drilled wells in broad valleys and along streams in uplands, but almost no water to drilled wells on hillsides or ridgetops. They do yield water to small springs. Water is hard and in valley bottoms may contain salt or hydrogen sulfide. Where thick limestone beds with little shale occur below stream level in valley bottoms or on uplands, they may have undergone solutional enlargement of fractures and bedding-plane openings. Wells drilled into these limestone beds may produce more than 500 gal/day. These thick beds also yield water to some large springs.

Garrard Siltstone (Okc)

Topography

The Garrard forms prominent ledges along hillsides.

Hydrology

The well-cemented siltstone and fine-grained sandstone and siltstone do not provide many openings for water and yields almost no water to wells. Water is hard.

Clays Ferry Formation and Kope Formation (Okc)

Topography

These formations create the rugged topography of narrow, steep-sided ridges with narrow V-shaped valleys of dendritic drainage. Steep slopes erode easily and are covered with thin limestone slabs in many places. In the lower part of the formation topography becomes more gently to moderately rolling uplands with small sinkholes and some underground drainage where limestone predominates.

Hydrology

These formations yield 100 gal/day to drilled wells in valley bottoms, but almost no water to drilled wells on hillsides or ridgetops. They do yield water to small springs. In the lower, limestone-rich section, drilled wells can yield 100 to 500 god in valley bottoms along streams. Water is hard in valley bottoms may contain salt or hydrogen sulfide. Shale has small, poorly connected openings, and ground-water circulation is slow; as a result, little water is available to wells and springs. On ridgetops the shale prevents downward percolation of water, and creates small semiperched water bodies in lower part of soil and upper part of weathered bedrock.

Upper Part of Lexington Limestone (Tanglewood Limestone, Millersburg, Strodes Creek, Devils Hollow, Sulfur Well, Brannon and Perryville Members) (Ol)

Topography

The upper Lexington forms broad flat valleys in uplands. Where dominantly limestone, it has well-developed subsurface drainage and many sinkholes, with gently sloping hillsides adjacent to small streams in uplands. The resistant shale and soft bentonite-rich beds form a subdued benchlike topography along hillsides and streams.

Hydrology

The upper Lexington yields more than 500 gal/day to wells in valley bottoms and along streams in uplands. It yields 100 to 500 gal/day to many perennial springs and more than 100 gal/min to a few large springs. The amount of water available in rocks of the Lexington Limestone is dependent on the amount of shale. Generally, throughout the whole Lexington Limestone section , the more shale found within the zone of interest, the less water will be found. The upper Lexington yields water to springs from resistant Brannon Member. Water is hard and may contain salt or hydrogen sulfide in some places. Water from wells near fault zones may contain objectionable amounts of salt.

Lower Part of Lexington Limestone (Ol) (Grier, Logana, Curdsville Members)

Topography

The lower Lexington forms rolling to dissected upland. Sinkholes are very common; the large ones occur in the Grier Limestone. Natural outcrops are rare in the rolling upland, but the limestone beneath hill slopes is evident from the benchlike or terrace like appearance of the slopes. Limestone crops out in discontinuous bands in the valley sides in the dissected part near the Kentucky River.

Hydrology

The lower Lexington yields 100 to 500 gal/day to wells in most valley bottoms and along streams in uplands; it yields up to 150 gal/min from thick limestone beds in the Curdsville along large streams. The lower Lexington also yields water to many small springs. Water is hard and may contain salt in valley bottoms.

High Bridge Group (Tyrone Limestone, Oregon Formation, Camp Nelson Limestone) (Ohb)

Topography

The High Bridge forms steep slopes and high cliffs along the Kentucky and Dix Rivers and lower parts of tributaries. The Camp Nelson forms flat terraces with occasional sinkholes in the bottom of the Kentucky River gorge and steep cliffs along the lower sides. It also extends up the large tributaries, forming flat bottoms and steep walls. The Oregon crops out in a band in the walls of the gorge and up a few large tributaries. The Tyrone crops out in the upper walls of the Kentucky River gorge and extends up the large tributaries nearly to the upland, forming broad, flat valleys with sinkholes and underground drainage.

Hydrology

The High Bridge yields 100 to more than 500 gal/day to drilled wells in valleys of the Dix and Kentucky Rivers and large tributaries. Yields have been reported as much as 225 gal/min to wells drilled into the Camp Nelson Limestone adjacent to the Kentucky River, from solution channels and fractures connected with the river. The High Bridge yields water to springs on hillsides and in steep walls along large streams. Water is hard and may contain hydrogen sulfide but generally of good quality. Wells drilled into the High Bridge through overlying rocks produce almost no water because bentonite beds in the Tyrone prevent recharge to underlying rocks except where the bentonite has been breached or removed by erosion.

Knox Group (Okx)

Topography

The Knox Group has no surface exposure in Kentucky, but underlies the entire state at varying depths.

Hydrology

In the Inner Bluegrass Region of Kentucky, fresh water has been found in the upper 100 to 250 feet of this largely untested dolomite rich aquifer. Wells often exceed 750 feet in total depth with high concentrations of dissolved solids found in many areas. Average reported yields range in the 10 to 20 gal/min range but as high as 75 gal/min.

You can find out more about the Knox aquifer.

The U.S. Geological Survey's Hydrologic Atlas Series, published cooperatively with the Kentucky Geological Survey, provides hydrologic information for the entire state.

Exploration for Ground Water

Ground water is precipitation that has drained through the soil into the gravels and bedrock fractures and faults below. It is found nearly everywhere, but useable, reliable quantities can only be tapped in sand, gravel, and rock formations that have sufficient void space to hold and conduct water. These formations are known as aquifers. Most ground water used for domestic supply comes from relatively shallow wells (less than 150 feet in depth) in fractured bedrock or unconsolidated materials. The bedrock may be shale, sandstone, siltstone, limestone, or coal. Water can be stored in all these rocks, but rapid movement of water is primarily controlled by secondary fractures--joints or faults that penetrate the rock near the land surface (Wyrick and Borchers, 1981; Kipp and Dinger, 1991).

Joints and faults in the earth’s crust may extend for tens of feet up to several miles in length. The more lengthy of these features, called linear terrain features, fracture traces, or lineaments, can be seen on different types of aerial photographs and satellite imagery. These features may collect, store, and transport large amounts of ground water that can provide sufficient water to communities and industry.

Little effort has been made in the past to determine the ground-water resource potential as it relates to high-yield wells. Recent efforts in the upper Kentucky River Basin in which satellite imagery was used to locate wells resulted in three out of four wells producing more water than 90 percent of the recorded wells in the area, and having enough water to supply from 50 to 250 homes per well.

Exploiting geologic features such as fracture traces and lineaments is a common technique used for the exploration of subsurface fluids, including ground water (Siddiqui and Parizek, 1971; Mabee and others, 1994) and petroleum (Driscoll, 1986). Fracture traces are linear expressions on the earth's surface that are less than 1 mile in length; those greater than a mile are termed lineaments. Linear features that are not readily apparent on the ground can often be distinguished at high altitudes. Currently, private vendors as well as foreign agencies have made high-resolution satellite photos and radar images available. These data can be used in detailed surficial analysis for linear features that can be related to high-production ground-water zones.

Karst

(*by James C. Currens, Kentucky Geological Survey*)

A karst landscape has sinkholes, sinking streams, caves, and springs. Kentucky is one of the most famous karst areas of the world. Much of the state's beautiful scenery, particularly the horse farms of the Inner Blue Grass, results from the development of karst landscape. Karst underlies regions of major economic importance to the state. Many of Kentucky’s cities, such as Frankfort, Louisville, Lexington, Bowling Green, Elizabethtown, Munfordville, Hopkinsville, Russellville, Princeton, Lawrenceburg, Georgetown, Winchester, Paris, Somerset, Versailles, and Nicholasville, are partly or entirely underlain by karst. Springs and wells in karst areas supply water to thousands of homes. Much of Kentucky’s prime farmland is underlain by karst. A substantial portion of the Daniel Boone National Forest, with its important recreational and timber resources, is underlain by karst. Caves also provide recreational opportunities and contain unique ecosystems. Mammoth Cave, with over 350 miles of passages, is the longest surveyed cave in the world. Two other caves in the state are over 30 miles long, and 10 Kentucky caves are among the 50 longest in the United States.

View state karst map

Although maps that show in detail where the karst terrane of Kentucky occurs have never been made, the areas underlain by rocks on which karst can develop have been mapped. The 1:500,000-scale geologic map (Noger, 1988) can be used to estimate the percentage of karst terrane in the state. Ninety-two of Kentucky's 120 counties contain at least some areas of karst. About 40 percent of the state is underlain by rocks with the potential for at least some karst development, recognizable on topographic maps, and 20 percent of the state has well-developed karst features.

Karst Regions

The karst of Kentucky occurs in five principal regions, but also in many scattered locations.

- The largest area is the Western Pennyroyal, arching from the Ohio River north of Elizabethtown southward, then westward through Bowling Green and Hopkinsville, then northward again back to the Ohio River. Many of the state's longest caves, and terrane most densely pocketed with sinkholes, are in this region.

- The next largest expanse is the Inner Blue Grass, surrounding Lexington and including Georgetown, Versailles, Winchester, and several other cities.
- The Eastern Pennyroyal lies east of the Inner Blue Grass and reaches from the Ohio River south-southwest to the Tennessee border. The Eastern Pennyroyal includes the communities of Mount Vernon, Somerset, and Monticello.
- The Carter Caves region, east-northeast of Winchester is the fourth region, but it is sometimes considered part of the Eastern Pennyroyal. Although no large communities are located on this karst, Carter Caves State Park, an important tourist attraction, is located here.

The last major karst area lies along the crest of Pine Mountain in southeastern Kentucky, where geologic forces have thrust the limestone from deep beneath the coal field to the surface. No communities occupy this karst area, but it is a significant recreational and ecological resource, and springs draining from it are important water supplies.

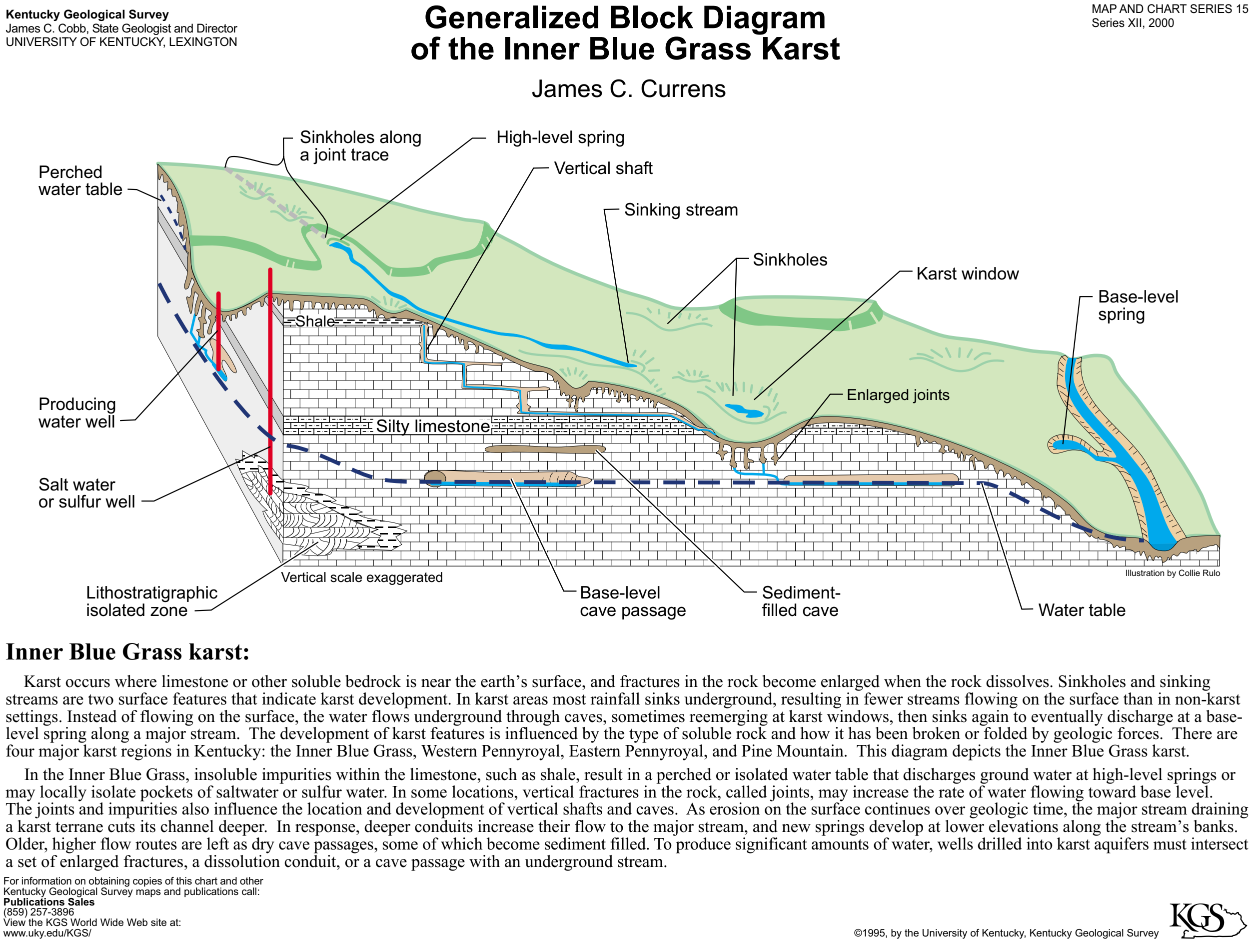
Karst terrane affects the lives of many Kentuckians every day. Most people don’t realize they are affected because the costs are hidden in the form of higher taxes and increased cost of living. Often enough, the consequences of living in a karst terrane directly affects people's lives. Of vital concern is protection of ground-water resources. For example, many communities in Kentucky were established near karst springs to take advantage of the reliable water supply. Because of pollution, most of these town springs have long since been abandoned as water supplies. Factories and homes built over filled sinkholes may be damaged as the fill is transported out of the sinkhole and the soil cover collapses. Also, structures built in sinkholes are often vulnerable to flood damage.

Flooding in a karst area.

Features of a Karst Landscape

The term "karst" is derived from a Slavic word that means barren, stony ground. It is also the name of a region in modern Slovenia near the border with Italy that is well known for its sinkholes and springs. The name has been adopted by geologists as the term for all such terrane.

A karst landscape most commonly develops on limestone but can develop on several types of rocks, such as dolomite, gypsum, and salt. The karst terranes of Kentucky are mostly on limestone and formed over hundreds of thousands of years. As water moves underground, from hilltops toward a stream through tiny fractures in the limestone bedrock, the rock is slowly dissolved away by weak acids found naturally in rain and soil water.



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MAP AND CHART SERIES 15
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Generalized Block Diagram of the Inner Blue Grass Karst

James C. Currens

Inner Blue Grass 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. 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 Blue Grass, Western Pennyroyal, Eastern Pennyroyal, and Pine Mountain. This diagram depicts the Inner Blue Grass karst.

In the Inner Blue Grass, insoluble impurities within the limestone, such as shale, result in a perched or isolated water table that discharges ground water at high-level springs or may locally isolate pockets of saltwater or sulfur water. In some locations, vertical fractures in the rock, called joints, may increase the rate of water flowing toward base level. The joints and impurities also influence the location and development of vertical shafts and caves. 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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Kentucky Geological Survey maps and publications call:
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View the KGS World Wide Web site at:
www.uky.edu/KGS/

Schematic diagram showing some of the important features of karst terrane. Other types of karst features are not illustrated.

An aquifer is any body of rock from which important quantities of drinkable water may be produced. Springs are sites where ground water emerges from an aquifer to become surface water. Springs occur along creeks and rivers where the water table meets the land surface. They also occur where rocks that do not allow water to flow easily, such as shale, underlie or have been faulted against permeable rock. The impermeable rock blocks the flow of the ground water, again forcing it to the surface. Karst springs occur where the ground-water flow has concentrated to dissolve a conduit or cave in soluble rock. The ground-water basin of a karst spring collects drainage from all the sinkholes and sinking streams in its drainage area. The water flowing from each sinkhole joins together underground to form ever-increasing flow in successively larger passages, which discharge at the spring. Karst springs or "cave springs" can have large openings and discharge very large volumes of water. The soil cover, narrow fractures, small conduits, and larger cave passages collectively form a karst aquifer.

A sinkhole is any depression in the surface of the ground into which rainfall is drained. Karst sinkholes form when a fracture in the limestone bedrock is preferentially enlarged. Sinkholes form in two ways. In the first way, the bedrock roof of a cave becomes too thin to support the weight of the bedrock and the soil material above it. The cave roof then collapses, forming a collapse sinkhole. Bedrock collapse is rare, and the least likely way a sinkhole can form, although it is commonly assumed to form all sinkholes. The second way sinkholes form is much more common and much less dramatic. As the rock is dissolved and carried away underground, the soil gently slumps or erodes into a dissolution sinkhole. Once the underlying conduits become large enough, insoluble soil and rock particles are carried away too. Dissolution sinkholes form over long periods of time, with occasional episodes of soil or cover collapse.

All of the dissolved limestone and soil particles eroded from the bedrock to form a sinkhole pass through the sinkhole's "throat" or outlet. The throat of a sinkhole is sometimes visible, but is commonly roofed by soil and broken rock and can be partly or completely filled with rubble. This opening can vary from a few inches in diameter to many feet. Normally, water flows out of the sinkhole throat to a conduit that drains to a spring. When sinkhole throats are totally blocked and little water can flow out, a "sinkhole pond" may form, a common sight in the Pennyroyal. Sinkhole ponds are temporary features and last only as long as the throat is tightly plugged.

Swallow holes are points along streams and in sinkholes where surface flow is lost to underground conduits. Swallow holes range in diameter from a few inches to tens of feet, and some are also cave entrances. Swallow holes are often large enough to allow large objects such as tree limbs and cobble-size stones to be transported underground. This means that waste dumped into sinkholes can easily reach underground streams. It is not uncommon for discarded automobile tires and home appliances to be found deep within caves with flowing streams. Likewise, sewage, paint, motor oil, pesticides, and other pollutants are not filtered from water entering a karst aquifer.

Karst windows are a special type of sinkhole that gives us a view, or window, into the karst aquifer. A karst window has a spring on one end, a surface-flowing stream across its bottom, and a swallow hole at the other end. The stream is typically at the top of the water table. Karst windows develop by both dissolution and collapse of the bedrock. Many karst windows originated as collapse sinkholes.

Karst locations are shown on a map of karst in the county.

More information on karst is available on the KGS Web site.

Water Quality

"Groundwater is a vital, renewable natural resource that is widely used throughout Kentucky. Wells and springs provide approximately one-third of public domestic water supplies in the state. Surface streams, the major source of Kentucky's water supply, are primarily sustained during base flow by groundwater discharge from adjacent aquifers. This resource is susceptible to contamination from a variety of activities at the land surface. Once contaminated, groundwater can be difficult or impossible to remediate."---Kentucky Division of Water, Groundwater Branch.

Quality of Ground Water in the County

The quality of ground water in the Blue Grass region varies considerably from place to place and is determined by its geologic source. In Madison County ground water is hard to very hard and may contain salt or hydrogen sulfide, especially at depths greater than 100 feet. The two most common natural constituents that make water in the Blue Grass region objectionable for domestic use are common salt and hydrogen sulfide.

At a time when surprisingly little information is available on ground-water quality, ground-water contamination has become one of the major environmental issues. Reliable information about water quality is necessary in order to develop plans for protecting ground water. The absence of accurate and broad perspectives on ground-water quality may lead to inappropriate and ineffective regulatory policies. Because ground water supplies a large percentage of rural drinking water and water for agricultural use, rural landowners have become increasingly concerned about the quality of ground water. The Kentucky Farm Bureau, Kentucky Division of Conservation, University of Kentucky Cooperative Extension Service, and the Kentucky Geological Survey conducted a water-quality survey of nearly 5,000 rural domestic wells. The results are discussed in "Quality of Private Ground-Water Supplies in Kentucky." Additional references are contained in the Kentucky Geological Survey Internet Water Research library.

Salt Water

Salt water (saline water) is found below fresh ground water at variable depths throughout the entire state of Kentucky. Depths to the saline groundwater range from 50 feet or less, down to 2,000 feet below land surface in Kentucky. "Salinity" is defined as a measure of the quantity of dissolved mineral matter or total dissolved solids (TDS) in water, reported in parts per million (ppm) or milligrams per liter (mg/L); The two forms of measurement usually are equivalent. The term “salt” or “table salt” as used by most people is pure sodium chloride. Sodium and chloride are generally the major component of saline waters in Kentucky, but are not the only constituents. Water having a TDS concentration of less than 1,000 ppm is classified as fresh and water having a TDS concentration of 1,000 ppm or more is classified as saline. Recommendations by the U.S. Public Health Service for drinking water suggest that total dissolved solids should not exceed 500 ppm, but less than 1,000 ppm may be used. In agriculture, the recommended TDS levels vary with uses, as shown in the following table, which was taken in part from "Fresh-Saline Water Interface Map of Kentucky" (Hopkins, 1966).

Upper limits of total dissolved-solids concentration in water to be consumed by livestock or used for crops.	
Crop	ppm
All crops, including forage	525
Most fruit and vegetable crops	1,400
Poultry	2,860
Pigs	4,290
Horses	6,435
Cattle (dairy)	7,150
Cattle (beef)	10,000
Adult sheep	12,900

Being aware of the depth to saline ground water is valuable when planning a water-supply well. Drilling a well too deep through the freshwater interval may cause a good well to be unsuitable for various uses. Care must be taken to prevent contamination of the freshwater zones by the deeper saline waters. Properly constructed water wells will screen the production zone in the targeted aquifer and isolate all other zones by casing and properly grouting and cementing the space outside the casings in the boreholes.

In Madison County the fresh-saline interface ranges from elevations of 400 feet mean sea level along the Kentucky River, up to 900 feet in the hilly southeastern corner of the county. Generally, salt water is found at depths greater than 100 feet below the level of the principal valley bottoms.

Sensitivity of Ground Water to Pollution

According to the Kentucky Division of Water, Groundwater Branch, Madison County has areas of low-moderate to high sensitivity to ground-water pollution (see "Report and Map on Ground-Water Sensitivity," adapted from the Kentucky Division of Water, 1994). The hydrogeologic sensitivity of an area is defined as the ease and speed with which a contaminant can move into and within a ground-water system. The sensitivity assessment addressed only the naturally occurring hydrogeologic characteristics of an area. Possible impacts of human activity upon ground water, such as mining, logging, industry, and the use of pesticides, injection wells, and landfills, were not considered in the production of this map. Because of its small scale and generalized nature, this map is not intended for site-specific use, such as detailed land-use planning for city, county, or state agencies. The map should prove useful as a broad-scale management, educational, and planning tool, however.

Maps and Data

More information may be found at the following Web sites:

Index to 7.5' Topographic and Geologic Quadrangle Maps

Download site for Geologic Quadrangle Maps

Download site for Topographic Maps

Download site for Aerial Photos (DOQQs)

Download site for Digital Elevation Models

GIS Data

Additional Readings

Dasari, M. Rao and Conkin, James E., 1989, Stratigraphy and clay mineralogy of Middle Ordovician metabentonites in Tyrone Formation at Boonesborough, Kentucky.

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Water-resource publications of the Kentucky Geological Survey may be viewed on the internet at the Kentucky Geological Survey Internet Water Research library.

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Siddiqui, S.H, and Parizek, R.R., 1971, Hydrogeologic factors influencing well yields in folded and faulted carbonate rocks in central Pennsylvania: Water Resources Research, v. 7, no. 5, p. 1295-1312.

Wyrick, G.C., and Borchers, J.W., 1981, Hydrologic effects of stress relief fractures on an Appalachian Valley: U.S. Geological Survey Water-Supply Paper 2177, 51 p.

Definitions of Geologic Terms

Alluvial deposits: Stream-sediment deposits of comparatively recent age.

Aquifer: Stratum or zone below the surface of the earth capable of producing water, as from a well.

Bedding plane: The division planes that separate the individual layers, beds, or strata of rock.

Bedrock: Solid rock underlying soils and unconsolidated materials.

Faults: Fractures in the earth's crust along which displacement has occurred. The presence of faults may be very important in the success of large-capacity wells. In general, faulting enhances the permeability of bedrock aquifers because the bedrock is broken and pulverized along the zone bordering the fault plane. This is especially true in limestone areas, where fracturing is enhanced by subsequent solution. High-capacity wells are commonly located in fault zones.

Joints: Widely space vertical cracks in the bedrock.

Limestone: Layered rock composed of grains of calcite cemented together; may contain fossils.

Sandstone: Layered rock composed of grains of sand cemented together.

Shale: Thin-layered rock composed of clay minerals.

Soil: Loose materials occurring between the ground surface and underlying bedrock.

Rock Descriptions

(Noger, 1988; Carey and others, 1994)

Limestone: Limestones are characterized by solution-enlarged joints and bedding planes that channel water into conduits. The majority of ground water flows through the conduits and discharges at springs along major, permanent streams. Wells drilled in these areas may produce only a little water, or hundreds of gallons per minute, depending on the chance intersection of an enlarged joint or other opening. Little water moves through the unaltered bedrock. Ground water flowing through fractures and solution openings is easily contaminated. These rocks are generally very hard, requiring blasting or heavy equipment for excavation, and the depth of soil coverage is highly variable. In some areas of Kentucky underlain by limestones, soils more than 30 feet thick have been reported.

Sandstone: These rocks are generally very hard, requiring blasting or heavy equipment for excavation. Sandstones tend to form thin soils and steep slopes. Ground water flows through openings between sand grains and along fractures (widely spaced cracks).

Unconsolidated deposits: These deposits consist of noncemented clay, sand, and gravel and are found primarily in stream valleys. West of Lake Cumberland, these deposits occur both in stream valleys and upland areas. They are easily eroded during rainstorms. West of Lake Barkley, these deposits include loess, a fine-grained material deposited by wind. These deposits yield large volumes of water where aquifers are extensive. Areas of terrace deposits and alluvium in upper stream reaches may be too small to sustain high rates of production.

Fractured shales: Fresh exposures of fractured shale are hard and require heavy machinery for excavation. Although jointing and bedding planes in these brittle shales allow ground-water movement, there is little storage in the unfractured material. Wells in these rocks typically produce little water.

Clay shales: These shales are easily excavated and restrict ground-water movement. The high clay content can produce slippage and workability problems. Joints and bedding planes tend to heal or become clogged, an although clay minerals have large intergranular storage of water, there is little or no permeability to allow its movement. Wells in these rock are generally dry.

Interbedded shales and limestones: Bedrock composed of 80 percent or more shale and 20 percent or less limestone. Limestone layers are usually 2 inches or less thick. These rocks are easily excavated and generally restrict ground-water movement. Oversteepened banks and artificial cuts are subject to slippage. These formations have some limited potential as aquifers, but the high clay content generally blocks small conduits in the limestone. Wells in these rocks are generally dry.

Interbedded clay shales and sandstones: Where clay shales are dominant, successful water wells are difficult to obtain. In areas where the unit is sandy, wells more commonly yield sufficient water for a domestic supply.

Interbedded limestones and shales: Contains more than 20 percent limestone. Where limestone exceeds 60 percent, wells may yield adequate water for a domestic supply.

Interbedded limestones, sandstones, and shales: A vertical sequence of alternating limestones, sandstones, and shales.

Coals, sandstones, and shales: This unit consists of a vertical sequence of coals, sandstones, and shales that is generally horizontally discontinuous. Wells that penetrate a section composed of more than 50 percent sandstone have better than average yields, and almost all wells will produce enough water for domestic supplies. Many wells will produce sufficient supplies for small industries. Wells completed in coals, or obtaining flow from coals, are high productive, but may be of marginal or poor water quality. Wells completed in shales are commonly adequate for domestic supplies, depending upon the occurrence of weathered fractures in the shale.