5 Water

Randa Harris

5.1 INTRODUCTION

Think how many times a day you take water for granted – you assume the tap will be flowing when you turn on your faucet, you expect rainfall to water your lawn, and you may count on water for your recreation. Not only is water necessary for many of life's functions, it is also a considerable geologic agent. Water can sculpt the landscape dramatically over time both by carving canyons as well as depositing thick layers of sediment. Some of these processes are slow and result in landscapes worn down over time. Others, such as floods, can be dramatic and dangerous.

What happens to water during a rainstorm? Imagine that you are outside in a parking lot with grassy areas nearby. Where does the water from the parking lot go? Much of it will run off as sheet flow and eventually join a stream. What happens to the rain in the grassy area? Much of it will infiltrate, or soak into the ground. We will deal with both surface and ground water in this lab. Both are integral parts of the water cycle, in which water gets continually recycled through the atmosphere, to the land, and back to the oceans. This cycle, powered by the sun, operates easily since water can change form from liquid to gas (or water vapor) quickly under surface conditions.

Both surface and ground water are beneficial for drinking water, industry, agriculture, recreation, and commerce. Demand for water will only increase as population increases, making it vital to protect water sources both above and below ground.

5.1.1 Learning Outcomes

After completing this chapter, you should be able to:

- Understand how streams erode, transport, and deposit sediment
- Know the different stream drainage patterns and understand what they indicate about the underlying rock
- Explain the changes that happen from the head to the mouth of a stream
- Understand the human hazards associated with floods

- Know the properties of groundwater and aquifers
- Understand the distribution of groundwater, including the water table
- Learn the main features associated with karst topography
- Understand the challenges posed by karst topography

5.1.2 Key Terms

Aquifer	Karst Topography
ischarge	Natural Levee
rainage Basin	Permeability
rainage Divide	Porosity
rainage Pattern	Recurrence Interval
loodplain	Stream Gradient

5.2 STREAMFLOW AND PARTS OF A STREAM

The running water in a stream will erode (wear away) and move material within its channel, including dissolved substances (materials taken into solution during chemical weathering). The solid sediments may range in size from tiny clay and silt particles too small for the naked eye to view up to sand and gravel sized sediments. Even boulders have been carried by large flows. The smaller particles kept in suspension by the water's flow are called suspended load. Larger particles typically travel as bed load, stumbling along the stream bed (Figure 5.1). While the dissolved, suspended, and bed loads may travel long distances (ex. from the headwaters of the Mississippi River in Minnesota to the Gulf of Mexico at New Orleans), they will eventually settle out, or deposit. These stream deposited sediments, called alluvium, can be deposited at any time, but most often occur during flood events. To more effectively transport sediment, a stream needs energy. This energy is mostly a function of the amount of water and its velocity, as more (and larger) sediment can be car-

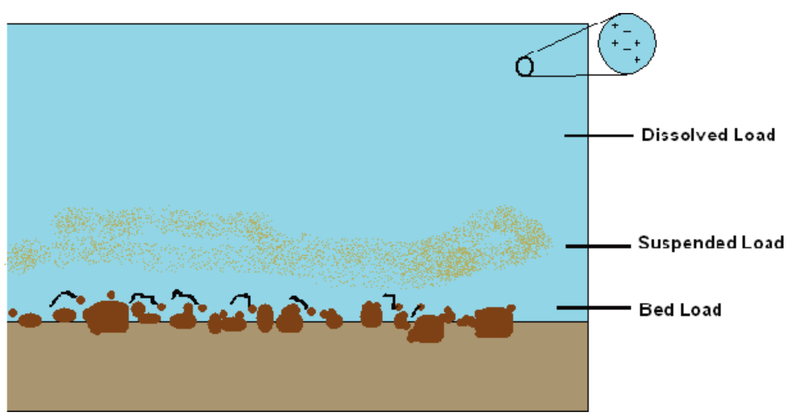

Figure 5.1 | An illustration depicting dissolved, suspended, and bed load.
Author: User "PSUEnviroDan"
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ried by a fast-moving stream. As a stream loses its energy and slows down, material will be deposited.

Under normal conditions, water will remain in a stream channel. When the amount of water in a stream exceeds it banks, the water that spills over the channel will decrease in velocity rapidly due to the greater friction on the water. As it drops velocity, it will also drop the larger sandy material it is carrying right along the channel margins, resulting in ridges of sandy alluvium called **natural levees** (Figure 5.2). As numerous flooding events occur, these ridges build up under repeated deposition. These levees are part of a larger landform known as a **floodplain**. A floodplain is the relatively flat land adjacent to the stream that is subject to flooding during times of high discharge (Figure 5.2).

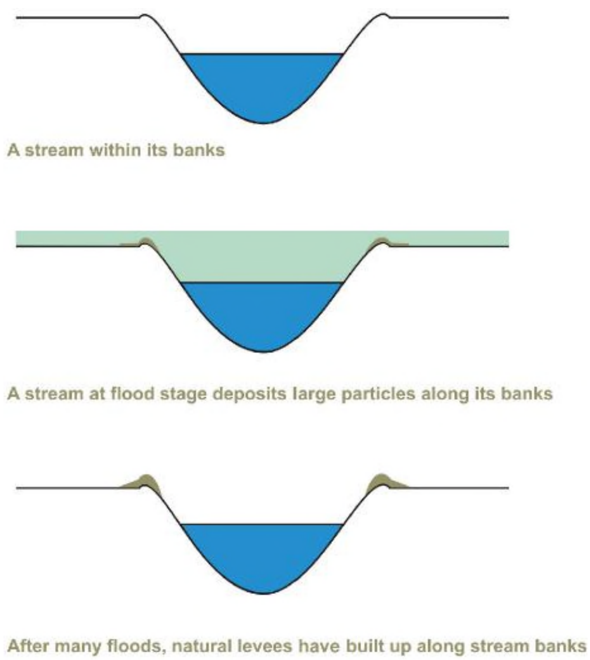

Figure 5.2 | After many floods, natural levees have built up along stream banks.
Author: Julie Sandeen
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5.2.1 Stream Drainage Basins and Patterns

The **drainage basin** of a stream includes all the land that is drained by one stream, including all of its tributaries (the smaller streams that feed into the main stream). You are in a drainage basin right now. Do you know which one? You can find out on the internet. Go to the Environmental Protection Agency's webpage (epa.gov) and search for Surf Your Watershed to find out. The higher areas that separate drainage basins are called **drainage divides.** For North America, the continental divide in the Rocky Mountains separates water that drains to the west to the Pacific Ocean from water that drains to the east to the Gulf of Mexico.

As water flows over rock, it is influenced by it. Water wants to flow in the area of least resistance, so it is attracted to softer rock, rather than hard, resistant rock. This can result in characteristic patterns of drainage. Some of the more common **drainage patterns** include:

- **Dendritic** – this drainage pattern indicates uniformly resistant bedrock that often includes horizontal rocks. Since all the rock is uniform, the water is not attracted to any one area, and spreads out in a branching pattern, similar to the branches of a tree.
- **Trellis** – this drainage pattern indicates alternating resistant and nonresistant bedrock that has been deformed (folded) into parallel ridges and valleys. The water is attracted to the softer rock, and appears much like a rose climbing on a trellis in a garden.

- **Radial** – this drainage pattern forms as streams flow away from a central high point, such as a volcano, resembling the spokes in a wheel.
- **Rectangular** – this drainage pattern forms in areas in which rock has been fractured or faulted which created weakened rock. Streams are then attracted to the less resistant rock and create a network of channels that make right-angle bends as they intersect these breaking points. This pattern will often look like rectangles or squares.
- **Deranged** – this drainage pattern does not follow the rules. It consists of a random pattern of stream channels characterized by irregularity. It indicates that the drainage developed recently and has not had time to form one of the other drainage patterns yet.

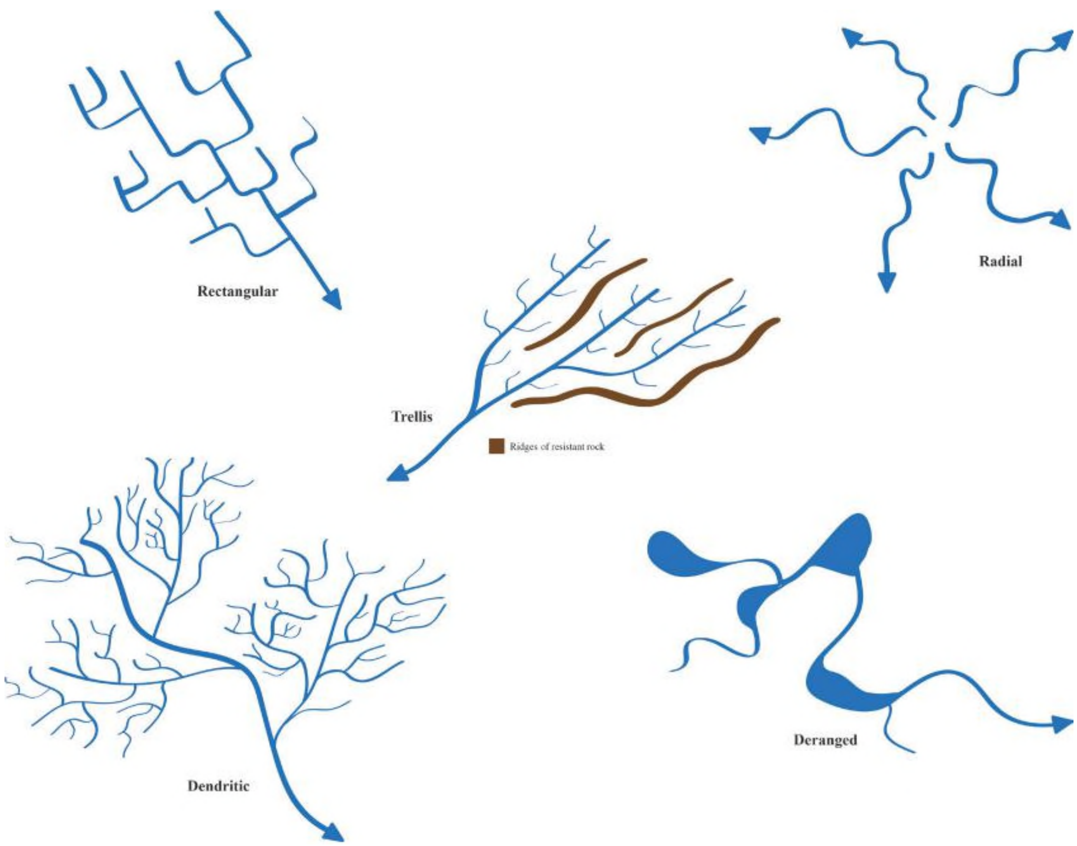

Figure 5.3 | Drainage patterns.
Author: Corey Parson
Source: Original Work

5.3 STREAM GRADIENT AND THE CYCLE OF STREAM EROSION

Stream gradient refers to the slope of the stream's channel, or rise over run. It is the vertical drop of the stream over a horizontal distance. You have dealt with gradient before in Topographic Maps. It can be calculated using the following equation:

Gradient = (change in elevation) / distance

Let's calculate the gradient from A to B in Figure 5.4 below. The elevation of the stream at A is 980', and the elevation of the stream at B is 920'. Use the scale bar to calculate the distance from A to B. Gradient = (980' – 920') / 2 miles, or 30 feet/mile.

Stream gradients tend to be higher in a stream's headwaters (where it originates), and lower at their mouth, where they discharge into another body of water (such as the ocean). **Discharge** measures stream flow at a given time and location, and specifically is a measure of the volume of water passing a particular point in a given period of time. It is found by multiplying the area (width multiplied by depth) of the stream channel by the velocity of the water, and is often in units of cubic feet (or meters) per second. Discharge increases downstream in most rivers, as tributaries join the main channel and add water.

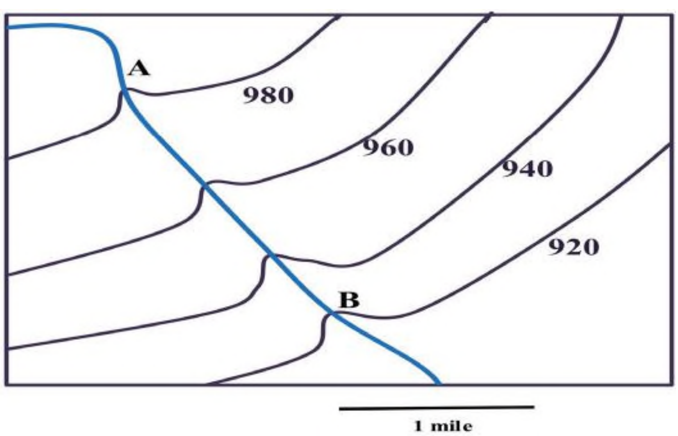

Figure 5.4 | Gradient calculation.
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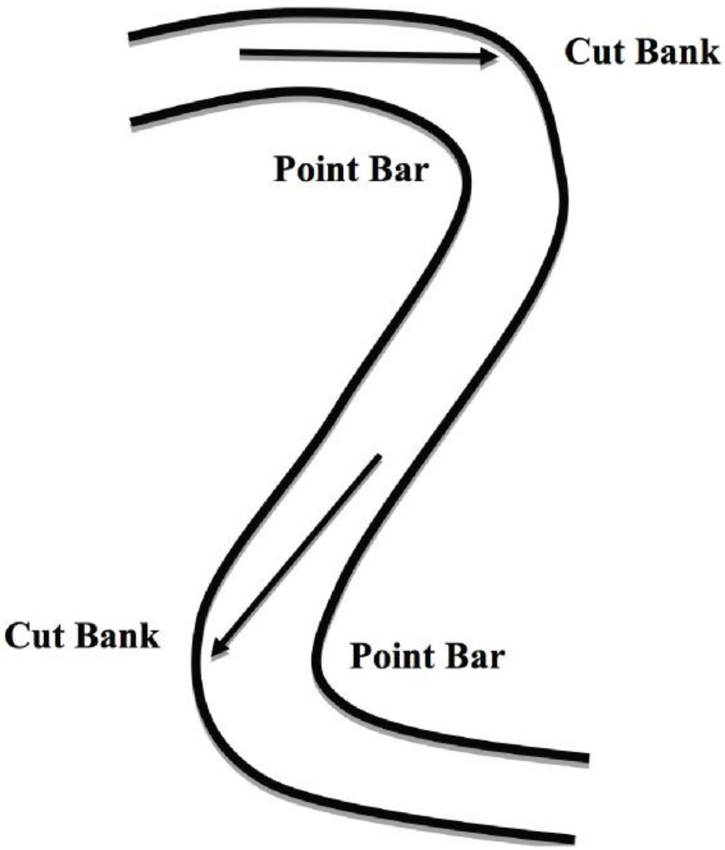
Sediment load (the amount of sediment carried by the stream) also changes from headwaters to mouth. At the headwaters, tributaries quickly carry their load downstream, combining with loads from other tributaries. The main river then eventually deposits that sediment load when it reaches base level. Sometimes in this process of carrying material downstream, the sediment load is large enough that the water is not capable of supporting it, so deposition occurs. If a stream becomes overloaded with sediment, braided streams may develop, with a network of intersecting channels that resembles braided hair. Sand and gravel bars are typical in braided streams, which are common in arid and semiarid regions with high erosion rates. Less commonly seen are straight streams, in which channels remain nearly straight, naturally due to a linear zone of weakness in the underlying rock. Straight channels can also be man-made, in an effort at flood control.

Streams may also be meandering, with broadly looping meanders that resemble "S"-shaped curves. The fastest water traveling in a meandering stream travels from outside bend to outside bend. This greater velocity and turbulence lead to more erosion on the outside bend, forming a featured called a cut bank. Erosion on this bank is offset by deposition on the opposite bank of the stream, where slower moving water allows sediment to settle out. These deposits are called point bars.

As meanders become more complicated, or sinuous, they may cut off a meander, discarding the meander to become a crescent-shaped oxbow lake. Check out Figure 5.6 to see the formation of an oxbow lake.



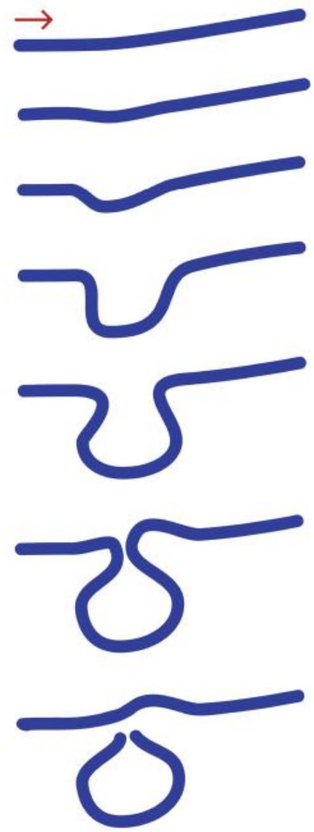


Figure 5.5 | (left) Parts of a meandering stream. The S-curves are meanders. The arrows within the stream depict where the fastest water flows. That water erodes the outside bank, creating a steep bank called the cut bank. The slowest water flows on the inside of the meander, slow enough to deposit sediment and create the point bar.
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Figure 5.6 | (right) Formation of an oxbow lake. A meander begins to form and is cut off, forming the oxbow.
Author: User "Maksim"
Source: Wikimedia Commons
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Even though streams are not living, they do go through characteristic changes over time as they change the landscape. The ultimate goal of a stream is to reach base level (the low elevation at which the stream can no longer erode its channel–

often a lake or other stream; ultimate base level is the ocean). While trying to reach this goal, the stream will experience the cycle of stream erosion, which consists of these stages:

- **Youthful (early) stage** – these streams are downcutting their channels (vertically eroding); literally they are picking up sediment from the bottom of their channels in an effort to decrease their elevation. The land surface will be above sea level, and these streams form deep V-shaped channels.
- **Mature (middle) stage** – these streams experience both vertical (downcutting) and lateral (meandering) erosion. The land surface is sloped, and streams begin to form floodplains (the flat land around streams that are subject to flooding).
- **Old age (late) stage** – these streams focus on lateral erosion and have very complicated meanders and oxbow lakes. The land surface is near base level.

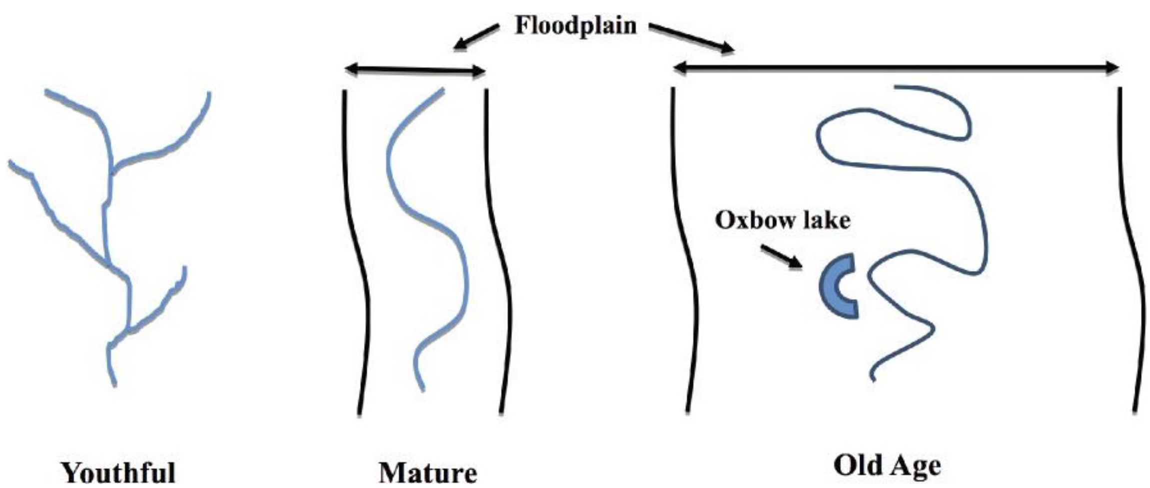

Figure 5.7 | Streams displaying the youthful, mature, and old age stages within the cycle of stream erosion. Note that the youthful stream does not have a floodplain.
Author: Randa Harris
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An interruption may occur in this cycle. If a stream suddenly begins to down-cut again, if sea level dropped (so base level dropped) or if the area around it was uplifted (think building mountains), then the stream would become rejuvenated. If the rejuvenated stream was in the old age stage, it will begin to form a deep V-shaped channel within that complicated meandering pattern that it has. This creates a neat geologic feature called an entrenched meander (Figure 5.8).

Figure 5.8 | Entrenched meanders along the San Juan River, Goosenecks State Park, Utah.
Author: User "Finetooth"
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5.4 LAB EXERCISE

Part A – Drainage Patterns

Map 5.1, located on the next page, is a portion of a topographic map from Royal Gorge, Colorado, courtesy of the USGS. Study the map and answer the questions below.

1. What type of stream drainage pattern is present on this map? This may be easier to determine by examining the tributaries to the main stream.

a. dendritic b. trellis c. radial d. rectangular

2. Based on the drainage pattern type, does the bedrock underlying this area consist of rocks uniformly resistant to erosion or rocks alternating between resistant and non-resistant layers?

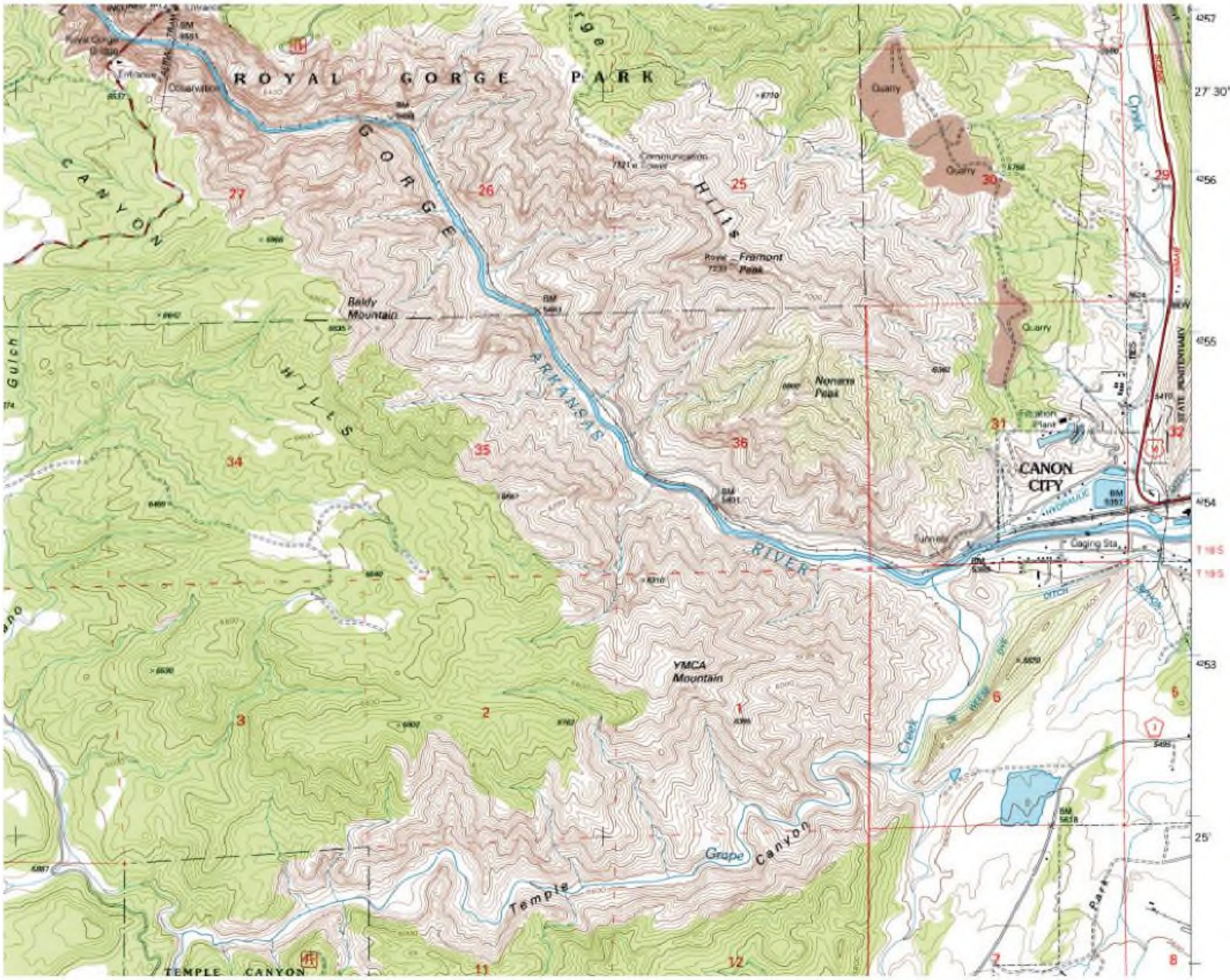
a. uniformly resistant bedrock b. alternately resistant and non-resistant bedrock

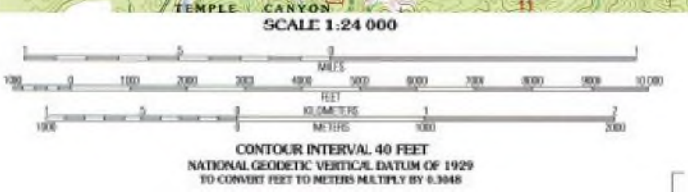
3. Are the rocks likely tilted and folded or horizontal?

a. tilted and folded b. horizontal

4. Are streams in this area downcutting or laterally eroding?

a. downcutting b. laterally eroding





Map 5.1 | Royal Gorge, Colorado 1:24,000 topographic map
Author: USGS
Source: USGS
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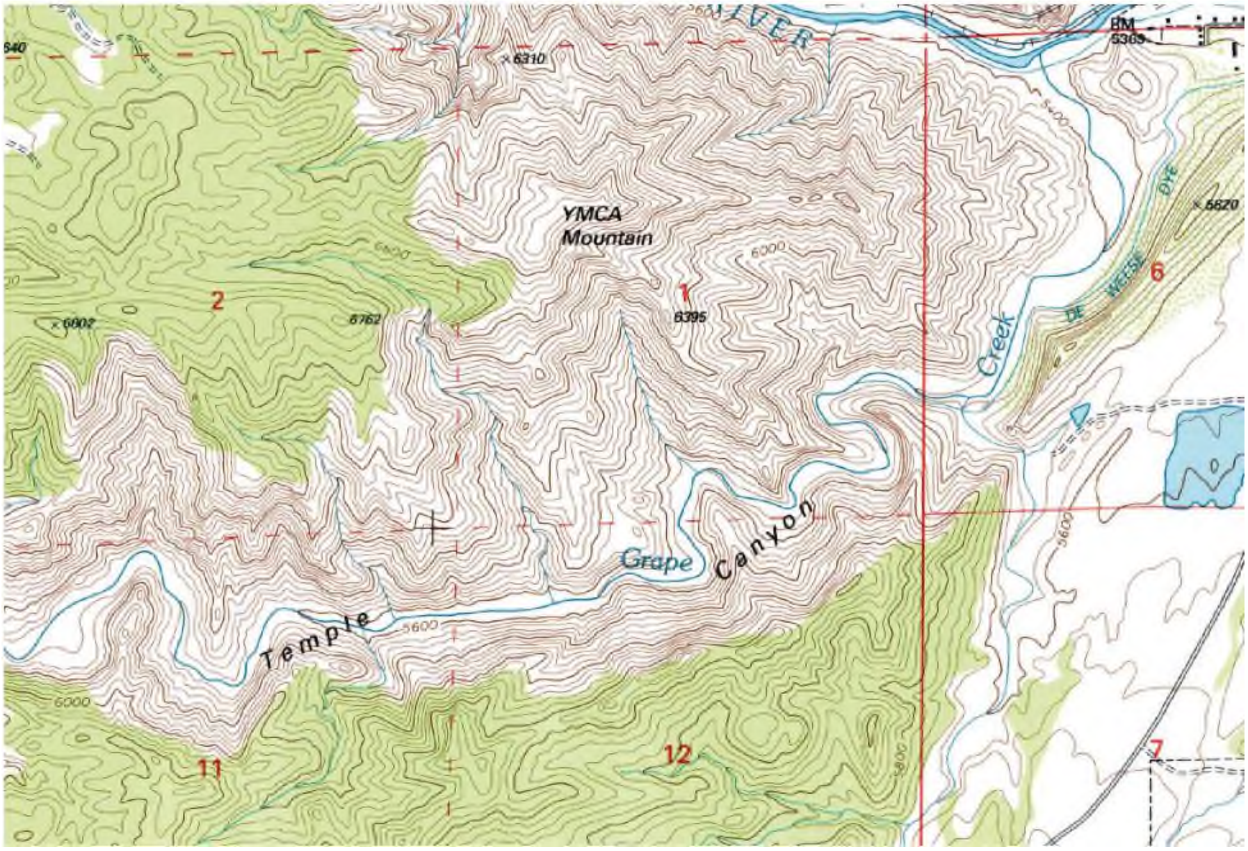
5. In which stage of the cycle of stream erosion is this area?

a. old age b. mature c. youthful

Map 5.2 is the southeast portion of the map above, magnified to show Grape Creek. Use this map to answer question 6.



Map 5.2 | A portion of the Royal Gorge, Colorado map, zoomed in at Grape Creek
Author: USGS
Source: USGS
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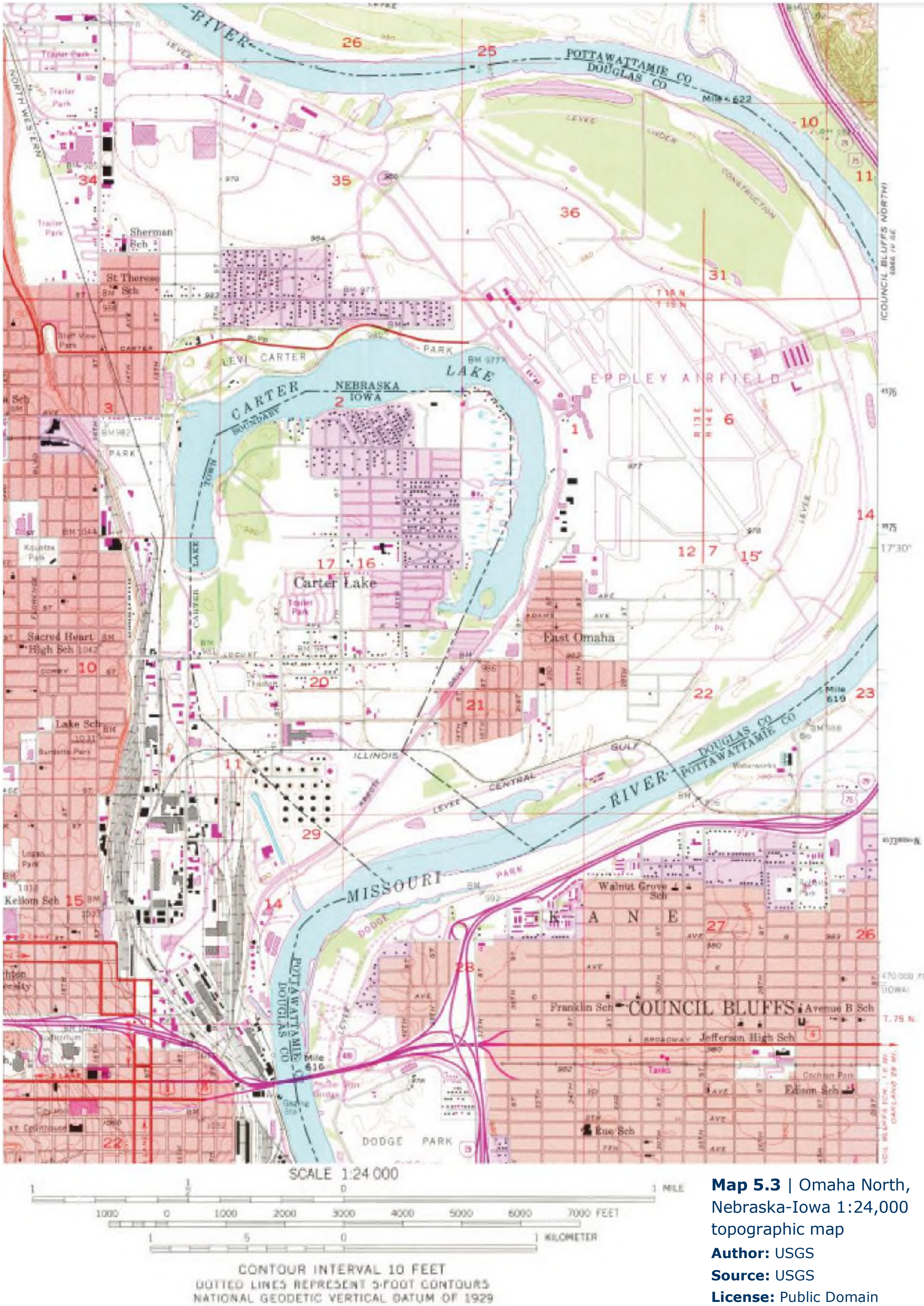
6. Calculate the stream gradient of Grape Creek in ft/mile. Use the index contour just above the "m" in Temple Canyon for your initial spot. Measure the gradient to the index contour past the word Creek (the last contour before it reaches Arkansas River). The distance between these areas is ~1.6 miles (measured along the curving distance of the non-magnified stream). What is the gradient?

a. 15'/mile b. 100'/mile c. 125'/mile d. 200'/mile

Use the Omaha North, Nebraska-Iowa Map 5.3 on the next page to answer questions 7-11.

7. Observe the stream on the Omaha N, Nebraska-Iowa quadrangle. In which stage of the cycle of stream erosion is this area?

a. old age b. mature c. youthful



Map 5.3 | Omaha North, Nebraska-Iowa 1:24,000 topographic map

Author: USGS

Source: USGS

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8. Compare the contour intervals from the Royal Gorge, Colorado map (map 5.1) to the Omaha N, Nebraska-Iowa map. Would you expect the gradient of the Missouri River in Nebraska to be greater or less than the gradient that you calculated for the Grape River in Colorado?

a. less than the Grape River gradient b. greater than the Grape River gradient

9. Locate the state boundary between Nebraska and Iowa along the Missouri River. Why does the boundary depart from the river channel?

a. when the boundary was created, Iowans wanted the Carter Lake area in their state

b. the boundary follows the course of the river at the time that it was drawn; the river has since moved

c. none of the above

10. What is the term for the geologic feature called Carter Lake?

a. entrenched meander b. oxbow lake

c. cutbank d. point bar

11. Was Carter Lake cut off before or after the state boundary between Nebraska and Iowa was drawn?

a. before b. after

5.5 FLOODING

Flooding is a common and serious problem in our nation's waterways. Flood stage is reached when the water level in a stream overflows its banks. Floodplains are popular sites for development, with nice water views, but are best left for playgrounds, golf courses, and the like. Have you ever heard someone say that a flood was a 1 in 100 year flood? Does that mean that a flood of similar magnitude will occur every 100 years? No, it only means that, on average, we can expect a flood of this size or greater to occur within a 100 year peri-

Figure 5.9 | USGS officials monitoring the flooding of Sweetwater Creek over I-20 in September, 2009.
Author: USGS
Source: USGS
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od. One cannot predict that it will occur in a particular year, only that each year has a 1 in 100 chance of having a flood of that magnitude. It also does not mean that only 1 flood of that size can occur within 100 years.

In order to better understand stream behavior, the U.S. Geological Survey has installed thousands of stream gauges throughout the country, locations with a permanent water level indicator and recorder. Data from these stations can be used to make flood frequency curves, which are useful in making flood control decisions. In western Georgia, a dramatic flood event occurred in September, 2009 that resulted in 11 fatalities, over $200 million in property damage, and closed Interstate 20 for a day. Rain fell from September 16-22, with a particularly intense period on September 20th. Use information below from a stream gauge located on Sweetwater Creek near Austell, Georgia, to create a flood frequency graph.

5.6 LAB EXERCISE

Part B – Recurrence Intervals

Data from the chart below was collected at the USGS site, and includes the 20 largest discharge events for Sweetwater Creek at station 02337000 from January 1, 2008 – May 1, 2015, excluding the dramatic 2009 flood (we will learn more about it later). In order to create a flood frequency graph, first the recurrence interval must be calculated (one is calculated below for an example). A **recurrence interval** refers to the average time period within which a given flood event will be equaled or exceeded once. To calculate it, first determine the rank of the flood, with a 1 going to the highest discharge event and a 20 going to the lowest discharge event. Calculate the recurrence interval using the following equation:

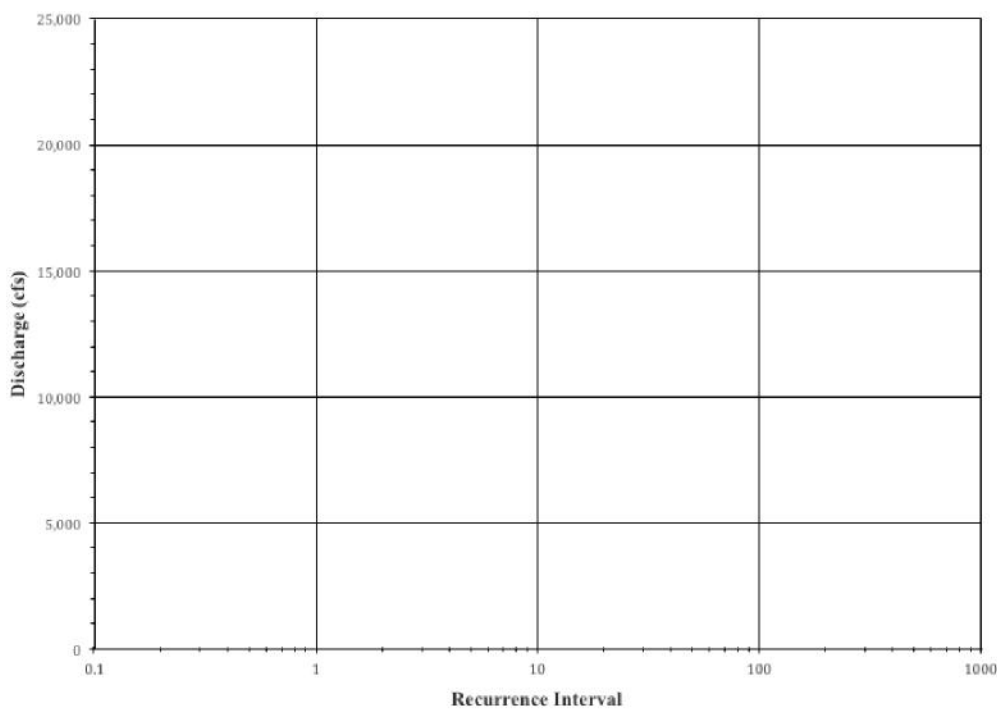
$$RI = (n+1) / m$$

where RI = Recurrence Interval (yrs)
n = number of years of record (in this case, 8)
m = rank of flood

eak Discharge Date	ischarge (cfs – cubic ft/sec)	Rank	Recurrence Interval
27/2008	140		
2/2009	360		
)/13/2009	290		
l/12/2009	120	1	9
2/3/2009	860		
2/10/2009	170		
2/19/2009	830		

eak Discharge Date	ischarge (cfs – cubic ft/sec)	Rank	Recurrence Interval
2/26/2009	650		
25/2010	500		
6/2010	680		
12/2010	600		
10/2011	350		
17/2011	100		
24/2013	060		
27/2013	190		
6/2013	610		
2/23/2013	790		
8/2014	170		
5/2015	970		
20/2015	940		

Now that you have completed the chart, plot the discharge against the recurrence interval on the following graph. Please note that the x-axis (for recurrence interval) is in logarithmic scale and you may need to estimate where the data points fall. A logarithmic scale is *non-linear*, based on orders of magnitude. Each mark on the x-axis is the previous mark multiplied by a value. Use a straight edge to draw a best fit line (a straight line along the graph that shows the general direction that the group of points seem to be heading – it doesn't have to hit every point on the graph) through the graph when you are done, and then answer the following questions. Make sure your best fit line continues to the end of the graph.



12. On which date did a flood event have a recurrence interval of 0.5?

a. 2/27/2013 b. 10/13/2009 c. 3/10/2011 d. 4/20/2015

13. Of the following dated flood events, which one would you expect to happen more often?

a. 8/27/2008 b. 2/24/2013 c. 2/6/2010 d. 12/23/2013

14. Observe your best fit line. What *approximate* discharge would be associated with a 50 year recurrence interval?

a. 2,000 cfs b. 4,750 cfs c. 8,500 cfs d. 14,000 cfs

15. Flood stage, or bankfull stage, on Sweetwater Creek occurs at a discharge of ~4,500 cfs. According to your best fit line, what is the recurrence interval of such a discharge?

a. 0.5 years b. 3 years c. 25 years d. 50 years

16. During the flood event of 9/23/2009, the discharge measured at this gaging station was 21,200 cfs. Note where this would plot on your graph. Would the recurrence interval for this flood plot at:

a. 100 years b. 300 years c. 700 years d. longer than 1,000 years

17. Is it possible that a flood with a similar discharge to that of the event from 9/23/2009 could happen again in the next 20 years?

a. Yes b. No

5.7 GROUNDWATER

It is best not to envision groundwater as underground lakes and streams (which only occasionally exist in caves), instead think of groundwater slowly seeping from one miniscule pore in the rock to another. Have you ever been to the beach and dug a hole, only to have it fill with water from the base? If so, you had reached the water table, the boundary between the unsaturated and saturated zones. Rocks and soil just beneath the land's surface are part of the unsaturated zone, and pore spaces in them are filled with air. Once the water table is reached, then rocks and soil pore spaces are filled with water, in the saturated zone.

The water table is said to mimic topography, in that it generally lies near the surface of the ground (often tens of feet below the surface, though this can vary greatly with location). The water table rises with hills and sinks with valleys, often discharging into streams. The water table receives additional inputs as rainfall infiltrates into the ground, called recharge. Its position is dynamic – during droughts the water table will lower and during wet times, it rises.

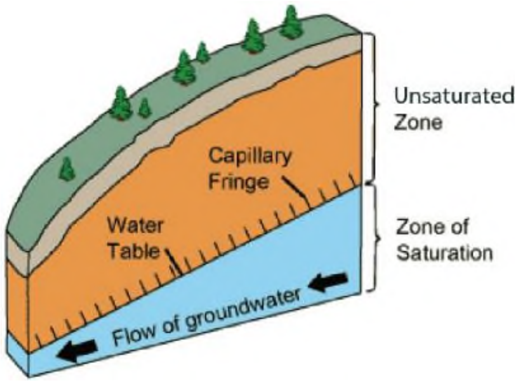


Figure 5.10 | The water table is the boundary between the unsaturated zone and saturated zone.
Author: USGS
Source: Wikimedia Commons
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Two important properties of groundwater that influence its availability and movement are porosity and permeability. **Porosity** refers to the open or void space within the rock. It is expressed as a percentage of the volume of open space compared to the total rock volume. Porosity will vary with rock type. Many rocks with tight interlocking crystals (such as igneous and metamorphic rocks) will have low porosity since they lack open space. Sedimentary rocks composed of well sorted sediment tend to have high porosity because of the abundant spaces between the grains that make them up. To imagine this, envision a room filled from floor to ceiling with basketballs (similar to a rock composed completely of sand grains). Now add water to the room. The room will be able to hold a good deal of water, since the basketballs don't pack tightly due to their shape. That would be an example of high porosity.

Permeability refers to the ability of a geologic material to transport fluids. It depends upon the porosity within the rock, but also on the size of the open space and how interconnected those open spaces are. Even though a material is porous,

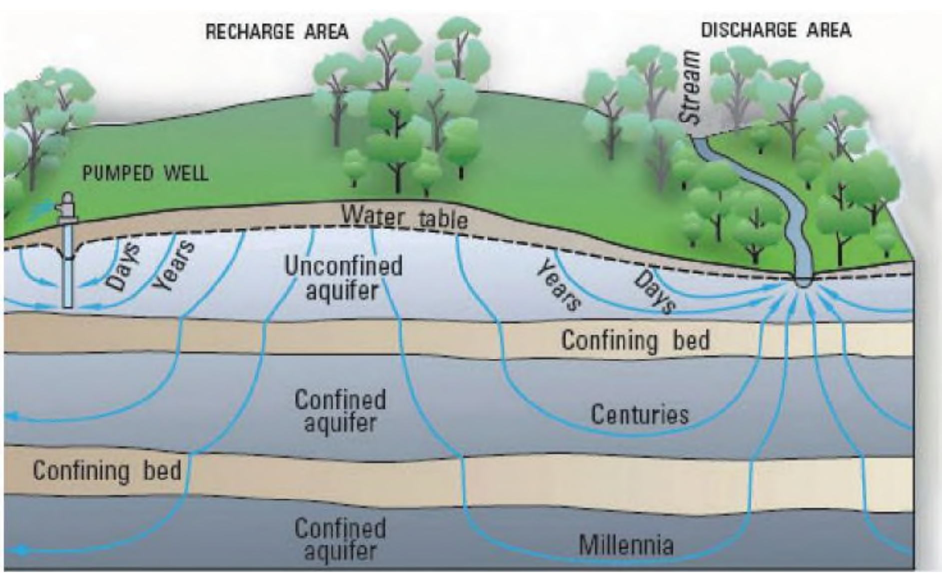

Figure 5.11 | Groundwater flow in both confined and unconfined aquifers.
Author: USGS
Source: USGS
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if the open spaces aren’t connected, water won’t flow through it. Rocks that are permeable make good **aquifers**, geologic units that are able to yield significant water. Sedimentary rocks such as sandstone and limestone are good aquifers. Rocks that are impermeable make confining layers and prevent the flow of water. Examples of confining layers would be sedimentary rocks like shale (made from tiny clay and silt grains) or un-fractured igneous or metamorphic rock. In an unconfined aquifer, the top of the aquifer is the water table.

Groundwater generally flows from areas of higher elevation to lower elevation in the shallow subsurface. Note the flow paths in Figure 5.11. Approximately 20% of the water used in the United States is groundwater, and this water has the potential to become contaminated, mostly from sewage, landfills, industry, and agriculture. The movement of groundwater helps spread the pollutants, making containment a challenge.

5.8 LAB EXERCISE

Part C – Groundwater Flow

Many gas stations use underground storage tanks (UST) to store fuel below the ground (you have likely seen a tanker truck at a gas station filling up the UST). These UST’s could leak, and gasoline could possibly reach the water table. In the diagram below, a business using a well has detected gasoline in their groundwater. To detect the source of the potential leak, contour the water table’s surface and determine its flow path. There are several gas stations in the diagram, and each has the potential to have the leaking UST. Seven monitoring wells are installed in the area, and you have data about the water table elevation within each well. Using that data (in elevation above sea level), contour this map as you would any other. Add the water table elevations to the map, and using pencil, contour the groundwater elevations using a contour interval of 2 feet. Noting that the gas should flow with the groundwater, determine the direction of groundwater flow and note the most likely gas station to be the source of the gasoline leak (in a real world scenario, once the likely culprit was determined, more monitoring wells would be installed and they would be tested for gasoline residue).

Table 5.1

Monitoring Well	Water table elevation (feet)
	94’
	90’
	88’
	86’
	86’
	83’
	80’

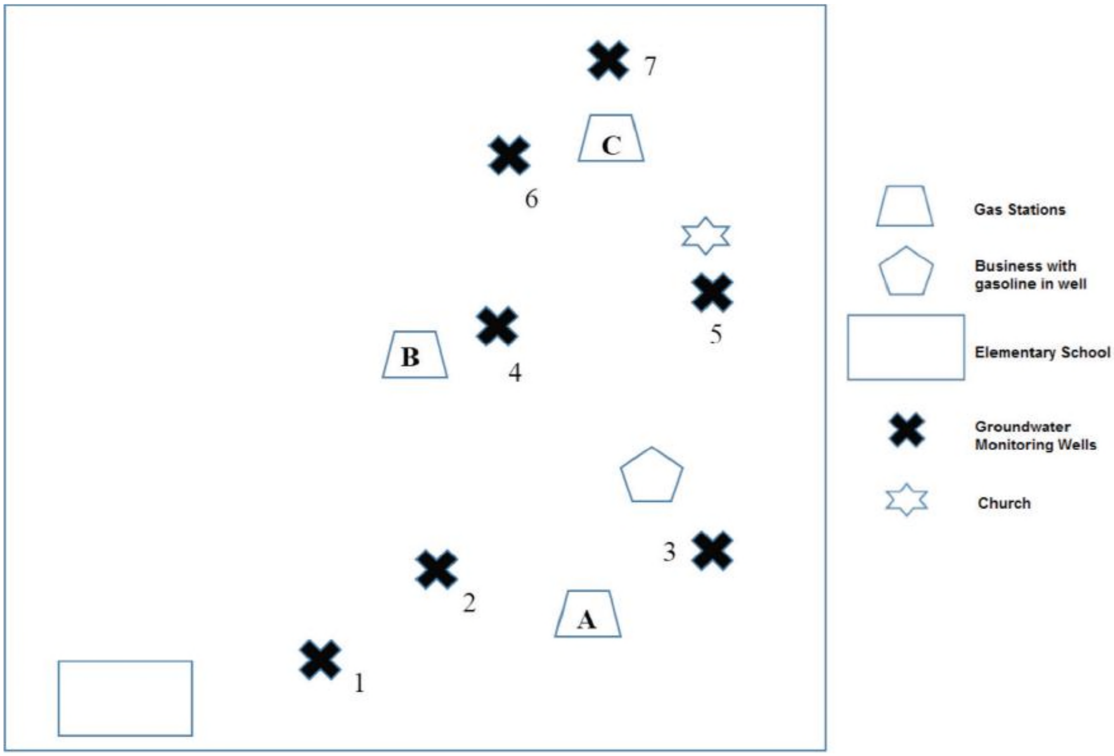

Figure 5.12 | Groundwater contamination exercise.
Author: Randa Harris
Source: Original Work

18. Which gas station is the most likely source of the gasoline leak?

a. Station A b. Station B c. Station C

19. Is the school likely to be at risk of contamination from this same leak?

a. Yes b. No

20. Is the church likely to be at risk of contamination from this same leak?

a. Yes b. No

5.9 KARST TOPOGRAPHY

The sedimentary rock limestone is composed of the mineral calcite, which is water soluble, meaning it will dissolve in water that is weakly acidic. In humid areas where limestone is found, water dissolves away the rock, forming large cavities and depressions which vary in size and shape. As more dissolution occurs, the caves become unstable and collapse, creating sinkholes. These broad, crater-like depressions are typical of **karst topography**, named after the Karst region in

Slovenia. Karst topography is characterized by sinkholes, sink lakes (sinkholes filled with water), caves, and disappearing streams (surface streams that disappear into a sinkhole). Living in karst topography poses its challenges, and approximately one fourth of Americans in the lower 48 states live in these regions. Sinkholes can appear rather rapidly and cause great damage to any structures above them.

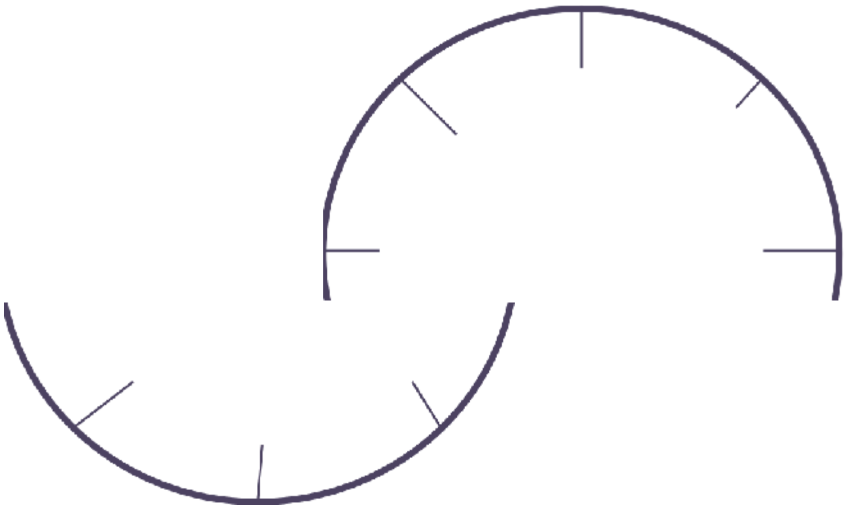

Figure 5.13 | Appearance of a sinkhole on a topographic map.
Author: Randa Harris
Source: Original Work
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5.10 LAB EXERCISE

Part D – Karst topography

Use the Mammoth Cave, Kentucky map (Map 5.4 located at the end of this chapter) to answer the following questions. Though it is old (1922), the general geology and landforms in this area have not changed.

21. Locate Little Sinking Creek in the southern portion of the map, north of Hwy. 68 and south of the Edmonson County Line. In which direction does it flow?

a. south b. north c. southeast d. northwest

22. Follow the creek along its path. Where does it wind up?

a. Along Hwy. 68 b. It disappears underground

23. Find Sloans Crossing. It is south of Mammoth Cave. What is the benchmark elevation at Sloans Crossing?

a. 600’ b. 630’ c. 800’ d. 834’

24. Now look farther south of Sloans Crossing at Hwy. 31W. Look closely at the topography south of highway, and it changes abruptly. What feature(s) can you observe south of Hwy. 31?

a. sinkholes b. disappearing streams

c. generally lower land surface elevations d. all of the above

25. Keeping the abrupt topography change in mind, which of the following is true?

a. In the northern portion of the map, the area is underlain by limestone

b. In the southern portion of the map, the area is underlain by limestone

26. Locate the Louisville and Nashville Railroad line just south of Hwy. 31. Would this be an easy location to maintain a railroad?

a. Yes b. No

Part E – Google Earth

The exercises that follow use Google Earth. For each question (or set of questions) paste the location that is given into the "Search" box. Examine each location at multiple eye altitudes and differing amounts of tilt. For any measurements that use the ruler tool, this can be accessed by clicking on the ruler icon above the image.

Search for 7 26 16.49S 75 00 00.06W and zoom out to an eye altitude of 15 miles.

27. How would one describe this river?

a. Straight b. Meandering c. Low sinuosity d. Braided

28. In this stream, erosion is occurring on the ________________________ because ____________________________, while deposition is occurring on the __________________________ because______________________.

a. point bars; the fastest velocity water flows to this point; cut banks; the slowest velocity water flows to this point

b. point bars; the slowest velocity water flows to this point; cut banks; the fastest velocity water flows to this point

c. cut banks; the fastest velocity water flows to this point; point bars; the slowest velocity water flows to this point

d. cut banks; the slowest velocity water flows to this point; point bars; the fastest velocity water flows to this point

Search for 63 55 55.23N 17 01 07.14W and zoom out to an eye altitude of 10,000 feet.

29. How would one describe this river?

a. Straight b. Meandering c. Low sinuosity d. Braided

30. What factors control the course of this river?

a. Steep gradient and high discharge

b. Low gradient and low discharge

c. Low gradient and abundant sediment supply

d. Steep gradient and low sediment supply

Search for 38 01 12.18N 121 43 20.02W and zoom out to an eye altitude of 30,000 feet.

31. The river in this area has a rather particular pattern, what geologic process caused this?

a. a meander eroded through its bank and created an oxbow lake

b. the river is in a karst terrain and disappeared into the ground

c. the river is following patterns, likely faults, in the underlying bedrock

d. during a flood the river breached the natural levee flowing into the floodplain

32. Zoom out and examine the surrounding area, what geological hazards are likely in the area?

a. sinkholes

b. flooding of urban areas

c. erosion and subsidence

d. none of the above

Search for 41 24 30.77N 122 11 46.23W and zoom to an eye altitude 50,000 feet.

33. What type of drainage pattern is present in this area?

a. Trellis b. Dendritic c. Rectangular d. Radial e. Deranged

34. What does this type of drainage pattern indicate about the area?

a. rocks in the area are homogeneous and/or flat lying

b. rocks in the area are alternating resistant and non-resistant, forming parallel ridges and valleys

c. stream channels radiate outward like wheel spokes from a high point

d. stream channels flow randomly with no relation to underlying rocks or structure

Search for 36 45 41.23N 85 18 34.22W and zoom out to an eye altitude of 25,000 ft. Although there is no stream present today, the stream channels can be clearly seen.

35. What type of drainage pattern was present in this area?

a. Trellis b. Dendritic c. Rectangular d. Radial e. Deranged

36. What does this type of drainage pattern indicate about the area? a. rocks in the area are homogeneous and/or flat lying

b. rocks in the area are alternating resistant and non-resistant, forming parallel ridges and valleys

c. stream channels radiate outward like wheel spokes from a high point

d. stream channels flow randomly with no relation to underlying rocks or structure

37. In what direction was the main river flowing?

a. west b. east c. north d. south

Search for 28 38 01.92N 81 22 44.78W and zoom out to an eye altitude of 13,000 ft.

38. How were these lakes formed?

a. they were man-made – all are dammed

b. they are formed by large rivers in the area

c. as sinkholes, as underlying soluble rock was dissolved and areas collapsed

d. they are impact structures that filled with water

39. What type of bedrock is present in this area?

a. limestone b. sandstone c. gneiss d. granite e. chert

Now let's travel to Mars! Mars has shown evidence of water, and NASA and others have been studying Mars intensely in recent years. Let's look at a few features on Mars. In the location toolbar across the top of Google Earth, locate the image that looks like the planet Saturn. Click the button to bring up several location options and select Mars. In the Layers box on the left, notice Global Maps. You may have to click on it to expand it. For today, we will use the highest quality images found in the Visible Images layer. The other layers are interesting, but won't be used today.

In the Search tab, type in Noctis Labyrinthus and zoom to -300 miles.

40. These features you are seeing are linear valleys. Assume that water flowed through these valleys at some time. What type of drainage pattern would this area represent?

a. Trellis b. Dendritic c. Rectangular d. Radial e. Deranged

41. Think about the drainage pattern you selected in the previous answer – what does this tell you about the underlying rocks?

a. the rocks are probably fractured

b. the rocks are uniformly resistant

c. the rocks are part of a topographic high, like a mountain

d. the rocks are alternately resistant and non-resistant

In the Search tab, type in Warrego Valles and zoom to -120 miles.

42. Notice the general shape of this feature. It is thought to have formed by the runoff of either precipitation or groundwater. What type of drainage does this appear to be?

a. Trellis b. Dendritic c. Rectangular d. Radial e. Deranged

5.11 STUDENT RESPONSES

1. What type of stream drainage pattern is present on this map? This may be easier to determine by examining the tributaries to the main stream.

a. dendritic b. trellis c. radial d. rectangular

2. Based on the drainage pattern type, does the bedrock underlying this area consist of rocks uniformly resistant to erosion or rocks alternating between resistant and non-resistant layers?

a. uniformly resistant bedrock b. alternately resistant and non-resistant bedrock

3. Are the rocks likely tilted and folded or horizontal?

a. tilted and folded b. horizontal

4. Are streams in this area downcutting or laterally eroding?

a. downcutting b. laterally eroding

5. In which stage of the cycle of stream erosion is this area?

a. old age b. mature c. youthful

6. Calculate the stream gradient of Grape Creek in ft/mile. Use the index contour just above the "m" in Temple Canyon for your initial spot. Measure the gradient to the index contour past the word Creek (the last contour before it reaches Arkansas River). The distance between these areas is ~1.6 miles (measured along the curving distance of the non-magnified stream). What is the gradient?

a. 15'/mile b. 100'/mile c. 125'/mile d. 200'/mile

7. Observe the stream on the Omaha N, Nebraska-Iowa quadrangle. In which stage of the cycle of stream erosion is this area?

a. old age b. mature c. youthful

8. Compare the contour intervals from the Royal Gorge, Colorado map (map 5.1) to the Omaha N, Nebraska-Iowa map. Would you expect the gradient of the Missouri River in Nebraska to be greater or less than the gradient that you calculated for the Grape River in Colorado?

a. less than the Grape River gradient b. greater than the Grape River gradient

9. Locate the state boundary between Nebraska and Iowa along the Missouri River. Why does the boundary depart from the river channel?

a. when the boundary was created, Iowans wanted the Carter Lake area in their state

b. the boundary follows the course of the river at the time that it was drawn; the river has since moved

c. none of the above

10. What is the term for the geologic feature called Carter Lake?

a. entrenched meander b. oxbow lake

c. cutbank d. point bar

11. Was Carter Lake cut off before or after the state boundary between Nebraska and Iowa was drawn?

a. before b. after

12. On which date did a flood event have a recurrence interval of 0.5?

a. 2/27/2013 b. 10/13/2009 c. 3/10/2011 d. 4/20/2015

13. Of the following dated flood events, which one would you expect to happen more often?

a. 8/27/2008 b. 2/24/2013 c. 2/6/2010 d. 12/23/2013

14. Observe your best fit line. What *approximate* discharge would be associated with a 50 year recurrence interval?

a. 2,000 cfs b. 4,750 cfs c. 8,500 cfs d. 14,000 cfs

15. Flood stage, or bankfull stage, on Sweetwater Creek occurs at a discharge of ~4,500 cfs. According to your best fit line, what is the recurrence interval of such a discharge?

a. 0.5 years b. 3 years c. 25 years d. 50 years

16. During the flood event of 9/23/2009, the discharge measured at this gaging station was 21,200 cfs. Note where this would plot on your graph. Would the recurrence interval for this flood plot at:

a. 100 years b. 300 years c. 700 years d. longer than 1,000 years

17. Is it possible that a flood with a similar discharge to that of the event from 9/23/2009 could happen again in the next 20 years?

a. Yes b. No

18. Which gas station is the most likely source of the gasoline leak?

a. Station A b. Station B c. Station C

19. Is the school likely to be at risk of contamination from this same leak?

a. Yes b. No

20. Is the church likely to be at risk of contamination from this same leak?

a. Yes b. No

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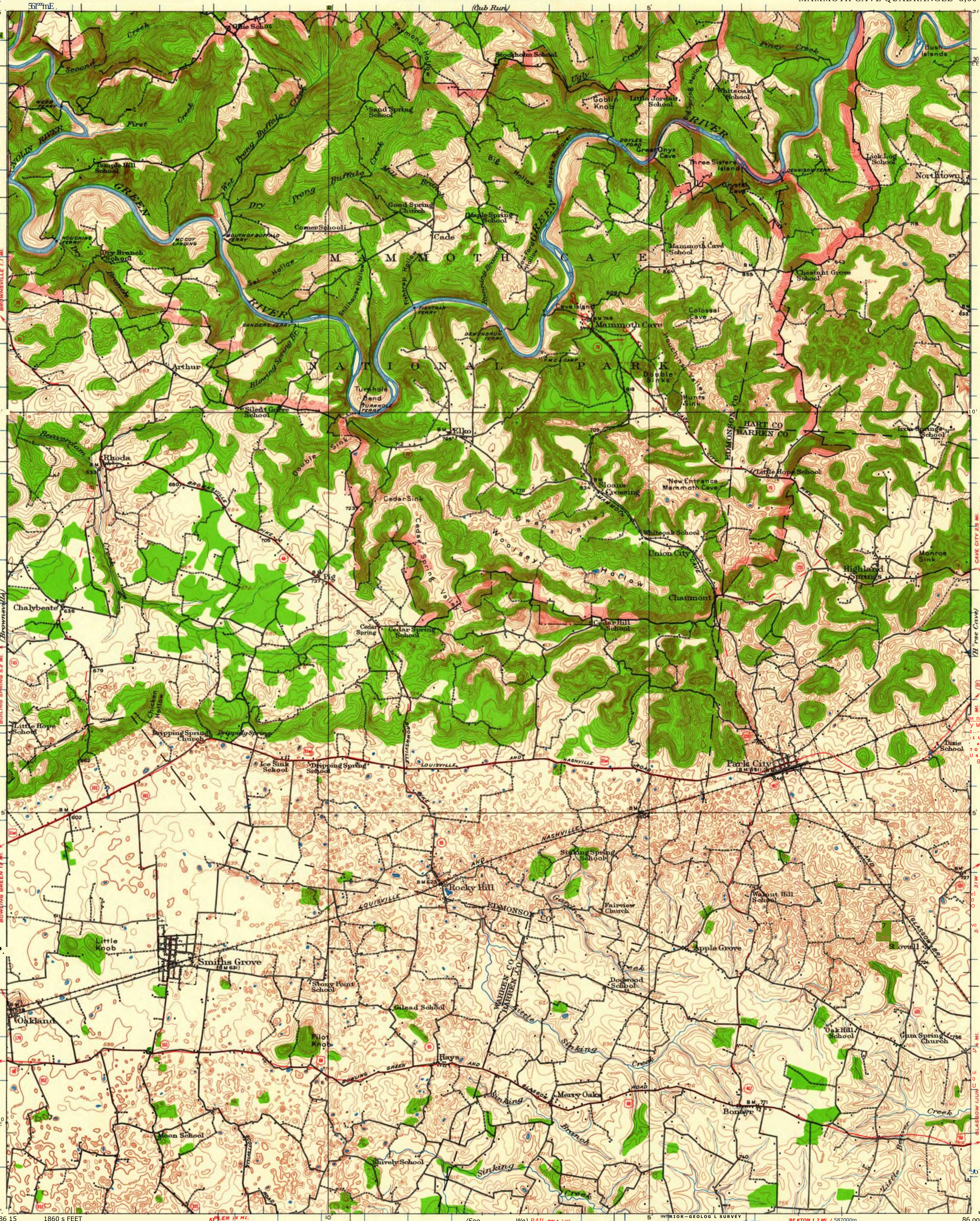
Map 5.4 | (appearing on following page) Mammoth Cave, Kentucky 1:24,000 topographic map
Author: USGS
Source: USGS

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

STATE OF TCPNTTJCKY
REFRESENTED BY'11±H,
DEPARTMENT OF MINES AND MINERALS

KENTUCKY
MAMMOTH CAVE QUADRANGLE



86°15' 1860 s FEET

Topography by C.W.Goodlove, W.R.Chenoweth, S.E.Clement, H.D.Clement, and Edgar Allen.
Control in part by S.Coast and Geodetic Survey. Surveyed in 1921-1922.

ROAD CLASSIFICATION

Heavy-duty — Light-duty
Medium-duty — Unimproved dirt

U. S. Route — State Route

APPROXIMATE MEAN DECLINATION, 1923

SCALE 1:62500

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

FOR SALE BY U.S. GEOLOGICAL SURVEY, WASHINGTON 25, D. C.
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

USGS
Historical File
Topographi,; Divisiott

Polyconic projection. 1927 North American datum
10000 foot grid based on Kentucky (South) rectangular coordinate system
1000-meter Universal Transverse Mercator grid ticks, zone 16, shown in blue

This area also covered by 1: 24000-scale maps

MAMMOTH CAVE, KY.
1922

TOPOGRAPHIC only