CHAPTER 8

STREAMS AND HUMID-CLIMATE LANDSCAPES

Better quality images can be found at http://www.nd.edu/~cneal/PhysicalGeo/Lab9/index.html

MATERIALS NEEDED

- Pencil and eraser
- Colored pencils
- Calculator
- Ruler

INTRODUCTION

Running water is the most important force shaping the Earth's surface. Even desert landscapes are dominated by drainage systems carved by infrequent rainstorms. Thus, many familiar landforms owe their origin to streams. In addition, many cities are located on rivers and depend on them for drinking water, freight transport, and recreation. In this lab you will learn how to determine the size, shape, and runoff characteristics of a drainage basin and to recognize and interpret the common erosional and depositional features formed by running water. You will see how these features depend on the underlying geology, climate, and changes in elevation relative to base level and time. You will also learn to use data from gaging stations to predict the frequency, size, and extent of major floods using data available on the World Wide Web.

The first step in erosion by running water is weathering. Weathering causes rocks at the surface to disintegrate and decompose. Because rainfall supports vegetation and vegetation holds a layer of soil in place over unweathered rock, humid landscapes tend to have relatively rounded ridges, valleys, and slopes. Despite these stabilizing influences, loose sediment and soil eventually move downhill by mass wasting or water erosion. Once they reach a stream, the sediments are carried farther downslope by fast currents. This lab focuses on the landscapes produced by streams in humid regions—those with annual precipitation of more than 50 cm (Fig. 8.1).

RUNOFF AND DRAINAGE BASINS

Streams are part of the hydrologic cycle, as shown in Figure 8.2. They carry water precipitated on the surface back to the oceans as surface runoff. Some of the precipitation returns to the atmosphere by evaporation and transpiration (emission through the leaves of plants), and some soaks into the ground and is carried away below the surface (the *infiltration loss* in the equation below). Water that enters the streams and makes up the *runoff* comes from direct overland flow and from water that moved underground before being discharged into the streams. Surface runoff, the runoff due to overland flow, can be expressed as:

$$\text{surface runoff} = \text{precipitation} - \text{infiltration loss} - \text{evaporation} - \text{transpiration.}$$

Anything affecting one of these terms affects surface runoff, so the percentage of precipitation that naturally runs off varies considerably worldwide. In Arizona, where precipitation is about 25 cm/year, evaporation and infiltration are high, and runoff is very low, typically 2 cm/year or less. In contrast, precipitation in Alabama is about 125 cm/year, and, because infiltration and evaporation are low, runoff is about 75 cm/year. Human activity also affects runoff. For example, runoff increases when the land surface is paved so that rain doesn't soak into the ground, or when vegetation is removed so that the amount of transpiration is reduced.

When water runs off a surface, it flows downhill and into a stream. The stream is part of a drainage network in which smaller streams feed larger

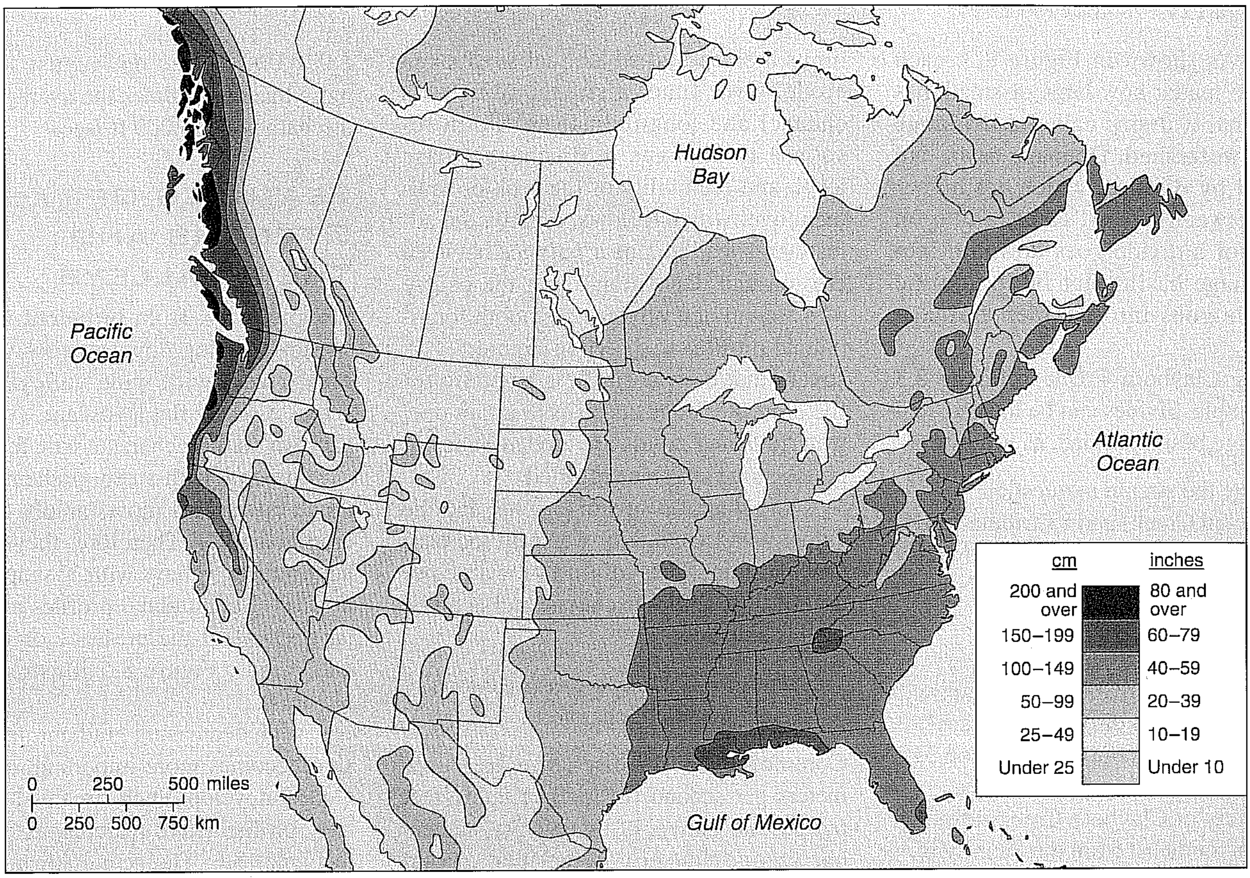

FIGURE 8.1
Average annual precipitation in the United States and Canada. Areas with more than 50 cm per year are considered humid. From *Geosystems,* 2nd edition by Robert W. Christopherson. Copyright © 1994. Reprinted by permission of Prentice-Hall, Inc. Upper Saddle River, N.J.

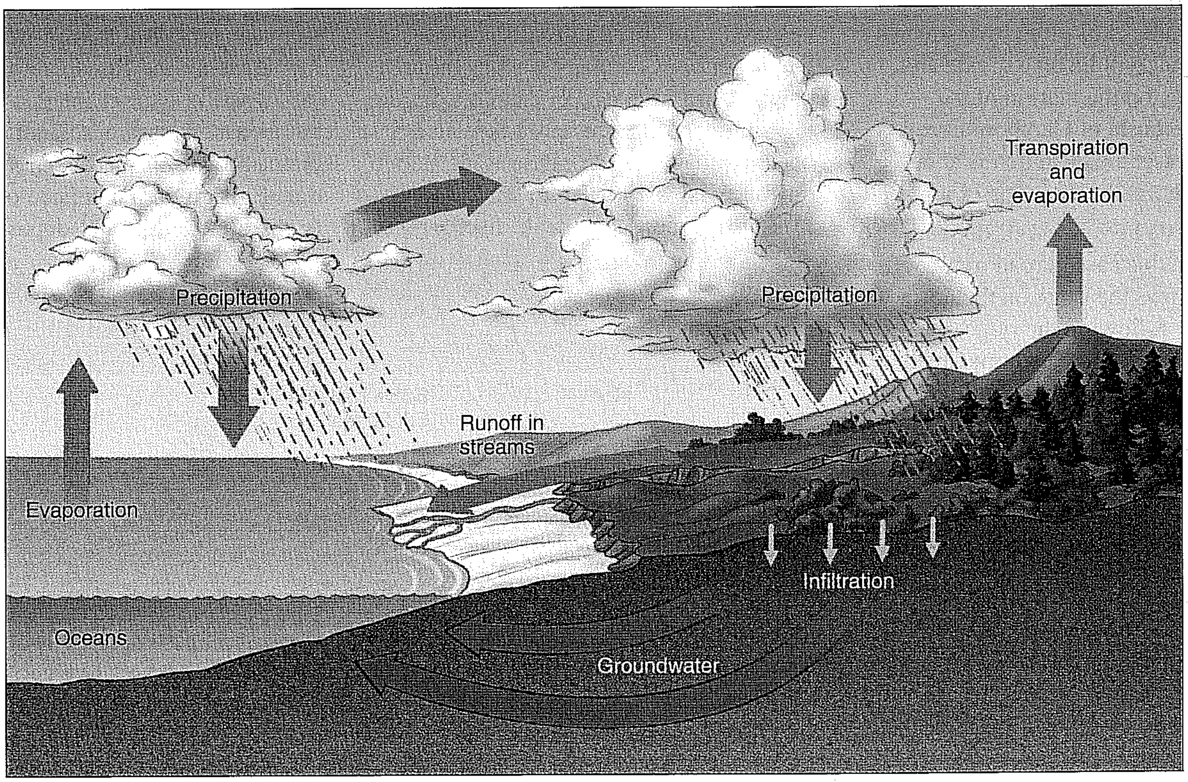

FIGURE 8.2
The hydrologic cycle. This chapter emphasizes runoff.

streams. As shown in Figure 8.3, each stream, no matter how large or small, has an area that it drains called a **drainage basin** or **watershed.** Drainage basins are separated by **divides,** which are higher points between basins. Rain falling on one side of a divide goes downhill into one drainage basin; that falling on the other side goes into another drainage basin.

Using Clayborn Creek in Figure 8.3 as an example, divides can be located, and the drainage basin outlined, as follows:

1. Locate the stream in question (Clayton Creek) and its tributaries and note which way each is flowing (i.e., which way is downhill). Note how contours crossing valleys "point" uphill.
2. Locate other streams on the map and note which direction they are flowing. For example, in Section 31 (red number 31 on Figure 8.3) a tributary of Clayborn Creek flows south-southeast from the vicinity of Inspiration Point. Another stream in the northeast corner of Section 31 flows north. Both streams flow away from a divide into their own drainage basins.
3. Find the highest point on a line between the ends of the two streams. That point will lie on a divide and, therefore, on the margin of the drainage basin of Clayborn Creek. In this case, the elevation is about 1440 feet.
4. The divide here is a well-defined ridge. In this case, a road more or less follows the ridge on the north side. By following the ridge, the drainage basin of Clayborn Creek can be outlined (the dashed line).

STREAM CHANNELS AND VALLEYS

Figure 8.4 shows a contour map of a stream and a topographic profile drawn along its length. The **longitudinal profile** illustrates how the **gradient** (see Chapter 6) gradually decreases from the **head** to the **mouth** of the stream. The mouth is the **base level** for a stream: it limits the depth to which that stream can erode. Over time, a stream adjusts its channel and longitudinal profile in response to changes in discharge, base level, and erodibility of the rock or sediment over which it flows. Ideally, the adjustments lead to a near *balance* between erosion and deposition along the course of a stream and produce a smooth longitudinal profile, as shown in Figure 8.4. A stream that does not have a smooth profile erodes or deposits so as to attain one: waterfalls and rapids are eroded, lakes or ponds along streams are filled.

The size of a stream channel and the velocity and volume of water all increase downstream. The volume of water per unit of time is the **discharge** and is given by this equation.

discharge = velocity × cross-sectional area of channel

Common units for discharge are cubic meters per second (m^3/sec) or cubic feet per second (ft^3/sec); for velocity, meters per second (m/sec) or feet per second (ft/sec); and for cross-sectional area, square meters (m^2) or square feet (ft^2). As discharge increases, so do all of its components. Thus, during flooding, velocity and channel size increase as the volume of water increases. Stream velocity, channel area, and discharge are recorded at *gaging stations* on many streams throughout the United States. For example, during the summer flood of 1993 (see Part IV opening image, p. 125), the gaging station on the Mississippi River at St. Louis, Missouri, recorded a peak discharge of 1,070,000 ft^3/sec on August 1. This is more than eight times the average August discharge of 133,000 ft^3/sec.

FEATURES OF STREAMS AND THEIR VALLEYS

Streams vary, from turbulent mountain streams rushing down narrow valleys to great rivers with wide valleys flowing across a nearly flat landscape. As streams vary, so do their characteristic features.

Streams with steep gradients tend to erode downward more rapidly than they erode laterally. Therefore, they typically have narrow valleys with V-shaped cross-profiles. Longitudinal profiles are irregular because of the presence of waterfalls and rapids. Figure 8.5 illustrates these features.

With decreasing gradient, lateral erosion becomes more important, and broad valleys develop. Such streams have a variety of distinctive features, as illustrated in Figure 8.6. The actual stream channel is much narrower than the valley, most of which is occupied by the **floodplain,** the area that could be submerged during a flood. Just adjacent to the channel are **natural levees,** low ridges formed by sandy sediments rapidly deposited by flood waters. **Backswamps** develop in low areas on the floodplain behind natural levees. A river channel is not straight, but meanders or winds about in the floodplain; a bend in the channel is a **meander.** Erosion on the outside of a meander forms a **cutbank,** and deposition on the

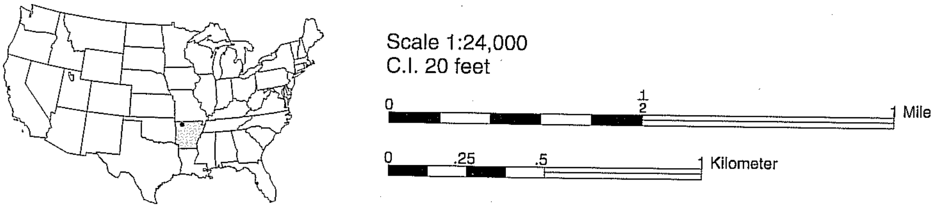

FIGURE 8.3
(Page 129) The drainage basin of Clayborn Creek and its tributaries is outlined on this portion of the Beaver, Arkansas/Missouri, quadrangle. Note that the divides connect the highest elevations between adjacent drainage basins. Water falling within the drainage basin moves downhill toward Clayborn Creek and eventually makes its way into the White River.


Hollow
Catron
Inspiration Point
Mullada
Clayborn Creek
Wallace Bluff
Crane Roost Bluff
TABLE ROCK LAKE
Fuller Cem
Busch Ch.
Dicks Creek
Creek
edar
C E D A R
30
31
36
35
34
6
1
2
62
BM 960
947
926
1268
1428
1336
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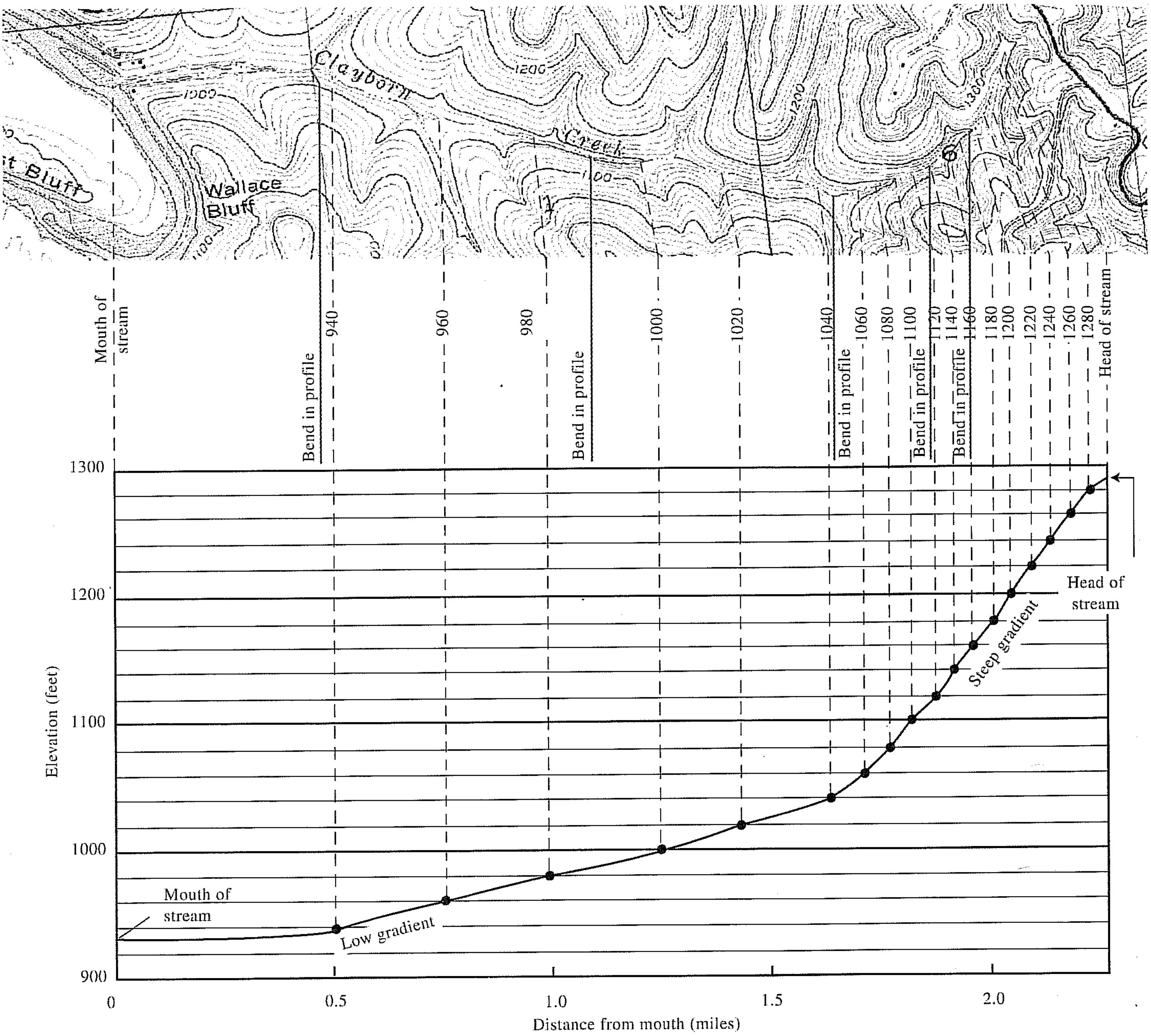


FIGURE 8.4
The longitudinal profile along Clayborn Creek was drawn by marking, on the top of the profile paper, points where contours cross the stream and labeling these points with their elevations. The profile follows the bends in the stream, not the straight-line distance between the head and the mouth. An easy way to follow along the stream when marking the contour-crossing points is to hold the paper down with a pencil where the stream bends, then rotate the paper to follow along the next stream segment. The locations of the bends are shown here for illustrative purposes only. Note that the gradient decreases from the head to the mouth of the stream. The vertical exaggeration is 15.9 times. (The horizontal scale is 1:22,850, and the vertical scale is 1 inch to 120 feet.)

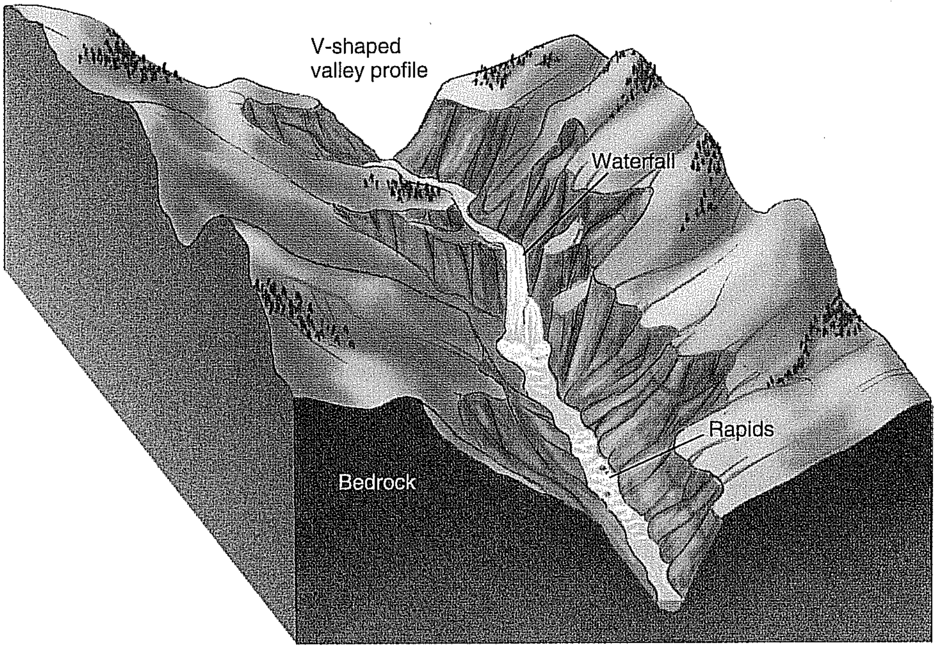


FIGURE 8.5
Features of a stream with a steep gradient.

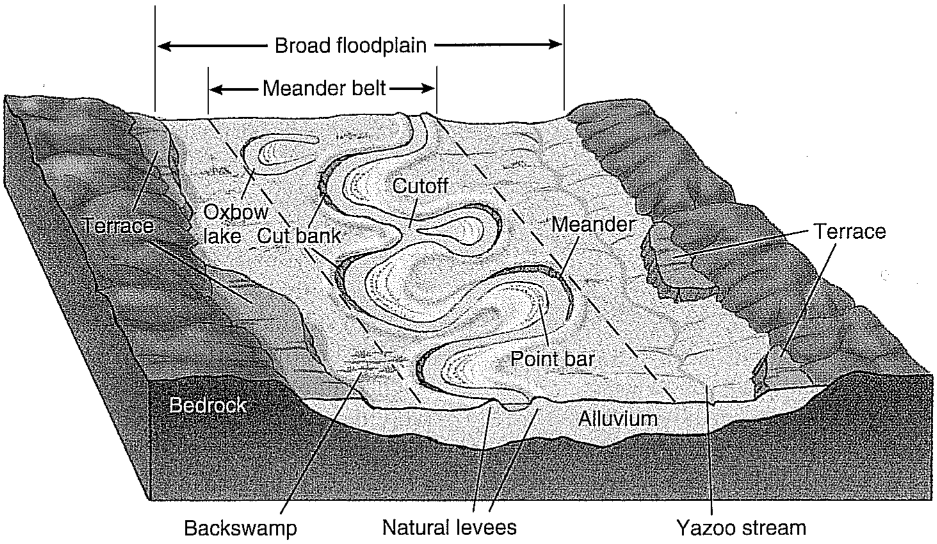


FIGURE 8.6
Features of a stream with a gentle gradient.

inside of a meander forms a **point bar.** This combined erosion and deposition causes the meanders to move across the floodplain. The **meander belt** is the zone in the floodplain within which meanders occur. The channel may take a shortcut across a meander loop to form a **cutoff,** or abandon the loop altogether to form an **oxbow lake.** Where floodplains are wide and natural levees are high, tributary streams may flow in the floodplain for long distances before joining the main river; such tributaries are known as **yazoo streams. Stream terraces** are step-like benches above the level of the present-day floodplain. They represent the remnants of preexisting floodplains or valley floors.

FLOODS AND RECURRENCE INTERVALS

A flood occurs when a stream overflows its channel. The size of a flood, as measured by maximum discharge, or by **stage** (elevation of water surface), varies from year to year. By analyzing the frequency of floods of various sizes, a *recurrence interval* can be developed for a river at a particular locality. The **recurrence interval,** usually measured in years, is the average interval between floods of a particular size. Thus, *on average,* a 100-year flood will recur at intervals of 100 years. That does not mean that a flood that size could not occur two years in a row; it means that the chance of it occurring in *any* year is 1 in 100. A *flood-frequency curve* plots discharge, or in some cases, stage, against recurrence interval, as illustrated in Figure 8.7.

Floodplain zoning is based on recurrence intervals. If planners know what stage a stream will reach in a 50-year flood, they can determine what parts of a floodplain are likely to be flooded about once every 50 years. They can then zone accordingly, deciding which areas are better for homes, businesses, and hospitals and which for parks and recreation. The data necessary to determine the size of a 50-year floodplain are available from gaging station records and flood-frequency curves.

LANDSCAPES IN HUMID AREAS

DRAINAGE PATTERNS

Drainage patterns reflect the characteristics of the underlying rocky materials (Fig. 8.8). Landscapes developed on flat-lying, homogeneous rock or unconsolidated sediments will naturally develop a **dendritic** (branching like a tree) drainage network. Water running off a volcano or uplifted dome will create a **radial drainage pattern** of streams flowing from a central point. If the underlying rock has been cut by fractures, these are more easily eroded and cause drainages to form a **rectangular drainage pattern.** In mountainous areas where rock layers

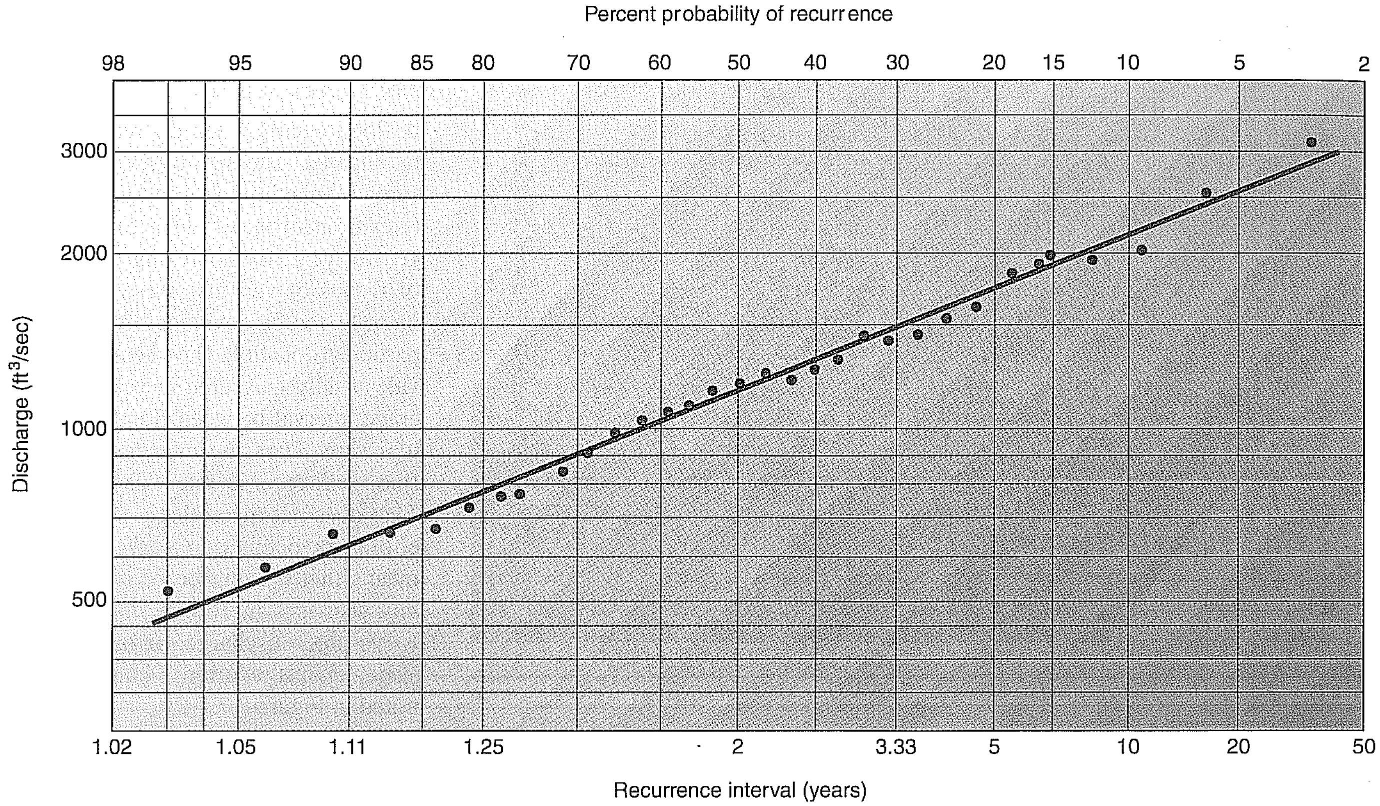


FIGURE 8.7
Flood-frequency curve for Rock Creek near Red Lodge, Montana, 1932 to 1963, using maximum annual discharge data from the USGS. From the *Recurrence Interval* (*RI*) scale (bottom), it can be predicted that, on average, a discharge of 2600 ft^3/sec will be attained every 20 years. Using the *Percent Probability of Recurrence* (*P*) scale on top, the same thing can be said in a different way: there is a 5% probability that a discharge of 2600 ft^3/sec will be reached in a given year. $P = 100/RI$.

have been folded and eroded to expose long resistant ridges, most streams will run along the valleys to join a larger river that has cut across the ridges. This forms a **trellis drainage pattern** (Fig. 8.8).

EVOLUTION OF STREAM SYSTEMS

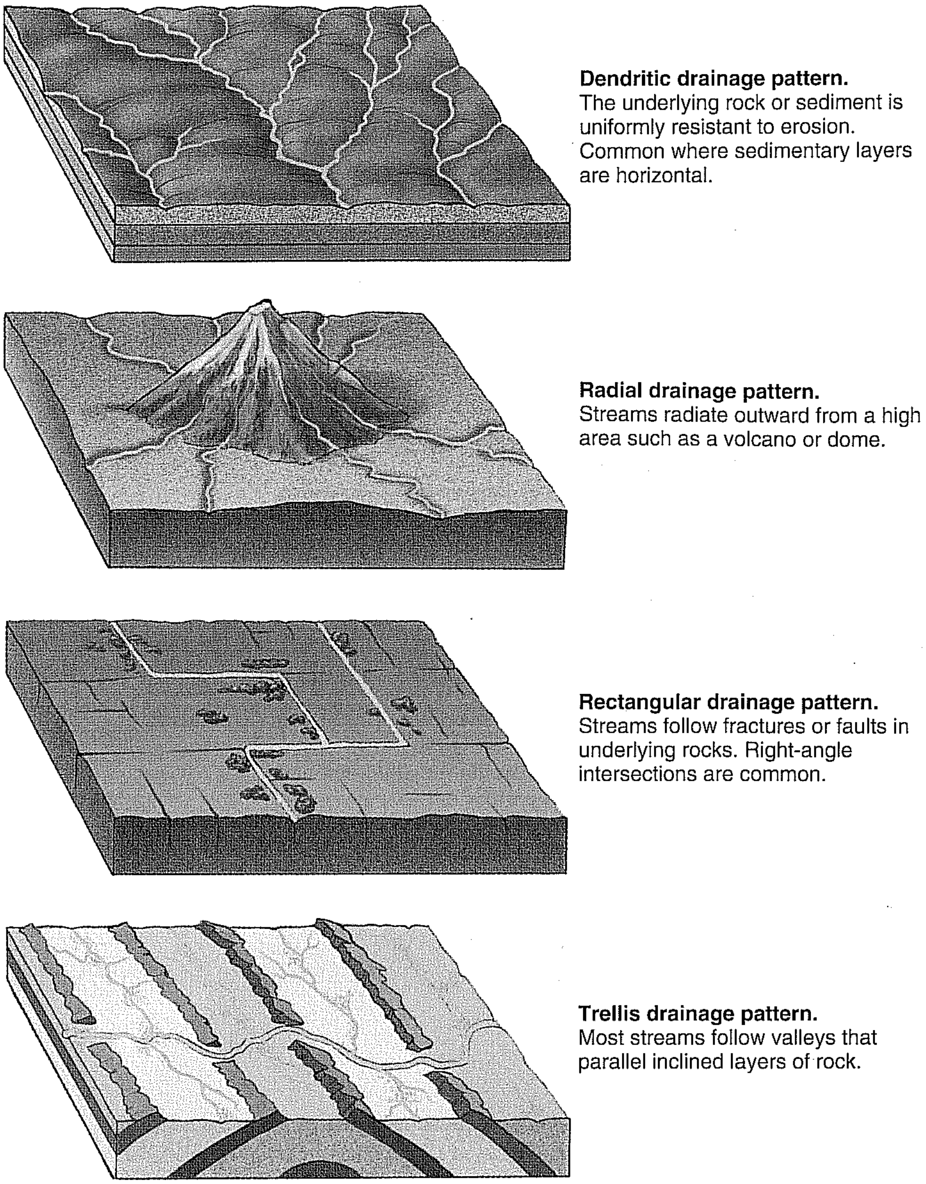
Stream valleys change with time in ways that are fairly predictable *if* the controlling factors remain constant. The following characteristics can describe the evolution of a single, long-lived drainage system or the features of a single river moving from the headwaters to the mid-section to the lowlands, especially if the headwaters are in the mountains.

Early-stage streams show steep gradients down to a base level created by a lake, larger river, or ocean. High-gradient streams cut deep into the landscape and form V-shaped valleys with narrow floodplains (Fig. 8.5). Waterfalls or rapids frequently occur. The surrounding landscape shows high hills, deep valleys, and prominent drainage divides.

With time, erosion does three things: it cuts farther back into the hills in a process called **headward erosion** (Fig. 8.9); it brings the elevation of most of the stream channel nearer to base level, thus reducing the river gradient; and it reduces the elevation and relief of the surrounding landscape. As a result, **middle-stage streams** are characterized by longer drainage systems with more tributaries, moderate gradients, and increasingly rare waterfalls and rapids. In addition, lower gradients reduce the importance of downcutting while increasing the importance of lateral (side-to-side) erosion. Lateral erosion creates meandering channels, wider flood plains, and broad, flat valleys within otherwise hilly landscapes.

With still more erosion, middle-stage streams become **late-stage streams,** which feature low gradients and extensively developed meander belts characterized by wide floodplains and extensive systems of oxbow lakes, backswamps, and occasional yazoo rivers (Fig. 8.6). While low hills may bound one or both sides of a late-stage floodplain, the surrounding landscape is overall fairly flat.

Headward erosion puts streams in adjacent drainage basins in competition with each other. Clayborn Creek (Fig. 8.3), for example, is trying to expand its area while at the same time the surrounding creeks are trying to expand their areas. If erosion rates on either side of a divide are the same, headward erosion stalls, the position of the divide stays about the same, and the landscape merely loses elevation. If



Dendritic drainage pattern.
The underlying rock or sediment is uniformly resistant to erosion. Common where sedimentary layers are horizontal.

Radial drainage pattern.
Streams radiate outward from a high area such as a volcano or dome.

Rectangular drainage pattern.
Streams follow fractures or faults in underlying rocks. Right-angle intersections are common.

Trellis drainage pattern.
Most streams follow valleys that parallel inclined layers of rock.

FIGURE 8.8
Four common drainage patterns.

erosion rates are higher on one side, headward erosion causes the faster-eroding stream to cut into the drainage basin of the other stream as it wears down the landscape. Eventually, the dominant stream can snare one or more tributaries of the other stream, thus **beheading** it in a process known as **stream capture** or **stream piracy** (Fig. 8.9).

Early geologists formulated the idea of stages in stream development in terms of a grand *erosion cycle.* However, this idea is complicated by the fact that the controlling factors of landscape development are rarely constant over the many millions of years it takes to go from early- to late-stage streams. A change in climate can increase runoff, thus causing a middle-stage stream to cut into its meander belt sediments and leave river terraces. Regional uplift of a stream or a drop in base level would also cause erosion by downcutting. The uplift of headwater tributaries or an increase in glacial activity could increase the amount of sediment coming into the middle stages of a river system and thus fill the valley with meander belt sediments. A rise in sea level or lowering of the land surface could also increase deposition of meander belt sediments. Additionally, a rim of resistant rock can temporarily create a secondary base level at a relatively high elevation within a river system. This causes meanders to develop upstream. Once the resistant rocks are breached by erosion, the river will cut into its old meander belt sediments and create terraces. Overall, many river systems reflect a complex mixture of present and past conditions.

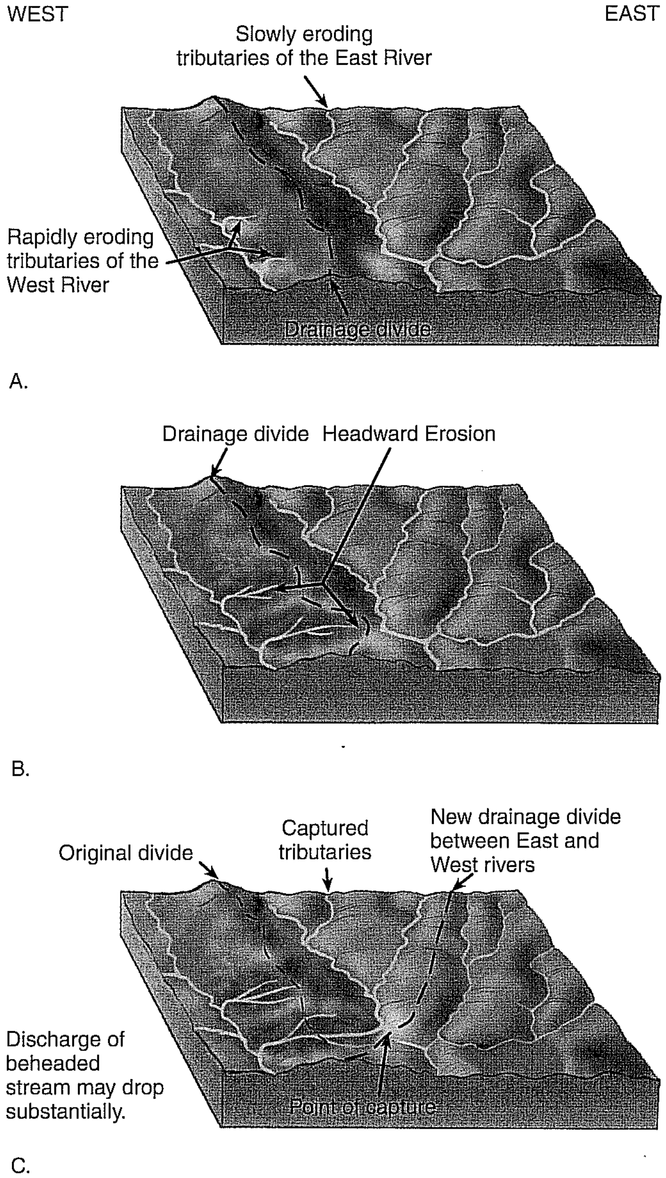


FIGURE 8.9

Headward erosion and stream piracy. A. Erosion is faster on the west side of the drainage divide than on the east. B. This enables several stream tributaries to cut into the divide and lengthen their drainages in a process called headward erosion. C. Stream piracy occurs when headward erosion cuts into a tributary from another stream system, thereby capturing its water flow.