CHAPTER 4

River Geomorphology and Floodplain Habitats

Charles Theiling

Geomorphology here includes the study of water, wind, and ice acting under gravitational forces to sculpt the surface of the land. River and hillslope processes provide central themes of geomorphology (Leopold et al. 1964). The Upper Mississippi and Illinois Rivers have transported the debris from weathering from the central part of the North American continent for millions of years. Much of the material through which these rivers flow was deposited over 500 million years ago when the region was covered by shallow seas. The rivers themselves were first formed millions of years ago. They have evolved in response to geomorphological processes since the last ice age to achieve the form found by early European explorers to the region. River engineering begun in 1824 has created a new environment within which the rivers continue to evolve.

Geomorphic Evolution of the River System

Present surficial hydrology and stream geomorphology of the Upper Mississippi River System (UMRS) are the result of glacial meltwater outwash, primarily from the late Wisconsinan ice age. About 12,000 years ago, the retreating late Wisconsin glacier separated the Illinois and Mississippi Rivers into their present positions and blocked its own drainage into Hudson Bay. This formed glacial Lake Agassiz over much of the Dakotas, Minnesota, and central Canada. For about 3,000 years high flows were maintained in the Upper Mississippi River (UMR) by overflows from Lake Agassiz through the glacial River Warren (now the Minnesota River) and from glacial Lake Superior through the St. Croix River. During the period that clear water overflowed from glacial lakes, the river above St. Louis, Missouri, cut deeply (up to 180 feet; 55 m) into the valley. Below St. Louis, glacial outwash cut a 5-mile wide, 360- to 450-foot (110- to 137-m) deep trench into the Paleozoic bedrock to Thebes Gap, below which the floodplain widens to about 50 miles (80 km; Fremling et al. 1989). The Illinois River was scoured by a series of great floods that resulted from failed ice dams in what is now the Chicago area (Simons et al. 1975).

As the glacier retreated northward, drainage from glacial Lake Agassiz and the Great Lakes was reestablished to the north and east, causing southward flow to cease. Because the reduced flows had lower sediment transport capacity, the Mississippi and Illinois River valleys partially filled with glacial outwash consisting of sand and gravel.

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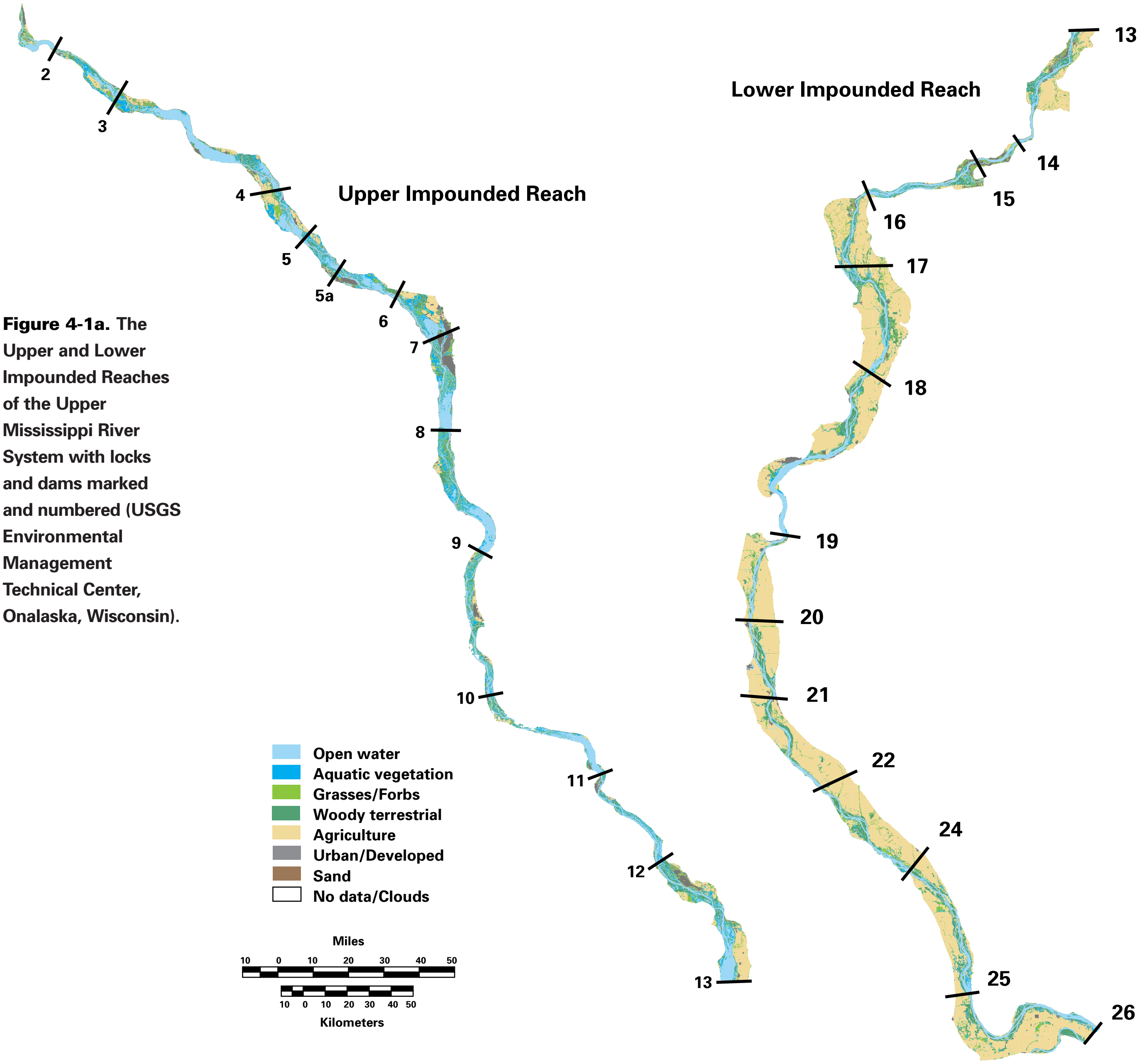

Figure 4-1a. The Upper and Lower Impounded Reaches of the Upper Mississippi River System with locks and dams marked and numbered (USGS Environmental Management Technical Center, Onalaska, Wisconsin).

Alternating broad and narrow reaches of present river floodplains reflect the nature of the gently sloping Paleozoic rocks into which the river is cut.

Since glacial times the ancestral valleys have continued to fill slowly with sediment because modern flow rates are not sufficient to transport all the glacial outwash (Nielsen et al. 1984). Evidence from core samples suggests a gradual reduction of flow since the Wisconsin glaciation—deeper core layers contain progressively coarser sand and gravel (Simons et al. 1975). Terraces, remnants of ancestral floodplains not scoured during postglacial floods, presently flank the valleys (Fremling et al. 1989). Most of the basin loess soil was formed by silt blown out of the river valleys by glacial winds that scoured the unvegetated outwash. The loess mantle thins as distance from the rivers increases (Nielsen et al. 1984).

Alternating broad and narrow reaches of present river floodplains reflect the nature of the gently sloping Paleozoic rocks into which the river is cut. Broad reaches developed where soft sandstone eroded, leaving high bluffs of erosion-resistant rock; narrow reaches are present where resistant limestone formations dip down to the river level (Fremling et al. 1989). The present river floodplain is relatively straight (Simons et al. 1975) and exhibits a general longitudinal

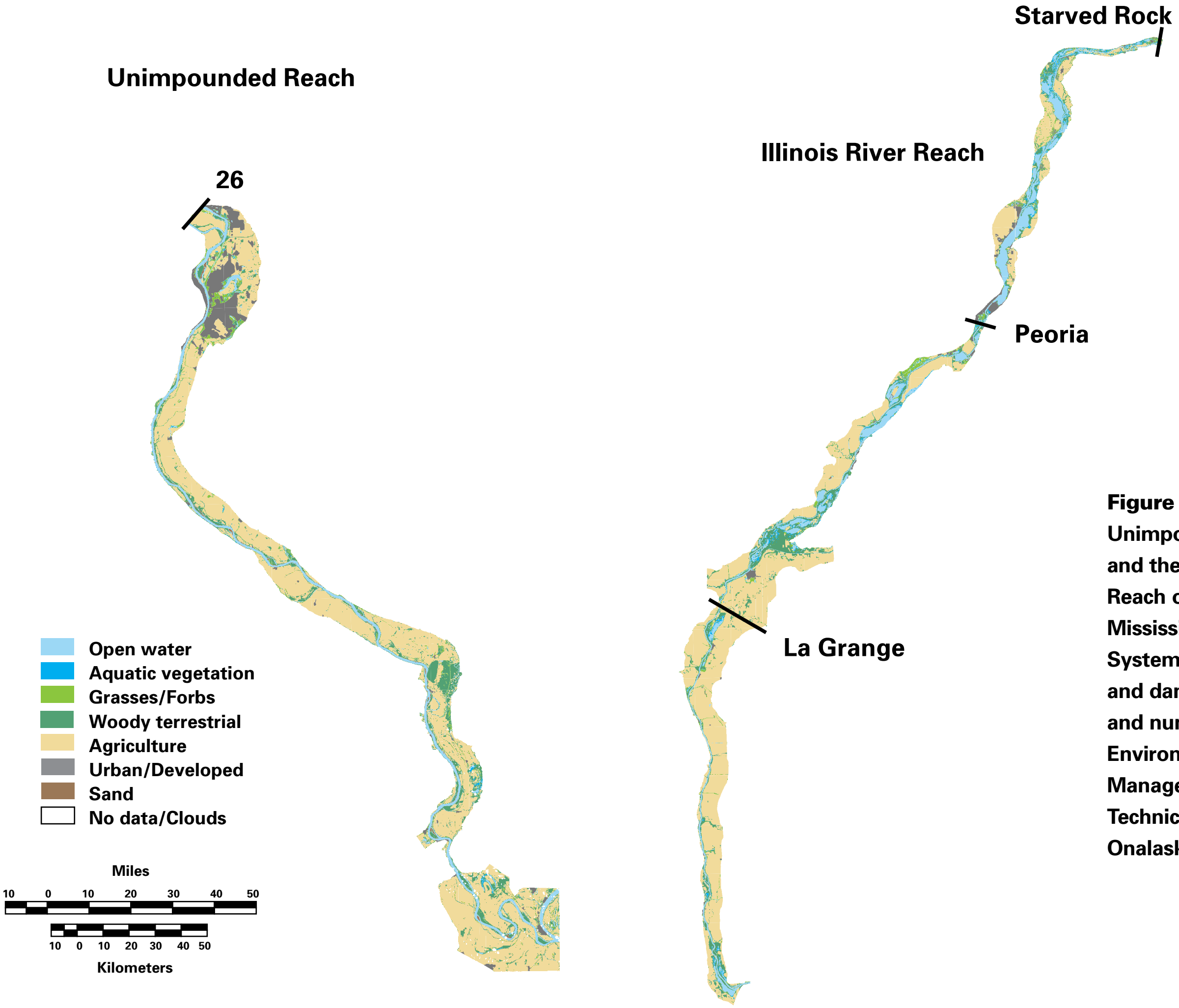

Figure 4-1b. The Unimpounded Reach and the Illinois River Reach of the Upper Mississippi River System with locks and dams marked and numbered (USGS Environmental Management Technical Center, Onalaska, Wisconsin).

pattern of increased flow, increased suspended sediments, and widening floodplains (Fremling et al. 1989).

Spatial differences in floodplain geomorphology and modern land use provide an ecological basis to separate the UMRS into four distinct river reaches. The Upper Impounded Reach (Figure 4-1a) of the UMR (regulated by navigation dams) extends from Minneapolis, Minnesota (Pool 1), to Clinton, Iowa (Pool 13), and is characterized by numerous islands and a narrow river-floodplain (about 1 to 3 miles [1.6 to 3.2 km]) that terminates at steep bluffs (Hoops 1993). The Lower Impounded Reach (Figure 4-1a) lies between Clinton, Iowa (Pool 14), and Alton, Illinois (Pool 26). In this reach, the river flows through a relatively narrow floodplain over glacial outwash below Clinton to Fulton, Illinois (Pool 14); between Fulton and Muscatine, Iowa (Pool 16), it flows over or near bedrock through an erosion-resistant rock gorge. Below Muscatine the floodplain generally expands across a wider alluvial valley between high bluffs, except for some areas in Pool 19, where the Keokuk Rapids once flowed, it is constricted by bluffs and underlain by bedrock. Islands here are typically fewer and larger than in the upstream reach. Between Clarksville, Missouri (Pool 24), and Alton, Illinois (Pool 26), the average width of the river floodplain is 5.6 miles (9.01 km) with an average slope of 0.5 feet per mile (Simons et al. 1975).

Below the confluence of the Mississippi and Missouri Rivers, the Unimpounded Reach (Figure 4-1b) exhibits a different character from the upper reaches. The river assumes a meandering pattern and has shifted its course many times over the years, leaving oxbow lakes and other backwaters. The river flows through alluvial lowlands, known as the American Bottoms, to the confluence of the Ohio River where the floodplain is up to 50 miles (80 km) wide. The Missouri River contributes significant quantities of water and sediment that make the Unimpounded Reach environment quite different from that of the Upper Mississippi and Illinois Rivers.

The Illinois River (Figure 4-1b) can be divided into the Upper and Lower Reaches based on geomorphic and ecological criteria (Sparks and Lerczak 1993). The Upper Illinois Reach above Starved Rock Lock and Dam is a young stream relative to the Lower Reach; the Lower Illinois Reach that extends downstream to the confluence with the Mississippi River is a much older remnant of glacial times (Sparks 1984). The Lower Reach is more characteristic of river-floodplain ecosystems in form and function than is the Upper Reach. The Lower Illinois has a stable, low-gradient channel (Mills et al. 1966; Talkington 1991) and a wide floodplain with numerous large lakes. The average floodplain width in the lower 80 miles (128.7 km) of the river is about 4 miles (6.4 km) (Simons et al. 1975).

Since the glaciers retreated, the hydrologic regime has shaped the channels and floodplains. The Upper Impounded Reach has a characteristic island-braided channel form that developed in response to conditions of sediment loading and stream power and gradient over the last 10,000 to 12,000 years (Simons et al. 1975; Nielsen et al. 1984). Glacial meltwaters washed large amounts of sand and gravel along the stream bed (bed load). As main stem river flow diminished and sediment loads declined, high-gradient tributary streams started head cutting (a process where the lower ends of tributaries degrade to the level of the river), delivering additional course sediments to the main stem river floodplain (Simons et al. 1975). The gradient and flow in the main stem Mississippi River were not great enough to transport this bed load out of the Upper Impounded Reach and delta fans formed at the mouths of many tributaries. High flows from the tributaries and the Mississippi River sometimes scoured new channels across the delta fans to establish the island-braided pattern (Nielsen et al. 1984). At other times large tree and brush piles blocked the head of a side channel, hastening its constriction with sediment and, eventually, vegetation. Lake Pepin is a large floodplain lake created when flow was blocked by a great delta at the mouth of the Chippewa River during glacial times (Nielsen et al. 1984). Islands in the Upper Impounded Reach are relatively stable, with most exceeding 300 years in age and many exceeding 3,000 years in age (James Knox, University of Wisconsin, Department of Geography, Madison, Wisconsin, personal communication). Floodplains in this reach are composed primarily of accumulated (vertically accreted) fine materials that overlay glacial-age deposits of sand and gravel.

The Lower Impounded Reach is similar to the Upper Impounded Reach in origin and island-braided channel forms. The channel position has been relatively stable since at least the early 1800s (Simons et al. 1975). Sediments delivered to this reach have a larger proportion of fine sediment carried in suspension than does the upstream reach. Although it is not known if sediment was carried in this way throughout presettlement times, we surmise the present situation likely is due to soil composition in the middle of the basin. Floodplain soils in the Lower Impounded Reach are thick layers of silt, sand, and gravel (alluvium) deposited behind natural levees during floods occurring over thousands of years. Before dam construction,

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the river contained extensive rapids near Rock Island, Illinois, and Keokuk, Iowa, where it flowed over exposed bedrock. The average depth of the Mississippi River north of the Missouri River was about 2.5 feet (7.6 km) at low flow.

Because of the influence of the Missouri River, the Unimpounded Reach has always been different from the rest of the UMR. Flow increases by nearly 50 percent below the confluence; the Missouri contributes vast quantities of sand and silt from the Rocky Mountains and Great Plains. Increased flows of water and sediment, especially during floods, contribute to channel migrations within the broad river valley. Although the river has been reasonably stable over the last 200 years (Simons et al. 1975), meander scars indicate channel migrations through geologic time.

The position of the Illinois River has been stable through time, as evidenced by numerous archeological sites dating back 10,000 years and still found along its banks (Sparks 1984). The floodplain was characterized by many backwater lakes separated from channels by natural levees. Flood flows from tributaries and in the main channel may have eroded natural levees and islands, forming new channels and backwaters, but the trend was toward filling in the river valley because flow generally was insufficient to transport the mass of sediment entering the broad floodplain. Given the glacial origin of the Illinois River Valley, the floodplains are much larger than would be expected for a river of its present size. The floodplain soils are a rich alluvium that overlay sandy glacial outwash.

Geomorphic Features of the Channels and Floodplains

Some types of geomorphic features are common to all river reaches (see *Geomorphic Features* sidebar). In 1993, Wilcox defined an aquatic habitat classification system. Land-cover classifications for terrestrial and aquatic plant communities also were developed for the Long Term Resource Monitoring Program (LTRMP). Aquatic areas defined by Wilcox (see Figure 2-5 and Table 2-1) are based on geomorphic and navigational features of the river system. Aquatic-area classes are useful to characterize physical processes related to water and sediment movement as well as associated biological communities. Main channel substrates typically are shifting sand. The undeveloped river was shallow and characterized by a series of runs, pools, and channel crossings that provided a diversity of depth along the main channel.

Secondary channels are present around main channel islands. Some are remarkably stable (Simons et al. 1975), but others are transient. These transient channels may fill, causing the island to join the bank. They may also grow and dissect the island or banks to form smaller interconnected tertiary channels. Secondary and tertiary channels have upstream and downstream connections to large channels and most have some flow.

Backwaters (including various kinds of floodplain lakes) are formed by the growth of natural levees, channel migrations, and fluvatile dams formed by tributaries or floodplain scouring. Most single-opening and isolated backwaters lack flow at low-river stage and tend to accumulate fine-grained sediment. The difference between isolated and contiguous backwaters is the presence of a permanent connection between the backwater and the river, although all may be inundated during floods. Backwaters may be scoured during high-flow periods that slow the rate of sediment accumulation. Low-river stages during drought periods may have exposed backwater sediments and helped maintain firm soils throughout shallow backwaters and at the margins of deeper ones. Isolated backwaters may originate from channel

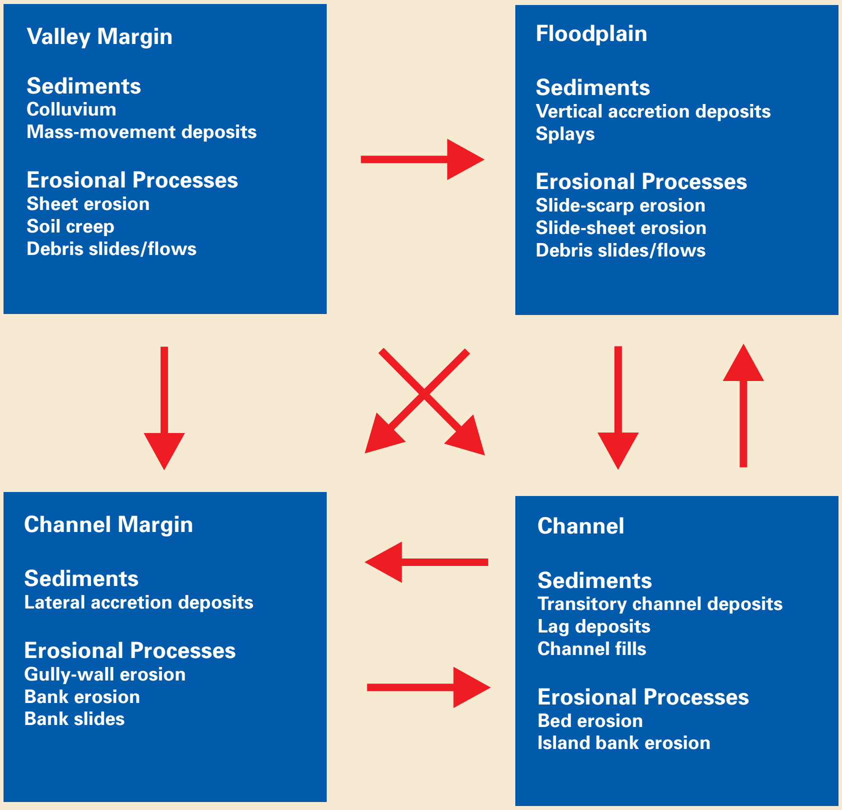
The difference between isolated and contiguous backwaters is the presence of a permanent connection between the backwater and the river, although all may be inundated during floods.

Upper Mississippi River System Geomorphic Features

Hank DeHaan

Geomorphic features formed from valley sediments are diverse, but some are common to all river systems. Their development can be associated with general links between sediment storage sites and erosional processes that occur within floodplain and channel areas, as shown in the graphic below. The boxes contain storage locations with example sediments and erosional processes. Arrows represent the links between the various storage sites. Understanding these relations is important for Upper Mississippi River System planning and management because it distinguishes the dominant erosional processes in the valley and the conditions under which storage of sediment may change (Ritter et al. 1995).

Gradually accumulated rock and soil (colluvium) and mass-movement deposits (e.g., alluvial fans) generally are located at the valley margin. These sediments are put in motion by sheets of running water (sheet erosion), slowly over gradual slopes (soil creep), and rapidly over steep terrain (debris slides/flows), and carried to the floodplain, channel margin, or stream channel. Deposits on the floodplain (overbank deposits) have various forms of vertical buildup (vertical accretion) and local, fan-shaped slopes (splays). This area may be eroded by slides cutting into banks (slide-scarp erosion), gradual slides of a wider expanse of land (slide-sheet erosion), or debris slides/flows that move sediments to the channel margin. Point and marginal bars (lateral accretion deposits) are formed in the channel margin. These sediments enter the channel by erosion of gully walls or stream banks. The sediments may accumulate in the channel (channel fills), be deposited and resuspended (transitory channel deposits), or form sand bars and islands when the deposit is not so transitory (lag deposits). Sediments may be taken up again by erosion of the stream bed or island banks and redeposited in the channel margin or in the floodplain as overbank deposits.



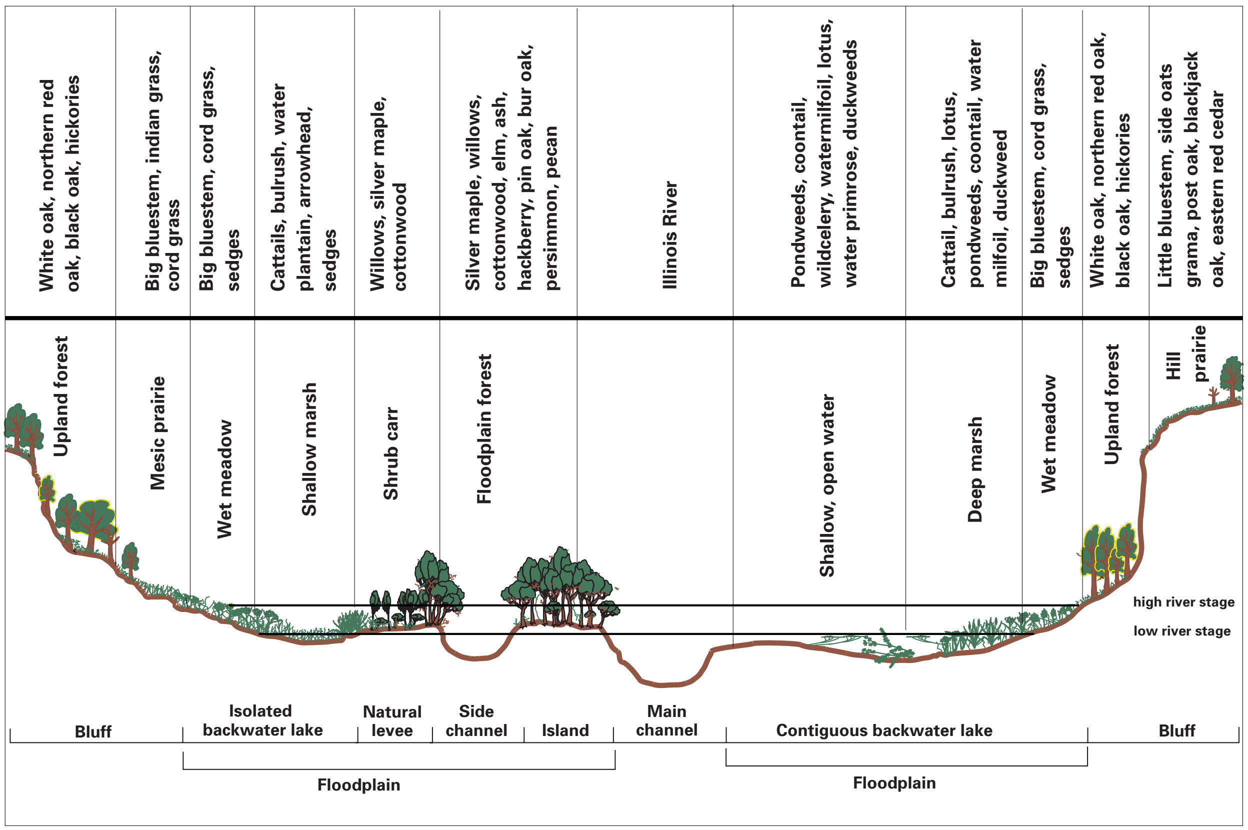


Figure 4-2. This hypothetical floodplain cross section illustrates the habitat types likely to occur on the Upper Mississippi River System (Source: John C. Nelson, Illinois Natural History Survey, Great Rivers Field Station, Alton, Illinois).

migrations (oxbow lakes) or the growth of natural levees. Beavers create many backwater areas by damming tertiary channels.

Generalized plant communities (habitat patches) typically develop in response to local landform, hydrology, and the physiological needs of the plants (Peck and Smart 1986; Galatowitsch and McAdams 1994). Plant communities, therefore, frequently are used to classify terrestrial habitat (see Figure 2-5) that may have evolved over many thousands of years following the retreat of the glaciers. As the climate warmed, river flows diminished to allow the development of plant communities in the modern floodplain. Climate remains an important determinant of biotic communities. Along the 800-mile (1,287-km) length of the UMR, temperature-moderated events at the northern edge of the basin can lag behind (in the spring) or precede (in the fall) those at the southern edge by 2 to 4 weeks (Lubinski 1993). As a result, plant communities exhibit a gradation, with subtropical species at the southern tip and north temperate species in the northern portion of the basin (Kuchler 1964; Curley and Urich 1993; Long Term Resource Monitoring Program, unpublished data). The duration of ice cover and the effects of ice flow on floodplain vegetation also differ from north to south.

Local climate, hydrology, fire, and floodplain landform all determined floral and faunal community composition at any particular location before European intervention. Despite broad differences in floodplain geomorphology, every reach likely contains the broad habitat types shown in Figure 4-2. Prairies and wet meadows once were a prominent feature of the floodplain landscape, but fire suppression and farming has eliminated most floodplain prairies (Nelson et al. 1996; see *Habitat Mosaic* sidebar, pages 8 and 9).

Long-lived plant communities such as forests develop over time in relation to the recurrence of disturbances such as floods,

Upper Mississippi River System Habitat Mosaic

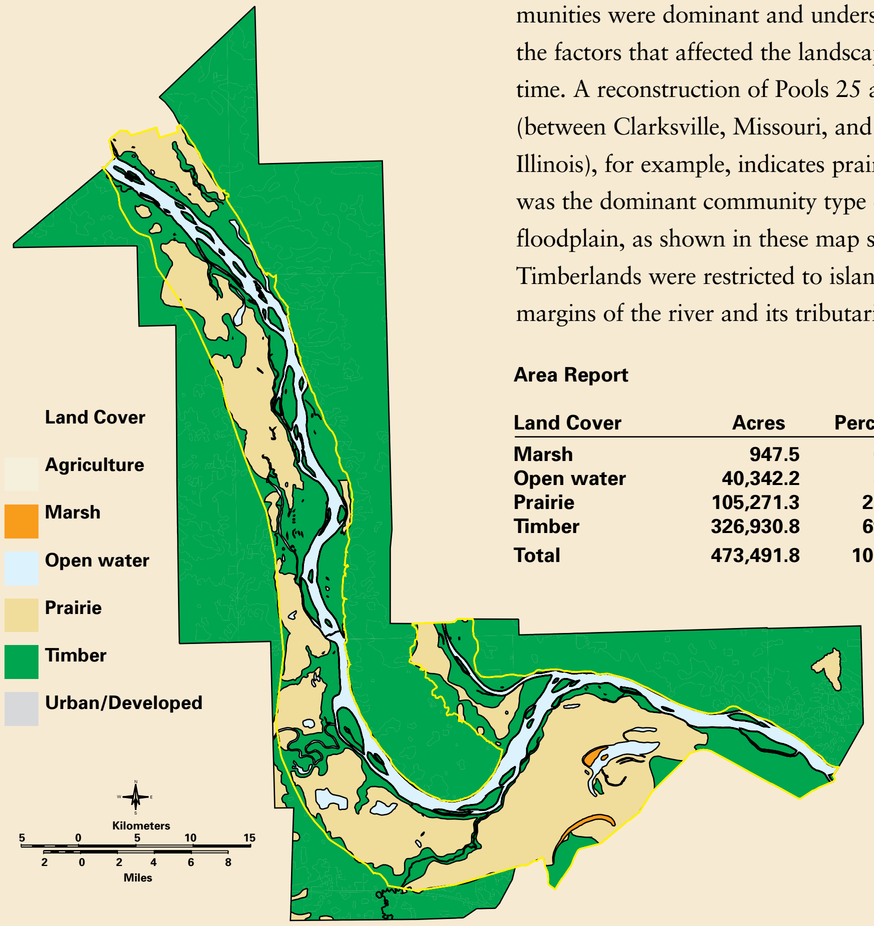
John C. Nelson

The geomorphic history of the Upper Mississippi River generally is discussed in terms of hundreds of millions and tens of thousands of years. However, the mosaic of habitats that greeted early European-American settlers evolved quite recently, about 4,000 years ago when the modern (Holocene) climate warmed and glacial flows subsided. Now, in a quest to establish baseline information needed for making future resource management decisions, researchers with the Long Term Resource Monitoring Program (LTRMP) are reconstructing a picture of this presettlement Mississippi River Valley and its natural habitats.

U. S. General Land Office surveys and survey notes are the primary sources for the reconstruction. These records contain, among other things, plat maps showing the location and extent of former prairies, timberlands, marshes, swamps, and rivers. The historic maps are being computerized into a geographic information system (GIS) format to make it easier to identify and quantify natural habitats present just before recorded human settlement within the river valley. From the valuable survey notes, researchers are able to differentiate the composition and structure of former timberlands on islands, floodplains, and adjacent uplands.

Investigation into presettlement characteristics of the UMRS is important for reframing assumptions about which communities were dominant and understanding the factors that affected the landscape over time. A reconstruction of Pools 25 and 26 (between Clarksville, Missouri, and Alton, Illinois), for example, indicates prairie once was the dominant community type on the floodplain, as shown in these map sections. Timberlands were restricted to islands, the margins of the river and its tributaries, and

Presettlement (1816) Land Cover of Mississippi River Reaches 25 and 26



Area Report

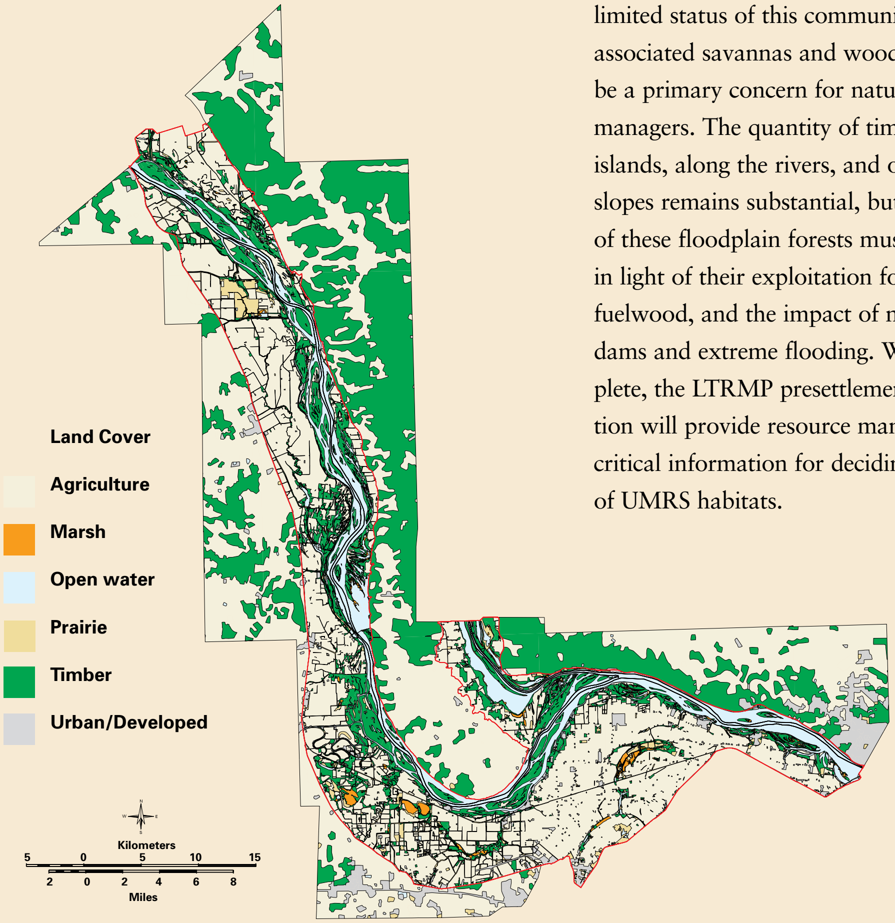
Land Cover	Acres	Percent
Marsh	947.5	0.2
Open water	40,342.2	8.5
Prairie	105,271.3	22.2
Timber	326,930.8	69.1
Total	473,491.8	100.0

valley slopes. Tree density and composition estimates indicate that oak savanna and oak woodland communities also were important features on the floodplain and adjacent uplands whereas close-canopy forests of cottonwood, hackberry, box elder, elm, ash, and silver maple prevailed on the islands. This apparent “mosaic” of habitats—prairies, woodlands, savannas, and forests—contradicts the long-held perception that forests alone once dominated the bottomlands of the Mississippi River Valley.

Environmental factors also are being reassessed. Flood disturbance, long regarded as a principal catalyst in the distribution of plant communities across the bottomlands of the Mississippi River landscape, now is viewed as only part of the picture. It is likely fire as well as floods helped shape and maintain the diversity of these presettlement habitats. Fire sweeping across floodplain prairies, especially those at high elevations that were dry in late summer, could explain why forests did not take over in the centuries before European-American settlement. Likewise, fires originating in bottomlands could have swept up valley slopes and helped sustain oak woodlands, savannas, and hill prairies in the adjacent uplands. At lower elevations of the floodplain—along the river, its tributaries, and islands—flooding was the central disturbance mechanism that maintained marshlands and forests.

Today, like much of the Midwest, Pool 25 and 26 landscapes are nearly devoid of prairie because of agriculture and urban development. Some small patches of prairie are found on the floodplain, but the present limited status of this community and its associated savannas and woodlands should be a primary concern for natural resource managers. The quantity of timberland on islands, along the rivers, and on valley slopes remains substantial, but the quality of these floodplain forests must be assessed in light of their exploitation for lumber and fuelwood, and the impact of navigation dams and extreme flooding. When complete, the LTRMP presettlement reconstruction will provide resource managers with critical information for deciding the future of UMRS habitats.

Modern (1989–94) Land Cover of Mississippi River Reaches 25 and 26



Area Report

Land Cover	Areas	Percent
Agriculture	254,557.4	53.8
Marsh	2,833.3	0.6
Open water	39,763.2	8.4
Prairie	12,953.8	2.7
Timber	144,507.2	30.5
Urban/Developed	18,876.9	4.0
Total	473,491.8	100.0

wind storms, and lateral channel migration (see Chapter 9). In wetland habitats, many plant species have life history strategies that enable them to survive in an environment in which water levels change substantially. Some annual emergent plants have tremendous growth rates on fertile alluvial soils exposed during late summer, and these emergent wetlands are among the most productive plant communities (Peck and Smart 1986). Other plants thrive equally well whether inundated or exposed and many species may be present in the seed bank at a single location awaiting favorable conditions to germinate. The wetland plant community composition in any year is dictated by spring and summer water conditions. Animal communities usually are opportunistic in their habits and exploit floodplain habitats as they occur to fulfill their own needs (Bellrose 1980; Bayley 1991).

Land-use change in the central portion of the basin was accelerated with development of the moldboard plow in 1837 and, after World War II, with the shift toward intensive mechanized row-crop farming.

Geomorphic Response to Land-Use Change in the Upper Mississippi River System Basin

Land-use and land-management practices within the basin have increased the rates of upland erosion and discharge of sediment from tributaries to the UMRS over presettlement rates (Knox et al. 1975; Knox 1977; Demissie et al. 1992). Upland erosion and UMR tributary sediment yields in Wisconsin were highest during periods of intensive farming and runoff during the 1850s through the 1920s, with erosion rates declining since then because of improved land-management practices (Knox et al. 1975; Trimble and Lund 1982; Trimble 1983).

Despite improved land management and reduced upland erosion rates, sediment discharge from tributaries to the UMRS continue to be influenced by two factors: (1) sediment previously deposited in tributary valleys and (2) historic changes in the channels of the tributary stream network (Knox 1977, 1989). Land-use change in the central portion of the basin was accelerated with development of the moldboard plow in 1837 and, after World War II, with the shift toward intensive mechanized row crop farming. Erosion rates have declined recently (see Chapter 5), but sediment storage in central basin tributaries also is significant (Demissie et al. 1992).

Geomorphic Responses to River Engineering for Navigation

The modern river has experienced a series of channel and floodplain modifications (see Chapter 3). Beginning in 1824, the U.S. Army Corps of Engineers began to improve and maintain the main navigation channel of the Upper Mississippi River. River engineering for navigation has since included clearing and snagging of woody debris, construction of channel training structures, impoundment by navigation dams, dredging, and placement of dredged material. These modifications have had a major effect on shaping the present UMRS.

Snag clearing improved navigation in the main channel but from most accounts had little effect on the general position of the channel. Flows and sediment distribution undoubtably were modified, but little has been documented about such change. Constructing wing dams and closing dams did begin to change the geometry of the river channels and floodplain as the position of the main channel was stabilized (Simons et al. 1975). Sediments that built up between wing dams and in side channels reduced the width of the river (Chen and Simons 1986), and the flow—concentrated in the main channel by wing dams and closing dams—gradually deepened the river as intended (Nielsen et al. 1984). Many new terrestrial areas were colonized by vegetation and incorporated into the surrounding floodplain environment. Throughout the whole river, but especially in the Upper Impounded Reach, dredging supplemented snag clearing and dike construction. Channel-maintenance dredging is estimated to have removed a large fraction of the total riverbed load transport in the upper pools of the Mississippi River (GREAT I 1980). Disposal of dredged material created numerous channel border islands (Simons and Chen 1979; GREAT I 1980). Many shallow aquatic areas near the main channel fringe also were filled with sand dredged from the navigation channel.

Dredged material disposal remains a problem but the process is better managed than in the past. Most dredged sand in the Upper Impounded Reach is now deposited in designated containment areas, placed behind levees, used for island construction or other habitat features, or transported out of the floodplain for beneficial use. Dredging and channel-training structures for maintaining the navigation channel above the Missouri River were supplemented by construction of navigation dams in the 1930s, but the navigation channel in the Unimpounded Reach still is maintained without dams.

The history of channel changes in the Unimpounded Reach is complex. The original channel width (ca. 1821) was 3,600 feet (1,097 m). Between 1821 and 1888, forests along the banks were cleared for steamboat fuel wood, lumber, and agricultural conversion. The soft alluvial banks were left exposed to river currents and eroded to a width of 5,300 feet (1,615 m) in that period. Evidence exists that many early French villages on the banks of the Unimpounded Reach were destroyed by channel migrations (Norris 1997). Extensive dike construction between 1907 and 1949 and subsequent sedimentation between wing dams effectively constricted the river to an average width of 3,200 feet (975 m; Strauser 1993). Side channels were closed off and others sedimented in, resulting in the loss of numerous side channels (Figure 4-3; Simons et al. 1975). Side-channel loss remains a major concern in the Unimpounded Reach and is the focus of ongoing studies and restoration efforts. New engineering approaches, such as bendway weirs and chevron dikes, may aid in maintenance of existing side channels (Davinroy 1990). Dredging is common in the Unimpounded Reach, but most dredged material is disposed of in the main channel where it eventually moves downstream as suspended sediment or bed load.

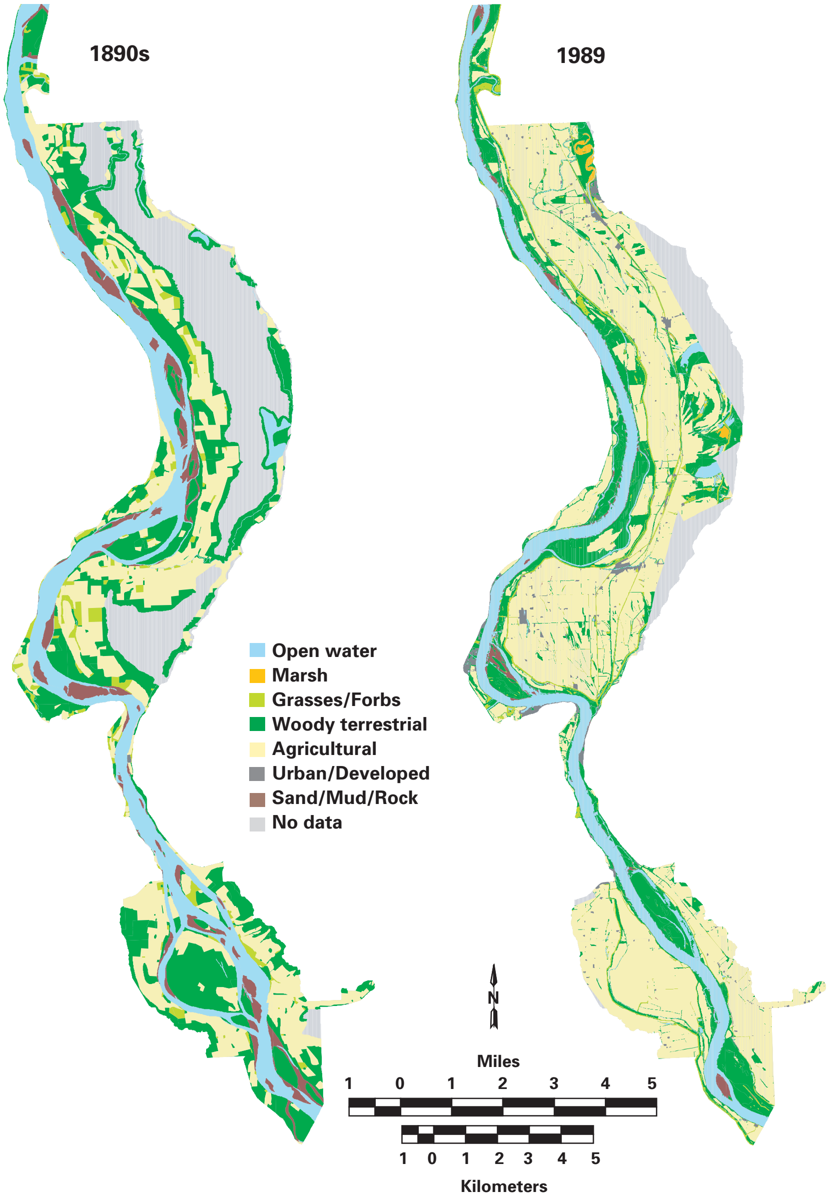


Figure 4-3. Turn-of-the-century (1890s) and modern (1989) land-cover maps of the Unimpounded Reach near Cape Girardeau, Missouri, demonstrate the loss of side channels because of wing dams and side channel closures built to maintain commercial navigation (Source: USGS Environmental Management Technical Center, Onalaska, Wisconsin).

Lock and dam construction in the reaches upstream of the Missouri River greatly modified the land and water features of the river. There are 29 dams on the Mississippi River and 8 dams on the Illinois River. The

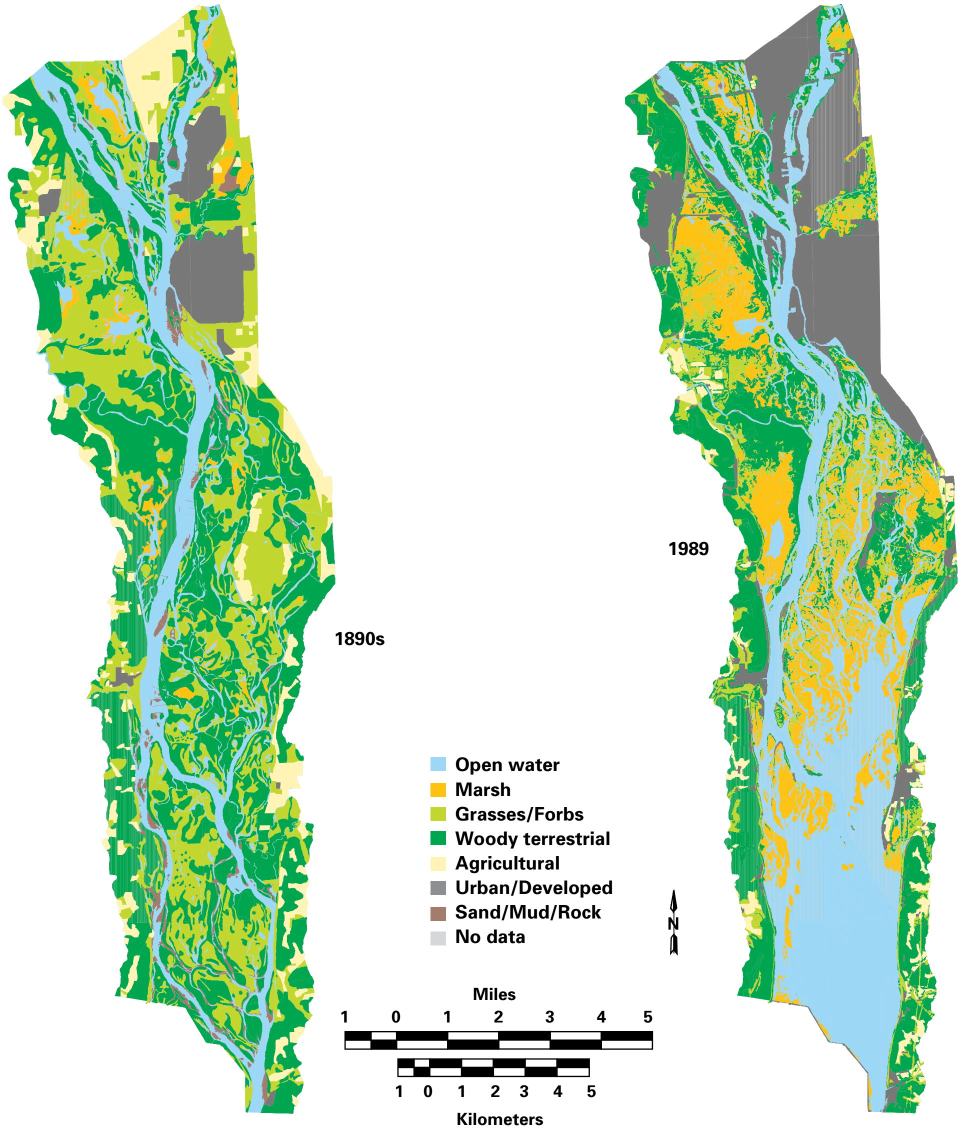


Figure 4-4. Turn-of-the-century (1890s) and modern (1989) land-cover maps of Pool 8 demonstrate the effect of impoundment on the river in most of the Upper Impounded Reach. Water levels were increased permanently in the lower half of the pools to create open-water areas close to dam and marshy areas near the middle reaches of the pools. The upstream reaches scoured deeper but were largely unchanged in shape (Source: USGS Environmental Management Technical Center, Onalaska, Wisconsin).

river reach between two dams is called a "pool," but these pools are river-like in form and function. Generally, the dams increase water levels, slow the current velocities, and flood low-lying floodplain areas in the lower one-third to one-half of the navigation pools. The effect is illustrated clearly in Pool 8 (Figure 4-4) and is most evident in pools in the Upper Impounded Reach (Figure 4-1). Pools in the lower floodplain and Illinois River reaches are affected to varying degrees by impoundment, but most retain a fairly straight channel with impounding effects less apparent than in upstream reaches (Figure 4-5). Water depths, however, are increased and the annual variation in water levels in the lower reaches of the pools is reduced (Theiling 1996).

A series of changes have occurred to the terrain since the dams were completed in the late 1930s. The changes are thought to have been rapid right after impoundment and may have slowed recently as the system approaches a new equilibrium within the physical constraints imposed by the navigation dams. Initially after water levels were regulated (i.e., raised and stabilized) by the dams, many islands were submerged; high spots on the flooded area became new islands in the lower one-third of many pools (Figure 4-6). Over time, wind-driven waves in impounded areas of the navigation pools have eroded shorelines and

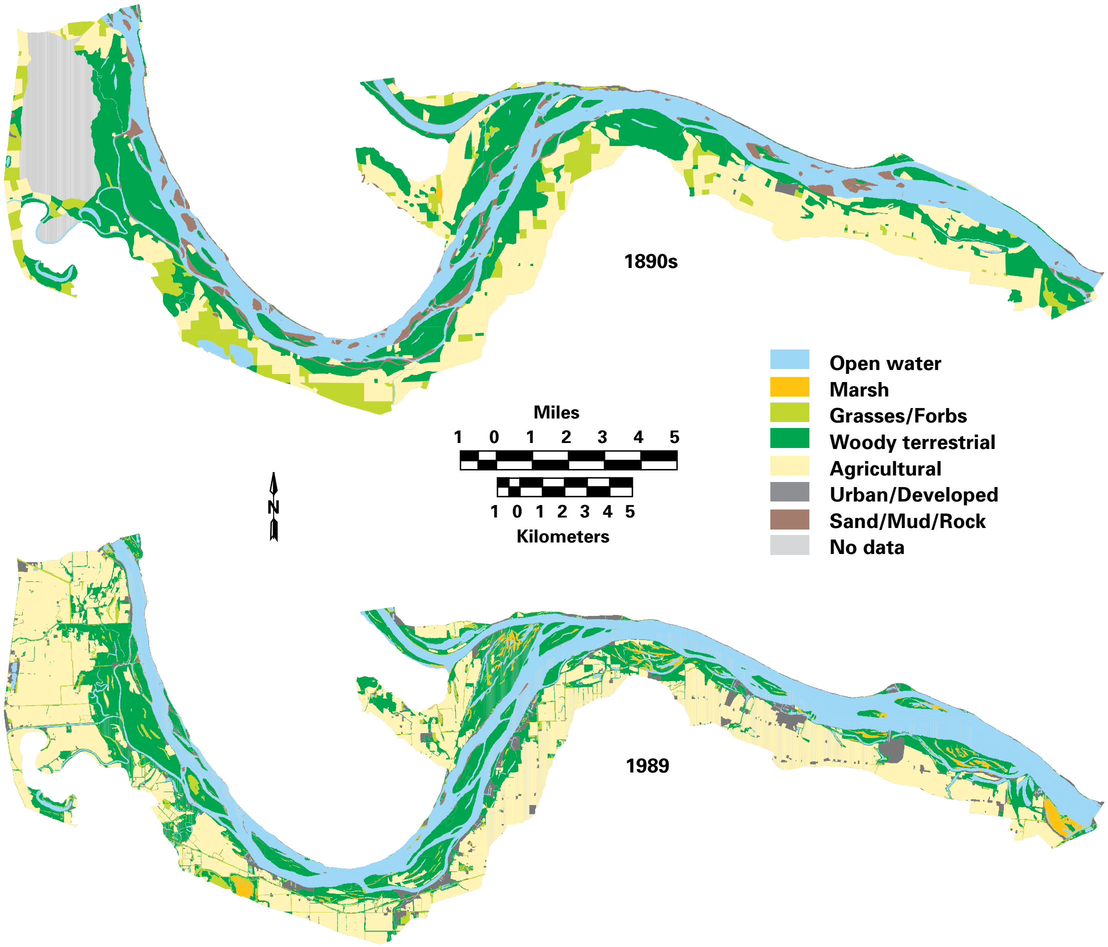


Figure 4-5. Changes in Pool 26 between the 1890s and 1989 demonstrate dam impacts in the Lower Impounded Reach. These are similar to the impact in upstream reaches, but impounded areas do not occupy as large a proportion of the floodplain as the upper pools. Water depths are increased and the annual variation in stage is reduced (Source: USGS Environmental Management Technical Center, Onalaska, Wisconsin).

islands. Boat-generated waves have had a similar effect and can be intensive in some river reaches (Bhowmik 1989; Johnson 1994). Wind-driven sediment resuspension and its transport in water currents have redistributed sediment, eroding shallow areas and filling in deeper areas of large floodplain lakes and impounded areas within some navigation pools. The result is general simplification of bottom topography. As islands eroded, wind and waves had a longer fetch to build up the energy that resuspends bottom sediments, thus limiting light penetration and aquatic plant growth.

The river has responded to impoundment and river regulation over the last 60 years. Initially, newly created backwaters and impounded areas were underlain by firm floodplain soils. The backwaters gradually accumulated fine sediments deposited in areas of low current velocity; coarser sand deltas developed where channels enter backwaters. Backwater sedimentation occurred throughout the impounded reaches of the UMRS, but these problems are most pronounced in the Illinois River and Lower Impounded Reach. Some backwaters have lost volume to sedimentation in the Upper Impounded Reach (see Chapter 8), but most remain in good shape and support diverse aquatic communities. Deeper portions of backwaters tend to fill first, which causes widespread loss of bathymetric diversity important to aquatic organisms (Bellrose et al. 1983).

The Illinois River and Pool 19 serve as illustrations of the effect of sedimentation in the UMRS, and although this is detailed in Chapter 14, we will discuss it briefly here. The outlook for the Illinois River backwaters is tenuous; average volume loss in Illinois River backwaters is 74 percent and remaining backwaters are projected to fill over the next

Some backwaters have lost volume to sedimentation in the Upper Impounded Reach but most remain in good shape and support diverse aquatic communities.

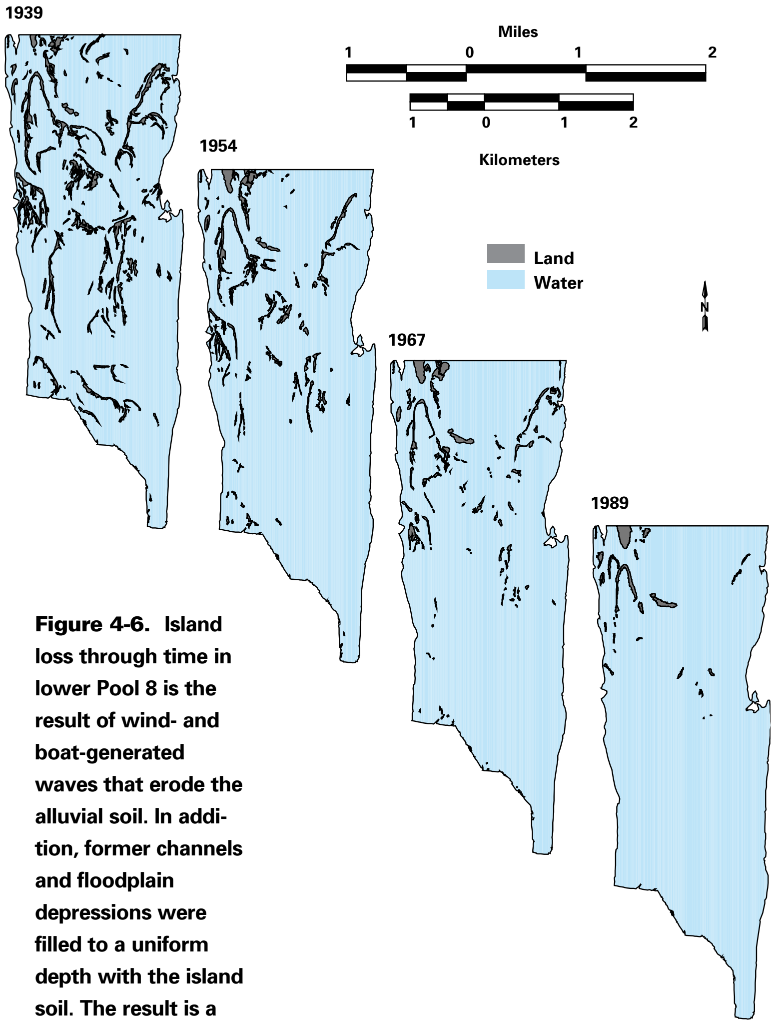


Figure 4-6. Island loss through time in lower Pool 8 is the result of wind- and boat-generated waves that erode the alluvial soil. In addition, former channels and floodplain depressions were filled to a uniform depth with the island soil. The result is a decrease in habitat complexity important to plants and animals (Source: USGS Environmental Management Technical Center, Onalaska, Wisconsin).

50 to 100 years (Bellrose et al. 1983; Demissie et al. 1992). Whereas the lakes may be present for many years, they may not provide habitat to support deep water communities, overwintering fish, or aquatic plants.

Several key factors relate to Illinois River sedimentation. First, most of the Illinois River Basin is in intensive row-crop farming, greatly increasing sediment transport rates (over presettlement rates) from the basin. Next, levee district development has reduced the area of the river floodplain over which sediments can be deposited, further increasing sediment deposition rates in backwaters. Third, sediments are silty and easily resuspended by waves because dams maintain high water levels and sediments are not exposed, dried, and compacted during low-flow periods. Finally, river gradient and stream power is not sufficient to transport much of the sediment load from the system.

The large pool formed by Lock and Dam 19 slowed current velocities, thereby allowing sediments to drop out in river eddies and in the impounded area (lower one-half) of the pool. As sediments were deposited, they accumulated in the river bed (aggradation) rapidly between 1910 and the mid-1940s but slowed in 1946 through 1983 (Figure 4-7; Bhowmik et al. 1986; Bhowmik and Adams 1989). The process of sedimentation was a key factor in development of plants beds thought to fuel high biological productivity in Pool 19 (see Chapters 8 and 10).

The examples described above are useful for illustrating the potential effect of sedimentation. They may not represent localized sediment dynamics, however, or sediment dynamics throughout the system. Radiological isotope-dating studies of sedimentation conducted in Pools 4 to 10 in the 1970s estimated average rates of 0.4 to 1.3 inches per year (1.0 to 3.3 cm per year) for the period of 1954 to 1964 and 0.3 to 1.8 inches per year (0.8 to 4.7 cm per year) between 1965 and 1976 (McHenry et al. 1984). These studies focused on backwaters and may have overestimated whole pool sedimentation rates. Concurrent depth sounding surveys in larger areas showed lower rates of sedimentation (McHenry et al. 1984).

Present surveys also show that sedimentation rates are lower (Koschgen et al. 1987; Rogala and Boma 1996) and reveal dynamic processes that may be responsible for maintaining backwaters (Koschgen et al. 1987; Rogala and Boma 1994). Rogala and Boma (1996) found sediment accumulation rates of 0.05 to 0.31 inches per year (0.12 to 0.80 cm per year) in repeated bathymetric surveys along benchmark transects in Pools 4, 8, and 13. By repeating surveys annually, Rogala and Boma (1994)

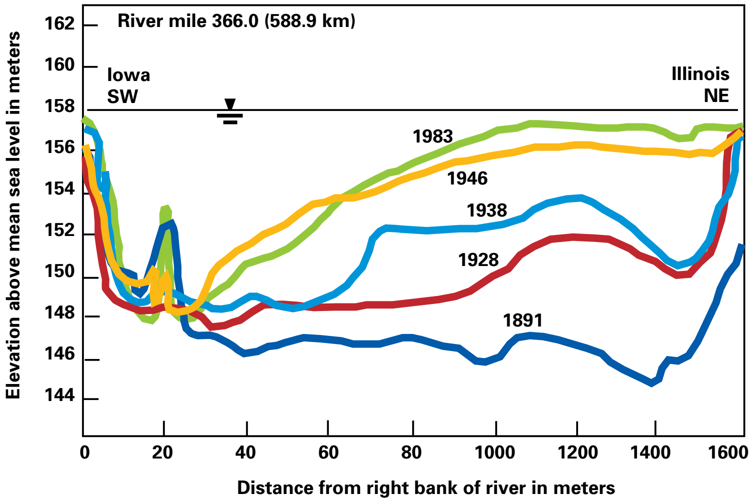


Figure 4-7. Sediment accumulation in portions of Pool 19 has been extreme through time and demonstrates the potential effect of sediment in the Upper Mississippi River System. The high rate of sedimentation is not representative of the entire river, but the profiles demonstrate that the rate of accumulation decreased with time (Source: Bhowmik and Adams 1989, reprinted with permission of the author).

also documented changes in sedimentation patterns that resulted from unusually high flow during summer 1993. The researchers determined that lake-like sedimentation processes prevailed most of the time and deeper areas accumulated the most sediment. Postflood surveys showed an opposite pattern with deposition in shallow areas and scouring in deeper areas, results characteristic of riverine patterns of sediment transport.

The present lack of sediment studies limit the ability to evaluate and predict the fate of backwaters systemically. However, ample site-specific evidence supports the claim that sedimentation is among the most critical ecological problems in the UMRS. The prediction that ecologically productive backwaters will fill and disappear in the next 50 to 100 years is alarming and clearly identifies sedimentation as a major concern of natural resource managers (Bellrose et al. 1983; McHenry et al. 1984; Demissie et al. 1992). Growth of deltas where channels enter impounded areas of the navigation pools may result in a future river planform that resembles preimpoundment conditions, with island-braided morphology, more tertiary channels, and fewer backwater areas than at present.

Impoundment that created the navigation pools also impounded the lower ends of many tributaries in the downstream portion of each pool. Sediment deposition in the hydrologically modified tributaries raised the base elevation of a number of tributaries, resulting in delta formation in the lower reaches of tributary rivers. This effect raised the floodplains and increased the amount of wetland areas in the lower reaches of some tributaries (James Knox, Department of Geology, University of Wisconsin, Madison, personal communication).

Recently initiated sediment budget studies for Pool 13 on the Mississippi River and La Grange Pool on the Illinois River are designed to measure sedimentation by tracking sediment inputs from tributaries and their transport out of or storage in each pool. The studies estimate bed load and measure total suspended sediments that enter from major tributaries and the main stem river upstream; they also measure suspended sediment exiting each reach. During 1995 in Pool 13, 97 percent of the flow and 67 percent of the sediment came from main stem sources. In La Grange Pool, only 55 percent of the flow and 22 percent of the sediment came from main stem sources. The difference implies that La Grange Pool is more influenced by tributaries and local factors (storms, land use, etc.) than Pool 13, which is influenced mostly by upstream factors.

The pools also differed in their ability to transport sediment. Pool 13 exported nearly all the sediment that entered from upstream and tributary sources. La Grange Pool, with a smaller watershed (less then one-third that of Pool 13) and lower water load (discharge less than half of Pool 13), received almost one and a half times the suspended sediment of Pool 13 and stored a significant portion of it. Although these are preliminary results, the differences are important when considering management responses to sedimentation and

Figure 4-8. Levee districts combat groundwater seepage using drainage canal networks and large pumps like this one on the Sny Levee District in western Illinois (Source: *St. Louis Post-Dispatch*).

the natural geomorphological variation throughout the UMRS (Robert Gaugush, USGS Environmental Management Technical Center, Onalaska, Wisconsin, personal communication).

Levee Districts

Levee district development in the Lower Impounded, Illinois River, and Unimpounded reaches provide protection from moderate floods and allow floodplain habitat conversion to agriculture. Exterior levees block moderate floods and interior drainage ditches and large pumps drain groundwater seepage (Figure 4-8). Conversion to farming is responsible for the loss of approximately 50 percent of the natural floodplain habitat in the Lower Impounded Reach and Illinois River (Figure 4-9), and more than 80 percent of the natural floodplain habitat in the Unimpounded Reach (UMRBC 1982). Levees also have an indirect impact that modifies sediment deposition and river-stage characteristics.

The Illinois River floodplain provides an example of the change that occurred when a rich mosaic of backwater lakes and channels was leveed and drained to support row crop agriculture (Figure 4-10; Mills et al. 1966). Remaining unleveed backwaters were ecologically impaired because dams increased their size and kept the backwaters permanently flooded. Levees also constricted the area over which sediments are distributed, resulting in increased sediment deposition in backwater lakes (Bellrose et al. 1983). Levees also contribute to increased river stages and more rapid fluctuations in flood flows (Belt 1975; Bellrose et al. 1983). Differences in the degree of levee district development among river reaches are responsible for many ecological differences and changes noted along the river.

Discussion

Presettlement conditions that shaped the river floodplain ecosystem have been changed by human activity at both the river floodplain and basin scale. Basin land-use conversions have increased sediment delivery to the system but land-conservation practices have reduced sediment yields in recent years (Knox et al. 1975). Extensive floodplain areas are sequestered from the river by levees for agriculture and urban development. The navigation pools in the impounded river reaches are 6 decades old and have undergone changes through sedimentation and shoreline (littoral) processes common to reservoirs. Perceived problems associated with sedimentation in the navigation pools may lie in human expectations for what the river should look like rather than the actual evolution of the system.

The navigation pools may continue to accumulate sediment and may change in appearance (planform) toward a semblance of preimpoundment conditions. Some backwaters will continue to change toward wetland and floodplain terrestrial habitat, while other backwater areas may attain an equilibrium geometry and continue to provide important off-channel aquatic habitat. Some approaches to limit the rate and effect of backwater sedimentation include constructing deflection dikes and low levees to block sediment-laden water from entering backwaters. Sediment has been removed from backwaters by dredging, but because dredge cuts may fill rapidly, the task can be expensive using current technology and might be considered impractical on a large scale. Modifying the system of channel-training structures could be used to influence flows through off-channel areas, and thus provide stream power to transport sediment and maintain important backwater habitats.

Channel maintenance dredging will be needed to continue maintaining adequate depth in the navigation channels. Dredged material can be used to reconstruct bank lines and river islands lost to erosion and create other floodplain habitat features.

Water-level management might improve sediment conditions in backwaters without relying on sediment removal. One suggested approach to treat sediments on a large scale involves lowering water levels (drawdowns) to expose sediments in shallow water areas. The approach has been used successfully by pumping water from leveed backwaters to promote emergent aquatic plants preferred by migratory waterfowl habitat (Reid et al. 1989). More recent efforts have demonstrated the effectiveness of pool-scale drawdowns to consolidate sediment and encourage the growth of emergent aquatic vegetation in Pool 25 (Strauser et al. 1995). Pool-scale drawdowns are under investigation in other reaches.

A forecast of the geometry of UMRS channels and floodplains would help river management. The U.S. Army Corps of Engineers Navigation Study is analyzing data on channel geometry, river planform, sediment delivery to the river, river engineering works, and hydrologic records to evaluate the cumulative effects of the navigation system since impoundment. The authors of the study also are preparing a geometry forecast of UMRS channels and floodplains. This forecast will be limited in resolution and certainty because the information is limited on past and present floodplain topography, sediment delivery rates from tributaries, and quantitative understanding of geo-

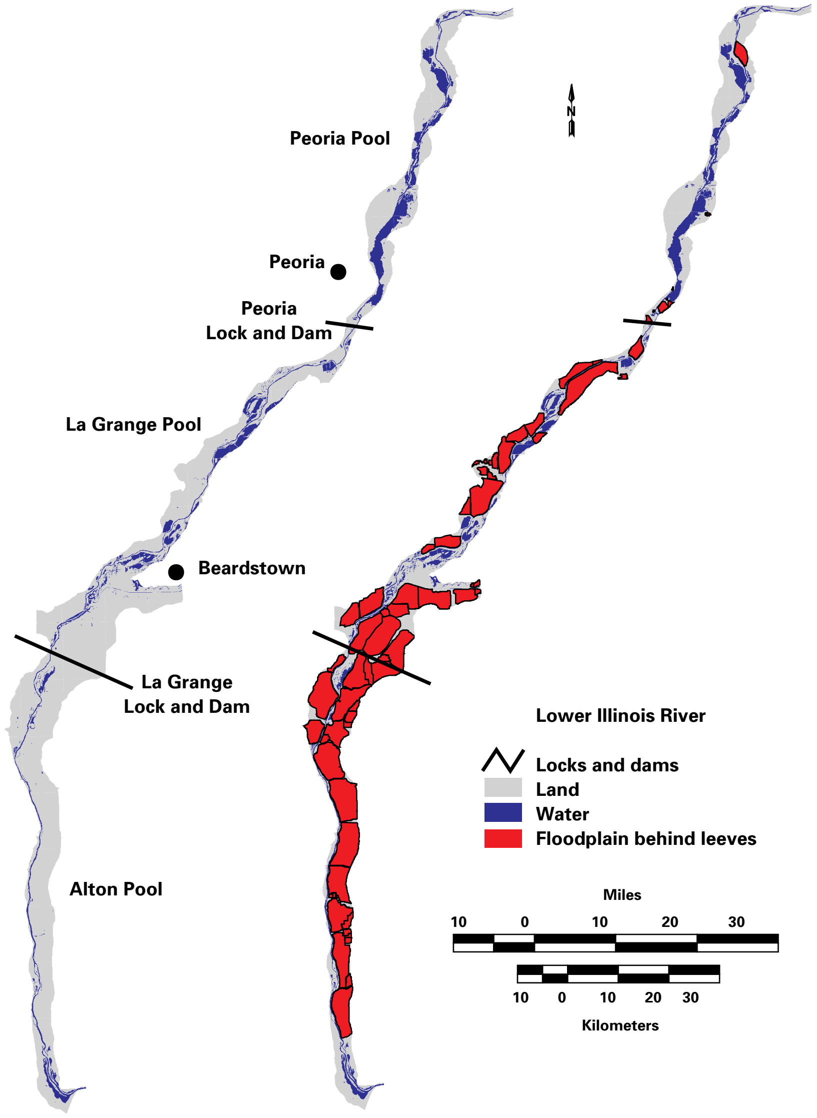
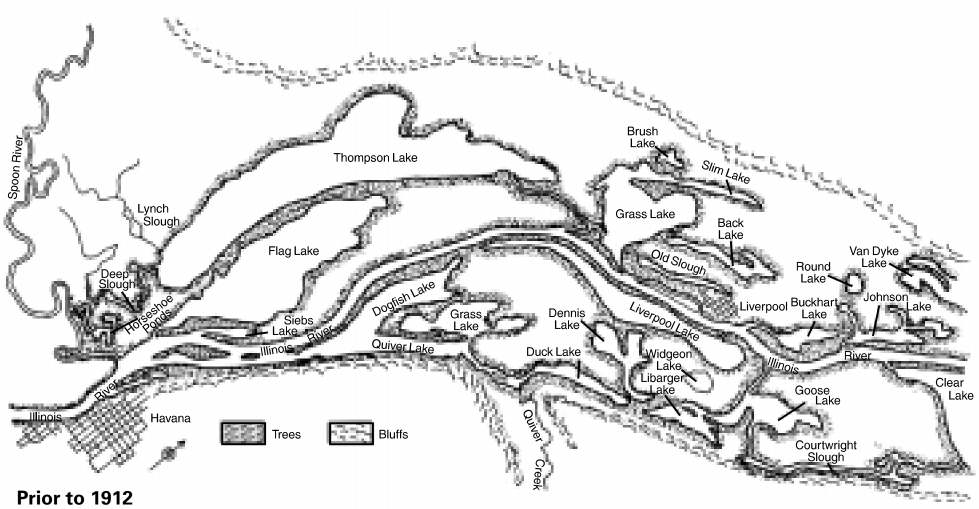
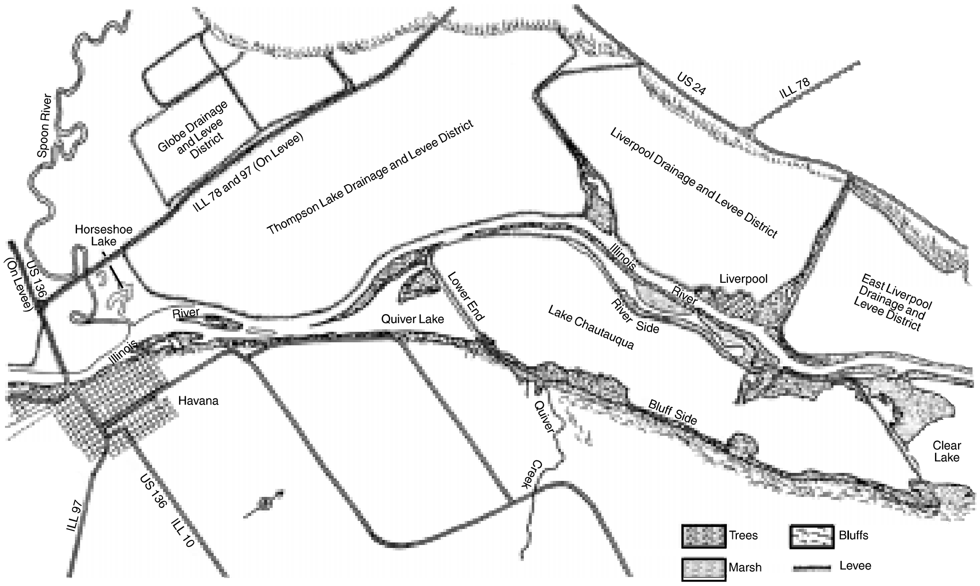


Figure 4-9. The Illinois River provides an example of the impact of habitat loss to levee districts. Approximately 50 percent of the river has been leveed. Source: USGS Environmental Management Technical Center, Onalaska, Wisconsin).

Figure 4-10. The Illinois River floodplain above Havana, Illinois, as it appeared before 1912 (top) and as it appears now (bottom). Note the elimination of backwater lakes by drainage and levee districts. Levee district development (as well as cutting forests and plowing prairies) caused significant habitat loss by draining former lakes and channels. The impact illustrated here is typical of developed regions of the Upper Mississippi River System floodplain (Source: Mills et al. 1966 and the Illinois Natural History Survey, Champaign, Illinois).



Prior to 1912



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morphic responses to impoundment, river regulation and channelization.

To better forecast geomorphic conditions, river managers need information on floodplain topography, bathymetry, sediment budgets within backwaters and navigation pools, sediment delivery by tributaries to the main stem rivers, and sources of sediment from within the UMRS. Increased understanding of geomorphic processes and probable future condition of the UMRS will allow more informed and effective management toward a desired future condition of the river system.

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