CHAPTER 5

Watershed Relations and Changes

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The Upper Mississippi River Basin (UMRB) is a major sub-basin of the entire Mississippi River, one of the largest and most diverse ecosystems in North America. The length of the Upper Mississippi River (UMR) is approximately 800 miles (1,287 km). The drainage area of the basin is approximately 189,189 square miles (489,980 km^2) and contains about 15 percent of the drainage area of the entire Mississippi River Basin. The Basin includes portions of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, South Dakota, and Wisconsin (Figure 5-1). More than 30 million people live in the basin that drains extensive metropolitan areas, forests, and farm lands. Major cities include Minneapolis and St. Paul, Minnesota; the Quad Cities (Bettendorf and Davenport, Iowa, and Moline and Rock Island, Illinois); St. Louis, Missouri; and Peoria and Chicago, Illinois, on the Illinois Waterway.

The UMRB has 12 major tributaries (see Table 7-1) whose influence on water quality are discussed in Chapter 7. Figure 5-2 (following page) illustrates the major and minor tributaries of the UMRB. The total length of basin streams mapped by the U.S. Geological Survey at 1:100,000 scale is about 30,700 miles (49,406 km). In Illinois, the state mapped streams at 1:24,000 scale maps and identified over 25,000 miles of Mississippi River tributaries in Illinois alone.

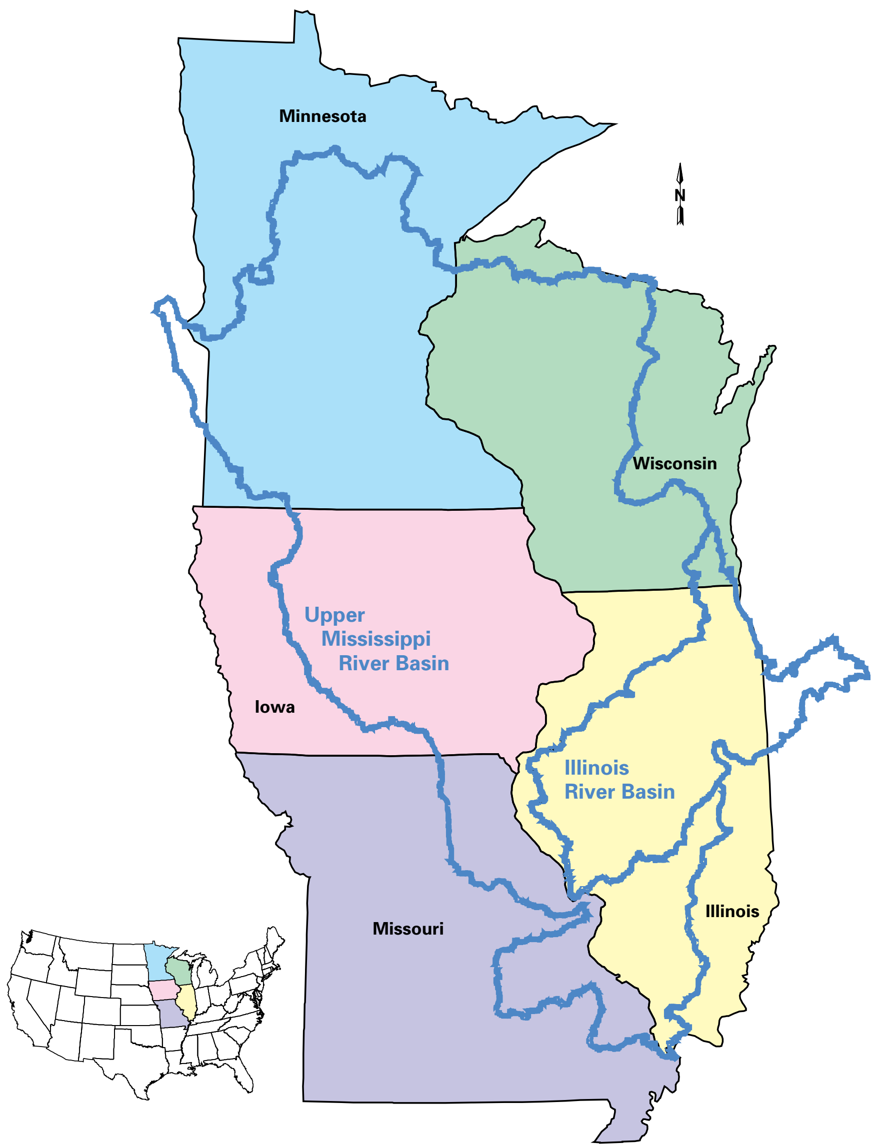
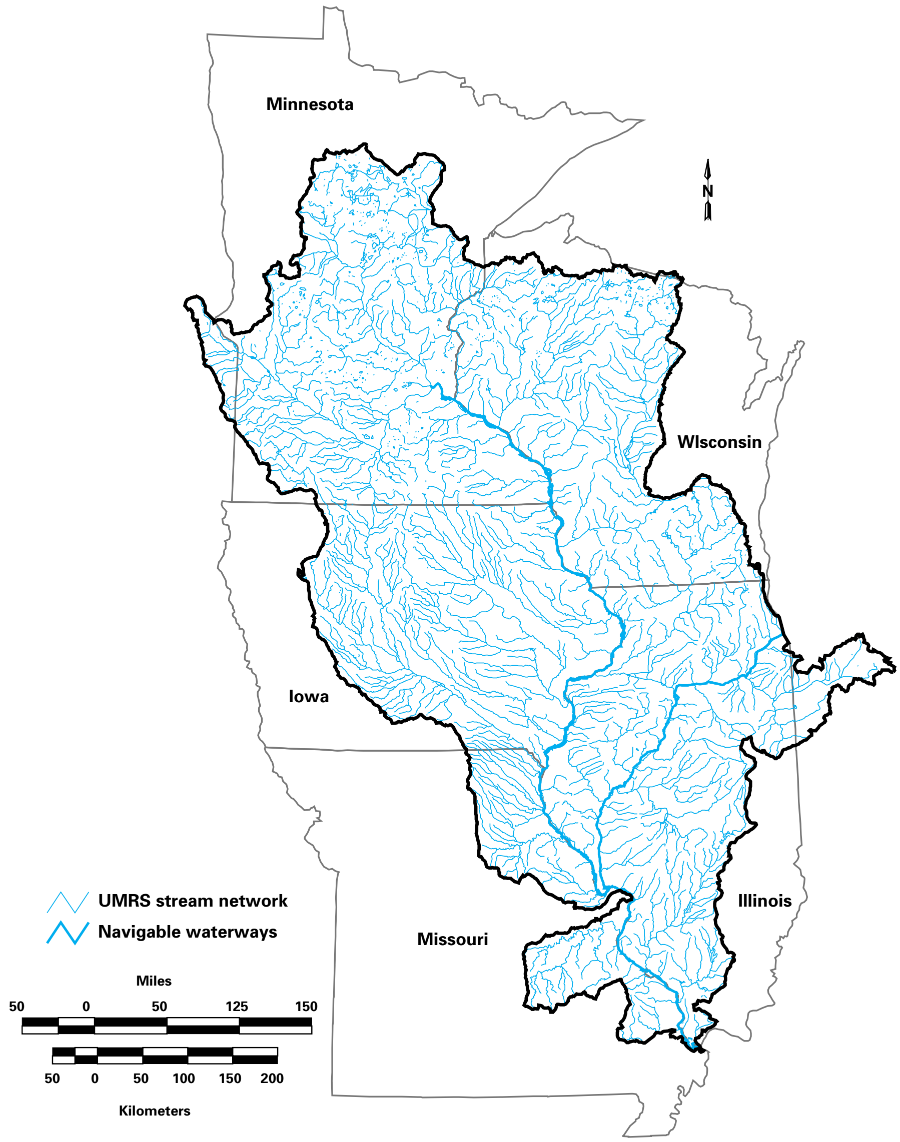


Figure 5-1. Basin outlines of the Upper Mississippi and Illinois Rivers.

Figure 5-2. The Upper Mississippi River stream network derived from 1:100,000 scale U.S. Geological Survey topographic maps that illustrates over 30,000 miles of streams, though many small streams are not detected.



Basin landscape, land use, and climate are important factors in the ecology of the Upper Mississippi River because of their effect on the distribution and rate of runoff, nutrient loading, sedimentation processes, and more recently, contaminant delivery to streams.

The climate of the basin is subhumid continental with cold, dry winters and warm, moist summers. Air masses of different origin commonly pass over the area causing frequent and rapid changes in weather. Average annual precipitation varies from about 22 inches (56 cm) in the western part to 34 inches (86 cm) in the east (Stark et al. 1996). About three-quarters of the total annual precipitation falls between April and September. The average monthly temperature ranges from about 11° F (-12° C) in January to 74° F (23° C) in July.

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Prior to European settlement, the UMRB delivered nutrients and sediments in two ways: (1) by undisturbed tributaries bordered by riparian forests and (2) by wetlands that stored water during wet periods and slowly released it during dry periods. High and low flows were buffered by the intact stream network and nutrient flows probably were more evenly distributed.

In the altered landscape of today, flows are concentrated in both space and time (Demissie and Kahn 1993; Hey and Philippi 1995). Because of modern urban and rural drainage networks, water reaches the rivers more quickly, with greater velocity, and at higher stages than in the past (Bellrose et al. 1983). The present landscape also delivers a variety of urban and agricultural contaminants that were not present in the past. Many contaminants (nitrogen and herbicides) are delivered in pulses that coincide with snow melt, spring rains, and planting and growing seasons.

Landscape Characteristics

Geology, geomorphology, and land-cover characteristics of the basin are diverse because they were formed by a combination of riverine and glacial processes during the Pleistocene epoch. The braided pattern of the Upper Mississippi River and the basin shape are the result of ice lobe movements and the presence of meltwater streams during glacial and interglacial events. The basin landscape, river valleys, and drainage networks throughout the basin were modified by such ice movements.

The UMRB consists of open and closed landscape systems. Open landscapes are characterized by well-developed stream networks that drain surface runoff while closed landscapes are areas of glacial drift marked by the presence of potholes and other depressions. Closed systems generally lack a well-defined stream network. Instead, they contain many wetlands and lakes where water may be lost by evapotranspiration and by infiltration to groundwater. Closed landscape systems can be found in the northwestern and southcentral part of the basin. The remainder of the basin consists of open landscape systems.

In recent decades, many of these landscape systems have been altered by human-made drainage systems (field tiles, ditching, and stream channelization) that increase the rate of runoff to the Upper Mississippi River. Diversion of Lake Michigan water to the Illinois River in the early 1900s increased streamflow in the UMRB. The diversion project increased the basin area by about 800 square miles (2,100 km^2). This increased area is negligible in relation to the remainder of the basin but ecologically significant for the river when the added population pressure of the Chicago Metropolitan Area—presently about 8 million people—is taken into account (see Chapter 14).

Soils and Sediment Levels

Soils in the basin generally are composed of heavy, poorly drained clays on ground moraine glacial tills and well-drained sands transported on outwash plains from their original sources during glacial episodes. Well-drained soils are found in the northwestern portion, the driftless area (southwestern Wisconsin), and the southern tip of the basin. In the floodplain, soils with higher water-retention capacity are found near the bluffs while heavier sands are found near the banks and in old channel meanders.

In the UMRB, the difference in the delivery rate and composition of sediment produced from individual tributaries is due primarily to the difference in topography, soils, and land use of each tributary watershed. Tributary watersheds in the middle and lower portion of the basin are underlaid with loess soils and farmed intensively. They produce large amounts of fine sediment compared to tributaries in the upper portion of the basin. The upper basin consists of glaciated regions with well-drained sandy soils covered by forest. The tributaries in these regions have low sediment yields, but the resulting loads consist of coarse glacial outwash that is stored in the

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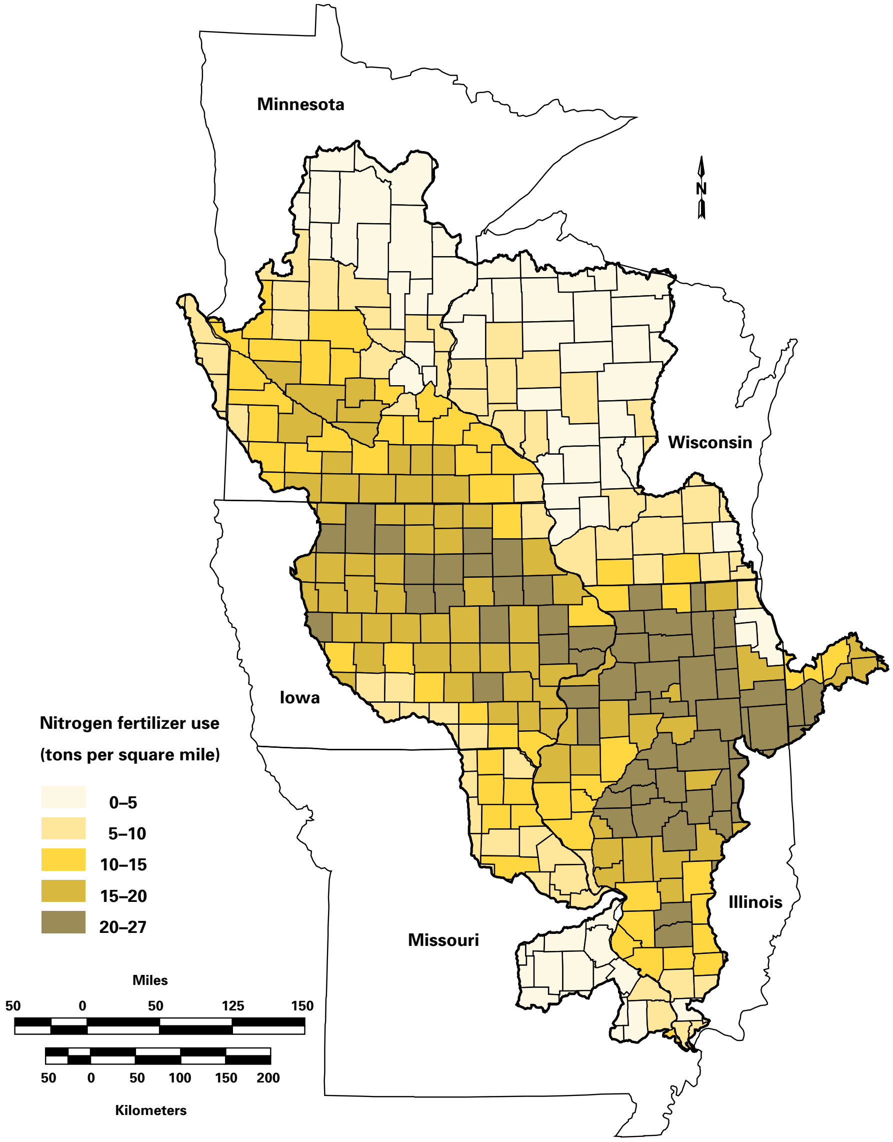
Figure 5-3. Estimated nitrogen fertilizer use (tons per square mile) in the Upper Mississippi River Basin (UMRB) between July 1, 1990, and June 30, 1991. Fertilizer use in the UMRB is among the highest application rate in the U.S. (Source: Battaglin and Goolsby 1995).



Throughout the basin, sediments stored in tributary channels present a major problem because treatments to reduce soil erosion on land may not benefit the river until stored sediments are transported by high flows.

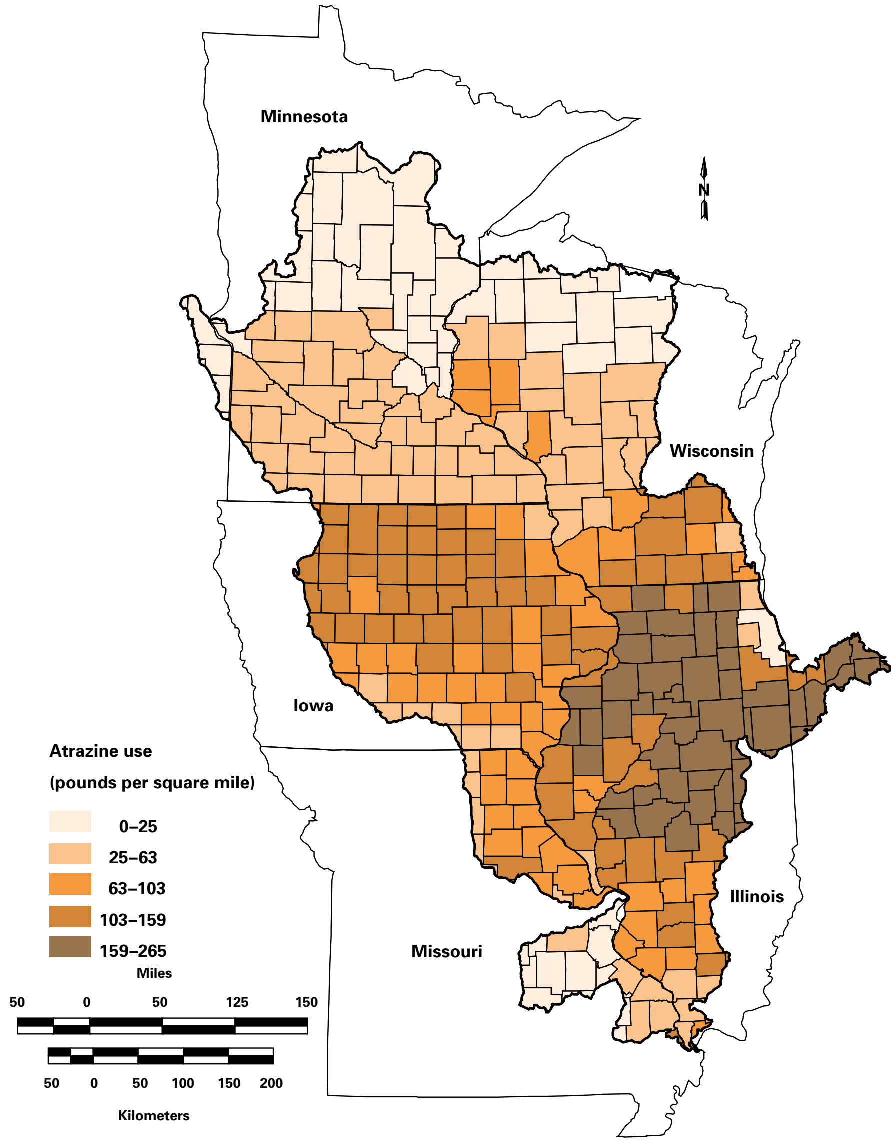
river channel (see Table 7-2). Sandy outwash is responsible for most dredging problems in the Upper Mississippi River (e.g., the mouth of the Chippewa and Wisconsin Rivers). Average soil loss in the basin is presently about 4.4 tons per acre per year (1,614 kilograms per hectare per year; U.S. Department of Agriculture, Natural Resource Inventory). In 1993, a very wet year, annual soil loss approached 20 tons per acre in Iowa (7,333 kilograms per hectare; Bhowmik 1996).

Throughout the basin, sediments stored in tributary channels present a major problem because treatments to reduce soil erosion on land may not benefit the river until stored sediments are transported by high flows. Demissie and others (1992) estimate that it could take 100–200 years to transport the sediments from some Illinois River tributaries. Knox (1977) found that although erosion rates in Wisconsin were reduced by soil conservation practices implemented in the 1930s, many streams still store significant amounts of sediment. The sediments originate both from glacial periods and mass erosion that occurred during the logging boom and early agriculture.

Land-Use Impact

In areas of the West and Midwest where cropland dominates the landscape, commercial fertilizers, manure, organic soils, and plant debris are the major sources of nitrogen that appear in most river waters (Puckett 1994). In the UMRB more than 60 percent of the land area is devoted to cropland or pasture (U.S. Department of Agriculture, Natural Resources Inventory). Between 1945 and 1985, the application rate of commercial fertilizers increased twenty-fold (Andrews and Fong 1996) and contributed to nutrient enrichment in the Upper Mississippi River System (UMRS). The UMRB accounted for 31 percent of total nitrogen delivered from the Mississippi River to the Gulf of Mexico between 1985 and 1988 (Alexander et al. 1995) despite being only 15 percent of the Mississippi River Basin land area.

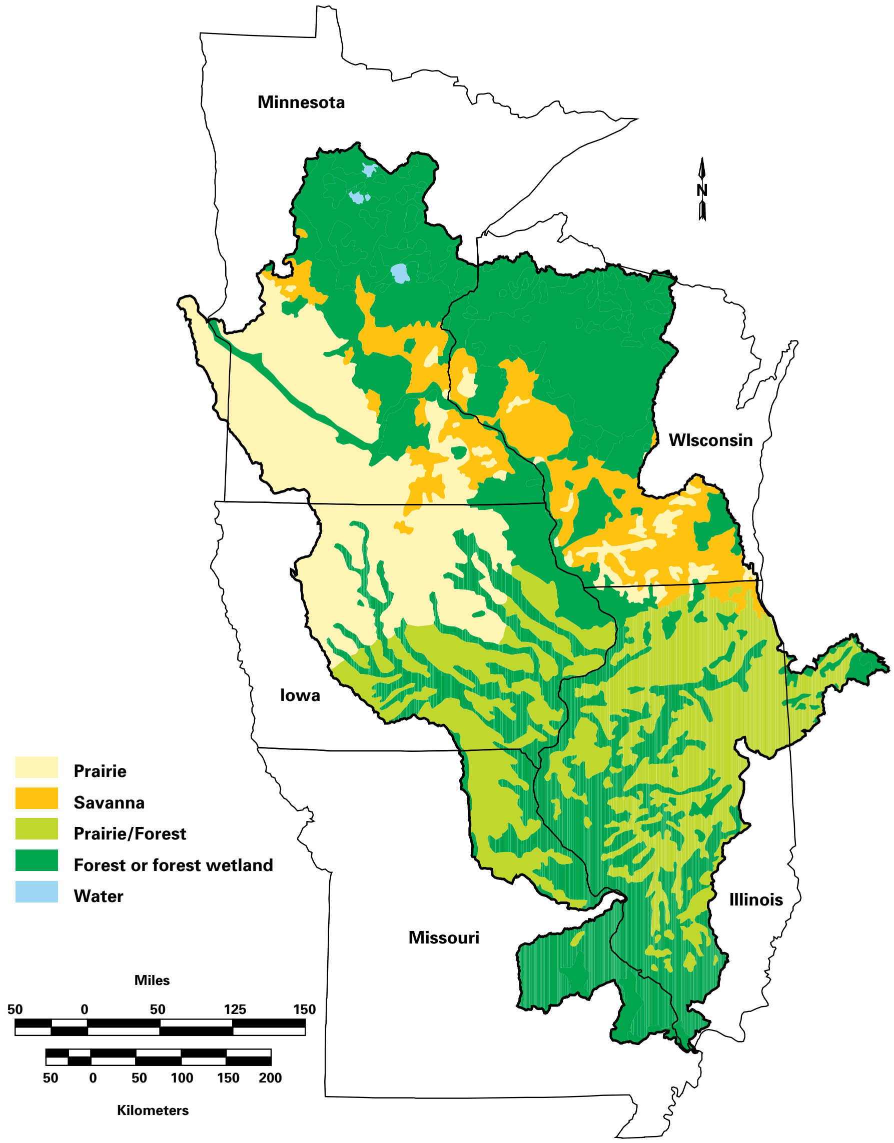
Not surprisingly, the UMRB is one of the largest consumers of commercial nitrogen in the United States (Battaglin and Goolsby 1995; Fallon 1996). Estimated annual nitrogen fertilizer use in the UMRB between July 1, 1990, and June 30, 1991 (Figure 5-3, facing page), suggests that substantial fertilizer applications in the basin contribute to high nutrient loads in the river and its tributaries. Presently nitrogen runoff to waterways is estimated to be about 7 percent of the total amount applied. Intensive farming practices are one variable in this equation. Livestock production, tile drainage systems, and leachable soils also help increase high nitrogen discharges to the Upper Mississippi River. Resulting high rates of nutrient loading downstream have contributed to development of a 7,000-square-mile zone (18,129 km^2) of reduced dissolved oxygen in the Gulf of Mexico (Alexander et. al. 1995; Sparks 1996). Those same high-nutrient loads also can increase biological production in the river, especially production of undesirable plant communities like blue-green algal mats.



In addition to fertilizers, modern agriculture relies heavily on the use of pesticides to control insects and weeds on crop fields. Figure 5-4 illustrates the estimated annual county-wide atrazine use between July 1, 1988, and June 30, 1989, in the UMRB. Atrazine is one of the most popular herbicides currently in use (Andrews and Fong 1996; Fallon 1996). Atrazine degrades rapidly in the environment and only about 3 percent of the amount applied reaches basin waterways. However, seasonal peaks in the Mississippi River sometimes exceed national water quality standards (see Chapter 7).

Figure 5-4. Estimated atrazine use (pounds per square mile) in the Upper Mississippi River Basin (UMRB) between July 1, 1990, and June 30, 1991. Pesticide use in the UMRB is among the highest application rates in the United States (Source: Battaglin and Goolsby 1995).

Figure 5-5. **The potential natural vegetation (if European settlement had not occured) of the Upper Mississippi River Basin shows the approximate distribution of vegetation classes. Though not detailed here, some data sources provide information to reproduce presettlement communities more accurately (Source: adapted from Kuchler 1964).**



Historical records indicate that forest and prairie were the major land cover types in the basin before European immigration.

Change Over Time

Figure 5-5 illustrates what the general distribution of natural vegetation might be in the UMRB today had European settlement not occurred. Figure 5-6 illustrates the current landscape. Historical records indicate that forest and prairie were the major land-cover types in the basin before European immigration. In the eighteenth and nineteenth centuries, settlers migrated to the basin to farm the rich prairie soils. They cleared away the natural vegetation and drained many wetlands to meet the demand for forest and agricultural products. Today agriculture is the dominant land use in the UMRB with over 60 percent of the total area intensively used for crop and pasture land. The major cash crops in the basin are corn and soybeans. Settlement activity essentially eliminated prairies and savannas from the landscape and the area under deciduous forest was reduced from about 33 percent to 18 percent. In total, more than 80 percent of the basin's landscape was altered over time to meet the needs of 30 million people and accommodate grain production for export.

Land conversion that resulted from

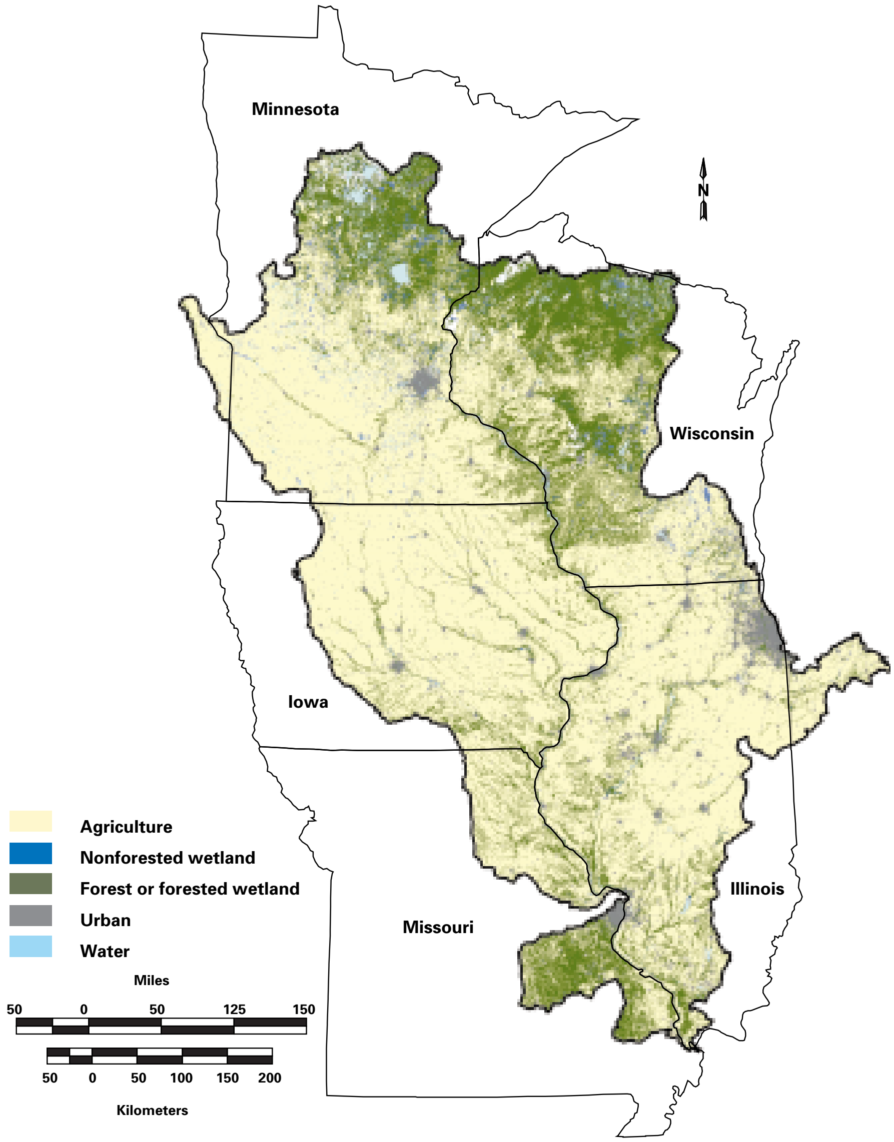


Figure 5-6. **The current land cover of the Upper Mississippi River Basin illustrates the dominance of agriculture. Large urban areas, though small by scale, concentrate people in ways that can increase anthropogenic pressure on the river (Source: USGS Environmental Management Technical Center, Onalaska, Wisconsin).**

settlement was widespread and affected most land-cover classes. Wetland loss, however, was particularly significant. In the UMRB and the Missouri River Basin, as much as 26 million acres (10.5 million ha) of wetland, or about 6 percent of the total area, has been drained since 1878 (Hey and Philippi 1995). In Illinois and Iowa, 95 percent of the wetlands have been lost. Wetland losses are critical because these natural areas help regulate hydrology, filter nutrients in water, and sustain highly diverse floral and faunal populations. Wetlands are important breeding areas for many migratory birds and mammals, and changes in the basin have affected these populations (see Chapter 13).

In addition to the loss of wildlife habitat, the UMRB has lost about 70 percent of its natural water-holding capacity over the past 150 years (Brady 1990). Storage dams, however, have made up much of the difference. Characteristics of the UMR hydrograph reflect these changes. Flood stages currently are higher and flood waters reach the river faster than in the past because wetland destruction and stream channelization have reduced the upland

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water retention capacity (Demissie and Kahn 1993). At the same time, low flows are lower in many tributaries and the unimpounded river because water that would have been released from wetlands during low-flow periods now is being shunted rapidly downstream rather than being stored in wetlands (see Chapter 6).

Recent efforts to improve soil conservation offer some hope that the problems of mass basin land conversion have been recognized and are being addressed. Between 1982 and 1992—two periods for which nationwide land use has been assessed—erosion rates from UMRB croplands decreased an average of 1.5 tons per acre per year (550 kilograms per hectare per year). Furthermore, 2.8 million acres (1.1 million ha) were taken out of agricultural production and 3.7 million acres (1.5 million ha) were enrolled in the Conservation Reserve Program (Susan Ploetz, U.S. Department of Agriculture, Natural Resources Inventory, St. Paul, Minnesota, personal communication).

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Discussion

We are able, within reason, to estimate changes in land-cover distribution within the UMRB and its impact on the UMRS. Nutrient transport is one example of the basin's influence on the river that serves to illustrate the linkage between the two parts of the river ecosystem.

Typically, nutrients entering from the basin fuels algal and plant growth in rivers. Macroinvertebrates convert plant energy to animal energy that is consumed by predators. Increased nutrient transport from the basin may have affected algae and plant production (see Chapter 8) and thus the entire river community. Sediments also can act as nutrient sinks (storage areas) and nitrogen may be so abundant that under certain environmental conditions it accumulates in its most toxic form, un-ionized ammonia. Ammonia toxicity can cause die-off of aquatic macroinvertebrates, important waterfowl, and fish food. Canvasback ducks apparently shifted migration patterns away from the Illinois River after widespread fingernail clam die-offs caused by high ammonia concentrations in the sediment (see Chapter 14). Similar effects attributed to sediment and other contaminants in the basin and the rivers are discussed later in this report.

Despite being unable to quantify change for many constituents in runoff, we do know that basin-level factors (sedimentation, nutrient enrichment, pollution) have degraded environmental quality in the river floodplain and beyond. Previous and ongoing studies have identified land-use practices that create high rates of erosion and runoff. Land management agencies could use this information to implement increasingly cost-effective measures to retain soil and contaminants in the uplands.

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