HABITAT NEEDS ASSESSMENT
FOR THE
UPPER MISSISSIPPI RIVER SYSTEM

Technical Report

October 2000

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The Upper Mississippi River System Habitat Needs Assessment was a cooperative effort of the state and Federal agencies represented by their logos below. These agencies have made great strides to protect and restore river habitats under the auspices of the Environmental Management Program. Reauthorization of the program continues the partnership and ensures that this Habitat Needs Assessment can be used to assist future Upper Mississippi River System Habitat Rehabilitation and Enhancement planning.

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Web Site:

www.umesc.usgs.gov/habitat_needs_assessment/emp_hna.html

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We also thank the members of the UMRS natural resource management community and the public that contributed to the many workshops and surveys needed to complete the HNA. It is continued cooperation and coordination among natural resource professionals and the public they serve that will protect and preserve the Upper Mississippi River System ecosystem for future generations.

Habitat Needs Assessment for the Upper Mississippi River System:

Technical Report

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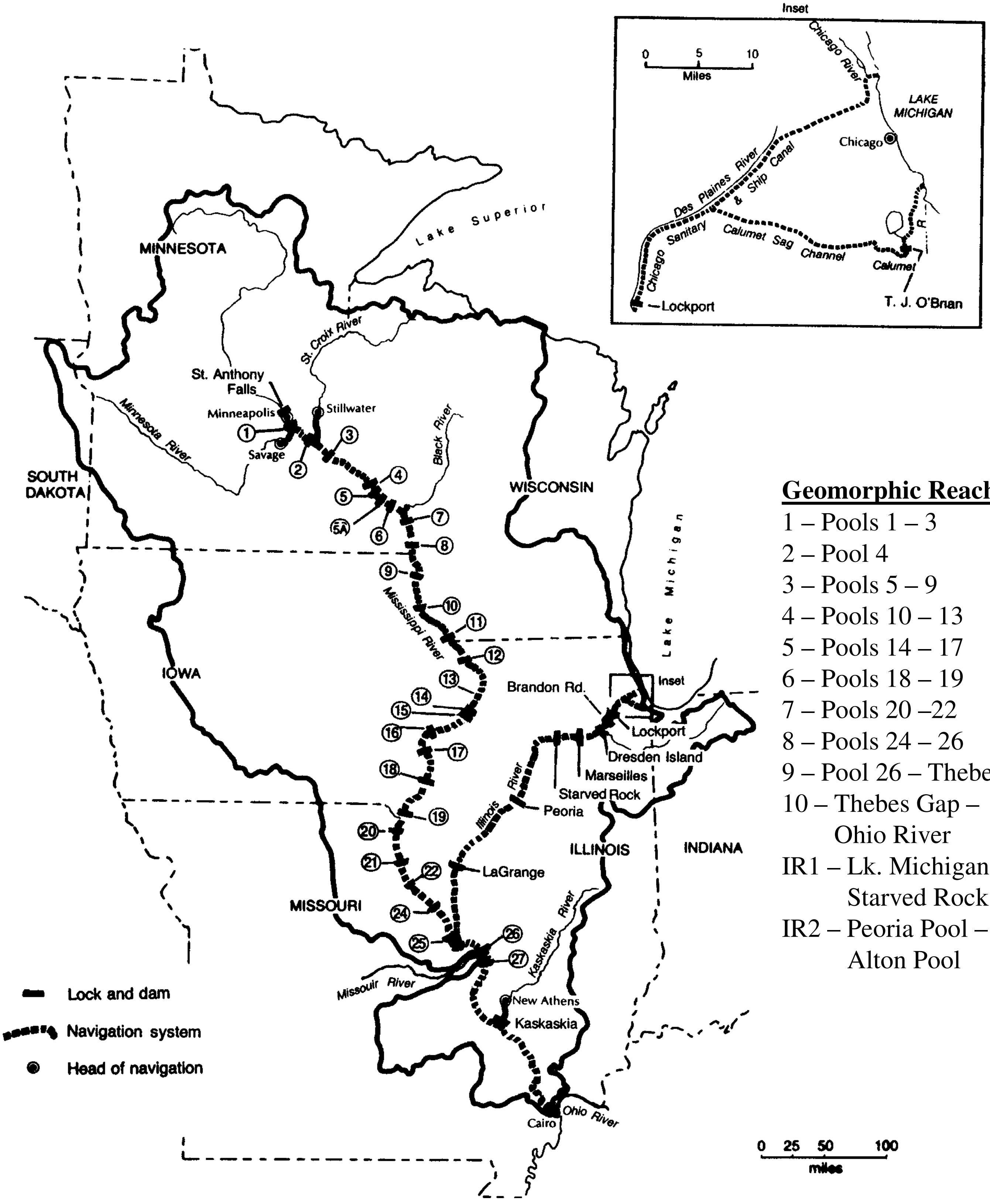
Upper Mississippi River Navigation System



Geomorphic Reaches

1 – Pools 1 – 3
2 – Pool 4
3 – Pools 5 – 9
4 – Pools 10 – 13
5 – Pools 14 – 17
6 – Pools 18 – 19
7 – Pools 20 –22
8 – Pools 24 – 26
9 – Pool 26 – Thebes Gap
10 – Thebes Gap – Ohio River
IR1 – Lk. Michigan – Starved Rock
IR2 – Peoria Pool – Alton Pool

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1 Introduction

The primary objectives of this initial Habitat Needs Assessment (HNA) are the evaluation of existing habitat conditions throughout the UMRS, forecasting future habitat conditions, and quantifying ecologically sustaining and socially desired future habitat conditions. The HNA addresses the system-wide, river reach, and pool levels of spatial scale and includes the bluff-to-bluff extent of the floodplain. The primary purpose of the HNA is to help guide selection, design, and evaluation of Habitat Rehabilitation and Enhancement Projects under a reauthorized Environmental Management Program. The HNA helps begin to identify, at the system, reach, and pool levels, the long-term habitat requirements and will serve to refine the focus of future system monitoring and research activities under the reauthorized EMP.

1.1 Background

The Upper Mississippi River Environmental Management Program (EMP) was authorized by Section 1103 of the Water Resources Development Act (WRDA) of 1986. The two main components of EMP are the Long Term Resource Monitoring Program and Habitat Rehabilitation and Enhancement Projects (HREPs).

The present EMP will end in the year 2002. The authorizing language in WRDA 1986 required an evaluation to determine the program's "effectiveness, strength and weaknesses and contained recommendations for the modification and continuance or termination" of the EMP. The Corps of Engineers, Mississippi Valley Division submitted its Report to Congress on the EMP to Corps Headquarters in December 1997. The report contained the following recommendations to Congress: continuing reauthorization of the EMP, increased annual funding for both the LTRMP and HREPs ($10M and $22.7M respectively), revised cost-sharing provisions for HREPs, and updated reports to congress at six-year intervals.

Several recommendations for modifying implementation of the EMP were also contained in the Report to Congress. One recommendation was to develop a Habitat Needs Assessment (HNA) as part of a continued UMRS-EMP. The Environmental Management Program Coordinating Committee (EMPCC), comprised of representatives from the Corps of Engineers, the U.S. Fish and Wildlife Service, the U.S. Geological Survey and the five UMRS States, supported the development of an HNA.

The Habitat Needs Assessment (HNA) was officially noted in the Report to Congress, An Evaluation of the Upper Mississippi River System Environmental Management Program, U. S. Army Corps of Engineers, Rock Island District, December 1997. The Report to Congress contained numerous references to the Habitat Needs Assessment and its intended purposes. These purposes include:

- describe historical and existing habitat conditions, and identify objectives for future habitat conditions;
- address a variety of habitat requirements including physical, chemical, and biological parameters;
- define habitat needs at system, reach, and pool scales;
- address the unique habitat needs of distinct river reaches and pools, while also assessing the importance of the UMRS to long distance migrants;
- achieve a collaborative planning process that produces technically sound and consensus based results;
- identify goals, objectives, and opportunities for habitat protection, enhancement, and restoration;

- help guide the selection and design of HREPs at multiple scales.

1.2 General Approach to Conducting a Habitat Needs Assessment for the UMRS

The HNA is a cooperative effort of natural resource agencies responsible for management of the UMRS to develop consensus based desired future habitat conditions and habitat needs. Development of this HNA for the UMRS is described in great detail in other sections of this report, but briefly, this HNA was largely based on a process of assessing existing conditions, forecasting future conditions, and identifying desired future conditions. Habitat needs were identified through comparison of desired and existing conditions. The HNA also included reviews of UMRS geomorphology and climate, historic land cover change, and ecological disturbances in the context of their influencing the natural potential, existing, and future habitat. New analytical tools developed for the HNA include a Geographic Information System (GIS) query tool to summarize land cover maps and to estimate potential species occurrence from land cover maps. A second new tool completed for the HNA was a terrestrial vegetation successional model to predict future land cover.

1.3 Application of a Habitat Needs Assessment to the EMP

The HNA will be one of many methods used to improve the scientific basis for selecting and planning future habitat projects. The present HNA provides a broad systemic analysis that can be used to assess the potential systemic contribution of proposed HREPs. A “living” HNA for the UMRS, one that is refined and updated as new information is developed, can become a major element in an adaptive management process. Refinements of the HNA will provide better estimates of potential habitat by using multiple data layers with better resolution than currently available. Habitat project implementation will continue to consider local river conditions, desired conditions, and evaluations of the potential effectiveness of habitat projects.

1.4 Need for a Habitat Needs Assessment

The Upper Mississippi River System (UMRS, including the Illinois Waterway) is a central feature in the ecology and economy of the Midwest, and in some cases, the hemisphere and the world. The river floodplain ecosystem supports more than 500 species of freshwater mussels, fish, reptiles and amphibians, birds, and mammals, and over 600 species of plants. The Mississippi Flyway provides migratory habitat for 40% of North American waterfowl and 326 bird species. Many of the rarest birds are the neotropical migrants that winter in South America and nest along the UMRS. The river currently supports 286 state-listed or candidate species and 36 federal-listed or candidate species of threatened or endangered plants and animals endemic to the Upper Mississippi River Basin (Theiling 1996). Economically, the river supports over $1 billion in annual recreation expenditures, it saves international commodity shippers over $1 billion annually, and is the source of drinking water for about 15 million people (USGS 1999).

Modifications for commercial navigation have altered the natural river floodplain ecosystem for more than 150 years. Snag clearing and large-scale fuel wood logging started in 1824. Channelization of rapids, dredging, wing dike construction, levee construction, deforestation, and agricultural and urban development all modified the river in the distant past, and many perturbations continue today (Merritt 1984, USGS 1999). The current major development features influencing the ecology of the rivers are the locks and dams that comprise the UMRS. Most of the navigation dams on the Mississippi and Illinois Waterways were constructed in the 1930s. The Open River reach of the UMRS is not maintained with navigation dams, instead channel training structures and dredging alone maintain navigable water depths given the discharge contributed by the Missouri river.

Ecological degradation of the UMRS stems from direct river floodplain development and indirect basin impacts (USGS 1999). In addition to river engineering to enhance commercial navigation, the river has been used to assimilate the waste from rapidly growing cities along its banks. In the 19th and much of the 20th Century, urban populations discharged raw sewage and industrial contaminants into the river. Many plants and animals dependent on good water quality were eradicated downstream of large urban centers and toxic contaminants still linger in the river's substrates. Most point-source pollution was controlled in the 1970s with the passage of the Clean Water Act, but non-point source pollution is still a problem. Sediment delivery from the basin is currently much higher than in the pristine river, although, sediment delivery has been reduced in recent years as a result of improved farming practices. Fertilizers and pesticides are also present in the run-off from farm fields. Many toxic compounds run-off the streets, shop floors, and garages in urban areas. Fertilizers and pesticides are also introduced from urban and suburban lawns, parks, and golf courses.

State and federal fish and wildlife managers and citizens have long recognized the ecological degradation of the river and have taken measures to protect the river. The Upper Mississippi River National Fish and Wildlife Refuge is celebrating its 75th anniversary since its establishment with the help of early conservation groups such as the Izzak Walton League. Federal involvement in UMRS habitat rehabilitation increased considerably in 1986 with the authorization of the Environmental Management Program (EMP). The program supports an ecological monitoring component, the Long Term Resource Monitoring Program (LTRMP), and a habitat restoration component, Habitat Rehabilitation and Enhancement Projects (HREP).

Twenty-four habitat projects were constructed as of early 1998 (at the time of the EMP Report to Congress). There are presently 28 projects completed, and 12 are under construction. About 13 projects are in various stages of planning, and design. Chapter 4 of the EMP Report to Congress (U.S. Army Corps of Engineers 1997) provides a detailed description of the HREP program. The EMP Report to Congress is available via the Internet through the Rock Island District home page at: http://www.mvr.usace.army.mil/pdw/emp/rtc_home.htm. Fact sheets and detailed information about individual habitat projects are available via the Internet at: http://www.umesc.er.usgs.gov/.

The 24 projects implemented as of early 1998 affect approximately 28,000 acres of aquatic and floodplain habitat. The 26 projects presently under construction and in general design will increase the total affected area to about 97,000 acres, approximately 11%of the total UMRS floodplain and aquatic habitat area, not counting agricultural and urban areas. The HREP projects incorporate a variety of habitat protection and restoration features.

The Habitat Needs Assessment for the Upper Mississippi River System was conducted to: describe historical and existing habitat conditions, identify objectives for future habitat conditions, define habitat needs at system-wide, reach, and pool scales, address a variety of habitat requirements including physical, chemical, and biological parameters, address the unique habitat needs of distinct river reaches, pools, and the system, and be a collaborative, technically sound, and consensus based effort. The HNA will be used as one of many tools to identify goals, objectives, and opportunities for habitat protection and restoration projects constructed under the authority of the Upper Mississippi River Environmental Management Program. This report describes UMRS geomorphology, climate, and geomorphic area and land cover types. An analysis of historic changes is presented to help identify the range of potential habitats once present in the UMRS. A geographic information system (GIS) based tool developed to provide unbiased analyses of potential species occurrence throughout the Upper Mississippi and Illinois

Waterways and their floodplains is introduced. A terrestrial vegetation successional model created to help estimate future terrestrial vegetation conditions is described. The HNA also included a future habitat condition prediction developed through a variety of quantitative and qualitative assessments. The last sections of the report summarize resource manager's desired future condition, habitat needs, and information needs.

2 UMRS Geomorphology and Climate

Floodplain geomorphology provides the template upon which plant communities and habitats develop. The geomorphology of the UMRS is of glacial origin, with most modern characteristics resulting from the Wisconsin Ice Age that ended about 11,500 years ago. The river initially cut deeply into its valley along a relatively straight southern course, but the valley has been filling ever since. Heavy glacial gravels and rocks have been overlaid with finer glacial till, sand, and in backwaters and floodplains, fine clays and silts. The geomorphology and topographic features of the river are diverse along its length, and also laterally from the channel to the bluffs.

2.1 Longitudinal Geomorphologic Variation

The longitudinal profile of the upper Mississippi River can be divided into at least ten major Geomorphic Reaches (Figure1 and 2; WEST 2000). The limits of the reaches are defined as:

Geomorphic Reach 1: Pools 1-3
Geomorphic Reach 2: Pool 4 (Lake Pepin)
Geomorphic Reach 3: Pools 5 – 9
Geomorphic Reach 4: Pools 10 – 13
Geomorphic Reach 5: Pools 14 - 17
Geomorphic Reach 6: Pools 18 - 19
Geomorphic Reach 7: Pools 20 – 22
Geomorphic Reach 8: Pools 24 – 26
Geomorphic Reach 9: Below Pool 26 to Thebes Gap
Geomorphic Reach 10: Thebes Gap to Ohio River confluence

Geomorphic reach 1, including pools 1 – 3 and upper pool 4, represents the area upstream from Lake Pepin. Lake Pepin once extended up through this reach, but post-glacial sediment accumulation has filled about 50 miles of the valley. Bed load from the headwaters and Minnesota River accumulated at a rate of about 25 ft/yr forming a narrow channel bordered by low floodplain. The riverbed is composed of graded layers of heavy glacial tills overlain by smaller gravel and sand. Many terrace remnants remain. The river plan form prior to major channel improvements was a classic braided channel through the expanding delta. The current rate of delta expansion is probably lower than in the recent past, but analysis of photographs between 1949 and 1989 show the active edge of the delta is expanding about 184 ft/yr. (WEST 2000). Impoundment in this reach has created the familiar form of a narrow river and relatively wide floodplain in the upper pool reaches, island braided middle pool reaches, and open water lower pool impounded and backwater areas. The reach is highly developed through Minneapolis-St. Paul, but less so in Pool 3. Urban development and pollution greatly impacted the reach, but recent improvements have been documented. The Minnesota Valley and Upper Mississippi Fish and Wildlife Refuges protect about 30%of the reach.

Geomorphic reach 2 includes Lake Pepin, a post-glacial lake impounded by the Chippewa River alluvial fan. The lake was formed in the early post-glacial period when the Mississippi River was deeply incised and coarse sediment from the Chippewa River filled the valley. The lake is slowly filling from the upstream end. Impoundment maintains high water levels downstream from Lake Pepin through the Chippewa delta, but has little impact on the form of the lake and the upper pool. Backwaters are larger and more abundant in the lower pool since impoundment, but Lake Pepin is very similar to its pre-development form. Development in the floodplain is limited, but the lake is popular for recreation. The Upper Mississippi Fish and Wildlife Refuges protect about 30% of the reach and Lake Pepin accounts for most of the rest of the reach.

Geomorphic reach 3 extends from the Chippewa River delta through Pool 9. It is a relatively steep reach dominated by sandy bed load from the Chippewa and, to a lesser extent, the Black rivers. The reach ends where the riverbed levels over the sediment hump created by the Wisconsin River. Prior to impoundment, the reach exhibited a classic island-braided form. Many wing dams and substantial dredging helped maintain navigation prior to lock and dam construction. Impoundment inundated the lower portions of the pools, submerging channels, islands, and floodplains. High elevation floodplain areas remained as islands, but post-dam wind-wave erosion in lower pools 5 through 9 has eliminated many of them. The middle portions of these pools display broad island-braided floodplains, and the upper reaches narrow to a more restricted island-braided channel. Islands in some upper pool reaches are eroding and dissecting. Tributary deltas may be expanding because of upstream erosion control and the mobilization of sediment stored in tributary streams (Knox and Faulkner 1994). La Crosse and Onalaska, Wisconsin and Winona, Minnesota are significant cities. The Upper Mississippi Fish and Wildlife Refuge protects most of the floodplain area in the reach.

Geomorphic reach 4 is a constricted valley reach extending from pool 10 through 13. Resistant limestone and dolomite formations constrict the river from the mouth of the Wisconsin River to upper Pool 13 where the valley fans out. Islands were not numerous in pools 10, 11, and 12 either prior to or following dam construction. Many wing dams and substantial dredging helped maintain navigation prior to lock and dam construction. Impoundment inundated much of the floodplain in the lower portions of the pools, creating the familiar upper pool to lower pool impoundment effects. Impounded portions of these pools are accumulating sediments from major tributaries, thus reducing bottom variability and depth diversity. Many inundated channels and floodplain depressions have filled to uniform depths. Dubuque, Iowa and several small cities occur in reach 4, but the Upper Mississippi Fish and Wildlife Refuge protects most of the floodplain terrestrial area.

Geomorphic reach 5 includes the highly constricted Fulton-Rock Island gorge in pools 14 and 15, and the wide valley expansion in pools 16 and 17. The portion of the reach through the gorge is a steep constrained channel with few islands and little floodplain terrestrial area. The river flattens in Pool 16 and large islands were formed when sediment was deposited in a main stem delta downstream of the steep gorge. Island formation in Pool 17 is similar to Pool 16, but the valley widens significantly in the ancient Iowa River valley. The plan form changes resulting from impoundment are not as apparent in geomorphic reach 5 compared to upstream reaches. Agriculture is an important component of the floodplain landscape; levees protect 12% and 74% of the pools 16 and 17 floodplain, respectively. The quad cities are a large urban concentration in reach 5, and less than 30% of the floodplain.

Geomorphic reach 6 consists of pools 18 and 19. Pool 18 and upper 19 are similar to reach 5, with many large islands and secondary channels. Impoundment effects are not pronounced in lower Pool 18. Lower Pool 19 was a steep rapids through a geologically young rock gorge from Fort Madison to Keokuk, Iowa prior to impoundment, but the hydroelectric dam constructed in 1913 inundated the gorge. Lock and Dam 19 creates a 38-foot head that impounds about one-half of the 46-mile long reach. Much of the impounded area has filled with sediment, aquatic plants grow in areas that were 30 feet deep when the dam was constructed. The dam is the major impediment to fish migration throughout the basin. The broad floodplain upstream from the gorge has largely been converted to agriculture. A little more than 30% of the reach is leveed. Several moderate sized cities occur in the reach, and less than 15% of the floodplain is in public ownership.

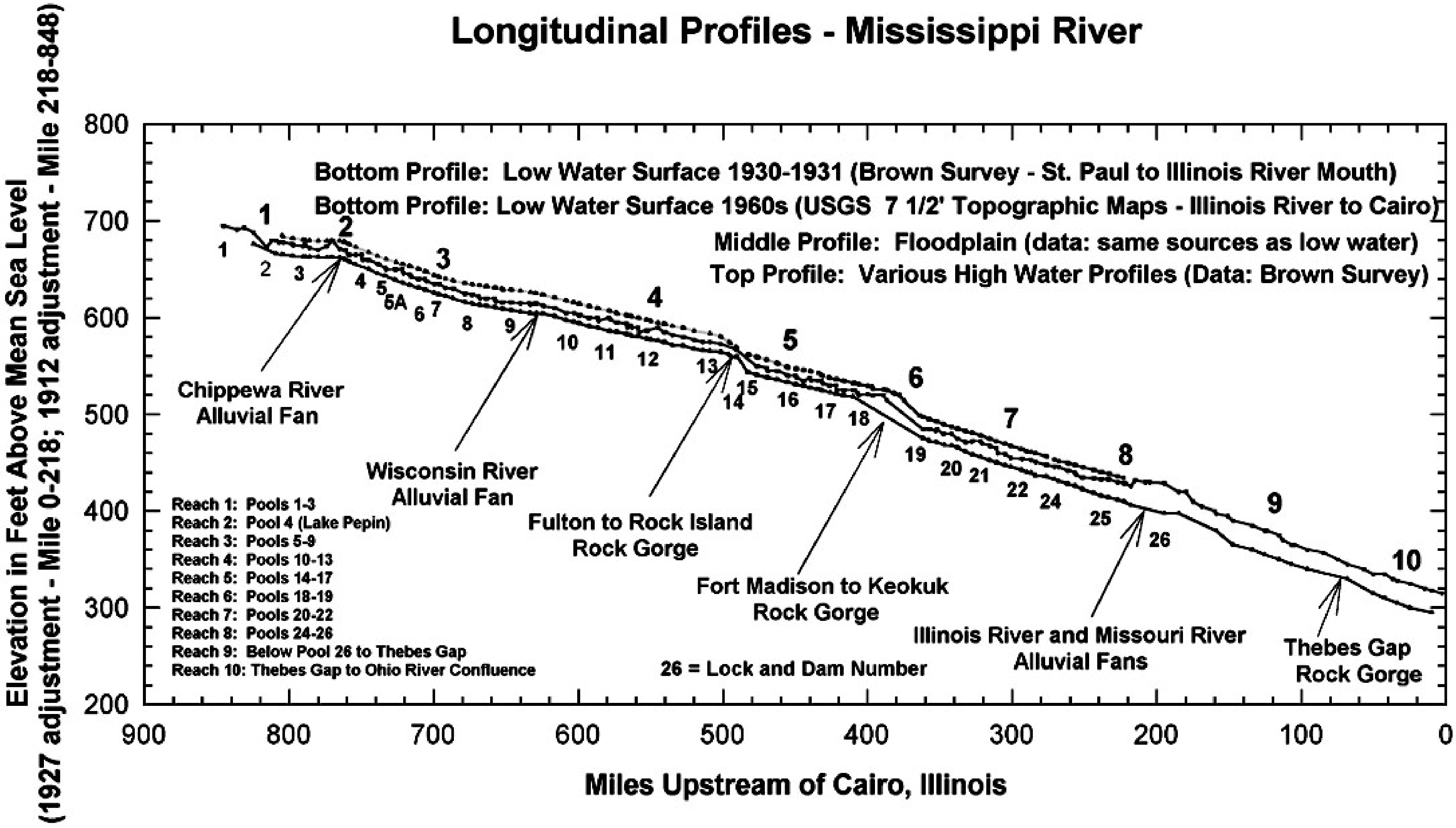

Figure 1. The upper Mississippi River is divided into 10 geomorphically based reaches that reflect the river's adjustment to glacial events and other geological controls in the region.

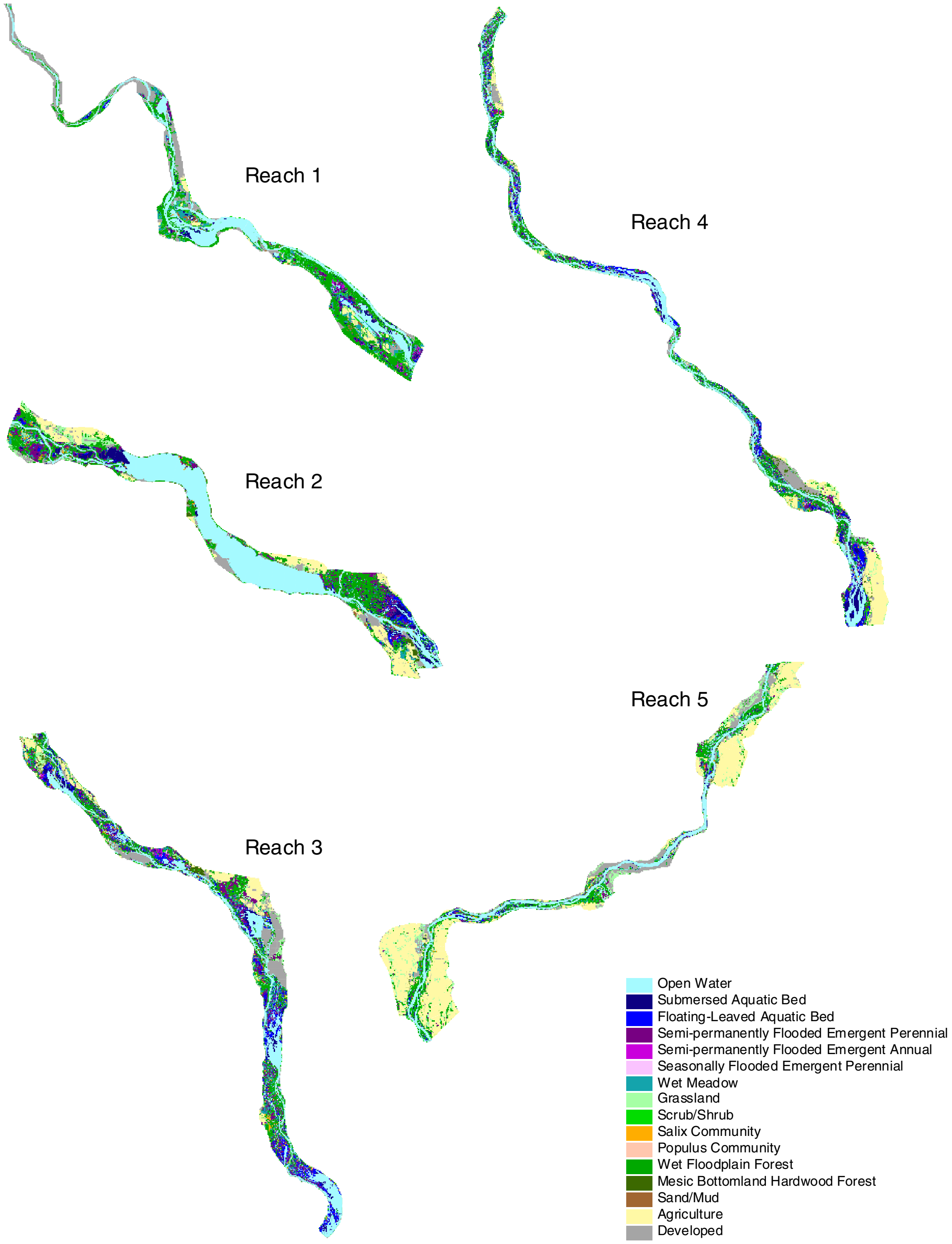

Figure 2a. Land cover in Upper Mississippi River System Geomorphic reaches.

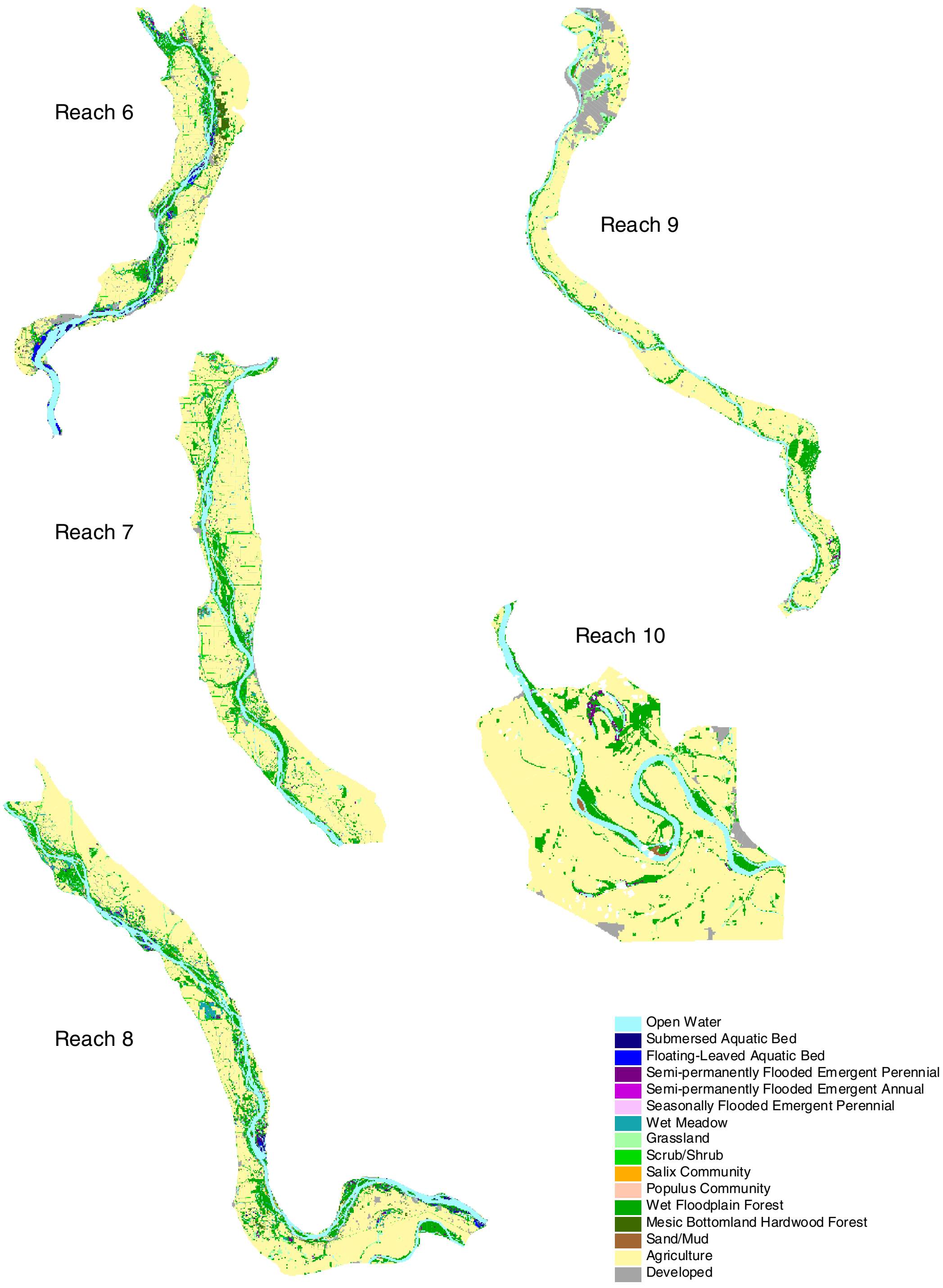

Figure 2b. Land cover in Upper Mississippi River System Geomorphic reaches.

Geomorphic reach 7, including pools 20, 21, and 22, is a surprisingly steep reach because of sediment from the De Moines River entering the Mississippi below Lock and Dam 19. The reach shows evidence of old meander belts through the post-glacial alluvial soils. The modern river resembles the pre-development plan form, but there are fewer shoals and sand bars exposed at low flows. Large island complexes and long interconnected secondary channels characterize much of the reach, but relatively simple channel reaches are evident too. Lower pool impoundment effects are not pronounced in plan form. Agriculture is the dominant floodplain landscape element. The floodplain in the reach is about 70% leveed. There is little urban development, but less than 10,000 acres of public land.

Geomorphic reach 8 includes pools 24, 25, and 26. The slope of the riverbed decreases through the reach to the hump of the Illinois and Missouri river alluvial fans. The Missouri River contributes most to this feature because of the lower flow and higher suspended sediment component of the Illinois River. The modern river resembles the pre-development plan form, but there are fewer shoals and sand bars exposed at low flows. Upper pool reaches of the pools have numerous large islands and mostly simple single thread secondary channels. Lower pool reaches generally have smaller and fewer islands. Impoundment effects are noticeable immediately upstream from locks and dams 25 and 26. Agriculture is the dominant floodplain landscape element. About 70% of pools 24 and 25 is leveed. Only about 23% of the Pool 26 floodplain is leveed on the available GIS coverages, but levees visible on topographic maps do not appear on the GIS maps. The coverage needs to be verified and updated. There is little urban development in the floodplain, but less than 15% of the floodplain is public land.

Geomorphic reach 9 includes the Mississippi south of Pool 26 to Thebes Gap at river mile 48. The floodplain is about seven miles wide and the river has meandered through it many times. The head of the reach is very steep because of the influence of the Missouri River alluvial fan. Prior to improvements for navigation the reach had many islands and ephemeral sand bars, but channelization and dredging has greatly simplified the river channel. Side channels provide most of the off-channel aquatic area and many are being lost to sedimentation and river training efforts. Closing structures and wing dams divert moderate and low flow currents away from, and often isolate, side channels, so only sediment laden flood flows influence the secondary channels. Scour holes below closing structures may be 50 – 100 feet deep and experience episodic periods of poor water quality when isolated from the river. Eight secondary channels were lost between 1880 and 1960; another 2 were lost between 1960 and 1989. Once huge quantities of sediment (orders of magnitude greater than from the Mississippi) delivered from the Missouri have been greatly diminished with the construction of the Gavins Point dam on the Missouri River in 1955. Riverbed degradation (i.e., scour) has significantly deepened the highly regulated channel. The floodplain is over 70% leveed, with agriculture dominating the landscape. The floodplain east of St. Louis Missouri is highly developed, but the rest of the reach is relatively free of urban development. There are only about 20,000 acres of public land.

The river channel in **Geomorphic reach 10** (Thebes Gap to the Ohio River) is very similar to reach 9, but the floodplain widens greatly below the rock gorge at the upstream end. The floodplain widens to about 10 miles and the river has two large bends. The bed slope continues to be steep because of scour through the gorge. The same impacts from navigation displayed in reach 9 are operating in reach 10.

The Illinois Waterway consists of two reaches separated at the Starved Rock Lock and Dam on GIS coverages, but geomorphologically at the Great Bend at Hennepin, Illinois where the glacial Mississippi River once flowed. The **upstream portion of the Illinois River** and its major tributaries making up the Illinois Waterway are geologically young tributaries and man-made canals that link the river to Lake Michigan. The reach is steep requiring the need for high lift dams with short pools that fill most of the former river valley. Much of the upper Illinois Waterway is highly urbanized. There are less than 500 acres of public land.

The **lower Illinois Waterway** reach, including Peoria, La Grange, and Alton pools, is a remnant of the ancient Mississippi River that once flowed across northwestern Illinois. Glacial flows down the ancient valley created a floodplain that is exceptionally large for the current river discharge. The floodplain has been filling with fine loess sediment for millennia and the current channel slope is very low. The three navigation pools in this reach are about twice as long as the longest Mississippi River pools. The modern river channel is relatively simple, with few islands and side channels, but many backwaters of differing degrees of connectivity fringe the channel. Prior to navigation and agricultural development, Illinois River backwaters were very numerous and diverse in shape, size, and depth. Currently, water level regulation maintains fewer, larger lakes with uniform shallow depths and silty substrates. Agriculture dominates the floodplain, which is about 50% leveed in the La Grange Pool and about 70% leveed in the Alton Pool. Urban development is significant in the Peoria, Illinois area, but the rest of the reach has only a few large towns. Less than 15% of the reach is in public ownership.

Additional river reaches covered by the EMP including portions of the Minnesota, St. Croix, Black, and Kaskaskia rivers were not investigated in detail in this report. These river reaches are important refuge or recreation areas that resource managers are concerned about, but the available spatial data used in the analysis is not available for all the areas.

2.2 Lateral Geomorphic Variation

Lateral variation in floodplain morphology can be very diverse in any given river reach, but some generalities can be described. Wilcox (1993) defined UMRS aquatic areas based on geomorphic and navigational features of the river system (Table 1; Figure 3). Floodplain area classes are not well defined because of a lack of detailed topographic data, but islands, contiguous floodplain area, and isolated floodplain areas have been delineated (Figure 3). Aquatic area classes are useful to characterize physical processes related to water and sediment movement as well as associated biological communities. The 15 class HNA geomorphic areas classification is explained in detail below in Section 5.

2.3 Substrates and Soils

Generally, the UMRS has sand substrate channels and floodplain soils underlain by graded glacial gravel over deeply buried bedrock. The floodplain elevation grades upward to the bluffs and flood frequency decreases along the gradient. Hills, ridges, and swales (floodplain depressions) may be present where former channels once flowed and formed natural levees. Terraces, former floodplain remnants, flanking the river valleys provide high elevation plateaus that may rarely flood. Floodplain soils are generally classified as “unconsolidated alluvium,” but the term does little to describe the diversity of soils in the UMRS. Former channels and levees may provide well-drained soils suitable to flood intolerant plants. Former lakes and marshes may provide impermeable clay composites that retain moisture. Most of the floodplain is sand covered with fine alluvial silt and clay creating a thick loamy soil. Islands are formed where channels cut through floodplains, where obstructions in the channel block flow, and as sand bars that become colonized and stabilized by vegetation. Islands were more abundant in the pre-impoundment, pre-channelization era.

Table 1. Upper Mississippi River System aquatic habitat classification system (Wilcox 1993).

- Channel
  - Main channel
    - Navigation channel
    - Sandbar
    - Channel border
      - Unstructured
      - Revetted bank
      - Wing dam
      - Closing dam
    - Tailwater
  - Secondary channel
    - Navigation channel
    - Sandbar
    - Channel border
      - Unstructured
      - Revetted bank
      - Wing dam
      - Closing dam
    - Tailwater
  - Tertiary channel
  - Tributary channel
  - Excavated channel
- Backwater
  - Contiguous
    - Floodplain lakes
      - Abandoned channel lakes
      - Tributary delta lakes
      - Lateral Levee Lakes
      - Scour channel Lakes
      - Floodplain depression lakes
      - Borrow pit lakes
      - Other artificial lakes
    - Floodplain shallow aquatic
    - Impounded
  - Isolated
    - Floodplain lakes
      - Abandoned channel lakes
      - Tributary delta lakes
      - Lateral levee lakes
      - Scour channel lakes
      - Floodplain depression lakes
      - Borrow pit lakes
      - Other artificial lakes
    - Floodplain shallow aquatic

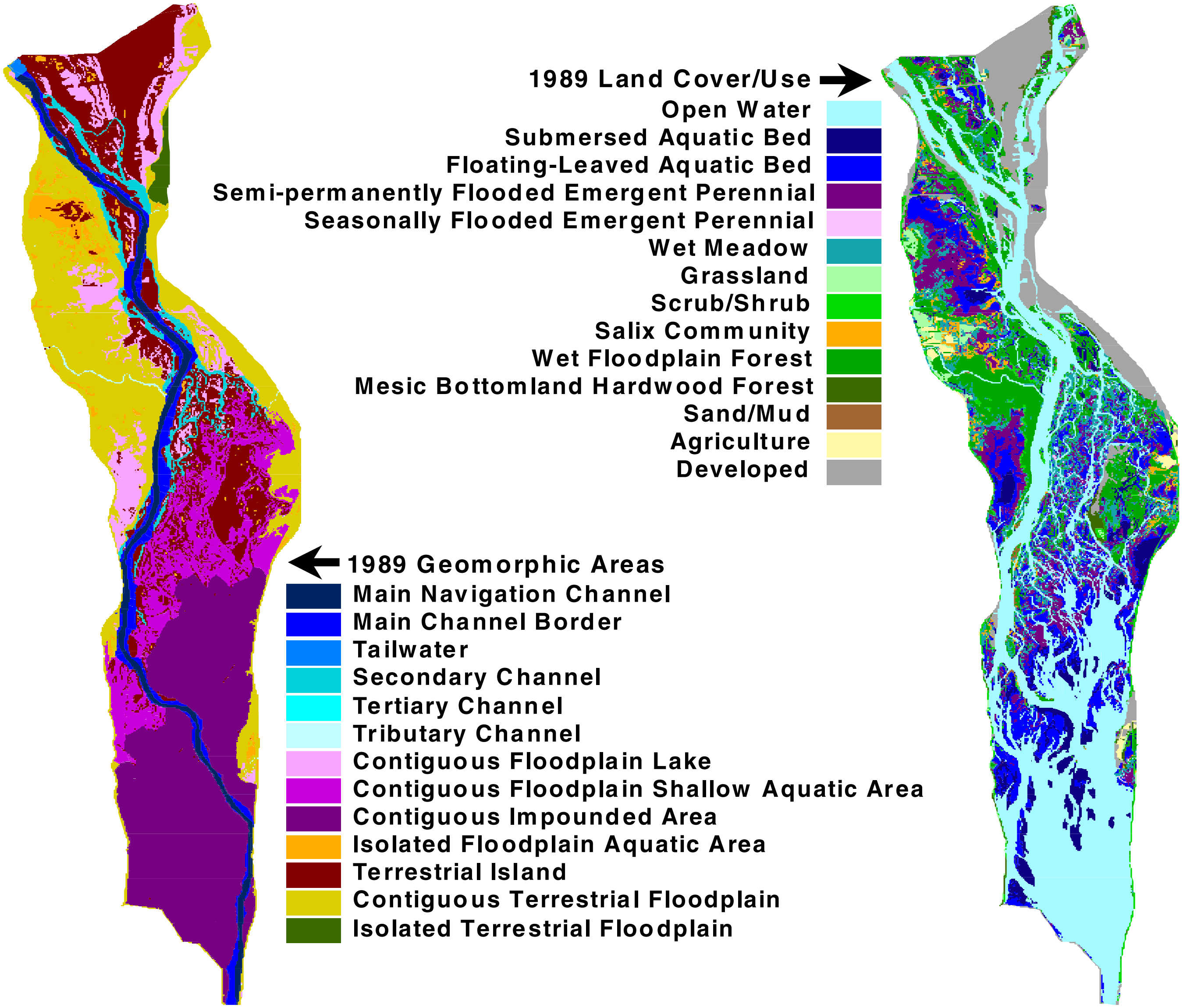

Figure 3. Examples of HNA land cover and geomorphic classes displayed on Pool 8 of the Upper Mississippi River System.

2.4 Climate

The climate of the UMRS is mid-continental, north temperate, but the great longitudinal extent of the river allows for significant variability. The river crosses six USDA plant hardiness zones (4a to 6b) and many plants species are unevenly distributed along the river. The river, however, also provides a warm microclimate within its valley that allows northward expansion of southern plant species. Average annual precipitation is slightly higher in southern river reaches. Minneapolis, Minnesota gets an average 28 inches of precipitation St. Louis, Missouri gets an average 38 inches (Table 2). There is an 11-degree difference in average air temperature between Minneapolis and St. Louis. Average annual water temperature measured at LTRMP field stations is similar in northern reaches, but increases about 3 degrees Fahrenheit in the southern river reaches. Average ice thickness declines in a southward direction along the river, but annual extreme events may be masked by the averages. Average snow cover is greatest in Minneapolis and declines in a southward direction where there is less than one-half as much snow in St. Louis. Major floods and droughts occur with about decadal frequency, with smaller variation evident in between (Perry 1994). Rainfall and discharge has been increasing over the past several decades (Knox 1993). Windstorms and tornadoes can cause widespread to localized impacts to forests.

Table 2. NOAA Climatic indicators for UMRS cities and river reaches.

City/LTRMP Field Station	Average Annual Air Temperature (Degrees F)	Average Annual Water Temperature (Degrees F)[a]	Average Annual Ice Thickness (Inches)*	Average Annual Snowfall (Inches)	Average Annual Precipitation (Inches)
Minneapolis –St. Paul, MN/Pool 4	44.9	22.9	13.2	49.7	28.32
La Crosse, WI/ Pool 8	46.3	23.0	12.0	43.1	30.55
Dubuque, IA/Pool 13	46.4	23.2	9.7	43.2	38.36
Moline, IL	49.6	--	--	30.1	39.08
St. Louis, MO/Pool 26	56.1	26.6	0.5	19.5	37.51

a = Data collected at LTRMP field stations. Provided by David Soballe, USGS UMESC, La Crosse, Wisconsin.

2.5 Summary

The influence of large scale geomorphologic and climate factors are quite variable among UMRS river reaches. The Mississippi River grades through island braided reaches, reaches with larger frequent, irregular islands, to the Open River reach with a meandering channel and occasional islands. The Illinois Waterway starts in constructed canals that connect to larger tributaries before joining the Illinois River. The Illinois River is geologically young above the Great Bend at Hennepin, Illinois, but it joins a broad, ancient glacial valley below the bend. Climate difference along the length of the river permit some sub-tropical tree species in the southern tip of the river, and north-temperate forests in the northern reaches. The response to and mechanisms supporting commercial navigation differ along the length of the river, but most responses appear to result in decreased habitat diversity and quality. Levees are most prominent on the Mississippi river below Rock Island and on the Illinois River below Peoria.

3 Historic Land Cover Change

Analysis of habitat change, plant community succession, and decisions regarding desired future conditions must rely on an understanding of the natural potential ecological conditions and the mechanisms responsible for change since European colonization. Modern plant communities do not reflect their former or potential distribution and composition because the UMRS has been repeatedly disturbed by human activity. The pre-European UMRS landscape has been reconstructed for parts of the UMRS using information gathered during early 1800s Government Land Survey office records (Nelson et al. 1994, Yin and Nelson 1995, Nelson et al. 1996, Nelson and Sparks 1998, John C. Nelson, unpublished data). The information is presented here along with contemporary UMRS landscape statistics to illustrate plant community changes over time and to briefly illustrate the activities that are responsible for historic change and future conditions.

U.S. Government Land Office (GLO) maps and survey notes are the primary source for reconstructing historic landscapes. The records contain, among other things, plat maps showing the location and extent of former prairies, timberlands, marshes, swamps, and rivers. The historic maps were digitized into a geographic information system (GIS) format to make it easier to identify and quantify natural habitats present prior to widespread European colonization and development. Survey notes allow the differentiation of the composition and structure of former timberlands on the islands, floodplains, and adjacent uplands (see Nelson et al. 1996 for methods). Interpretation of GLO surveys and GIS database development are ongoing, but 10 river reaches in 8 of the 12 UMRS geomorphic reaches have been completed. Land cover unit area estimates must be carefully interpreted because mapping methods in the early 19th Century lacked the precision of modern methods. The approach is very useful, however, for illustrating historic landscapes at a coarse scale. Detailed studies in Pools 25 and 26 (Nelson et al. 1996) and river miles 0 to 80 on the Mississippi (Yin and Nelson 1995, Yin et al. 1997), and at the Illinois River confluence (Nelson et al. 1994, Nelson and Sparks 1998) permit summaries of forest compositional change in these locations.

3.1 Landscape Perspective

Land cover community change differs among geomorphic reaches, though pools 13, 17, 22, 24, 25, and 26 show similar magnitude and type of change (Table 3; Figure 4). Pool 4 is unusual among other Upper Mississippi River pools in that Lake Pepin, a natural main stem lake, dominates Pool 4 land cover (Table 3; Figure 4). Water is the dominant cover type in the landscape, and the proportion of water remains very similar after impoundment. Marsh habitats were small components of the landscape in both time periods, but their percent composition increased fourfold in the later time period. The amount of prairie remained similar, but the amount of timber was halved. Timber in the Chippewa River delta was likely inundated and killed when dams were constructed. The remaining forest loss is likely attributable to development and agriculture.

The increase in the open water class between pre-settlement and 1989 in Pool 8 (150%) far exceeds that of any other reach presented (Table 3; Figure 4). Impoundment by navigation dams flooded most of the lower one-half of the pool and killed most of the terrestrial plants, as occurred to some degree with most of the pools in geomorphic reach 3. The proportion of timber in Pool 8 dropped 38%. Some was likely lost to development (11%), but the remainder was likely flooded and killed or swept away as islands eroded. Marsh area was reduced by about one-half, but prairie area increased slightly. Agriculture is a small component of the landscape, but the proportion of developed area is highest among all the reaches.

Table 3. Percent composition of land cover types in selected Upper Mississippi and Illinois river reaches in pre-settlement (ca. early 1800s) and contemporary (1989) periods.

Geomorphic Reach	Pool	Pre-Settlement					Contemporary						
		Open Water	Marsh	Prairie	Timber	Swamp	Open Water	Marsh	Prairie	Timber	Swamp	Developed	Agriculture
1	--	--	--	--	--	--	--	--	--	--	--	--	--
2	4	49.8	1.5	7.9	40.2	0.2	53.0	6.0	5.0	23.0	0.0	5.0	8.0
3	8	21.0	14.8	8.0	55.5	0.6	52.8	8.1	9.8	17.7	0.0	11.1	0.5
4	13	19.7	4.5	35.1	39.1	1.6	19.6	18.3	5.3	18.6	0.0	6.6	31.6
5	17	14.6	0.7	57.0	25.8	1.9	25.4	1.8	6.6	28.4	0.0	5.4	32.4
6	--	--	--	--	--	--	--	--	--	--	--	--	--
7	22	13.3	0.0	35.0	51.7	0.0	9.9	0.1	3.6	12.2	0.0	1.8	72.4
8	24	13.2	0.1	46.4	40.3	0.0	10.3	0.7	3.3	13.4	0.0	0.9	71.4
	25,26	18.3	0.4	46.3	35.0	0.0	17.9	1.3	5.6	18.6	0.0	3.1	53.4
9	--	--	--	--	--	--	--	--	--	--	--	--	--
10	OR	6.9	0.0	0.0	86.7	6.4	3.6	0.0	2.4	20.9	0.0	0.4	68.0
IR 2	LaGr	15.3	2.4	20.3	57.5	4.1	17.5	1.9	9.8	22.9	0.0	2.5	45.4

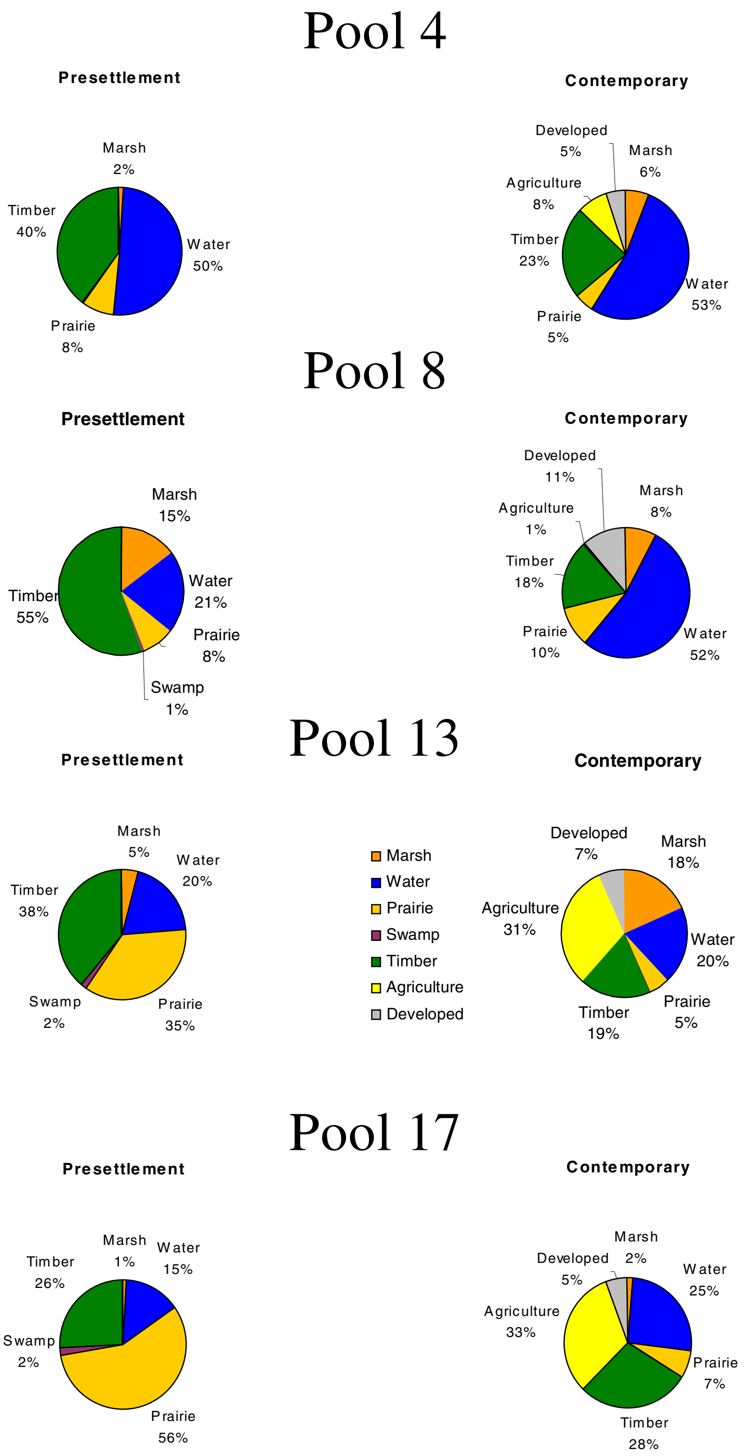

Figure 4a. Pre-settlement and contemporary land cover in selected Upper Mississippi and Illinois river reaches.

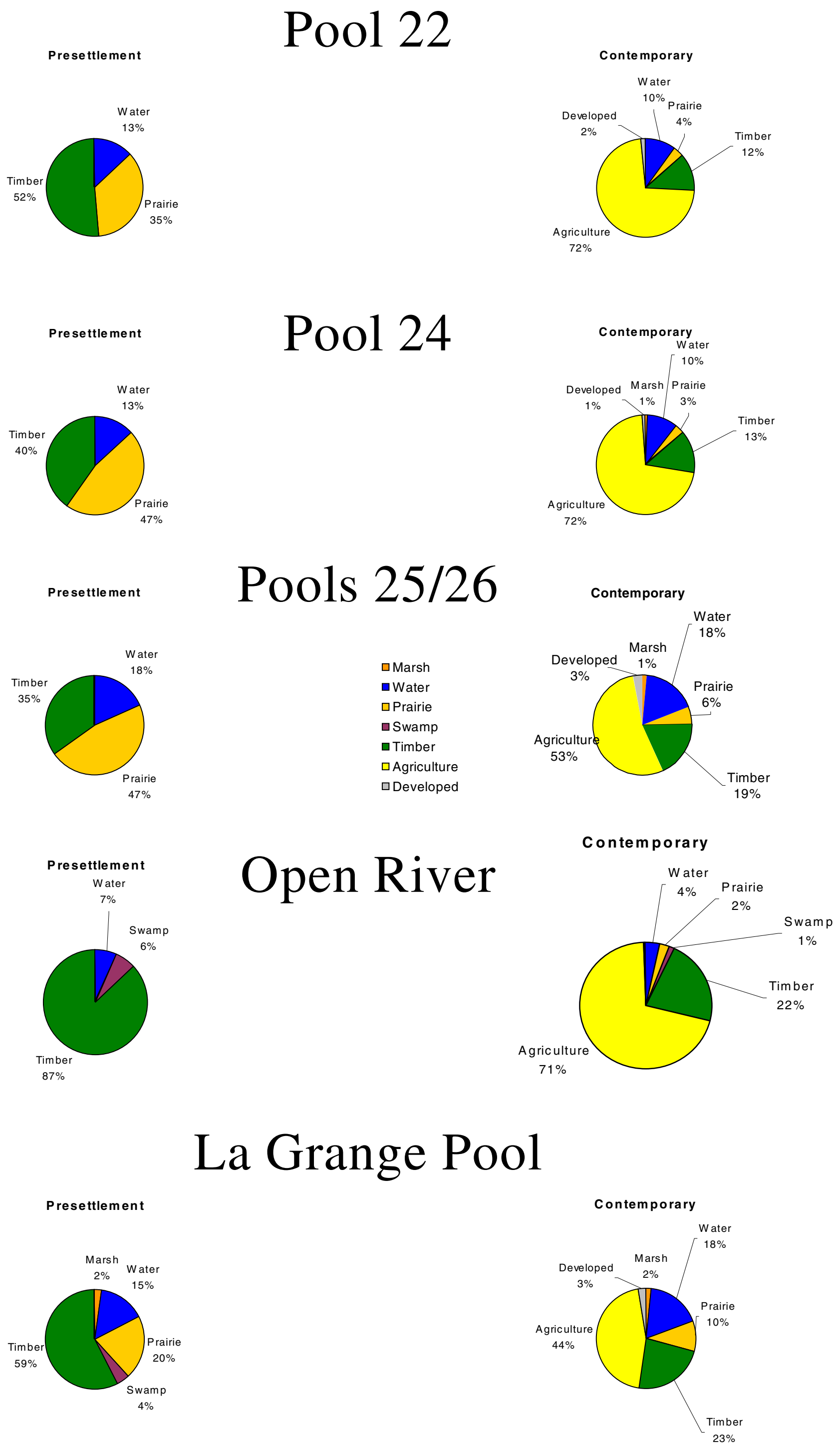

Figure 4b. Pre-settlement and contemporary land cover in selected Upper Mississippi and Illinois river reaches.

Pool 13 experienced very little change in the proportion of open water in the early and late time period (Table 3; Figure 4). The increase in open water impounded area in the lower end of the pool may have been balanced by loss of aquatic area elsewhere in the pool. The area of marsh habitats increased from only 4.5% to 18.3% of the Pool 13 area, probably in response to the creation of shallow aquatic areas in the lower pool and loss of depth in backwaters that allowed emergent plant growth. Prairie area was reduced from 35% of the area to 5%. Most of the area was likely converted to agriculture, which occupies about 32% of the contemporary floodplain. Impacts of development and inundation reduced timber area in Pool 13 by one-half (~40% to ~20%).

The proportion of open water area in Pool 17 increased from 15% to 25% of the Pool 17 area between pre-settlement and 1989 periods (Table 3; Figure 4, Figure 5). The change is difficult to detect in plan form view, but there appears to be a slight widening of the channel areas, no large impounded or backwater areas were created. Marsh area increased very slightly, but it is a very minor component of the reach in both periods. Prairie area decreased from 57% in the pre-settlement period to only 7% the latter time period. Much of the area was converted to agriculture, which occupies about 30% of the modern floodplain area. Timber area increased slightly in the later time period, perhaps encroaching into former prairies. Developed area displaced about 5% of the pre-settlement communities.

Pool 22 lost a small proportion of aquatic area between pre-settlement and contemporary periods (Table 3: Figure 4). The marsh class was absent in the early period and barely present in the modern era. Prairie had been a substantial component of the pre-settlement landscape at 35% of the reach, but it was reduced to only 4% of the modern landscape. Timber occupied more than one-half of the floodplain in the pre-settlement era, but was reduced to 12% of the floodplain area in 1989. Most of the former prairie and timber was converted to agriculture, which occupies more than 70% of the modern landscape. Floodplain development is a very minor component of the modern landscape.

Pool 24 has developed similarly to Pool 22. The proportion of the Pool 24 floodplain classed as open water decreased slightly between the pre-settlement modern eras (Table 3: Figure 4). Marsh area, a small landscape component in both periods, increased in the latter period. Prairie was the dominant land cover class in the pre-settlement era at 46% of the floodplain area. It was largely converted to agriculture, and only 3.3% of the floodplain was classed prairie in 1989. Timber was the second most prominent land cover class in pre-settlement Pool 24; it covered about 40% of the floodplain. Logging and agricultural clearing reduced timber cover to only 13% of the modern floodplain area. Floodplain development is a very minor component of the modern landscape.

Open water was a larger component of the pools 25 and 26 floodplain landscape than pools 22 and 24 (Table 35: Figure 4), but the changes over time are similar in these reaches. The open water class area changed very little between pre-settlement and contemporary periods. Marsh area was a small landscape component in both time periods, but it did increase in the latter period. Prairie was, again, the major landscape component at 46% of pre-settlement floodplain area, but it was reduced to only 6% of the contemporary floodplain area. Agricultural conversion displaced most of the pre-settlement prairie and currently occupies over 50% of the floodplain area. Timber area was reduced from 35% of the pre-settlement floodplain to about 20% of the modern floodplain area. The degree of development was slightly higher at 3.1% of modern floodplain area than pools 22 and 24, but lower than the northern pools.

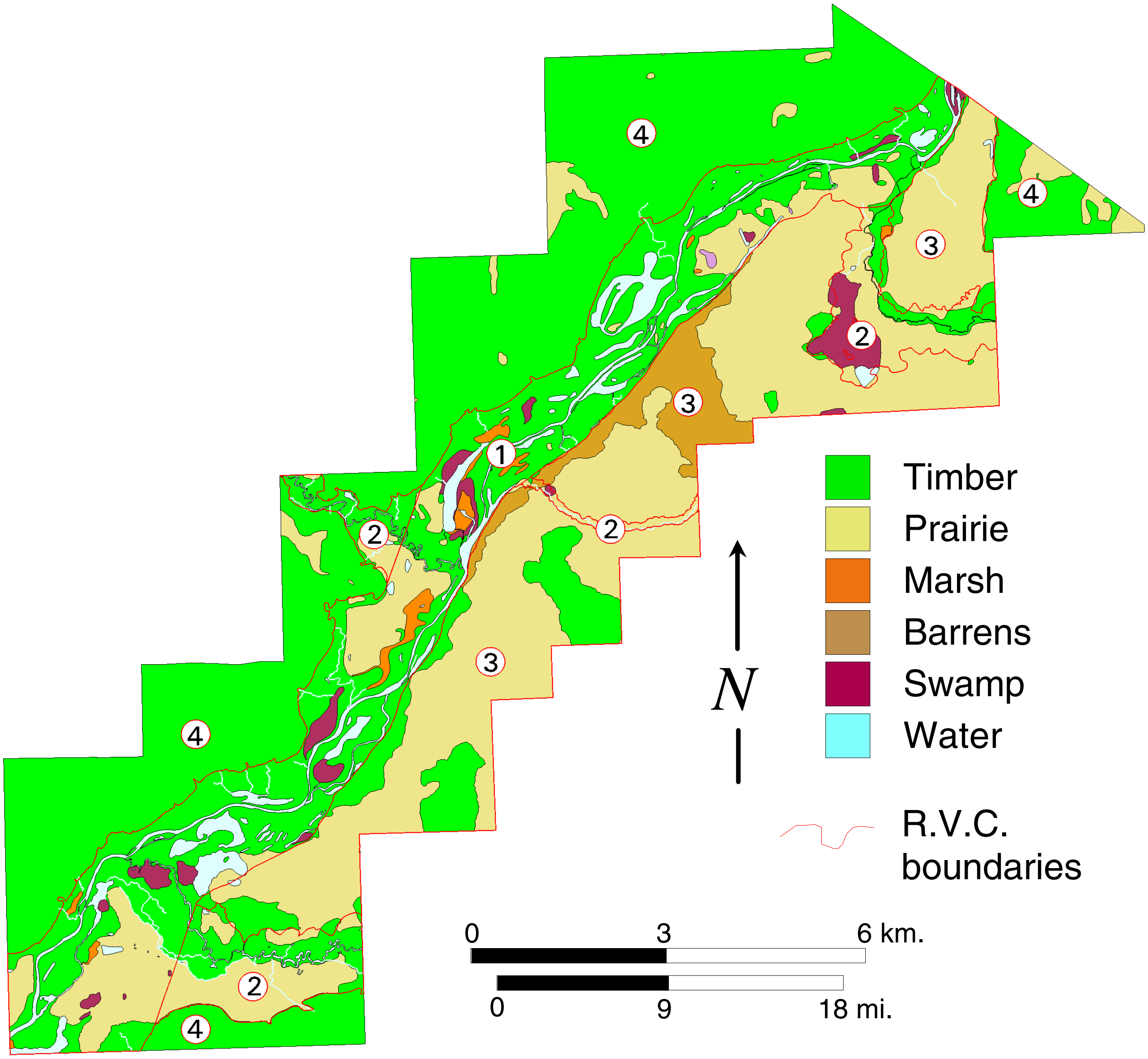

Figure 5a. Pre-settlement geographic information system land cover map of the lower-middle Illinois River valley. Map numbers indicate river valley categories; 1=bottomlands, 2=tributary floodplains, 3=terraces, 4=uplands.

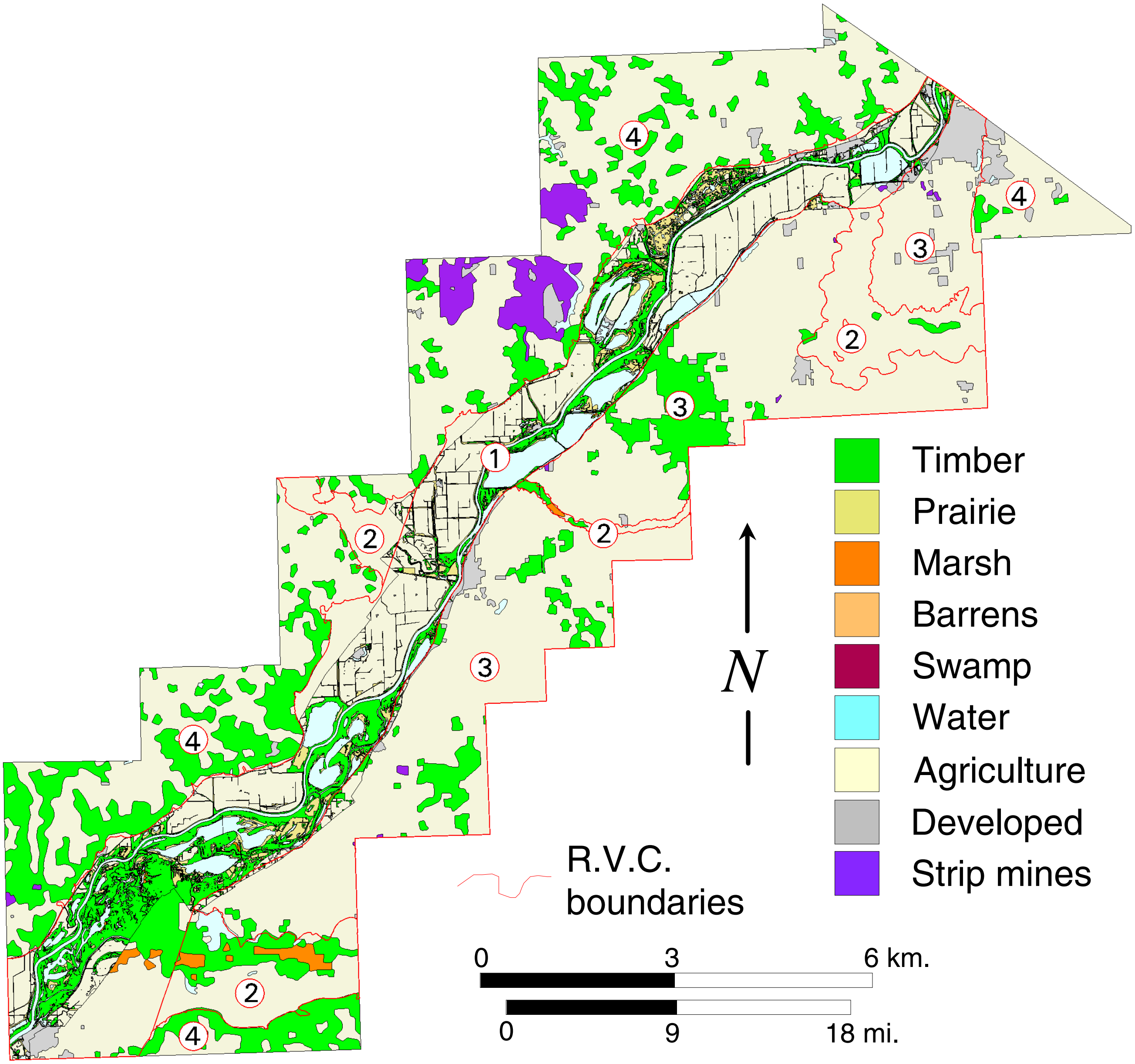

Figure 5b. Modern geographic information system land cover map of the lower-middle Illinois River valley. Map numbers indicate river valley categories; 1=bottomlands, 2=tributary floodplains, 3=terraces, 4=uplands.

The lower portion of the Upper Mississippi River Open River reach (river miles 0-80) supported a much different pre-settlement environment than the northern river reaches. The pre-settlement landscape was almost completely forested, with timber covering 87% of the landscape and forested swamp covering 6% of the floodplain (Table 3: Figure 4). Open water was the only other land cover class, occupying 7% of the pre-settlement floodplain area. Open water in the modern era was reduced to about one-half of its pre-settlement proportion of the floodplain (6.9% to 3.6% of floodplain area). The loss is because of narrowing of the channel and loss of secondary channels. Agriculture is the dominant cover type in the modern era, occupying about 70% of the floodplain area. Timber covered about 20% of the floodplain in 1989, but most was restricted to islands and the land between the river and set back levees. Prairie occurs in 1989 as a landscape component in leveed areas.

The Illinois River below the Great Bend at Hennepin, Illinois differs from the Mississippi River in that it is a very low gradient river. The pre-settlement river in the La Grange reach had many backwaters of various degrees of connectivity with the main channel compared to the Mississippi River. Open water increased slightly in the modern era (Table 3: Figure 4, Figure 6), but importantly, the distribution of the water changed from numerous small lakes to several very large open backwater areas. The marsh component of the landscape decreased slightly in the contemporary era. Prairie occupied about 20% of the pre-settlement floodplain areas, and still accounts for 10% of the floodplain area. Timber fringing channels and backwater lakes was the dominant pre-settlement cover type, occupying almost 60% of the floodplain. Levee construction and agricultural conversion reduced timber cover to 23% of the modern floodplain area. Swamp areas present in the pre-settlement era were absent in 1991. Agriculture behind protective levees occupies about 45% of the modern landscape.

The development of historic land cover data at the pool reach scale helps interpret pre-settlement landscape differences along the Mississippi River, and when more data are available, clear trends or patterns may be defined. Lake Pepin is a unique feature in the upper part of the Mississippi River, but the terrestrial areas upstream to Minneapolis were likely similar to the highly timbered island braided floodplains upstream and downstream from Lake Pepin. The Pool 8 pre-settlement landscape was also a highly timbered island braided landscape, with multiple channels winding through a relatively narrow floodplain. This characteristic landscape probably existed throughout the Chippewa River delta that extends through geomorphic reach 3. Geomorphic reach 4 is influenced by the Wisconsin River, and other tributaries that continue to affect floodplain development through geomorphic reach 8. The island-braided pattern subsides through geomorphic reaches 4 though 8 to a more frequent and irregular island pattern, with split islands common. Island braiding occurs downstream of resistant rock gorges at Rock Island, Illinois and Keokuk, Iowa, and at large tributary confluences. Local differences are evident, but in general, the floodplain widens significantly and lateral terraces are more prevalent. The prairie land cover class occurrence increases on the high elevation floodplain terraces. The proportion of timbered area in the geomorphic reach 4 to 8 landscape is the lowest among the river reaches whose historic landscapes have been interpreted. The environment downstream from the Missouri River (geomorphic reaches 9 and 10) differs from upstream river reaches because the Missouri River increases stream flow about 50% and, before dams were constructed in the 1950s, greatly increased sediment delivery. The Mississippi River south of the Missouri River was a meandering stream with many islands and bars. The pre-settlement landscape from river mile 200 to 80 has not been analyzed completely, but the area between river miles 200 and 118 supported landscapes similar to geomorphic reaches 4 through 8 (Kathy McKeever, Illinois Natural History Survey, Brighton, Illinois, unpublished data). The river mile 80 to 0 reach was unique in the Upper Mississippi River because it was almost completely forested and its

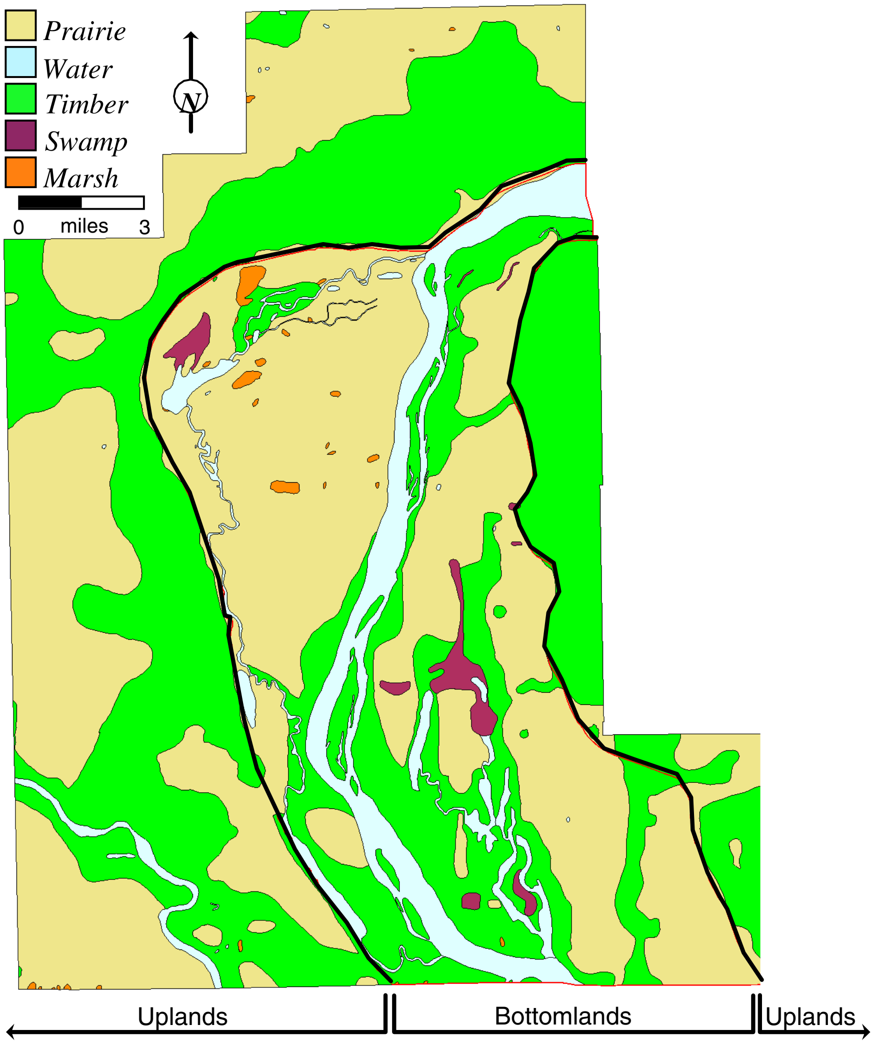

Figure 6a. Pre-settlement land cover map along Mississippi River Pool 17. Data obtained from US General Land Office township plat maps recorded between 1817 and 1837.

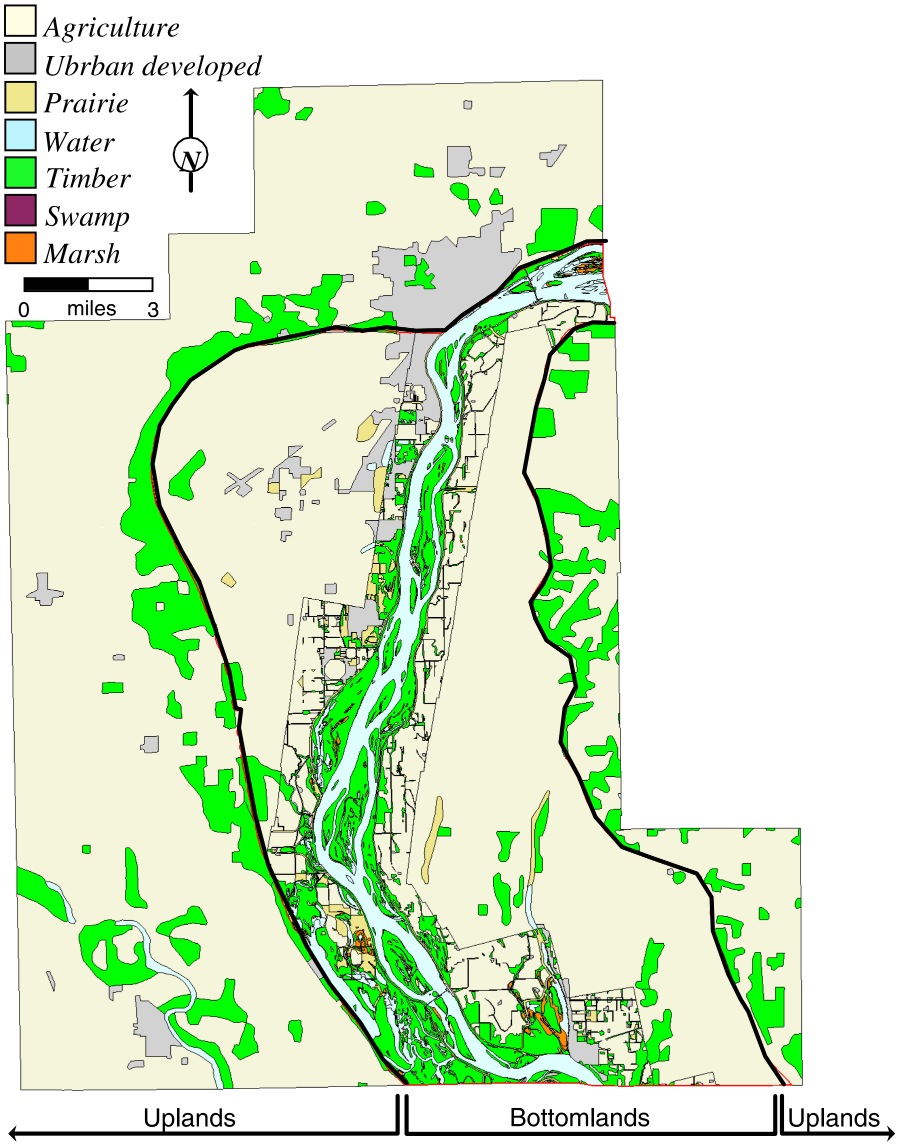

Figure 6b. Modern land cover map along Mississippi River Pool 17. Data along the river corridor were obtained from aerial photographs taken in 1989. The remaining land cover data were obtained from satellite imagery taken between the late 1970s and early 1980s.

composition included species common to southern bottomland hardwood forests. The Lower Illinois River reach differed from the Upper Mississippi River because of its high proportion of forest fringed backwater lakes and channels. Forest was the major pre-settlement component of the landscape in the La Grange Pool reach, but prairies were common also. Prairie was more common than upstream, but timber remained the dominant pre-settlement land cover type at a study site on the lower Illinois River near the confluence with the Mississippi River. The remainder of the Illinois River likely supported prairies and savannas on drier sites and forests on wetter sites to create highly diverse habitats.

Humans have greatly influenced UMRS terrestrial plant communities for over 150 years through direct impacts of exploitation of resources and encroachment into floodplain habitats, and indirectly through the regulation of important ecological control mechanisms. The influence of commercial development of the UMRS landscape started in earnest in 1824 when the Department of the Army was directed to clear obstructions from the river. Early navigation projects (ca. 1880s to 1930s) altered the formation of bars and islands through dike construction and dredging. Agricultural development and levee construction around the turn of the 20th Century eliminated native communities and decreased the lateral connectivity of the river. Levees currently protect about 3% of the floodplain in geomorphic reaches 1 through 4, 50% of the floodplain in geomorphic reaches 5 through 9, 80% of the floodplain in geomorphic reaches 9 and 10, and 60% of the Lower Illinois River reach. Logging for lumber, steamboat fuel wood, and land conversion reduced the amount and diversity of floodplain forests. River regulation affected most of the river system in the late 1930s. Generally, when water levels were raised and stabilized in the lower portion of the pooled reaches the water table rose and decreased the rooting depth available to trees. The Open River reach of the Mississippi River has been substantially deforested, channelized, and leveed. The main channel is deeper, narrower, and more uniform as a result of channel training. Except for narrow strips of floodplain along the river, the floodplain has been isolated from the river by large levees that prevent flooding in most years. Leveed areas are almost completely developed for crop production. The Illinois River was first subjected to increased water levels and massive pollution when the diversion from Lake Michigan was opened. Navigation dams further stabilized high river stages. Levee district development and agricultural development on the floodplain sequestered about 60% of the floodplain. An important factor influencing modern habitat quantity and quality is the presence of public land, which is much more abundant in geomorphic reaches 1 through 4 than in other reaches.

3.2 Forest Successional Change

The set of natural disturbances that controlled UMRS terrestrial vegetation succession has been altered on a large scale through time. Humans have also introduced new disturbances that greatly altered the UMRS landscape. Some impacts span the entire river, while others are localized. The availability of pre-settlement forest community structure and plat maps helps ecologists conceptualize natural successional change. Modern mapping and surveys allow the study of plant community change in great detail.

3.2.1 Upper Pooled Reaches

Terrestrial plant communities in the upper pooled reaches of the Upper Mississippi River (Pools 1 – 13) have been most affected by logging, water level regulation, island erosion, and invasive and damaging exotic species. Moore (1988) found that the pre-settlement forest community was dominated by maple, elm, and ash, species that remained dominant in 1983. GLO surveys in pools 4, 8, and 13 reveal that forests were the major cover type in much of the upper river. Logging during the colonization and steamboat eras cleared much of the forested area. Some areas were converted to agriculture or other development, but many areas grew back as forests.

The changes during this period are not well understood, but the establishment of the Upper Mississippi River Fish and Wildlife Refuge protected most of the floodplain in this river reach from development. River regulation inundated low elevation floodplains and raised the water table in the navigation pools. This directly inundated and killed many thousands of acres of standing timber. The raised water table saturated the shallow root zone killing flood intolerant trees and making other species more susceptible to wind-throw and bank erosion because rooting depth was decreased. Moore (1988) suggested that tree growth and reproduction at his Effigy Mounds site was diminished when the river regulation raised the water table. Water level stabilization has also limited the regeneration of pioneer species such as cottonwood. Following water level regulation, high elevation floodplain ridges and natural levees remained as islands in some impounded pool reaches. These islands and the forest community associated with them have eroded through time. The forested areas have not been replaced, and the aquatic areas remaining are degraded. Though Moore found some stability in forest composition, recent forest surveys reveal that wet meadow communities are replacing forests (Randy Urich, U.S. Army Corps of Engineers, St. Paul, Minnesota, personal communication). A European ecotype of the native reed canary grass (*Phaliaris arundinacea*) was introduced for agricultural purposes and has invaded lower elevation areas of the floodplain in northern river reaches. The exotic grass aggressively invades forest clearings and thinnings, and its dense growth prevents tree germination. Dutch elm disease devastated elm trees in the UMRS. A fungus that interferes with sap flow killed the large elms, once common to the UMRS. The many dead trees did provide habitat for cavity nesting birds, but most snags have fallen and elm snags are scarce. The combined impact of these influences has produced forest communities that cover less area than in the past, have lower diversity, and are composed of even aged trees (Yin 1999). Wet meadows are increasing their distribution in forest clearings and newly created landforms.

3.2.2 Lower Pooled Reaches

Pre-settlement terrestrial plant communities in the lower pooled reaches (pools 14 to 26) of the Upper Mississippi River were dominated by prairies on high elevations and forests on low elevation areas. Between the two was an intergrade of oak savanna. Oaks also occurred on floodplain ridges and natural levees. Nelson et al. (1996) speculated that fire was the prime factor controlling succession on the high elevation floodplain and that flooding controlled succession in low elevation areas. The pre-settlement forest community was diverse, with hackberry, pecan, elm, willow, and cottonwood as co-dominants. Many of the same perturbations occurring in the upper pools occurred in the lower pools. Logging was extensive and had impacted much of the reach by the late 19th Century. Prairies were widely converted to agriculture as were cleared forests. The savanna community is currently rare because fire has been controlled and such areas have overgrown with forest or been planted with crops. Impoundment raised the water table and impacted trees similarly to the impacts upstream, but large open impounded areas are not common in the lower pools and it is likely that fewer trees were directly flooded. Levees increase river stage during moderate floods, which may impact reproduction of flood intolerant species if seedlings are inundated frequently or for long periods during the growing season. The exotic reed canary grass has not impacted this reach as severely as it has upstream, but damage from Dutch elm disease has been extensive. The modern forest has low species diversity, with silver maple being the single dominant species. Mast communities are not being replaced for lack of suitable seed stock and seedling habitat. The silver maple community appears to be expanding and will likely be self-sustaining for the foreseeable future. In fact, Yin (1999) demonstrated that despite timber die-offs, forest communities following extreme flooding in 1993 were regrowing to the mixed maple forest that existed prior to the flood.

3.2.3 Open River Reach

The Open River reach of the Upper Mississippi River has always differed from the upper reaches because of the influence of the Missouri River. Rather than being a stable island braided stream, the Open River assumes a meandering pattern. McKeever et al. (unpublished data) report that prairies continued to dominate the floodplain south to the Kaskaskia River (river mile 117) in the pre-settlement era. Further south, the prairie peninsula gives way to the Ozark region and floodplain prairies drop out. Yin et al. (1997) report a nearly completely forested pre-settlement floodplain between river miles 30 and 80, and a forest community with species characteristic of the southern bottomland hardwood region. Cottonwood dominated the forests close to the river, but elm, hackberry, sweet gum, and ash were co-dominants on the broad floodplain. The floodplain south of St. Louis has been nearly deforested or developed for agriculture over time, and the forests that remain are all new growth in harvested areas or on newly formed land. Levees increase river stage during moderate floods, which may impact reproduction of flood intolerant species if seedlings are inundated frequently or for long periods during the growing season. Modern forests are mostly restricted to the land between the river and levees and on islands. Yin (1999) investigated succession in these areas following extreme flooding in 1993. He found that prior to the flood, the forest was co-dominated by silver maple, cottonwood, and willow, but that the sapling layer was dominated by silver maple. This suggested that without a change in controlling mechanisms, the forest community would be overtaken by silver maple, as occurred in the pooled reaches. The extreme flood killed or crippled existing sapling trees, which allowed a post flood seedling community to develop. The post flood seedling community resembled the overstory forest composition, which suggested that the co-dominance of silver maple, cottonwood, and willow would be maintained for the next 50 to 70 years. Yin speculated that disturbances would be frequent enough to maintain the presence of early successional species for the foreseeable future.

3.2.4 Lower Illinois River

Nelson et al. (1994), Nelson and Sparks (1998) and Nelson (unpublished data) reconstructed the pre-settlement landscape of two portions of the lower Illinois River. The analysis revealed that forest was the major component of the landscape in the La Grange pool and near the confluence with the Mississippi River. Pre-settlement forests at the Mississippi River confluence were composed of hackberry, pecan, elm, willow, and cottonwood that fringed river bank lines and low elevation floodplains surrounding the numerous backwater lakes. Prairies were distributed toward the bluffs on high elevation floodplains. A low tree density indicated savanna landscapes were common. Settlement between 1817 and 1903 resulted in the conversion of prairies and savannas to agriculture and logging of the forests. In 1900, the diversion of Lake Michigan water via the Chicago Sanitary and Ship Canal increased water levels about 4.5 feet in the Havana, Illinois area. The water level increase killed low-lying forests and increased the water table. Higher water table elevations favored flood tolerant species such as silver maples and forced out less tolerant mast producing species. Lock and Dam 26 increased water levels again when put into operation in 1938. Again, trees at lower elevation were killed, and a similar flood tolerant community developed. The extreme flood in 1993 killed about 40% of the mature trees in the study area, and saplings and oaks showed near complete mortality. Silver maple was the dominant species among post flood seedlings, which bodes well for its continued dominance. Nelson and Sparks (1998) conclude that natural regeneration of oaks is unlikely because of the loss of adult trees as a seed source, in addition to the hydrologic modifications. The Lower Illinois River has a very high sedimentation rate and backwaters are filling rapidly (Bellrose et al. 1983). Willows rapidly colonize mudflats along backwater lake margins. The willows community is eventually replaced by silver maple. Forest composition and plat map results from the La Grange reach are unpublished, but similar influences have affected the river upstream also.

3.3 Summary

The UMRS ecosystem has been greatly altered to support agriculture, navigation, and urban/rural development. The pre-settlement landscape in northern river reaches (pool 1 to 13) was characterized by riparian forests interspersed with marshes and wet prairies. The pre-settlement landscape in intermediate latitude river reaches (pool 14 to the Kaskaskia River and the lower Illinois River) was characterized by riparian forests that graded through savannas, that then gave way to prairies. The southern-most river reach (below the Kaskaskia River) supported mature southern bottomland hardwood communities that covered the entire floodplain. River impoundment flooded much forested area in northern reaches, but large portions of forest remain relatively intact in refuge areas. In other river reaches, most natural floodplain communities have been replaced by agriculture. Channel dynamics and water levels fluctuations that support diverse, productive floodplain communities have been altered throughout the UMRS.

4 UMRS Ecological Disturbances and Habitat Forming Processes

Landscape ecology is becoming a general framework for the study and management of natural resources. Landscape elements include patches, corridors, and background matrix (Forman and Godron 1986). Patch dynamics (Thompson and Willson 1978) are driven by both natural and human disturbances. Natural disturbances include geomorphic, climactic, physical/chemical and biological processes that form the physical template of habitats in the landscape, affecting the distribution and abundance of life forms. Disturbances can be described in terms of their frequency, timing, duration, severity, spatial extent of effect, and predictability (Pickett and White 1985).

Landscape ecology has focused on terrestrial systems. Landscapes of floodplain rivers are considerably more dynamic than most terrestrial landscapes, characterized by rapidly changing fluvial conditions and shifting ecotones (Salo 1990). Large rivers are dynamic environments subject to many types of habitat forming processes and disturbances, each having characteristic recurrence intervals, timing, duration, intensity, spatial extent and predictability. Some disturbances, such as spring floods, occur frequently, but vary in magnitude. Other disturbances may occur infrequently and be of limited extent, but have impacts beyond their immediate area of influence, such as Log jams initiating filling of secondary channels. In many ways, natural disturbances are important control mechanisms that maintain native plant and animal communities (Welcomme 1979, Junk et al. 1989, Bayley 1995, Sparks 1995). Human disturbance of rivers must be viewed from the perspective of altering the scales of occurrence, timing, and intensity of natural disturbance regimes (Sparks et al. 1998, Ward et al. 1999). Human activities alter the natural disturbance regimes through river regulation, land use changes, direct physical alterations such as channelization, exploitation of organisms, and introduction of pollutants and exotic species.

In this discussion of habitat-forming processes and disturbances for the UMRS-EMP Habitat Needs Assessment, processes and disturbances are described according to their scales of occurrence and intensity. Influences of both natural and human disturbances are discussed (Table 4).

4.1 Natural Disturbances

4.1.1 Floods

The channel geometry of alluvial rivers is a function of the flow, the quantity and character of the sediment in movement, and the character of the materials in the bed and banks. Two processes are responsible for the formation of floodplains, deposition of sediment on the inside of river bends and deposition from over bank flow. The greatest amount of sediment is conveyed when rivers are at or near bank full flow, when the river begins to overflow onto the floodplain. This level of river discharge corresponds to the 1 to 2 year recurrence interval flood (Leopold et al. 1964). The bank full flood is therefore a primary shaping disturbance that sets the template of the river channel habitats. Lower frequency but larger floods are responsible for forming the shape of the floodplain.

Junk et al. (1989) postulate that the annual flood is an important factor maintaining the ecological integrity of large floodplain rivers. They and others (Welcomme 1979, Bayley 1995, Johnson et al. 1995, Sparks 1995, Sparks et al. 1998, Ward et al. 1999) theorize that

Table 4. Selected disturbances influencing Upper Mississippi River System habitat formation and maintenance.

Disturbance Mechanism	Recurrence Interval (years)	Area of Influence (acres)	Comment
Natural			
Annual flood	1 - 2	10^3 - 10^4	Discharge and amplitude increase downriver
Major flood	100 - 500	10^4 - 10^6	Entire floodplain covered, except leveed areas
Drought	10 - 100	10^6 - 10^7	Affects both terrestrial and aquatic resources
Sedimentation	1 - 10^4	10 - 10^6	Spatially variable, episodic
Channel avulsion	1 - 500	10 - 10^3	Limited in UMR - island-braided plan form
Waves, sediment resuspension, and erosion	< 1	10 - 10^3	Occurs throughout UMRS in areas with >fetch
Fire	10 - 100	10 - 10^4	Largely controlled
Ice	1 - 5	10^4 - 10^6	Common in northern reaches of UMRS
Tree wind-throw	1 - 500	1 - 10^3	Increased by effects of impoundment
Log jams and debris piles	1 - 10^3	1 - 10^3	Occur throughout the UMRS, mainly at inlets
Beavers, floodplain impoundments	10 - 100	1 - 10^3	Common throughout UMRS
Herbivores	1	1 - 10^6	Many herbivores - large mammals now scarce
Anthropogenic			
River regulation	Continuous	10^7	Headwaters reservoirs, main stem dams
Impoundment	Continuous	10^6	Extensive floodplain inundated by nav. dams
Dredging, material placement	1	10^5	Occurs throughout the UMRS, less than past
Channel training structures	Continuous	10^6	Most built prior to impoundment, some new
Commercial navigation traffic	Continuous	10^6	Traffic greater in southern reaches of UMRS
Recreational boat traffic	Continuous	10^6	Traffic greater in northern reaches of UMRS
Levees	Continuous	10^6	Most levees in southern reaches of UMR, IR
Agriculture	Continuous	10^7	Most ag. use in southern reaches of UMR, IR
Logging	Occasional	10^6	Present logging of floodplain forest limited
Urban development	Continuous	10^5	Present development along UMRS limited

Table 4. Continued.

Mining	Occasional	10^4	Some sand/gravel mining ongoing
Parasites and disease	Continuous	10^7	Many introduced pathogens (e.g., Dutch elm)
Exotic species	Continuous	10^7	Many introduced species (L. Michigan -> IR)

an annual flood pulse that inundates floodplains and transports terrestrial plant energy to the aquatic system and nutrients from the river to floodplain soils increases productivity in warmer climates. Many fish species have evolved to make use of the seasonally available habitats in floodplain rivers. Plant communities are distributed within the floodplain in relation to their tolerance of flooding and soil drainage patterns. The seasonal timing and duration of floods are important factors. Short floods may not provide time for fish spawning on the floodplain. Long floods may kill intolerant or moderately tolerant plant communities, resetting vegetation succession. Early spring flooding will not benefit fish if they are not ready to spawn. Early floods that convey pan ice can be very destructive to riparian vegetation, and serve to set back vegetation succession. Late summer flooding may prevent plant germination or drown growing plants. The volume of a flood is important because a small flood will limit the exchange of nutrients and organisms. Large floods inundate high elevation plant communities not well adapted to flooding.

The volume of water and sediment in rivers is dependent on regional climate, a factor that has changed throughout the post-glacial history of the UMRS. Massive clear-water floods from glacial lakes carved the river valleys and then huge quantities of gravel and sand were delivered as glaciers melted and flow diminished. Modern flows are not sufficient to mobilize glacial sediments that were deposited in the main stem river valleys. Sediment delivered from tributaries continues to accumulate in the UMRS floodplains, resulting in a system that is generally aggrading (Fremling and Claflin 1984, Sparks 1984, Knox 1989). Knox (1993) described a warm climate period between 5,500 and 3,300 years ago that corresponded with 15% less precipitation and flood stages 20 to 30% lower than modern floods. The warm period was followed by a shift to cooler and moister conditions approximating modern values. The cool period was accompanied by the occurrence of very large floods approximating the modern 500-year flood. Knox (1993) concludes that these variations in river flow were caused by very small changes in climate, a change of 1 to 2 degrees Celsius mean annual air temperature and a mean annual precipitation change of 15 to 20 percent. Examining the historical stream gage record, Knox (in WEST 2000) also noted changes in the distribution of maximum floods corresponding to climatic variations. He showed that the magnitude of the 50-year flood was 40 to 47% smaller during the period between 1896 and 1949, and that larger floods were associated with earlier and later years within that period. Extreme floods were especially likely when one wet year is followed by another wet year, as occurred in 1993. Knox (in WEST 2000) notes an anomaly in the present era. Although our climate has warmed over the last 100 years, the occurrence of large floods has increased. Also, river discharge during winter has increased. He speculates this may be coincidental with increased precipitation in the basin or rapid warming and the forcing of unstable atmospheric circulation regimes. The historic evidence presented, coupled with evidence of recent rapid global warming, Knox suggests, raises the need to better understand the mechanisms underlying climate and stream flow.

The pre-dam hydrologic record for the Mississippi River above the confluence of the Missouri River exhibited a seasonal pattern of spring flooding, followed by summer low flows, usually a slight rise in the fall, and low winter flows. The Illinois River and the Mississippi below the Missouri River rose and fell gradually through the winter and early spring, dropping through the summer, and with low flow occurring in the fall (Grubaugh and Anderson 1988, Theiling 1996, Sparks et al. 1998). Knox (1984) examined the long term historic record at gauges along the length of the river and identified approximate 11 year cycles of increasing discharge followed by extreme droughts (Table 4; Figure 7). Perry (1994) correlates the cycle with total solar irradiance as it affects tropical ocean temperature anomalies and 5-year time lagged influences on the position

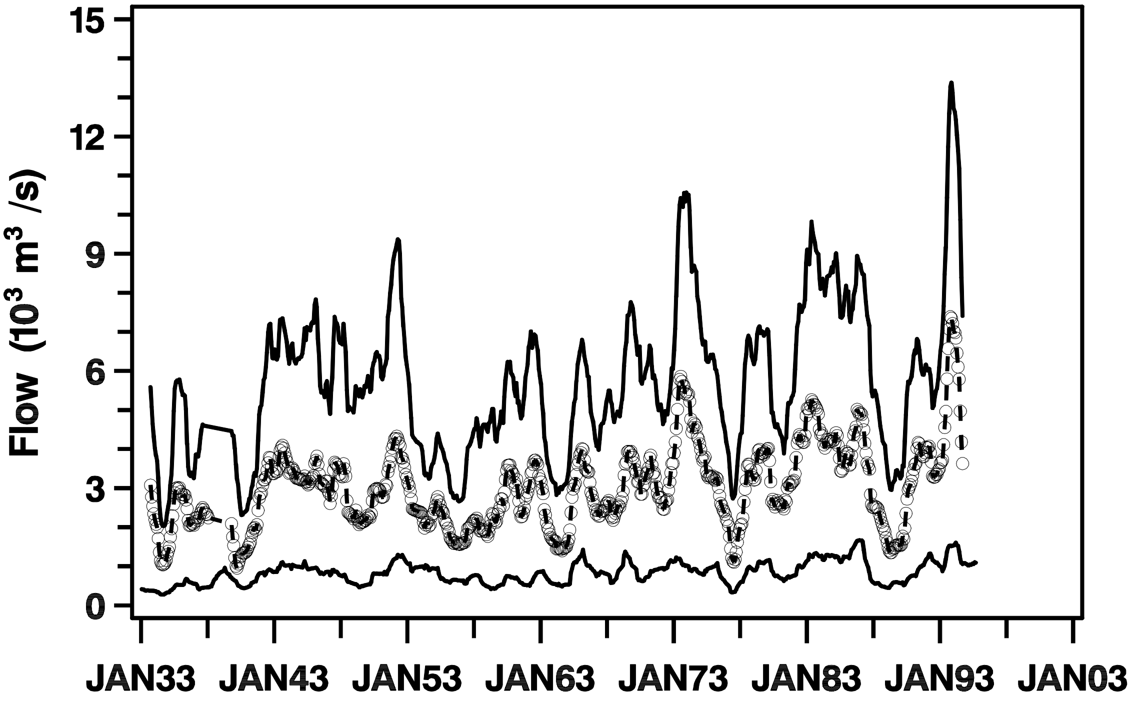

Figure 7. Daily discharge records at Winona, Minnesota (lower line), Alton, Illinois (middle line), and Thebes Illinois (top line) show approximately decadal fluctuations in high and low flow, an increase in discharge over the last 60 years, and an increase in the frequency and amplitude of multiyear fluctuation in recent decades (also reported by Knox 1984).

of the jet stream. A trend of gradually increasing discharge and an increase in the frequency and amplitude of multi-year fluctuations was also apparent. Over the last 75 years Mississippi River discharge has been increasing coincident with increasing precipitation in the basin, and large floods are more common (Knox in West 2000).

In addition to the potential effects of human activities on climate in the UMRS basin, a variety of human activities have affected the UMRS floods and the hydrologic regime. Land use in the basin, wetland drainage, and channelization of tributaries has accelerated routing of tributary flows to the main stem river, contributing to flood peaks. Storage of spring runoff in headwaters reservoirs has only slightly attenuated peak floods on the northern main stem UMR. The large capacity of the Missouri River reservoirs has greatly attenuated flood peaks on the UMR below the Missouri River confluence.

Navigation dams do not significantly affect flood stages because the dam gates are raised from the river at moderate river stages. At low to moderate levels of river discharge, the navigation dams impound water over extensive areas of river floodplain, changing the formerly seasonally-flooded floodplain terrestrial areas into continuously inundated shallow aquatic and wetland habitats. Flood stages in leveed reaches are currently higher for commensurate levels of discharge than in the past because levees constrict the floodway (Belt 1975, Bellrose 1983, Wlosinski 1999). Levees also restrict the lateral extent of flooding, which reduces animal migrations and nutrient exchange in flooded terrestrial areas and concentrates sediment in backwaters and contiguous floodplains.

4.1.2 Drought

Drought is an important control mechanism because of the physical, chemical, and biological reactions associated with extreme low water levels (Junk et al. 1989). The intensity (lack of precipitation), spatial extent and duration of droughts are highly variable. An extended drought occurred from 5,500 to 3,300 years ago. In the historic record, the first one-half of the 20th Century was dryer than the second one-half of the century. There also appears to be about 11 year periods between extreme droughts during the period of record (Knox 1984, Perry 1994; Table 4).

The primary physical effect of droughts on the unregulated UMRS was to greatly reduce the area and volume of floodplain water bodies, generally constraining aquatic life to channel habitats. Very low levels of river discharge reduce current velocities allowing lentic species to occupy channel habitats. Fish and amphibians stranded in drying floodplain water bodies were subject to predation by birds and furbearers.

Aquatic sediments were dewatered and oxidized, becoming more resistant to resuspension upon re-flooding. Seeds of emergent aquatic plants had an opportunity to germinate, providing considerable biomass and recycling of nutrients upon re-flooding. Many species of perennial emergent aquatic plants can only become re-established during drought periods when mud flat conditions allow germination of seeds.

Chemical responses to drought are quite complex as river soils are periodically inundated or exposed, experiencing anaerobic and aerobic conditions, respectively. Nitrogen, Manganese, Iron, Sulfur, and Carbon are all important nutrients, or potential toxins, whose availability in their oxidized or reduced state changes with pH and redox potential. The details of chemical transformations are beyond the scope of this discussion, but Mitsch and Gosselink (1986, Chapters 4 and 5) cite several sources documenting high rates of nutrient cycling in hydrologically variable environments.

Although human activities may be affecting the climate in the UMRS Basin, their influence on the occurrence of droughts is unclear. Impoundment of the navigation system on the UMRS has prevented the low water levels that formerly occurred during droughts.

4.1.3 Sedimentation

Sedimentation occurs when sediment is mobilized, conveyed, and deposited by water. River currents and waves suspend and convey sediment particles, which fall out of suspension and accumulate in lower energy areas. Tributaries constantly convey sediment to the main stem rivers. Large quantities of sediment are conveyed and deposited during floods. Bank full (approximately 1 to 2 year recurrence interval) floods convey the most sediment. Larger floods go over bank and deposit sediment on the floodplain. Although some sediment flow occurs continuously in the UMRS, sediment movement and deposition are very episodic (Table 4). Sedimentation is also spatially concentrated in low-energy areas in the UMRS, especially near tributaries that convey large volumes of sediment.

Bed load movement in the UMRS occurs in channels. Fluvial processes, primarily from bed load material transport, form point bars, shoals, islands, natural levees, deltas, and other channel features. Over bank flows can breach natural levees and deposit bed load sediments in sand splays on the floodplain. Suspended sediments are generally fine-grained silt and clay transported in suspension. Much of the suspended sediment load is flushed through the system, but it can also be trapped by riparian vegetation or settle out in low energy areas in backwaters and on the floodplain. Generally, the coarser sediments are conveyed in channels and deposited in channels, on natural levees, and in immediate over bank areas. Fine sediments are transported over natural levees and deposited in backwaters and on the floodplain. The rates and patterns of sediment deposition form the physical template of river habitats and control the soil conditions for floodplain vegetation.

Suspended sediment concentration increases significantly along the length of the river. Suspended sediment discharge is180 times greater in Chester, Illinois ($163x10^6$ tons/yr, RM110) than in Winona, Minnesota ($9x10^5$ tons/yr; RM726; WEST 2000, Table 5-3). The influence of the suspended sediment load from the Missouri River is evident in the Open River where suspended sediment concentrations are more than four times greater that the reach upstream of the Missouri River (WEST 2000). Suspended sediment loads have been decreasing in the recent historic record, probably because of improved land use and construction of tributary reservoirs (Knox 1989, WEST 2000), but present over bank tributary floodplain sedimentation rates (0.3 cm/yr to 4.0 – 5.0 cm/yr) greatly exceed the average pre-settlement rates (0.02 cm/yr; Knox 1989). The highest tributary sedimentation rates occurred at the lowest parts of the valleys where the controlling base level of the Mississippi River is approached. Meade (1995) illustrates the large reduction in the contribution of Missouri River sediments following the construction of large hydroelectric dams.

The impacts of sedimentation are exhibited as vertical accretion on floodplain areas and aquatic area filling. The extent of backwater filling in the Illinois River is well documented (Bellrose 1983, DeMisse et al. 1992, Bhowmik and DeMisse 1989) and selected areas of the Mississippi River have also been investigated (Simons et al. 1974, Knox 1977, Nielsen et al. 1984, McHenry et al. 1984, Bhowmik et al. 1986, Chen and Simons 1986, Rogala and Boma 1996, WEST 2000). Modern rates of sediment accumulation greatly exceed pre-settlement rates (Knox 1989, DeMisse et al. 1992), though improved soil conservation practices have reduced upland soil loss over the last several decades (WEST 2000). Bellrose et al. (1983) and DeMisse et al. (1992) predicted that most Illinois River backwater lakes would fill and convert to wetlands in the next 100 years. WEST (2000) estimated plan form change for the pooled reaches of the Mississippi River, but no systemic predictions were made because habitat forming processes and channel management activities differ along the river. Instead, dominant geomorphic processes were predicted for 10 distinct reaches. The mechanisms for change are varied, but generally, aquatic area was projected to increase slightly or remain stable north of Rock Island and to decrease or remain stable south of Rock Island. There is little information to base loss of depth in most Mississippi River backwater habitats, but Bellrose et al. (1983), WEST (2000) and James Rogala (USGS Upper Midwest Environmental Science Center, La Crosse, Wisconsin, unpublished data) document filling of deeper areas first and a loss of underwater topographic variation.

Large, permanent, shallow floodplain lakes and impounded areas were created when the dams were put into operation (Fremling and Claflin 1984, Starrett 1972). These areas have low current velocities and are subject to sediment deposition. Initially, impounded areas had diverse bottom topography but sediment deposition has filled deeper areas creating a uniformly level topography (James Rogala, USGS Upper Midwest Environmental Science Center, La Crosse, Wisconsin, unpublished data). In the Illinois River, backwater lakes have filled to uniformly shallow platter-shaped lakes that are losing surface area from their margins (Bellrose et al. 1983). The large and deep reservoir impounded by Lock and Dam 19 (Keokuk hydroelectric dam) in 1913 has mostly filled in with sediment (Bhowmik et al. 1986). Many of the channel forming processes that maintained diverse habitats were arrested by reductions in current velocities in impounded areas (Chen and Simons 1986). Cobble and gravel substrates in impounded areas are likely to have been buried by sand that is not mobilized in the low current environment.

4.1.4 Channel Avulsion

Channel avulsion is lateral channel movement, a natural fluvial process that occurs at scales on the order of 10s to 1,000s of years (Salo 1990) in natural channels (Table 4). The Upper Mississippi River channel position has been stable for the last 150 – 200 years (Chen and Simons 1986). Knox (in WEST 2000) observed that many of the larger islands in the island-braided UMR have been stable in plan form for thousands of years. Channel training structures associated with the navigation project (see below) have stabilized the plan form in dynamic areas of the river. Channel avulsion is limited to small areas. In addition to limiting lateral channel movement, human activities have also affected UMR channel geometry. Norris (1997) described extensive bank erosion and channel widening associated with the steamboat navigation downstream of the Missouri River confluence. There, the channel has narrowed to its approximate pre-steamboat width in response to channelization efforts, but the riverbed is greatly down cut. Island dissection has been documented in portions of pools 7 and 8 (WEST 2000). UMRS channels are so extensively stabilized that no new significant channels were created during the 100 to 500 year recurrence interval flood that occurred in 1993.

4.1.5 Waves, Sediment Resuspension, and Bank Erosion

Wind generated waves occur in large open water areas, especially those oriented such that prevailing winds blow along the long axis of lakes, impounded areas, and channels. Wind-generated waves force littoral drift of sediment along riverbanks, lakeshores and islands, creating beaches, sand spits and bay mouth bars. Wind-generated waves and sediment resuspension have eroded shallow areas and filled deeper areas within the impounded lower reaches of navigation pools, reducing bathymetric diversity. Wind generated waves are responsible for the erosion of islands in the impounded areas of several pools in UMR geomorphic reaches 3 and 4.

Boat-generated waves resuspend sediment in near-shore zones, and erode shorelines in river reaches where riverbanks and islands are close to the navigation channel. Boat-generated waves have caused considerable erosion and bank line recession in narrow channels on the UMR that carry high rates of recreational boating traffic (Johnson and Davis 1990). The frequency of recreational boat wake wave disturbance on heavily used reaches of the UMR can be high during summer weekends, resulting in nearly continuous wave attack on shorelines. Commercial vessels (towboats and barges) also generate wake waves, cause drawdown and return waves along riverbanks in narrow channel areas, and contribute to sediment resuspension and bank erosion (Johnson 1994, Bhowmik et al. 1999). The propeller wash of large boats in shallow areas can erode sand dune formation on the bottom of the river.

Waves resuspend sediment in shallow water areas where wave shear stress is sufficient to mobilize sediment. In some UMRS floodplain water bodies, wind disturbance is frequent enough to maintain high turbidity throughout the growing season (Sparks et al. 1990). Sediment resuspension is common in larger shallow areas throughout the UMRS. Wind speed and sediment resuspension is generally greatest in the spring in the UMRS, coinciding with snowmelt and early warming. The frequency and duration of wind-induced sediment resuspension is locally influenced by water depth, sediment type, fetch length, fetch direction, river valley orientation, and weather patterns (Table 4). Although resuspended sediment can limit the establishment and growth of aquatic vegetation, aquatic plants effectively reduce wind fetch and wave energy available for sediment resuspension.

Fish and furbearers can also resuspend sediment. Carp, bullheads, and gizzard shad all resuspend sediment when feeding. Bioturbation and resuspension of sediment by fish is most pronounced in more isolated floodplain water bodies. Muskrats and beavers graze on aquatic plants and conduct extensive excavations.

4.1.6 Fire

Fire is an important factor in the development of many plant communities. Prior to European settlement, much of the UMRS floodplain was prairie, which was subject to frequent fires caused by lightning strikes and native people. The natural frequency of fire at any one location on UMRS floodplain prairie areas was probably on the order of once per decade (Table 4). The UMRS channels and floodplain water bodies protected areas generally on the northern and eastern sides of the river from fires that burned in from the west, driven by prevailing winds. Native Americans used fire extensively to suppress woody vegetation and to maintain good grazing conditions for bison and elk. Native Americans greatly increased the frequency of fires in the tall grass prairie. Nelson et al. (1996) found that prairies were an important component of the floodplain land cover in the early 19th Century. They also noted that floodplain plant communities progressed through grassland, savanna, and forest communities from the bluff to the river as the influence of fire was superceded by the influence of flooding. Early photos of the UMR show prairie areas on the river bluffs that have since become wooded (Anfinson 1997). The control of wildfires is one of many factors that has eliminated prairies and modified forest community structure.

4.1.7 Ice

Ice forms over most of the northern reaches of the UMRS nearly every year, and over the slower current areas of the southern UMRS less frequently. Ice restricts movements between floodplain water bodies, limits diffusion of dissolved oxygen from the air into the water, and with snow cover, limits light to aquatic habitats during winter. In extreme conditions, organic activity and decomposition can significantly reduce dissolved oxygen and alter pH and nutrient composition leading to toxic water quality conditions. Disturbance by moving ice is an important factor in north temperate rivers (Scrimgeour et al. 1994), including the Mississippi River where pan ice commonly exceeds one foot in thickness. Pan ice can freeze riverbed substrates, kill macroinvertebrates in the ice-contact zones, and cause displacement of anoxic interstitial water from the sediment into the remaining water column. Falling water levels and pan ice during winter can entrap furbearers in their dens and prevent access to food caches. During ice-out, large sheets of ice can float into or be pushed onto islands and floodplain areas where it can scour the terrain and topple trees, especially if coupled with flooding. Floating ice mobilizes and grinds up woody debris. Ice is pushed onto lake shorelines by wind, disturbing substrate, uprooting vegetation, and leaving lakeshore ice-push deposits. Below zero air temperatures coupled with open water can result in frazil ice, which accumulates on underwater substrates. Frazil ice may impose severe stress on fish and other aquatic organisms. These ice-related disturbances occur nearly every year in the northern reaches of the UMRS, but less frequently in the southern parts of the system (Table 4). The ecological impacts of ice have not been studied on the UMRS.

4.1.8 Tree Wind-Throw

Extreme winds capable of toppling mature trees are common on the UMRS. Strong winds are typically associated with thunderstorms and tornados. Tornado damage has the potential to be severe depending on its path. Microbursts associated with thunderstorms can cause more localized damage. Tree wind throw may be important to support plant species diversity because the openings created allow other species to colonize the areas. Increased water table elevation because of impoundment limits the root zone for trees, which may lead to higher rates of wind-throw in lower pool reaches. Wind storms of sufficient intensity to overturn trees may occur on average about once every few hundred years at any point in the UMRS region (Table 4). The extent of tree damage because of windstorms can range from very localized to tens of square miles. Windstorms occurring with storms that deposit ice on trees are particularly devastating, causing considerable damage to tree limbs.

4.1.9 Log Jams and Debris Piles

Log jams occur when floating woody debris is transported by river currents and obstructs channel areas. Log jams can occur in all aquatic habitats, and even in floodplain terrestrial areas during flooding. The structure of the woody debris in aquatic areas provides substrate for aquatic invertebrates, fish, wading birds, and turtles, and helps maintain high habitat diversity (Shields and Smith (1992). In terrestrial areas, wood and brush piles provide nesting areas for birds and shelter for small mammals and furbearers. Log jams and debris piles can also modify habitats by modifying river currents, trapping sediment, or creating hard points that induce scour during floods. Where secondary channels are obstructed, Log jams may induce sedimentation that isolates the secondary channel from the river. Woody debris was likely an important factor determining channel geometry, avulsion, and flow splits in the past. The phenomenon is widespread in the river system, but the effects are exhibited locally.

Woody debris enters the river by a variety of mechanisms, but is probably much less prevalent now than in the pre-settlement era. Snag clearing initiated in 1824 removed woody debris from the channel to create a channel that could move new woody debris more efficiently and scour deeper. Trees along the channel bank line were also removed for hundreds of feet away from the river to prevent future log jams (Theiling 1999). Changes caused by snag clearing in the UMRS were never documented and are unlikely to be reconstructed. Dutch Elm disease increased the amount of woody debris contributed from the UMRS floodplain forests, and tree mortality from the 1993 flood has produced more in the lower reaches of the system.

4.2 Biotic Disturbances

The riverine environment created by physical processes (movements of water, energy, and matter) is spatially extensive and temporally variable, it creates the habitat template for plants and animals. The habitat is further modified by the activities of large animals, which eat vegetation, burrow and wallow, and build dams (Naiman and Rogers 1997).

4.2.1 Beavers

Beavers were once abundant in the UMRS Basin. They greatly modified the stream drainage network with small dams, including the seasonally flowing channels in the UMRS floodplains. The numerous beaver dams and ponds existed throughout the UMRS Basin slowed the rate of runoff (Hey and Phillipi 1995). Beavers provided the primary economic incentive for the first

Europeans to explore the area, and the ensuing fur trade decimated the beaver populations. The popularity of furs and the trapping of beavers have declined markedly since the mid 1900's. Beavers are again abundant throughout the UMRS. Beavers and their dams are routinely removed as nuisances in agricultural and urban areas. In the UMRS floodplains, beaver dams create a large number of shallow water bodies that are important for other furbearers and waterfowl. Beaver excavations form connecting channels between floodplain water bodies, allowing the movement of fish. Beaver excavations provide dens for other furbearers, and contribute to erosion of riverbanks. Beaver dams tend to impound less than 100 hectares, and last less than 10 years, although there are larger and longer-lasting exceptions.

4.2.2 Herbivores

Large herds elk and bison were eliminated from the UMRS in the 1800's. Their impact on floodplain plant communities has not been estimated

4.2.3 Mussel Beds

Extensive mussel beds once existed in the Mississippi and Illinois rivers north of the Missouri River. The structure mussel beds create and their high-density beds and relic shells added stability to sediments in river channels and created diverse microhabitats. Many other invertebrate species inhabit mussel beds, and the abundant food resources attract fish. In a symbiotic feedback loop, mussels use fish as hosts for their parasitic larval glochidia. Mussel beds have been reduced in distribution by commercial harvest, pollution, sedimentation, channel training, and dredging.

4.3 Human-Induced Disturbances

A variety of human activities create ecological disturbances, which affect the condition of natural riverine habitats and the biota. The following paragraphs describe the anthropogenic disturbances that are now characteristic of the UMRS.

4.3.1 Impoundment and River Regulation

River regulation in the UMRS basin has significantly altered the hydrologic regime, and the pattern of natural hydrologic disturbances. The scales of occurrence and magnitude of these changes to the natural hydrologic regime have not yet been quantified.

Dams have been built throughout the UMRS basin to attenuate floods, augment low flows, generate hydropower, for water supply, and for recreation. The total volume of headwaters reservoirs on the UMRS is relatively small in comparison to runoff volume, so the headwaters dams do relatively little to attenuate peak flood flows on the main stem UMR and Illinois Rivers. The Missouri River, however, has a series of large main stem dams, which impound several years of runoff volume, and greatly affect flood peak flows in the Mississippi, downriver from the Missouri River confluence.

Dams constructed to maintain the minimum nine-foot navigation channel on the UMR and Illinois Rivers have caused a variety of ecological changes (Fremling and Claflin 1984, Sparks 1995). The dams impounded water in the pools and permanently inundated floodplain areas and islands that had previously been subject to seasonal flooding. Terrestrial plant communities were flooded, killed, and replaced by aquatic habitats. Increased water table elevation because of impoundment limits the root zone for trees, which may lead to higher rates of wind-throw.

Stabilized water levels may also be limiting regeneration of pioneer tree species such as cottonwood (Nelson et al. 1994, Yin and Nelson 1995, Nelson and Sparks 1998, Knutson and Klaas 1998) and emergent aquatic plant marshes that develop on exposed substrates (Sparks et al. 1998). Impoundment of the navigation system increased the extent of continuously flooded aquatic and wetland habitats at the expense of seasonally inundated floodplain habitats. The overall productivity of the river system may have been reduced, from a natural floodplain river system with significant changes in seasonal water levels to an ecosystem in which seasonal low water conditions no longer occur (Bayley 1991).

Large, permanent, shallow floodplain lakes and impounded areas were created when the dams were put into operation (Fremling and Claflin 1984, Starrett 1972). These areas have low current velocities and are subject to sediment deposition. Initially, impounded areas had diverse bottom topography but sediment deposition has filled deeper areas creating a uniformly level topography (James Rogala, USGS Upper Midwest Environmental Science Center, La Crosse, Wisconsin, unpublished data). The large Pool 19, impounded by the hydroelectric dam at Keokuk Iowa in 1914, has lost most of its original volume to sedimentation (Bhowmik et al. 1986). In the Illinois River, backwater lakes have filled to uniformly shallow platter-shaped lakes that are losing surface area from their margins (Bellrose et al. 1983). Many of the channel forming processes that maintained diverse habitats were arrested by reductions in current velocities in impounded areas (Chen and Simons 1986). Cobble and gravel substrates in impounded areas are likely to have been buried by sand that is not mobilized in the low current environment.

Except in the immediate tailwater areas below the dams, river regulation on the UMR dampens the amplitude and frequency of water level fluctuations caused by changes in river discharge, because of the need to maintain target water levels at the dams and at the control points for navigation. Some pools have secondary, mid-pool control points that are used to reduce flooding during moderate flow. Control at mid-pool can create lower pool drawdowns from 1 to 6 feet, with the biggest drawdowns (> 1 foot) in pools 24, 25, and 26. Large areas in to lower portions of the pools may be exposed during drawdowns. On the Illinois River, river regulation imposes increased amplitude and frequency or water level fluctuations because of flow augmentation from Lake Michigan and because of the design of the dams. The Illinois River dams have wicket gates that are lowered and raised from the riverbed, creating the water level fluctuations, which can cause severe short-term disturbances to aquatic life in the Illinois River.

The UMR navigation dams restrict fish movement during the majority of the year when the gates are in the water (Wilcox et al., in press; see Existing Conditions Chapter also).

4.3.2 Clearing, Snagging, and Dredging

Snag removal was initiated on the UMR in 1824 to clear the navigation channel. Trees that could fall into the river were cleared from the riverbanks to prevent hazards to navigation (Theiling 1999). Many trees were cleared from the riverbanks to provide fuel for steamboats in the mid to late 1800's (Norris 1997). Clearing and snagging are no longer conducted on the UMRS.

Dredging is routinely conducted to maintain the UMRS navigation channels. Areas subject to direct disturbance include the dredged riverbed and the dredged material placement areas. Dredging and dredged material disposal practices have changed significantly through time. Early dredging was conducted without regard to environmental impacts. Dredged material was used to fill between wing dams to help deepen the navigation channel. Few records of early dredge activities exist. In the modern era, dredging frequency and volume has been reduced, and material disposal practices have been improved to reduce their environmental impacts.

A minimum of 3,114 acres of UMR main channel habitat within the St. Paul and Rock Island Corps of Engineers Districts has been disturbed by channel maintenance dredging during the period 1975 through 1996. This is approximately 6.2% of the total UMR main channel habitat area in the pools 4 to 10 river reach (LTRMP classification, main navigation channel and channel border area), and 2.0% of the main channel area in the Pools 11 through 22 reach. Of the dredge cuts within the St. Paul District, 288 acres have been dredged more than four times during the 1975 - 1996 time period, 115 acres have been dredged four times, 164 acres have been dredged three times, 273 acres have been dredged twice, and the rest, 699 acres, have been dredged only once. In the Rock Island District, dredge cuts covering a total of 56 acres have been dredged more than four times, 62 acres have been dredged four times, 117 acres have been dredged three times, 309 acres have been dredged twice, and 1,032 acres have been dredged only once.

The available dredging records for the UMR within the St. Louis District did not allow an analysis of both the dredge cut areas and dredging frequencies.

On the Illinois River during the 1975 through 1996 period, dredging has disturbed 813 acres of main channel habitat. Of the Illinois River dredge cuts, 36 acres have been dredged more than four times, 31 acres have been dredged four times, 66 acres have been dredged three times, 161 acres have been dredged twice, and 519 acres have been dredged only once.

Dredging disturbs the riverbed, removing mussels, other macroinvertebrates, and the channel bed forms. Frequently dredged cuts (once every 5 years or less) probably do not support much benthic life compared to other undisturbed channel areas.

Available dredging records for 1956 - 1997 in the St. Paul District reach of the UMR indicate that dredged material has been placed over a total of 1410 acres, or about 0.5% of the total aquatic and floodplain habitat. The St. Paul District plans to place nearly all dredged material at designated placement sites in floodplain terrestrial areas, except where placed at upland sites for beneficial use or used for habitat restoration projects such as island construction.

In the Rock Island District, over the 1940 - 1997 period of record, dredged material has been placed in 1,918 acres of open water area and 1,153 acres of wooded terrestrial area. Future placement of dredged material will be primarily on floodplain terrestrial areas, behind levees, and in agricultural fields, except where used for habitat restoration projects such as island construction.

On the Illinois River, dredging records are incomplete, but nearly all of the dredged material has been placed in main channel border areas (499 acres) and along the riverbanks (1,009 acres). Future dredged material placement along the Illinois River will be behind levees on agricultural land.

In the St. Louis District, dredged material has been historically placed in open water within the main channel and channel borders. Dredging requirements and practices are reviewed with natural resource managers annually. Current dredging practices are likely to continue for the foreseeable future.

Dredged material placement sites in floodplain terrestrial areas are hot, dry, and hostile sites for plant recolonization, if the dredged material deposit is high above the water table and fine-grained material is not placed on top. Recolonization of floodplain forest onto bare dredged material can take 25 years or more. If the dredged material is covered by soil or sediment deposited during floods, the sites are more hospitable to a wide range of plant species. Disposal site restoration is included in St. Paul District channel management plans. Many historic placement sites cannot be easily recognized from the surrounding floodplain areas.

4.3.3 Channel Training Structures

Channel training includes construction of a variety of structures (wing dams, closing dams, bank revetment) designed to maintain the alignment of the navigation channel and to stabilize the riverbanks (Simons et al. 1974, Chen and Simons 1986).

Early bank stabilization measures on the UMR involved clearing and grading the banks, and layering them with brush mats and limestone rock. Today, brush mats are not used in constructing rock revetments. Rock revetment is the most common bank stabilization technique and it is especially prevalent in the Open River reach. Rock revetments have been placed at the head of many islands to stabilize them. Rock revetments provide substrate for macroinvertebrates (Beckett et al. 1983, Baker et al. 1991) and structure for fish (Baker et al. 1991). Many fish species have a high affinity for rock revetment bank lines (Pennington et al. 1983, Farabee 1986).

Wing dams (called rock dikes in the lower Mississippi River) are structures constructed perpendicular from the bank to divert flow away from the bank, forcing it into the main channel. They have been constructed of rows of wooden posts, layered willow mats and rock, and currently from rock alone. The wing dams create eddy currents that can trap sediment, causing filling between wing dams thus narrowing the channel (Chen and Simons 1986, Shields 1995). Dredged material used to be placed between wing dams to narrow and stabilize the alignment of the navigation channel. Much of the length of wing dams originally constructed is now buried. They also cause scour in the channel because current velocity is increased between the distal end of the wing dam and the opposite bank (Chen and Simons 1986). Many wing dams north of Rock Island were constructed during the development of the four and six-foot channel projects. Most wing dams constructed prior to the nine-foot channel project are still present, but they have been submerged. The submerged wing dams still function to concentrate flow in the navigation channel, but they do not alter flow lines to the degree that emergent wing dams do. Wing dams constructed after the nine-foot channel project may or may not emerge from the surface of the water. In the Open River reach, wing dams are the primary channel management measure. They are high enough to be emergent most of the time. Filling between wing dams and in secondary channels has greatly simplified aquatic habitats in the Open River reach (Simons et al. 1974, Chen and Simons 1986). The Open River reach main channel has also been significantly deepened by wing dam induced scour (Simons et al. 1974, Chen and Simons 1986). Several techniques have been investigated to improve habitat for fish in dike fields (Niemi and Strauser 1991).

Closing dams are rock structures constructed across secondary channels to concentrate flow in the main channel. Some closing structures in the lower pools and un-impounded reach of the UMR are notched in the middle to allow flow into the secondary channels and small boat access. Closing structures constructed in the upper pools for the 4.5- and 6-foot channel projects were submerged when the dams were built. In extreme cases in the Open River reach, closing structures isolate secondary channels from the main channel when the river stage is low. Closing structures also modify hydraulics and sediment transport in secondary channels, which may lead to rapid filling and secondary channel loss (Shields and Abt 1989).

Several new types of training structures have been investigated recently. Bendway weirs are structures designed to reduce dredging requirements in large river bends. Constructed in series, bendway weirs progressively divert flow to simulate straight channel hydraulics through the bend. The approach increases sediment transport capability, thus reducing dredging requirements (Davinroy 1990). The technique may impact fish habitat with the erosion of the toe of gradually sloped sand bars, it may also create new habitats in the rock weir fields. Chevron dikes are ‘V-shaped’ structures constructed in series to divert flow away from secondary channels. They provide the same hydraulic effect as closing structures, but they don’t isolate secondary channels (Theiling 1995). Their ability to help maintain secondary channels has not been thoroughly evaluated. The use of piles of rock, called “multiple round points”, to replace linear wing dams is also being investigated.

Although the plan form of the UMR was fairly stable over the centuries prior to construction of the navigation system, the numerous channel training structures on the UMR have further stabilized the river plan form and main channel alignment. Generally, channel training structures prevent channel avulsion, new channel and island formation, narrow the river, and deepen the river. The net effect is considerably more boulder substrate in the river, a deeper main channel, fewer undercut banks, less woody debris from caving banks, and fewer, smaller scale, and less-frequently changing river features such as tertiary channels, sand bars, and islands.

The low gradient of the Illinois River does not provide the erosive energy to cause major channel avulsion. Revetments and wing dams are uncommon on the Illinois River (WEST 2000).

4.3.4 Commercial and Recreational Navigation Traffic

Commercial (towboats and barges) and recreational boating traffic cause a variety of hydraulic disturbances. Passing commercial tows cause wake waves that resuspend sediment in near-shore zones and erode river banks, produce drawdown and return waves along shorelines which also resuspend sediment, generate return currents because of displacement of water by the passing tow, entrain large volumes of water through propellers, produce high-velocity propeller jets and associated waves and turbulence. Recreational boats also generate wake waves that can resuspend sediment in near-shore zones and erode riverbanks. Recreational boats also entrain water through propellers and generate smaller propeller jets. The spatial extent, frequency, timing, and magnitude of these hydraulic disturbances are directly related to the vessel traffic rates, vessel configurations, channel dimensions, and river stage.

The hydraulic disturbances produced by passing vessels cause a variety of biological responses, including physical damage to aquatic plants by waves and changing currents, suppression of plant growth because of resuspended sediment, mortality to fish during propeller entrainment, disturbance of spawning fish, displacement of fish from their habitats, displacement of mussels, and dune smoothing. The hydraulic disturbances produced by passing vessels and the associated biological responses have been described in the many reports on this subject associated with the LTRMP and the Upper Mississippi River – Illinois Waterway Navigation Study (e.g., Bhowmik, et al. 1993, Mazumder et al. 1993, Bhowmik et al. 1995, Gutreuter et al. 1999).

4.3.5 Levees

Levees are most prevalent in the Mississippi River south of Rock Island and in the La Grange and Alton pools on the Illinois River. The majority of levees were constructed to protect agricultural areas from moderate floods. The environmental impacts of levees and the development they allow are extensive. Natural vegetation in leveed areas has been removed and largely converted to agriculture. Wetlands were filled and the floodplain behind levees has been drained and leveled. Floodplain lakes have been isolated from the river and tributaries have been channelized. The areas protected by levees have lost much of their habitat value.

Levees also alter physical and biological processes in the rivers. River stages are higher for commensurate flow volume than they were before levees were widespread (Belt 1975, Bellrose 1983, Meyers and White 1993, Wlosinski 1999). The levees also concentrate river flow and the particulates carried in suspension. Sediment is constrained in the remaining contiguous floodplain where it settles out, causing rapid filling in backwater lakes (Bellrose 1983). The effects are particularly pronounced in the lower Illinois River. Levees reduce river-floodplain connectivity, which may limit production of floodplain spawning fishes and reduce nutrient transfer between the rivers and their floodplains (Sparks 1995, Ward et al. 1999).

4.3.6 Agriculture

Agricultural development has converted much of the diverse floodplain landscape to monocultures of corn and soybeans (Nelson et al. 1994, Yin and Nelson 1995). Evidence suggests that floodplain prairies were developed first. Logging for steamboat fuel wood and lumber, in addition to clearing for crops, allowed the development of more of the floodplain. The impacts are very pronounced in the Open River (river miles 0 to 80) where a completely forested floodplain was almost entirely converted to agriculture (Yin and Nelson 1995). Agriculture is the dominant land cover south of Rock Island on the Mississippi River and on the lower Illinois River.

Crop production in the floodplain and throughout the basin relies on nutrient applications to boost production and pesticides to reduce crop loss. The chemicals used on farm fields are highly soluble in water or readily adhere to particulates, which allows their transport for great distances in runoff. Nutrient and pesticide concentrations in the rivers do not typically exceed health standards, but they have periodically, following large, widespread spring storms that coincide with chemical applications (Antweiler et al. 1996, Goolsby and Pereira 1996). Sediment delivery from upland areas increased greatly with the advent of mechanized row crop agriculture and the channelization of ditches and tributaries (Knox 1977, DeMisse et al. 1992).

4.3.7 Logging

Logging has affected much the UMR floodplain at one time, especially during the steamboat era (Norris 1997). Logging records are not available from the past, but modern surveys show that the majority of the floodplain forest is composed of even aged trees (Yin 1999). Land cover analysis from pre-settlement and contemporary periods shows that forests are less abundant now than in the past (Nelson et al. 1994, Yin and Nelson 1995). Impoundment of the navigation system caused extensive loss of floodplain forest. Some areas in the present navigation pools were logged prior to impoundment.

Logs cut in the northern part of the UMR basin were also transported along the river. Large secondary channels were used as sorting areas where log rafts were made up that were floated to mills in cities down river (Merritt 1984). Waterlogged woody debris covered the bottom and littered the shores of the UMR. Sawdust accumulated below mill towns and impeded navigation. Erosion from clear-cut areas throughout the upper basin increased sediment transport to the river (Knox 1977, 1989).

4.3.8 Urban Development

Approximately three percent of the Upper Mississippi River Basin was classified as urban area in 1980. Apart from the direct destruction of native communities, urbanization affects habitats far beyond the extent of city limits. The concentration of people in urban areas in the late 1800's created many challenges for public health and waste treatment (Fremling 1964, Starrett 1972, Corbett 1997). Sewer systems were developed in response, and they transported huge quantities of raw sewage to the rivers. In areas downstream of Minneapolis, Rock Island, St. Louis, Peoria, and Chicago, river water quality was sufficiently degraded to eradicate sensitive species. Sewage treatment, introduced primarily to protect human health, eventually benefited the rivers. Continued urban growth required the development of larger, more efficient sewage treatment facilities, and more stringent water quality regulations enacted in the 1970s dramatically improved water quality (Soballe and Wiener 1999). Ongoing improvements to drainage infrastructure and treatment facilities are projected for the future.

Industrialization in urban areas introduced a variety of new chemical compounds into the environment. Rivers were the primary waste disposal source for most industries and over time, enormous quantities entered UMRS waterways. PCBs, lead, cadmium, mercury, and many other toxic compounds have been detected in river sediments. They have been implicated in the eradication of sensitive species and the disfigurement of hardy species (Sparks 1984). Many compounds are detectable in the tissues of benthic animals (Steingraeber and Wiener 1995). A full discussion of the impacts of point source pollutants is beyond the scope of this report, but significant control of chemical pollution was enacted in the 1970s and discharges have been significantly reduced. There is evidence that toxic sediments are being buried by cleaner sediment over time (Sparks and Ross 1992).

Urban non-point source runoff or storm water runoff has been recognized as a cause of water quality degradation and contains very large quantities of heavy metals (Wilbur and Hunter 1979, Owe et al. 1982, Livingston and Cox 1985). Heavy metals found in urban runoff are 10-10,000 times the concentration of heavy metals found in sanitary sewage (Wanielista 1978). Among the toxic heavy metals detected in storm water runoff, lead, zinc, and copper appear to be the most abundant and detected the most frequently (Nightingale 1987). Cadmium, although not present in high concentrations in all urban environments, is significant because of its extreme toxicity (Wigington et al. 1983). Heavy metal sources are largely associated with the operation of motor vehicles, atmospheric fallout, and road surface materials (Harper 1985). Some sources of heavy metals are displayed in Table 5. Metal contamination is more widespread from commercial and roadway development than from residential, light industrial, or mixed urban land use (Whalen and Cullum 1988). To address concerns regarding non-point-source runoff, many cities, municipalities, and states have implemented regulations requiring that storm water runoff be treated in a pond or other alternative system (Source: Kym Campbell, Cadmus Group, Inc., Oak Ridge, Tennessee).

Table 5. Sources of heavy metals found in storm water runoff. Sources: Wigington et al. 1983, Harper 1985, Whalen and Cullum 1988, Harper 1990, Campbell 1995.

Source	Cadmium	Chromium	Copper	Nickel	Lead	Zinc
Gasoline	X		X		X	X
Exhaust Emissions				X	X	
Motor Oil and Grease	X		X	X	X	X
Antifreeze			X			X
Undercoating					X	X
Brake Linings		X	X	X	X	X
Rubber	X		X		X	X
Asphalt			X	X		X
Concrete			X		X	X
Diesel Oil	X					
Engine Wear			X			

4.3.9 Mining

Lead mining was one of the earliest industries in the Mississippi River. Mining activities released large quantities if lead, cadmium, and other elements into the environment (Knox 1989). The impacts of mining were not quantified, and the practice has long since ended in most of the basin. Where still active, mining is more heavily regulated. Quarries are common along the river bluffs. Where established, quarry operations destroyed native landscapes and left scars of exposed rock. Sand and gravel mining in the river channel is common.

4.3.10 Parasites/Disease

Dutch elm disease was first detected in 1917 in Holland from where it has spread quickly to other European countries. It reached England in 1927 and invaded the U.S. around 1930. A second invasion of the North American continent occurred in 1944 in Quebec. The disease is caused by a fungus (*Ceratocystis ulmi*), which enters the tree through holes made by bark beetles (*Scolytidae* spp.) and produces toxins, which interfere with sap flow. Dutch elm disease is one of the most devastating tree diseases to invade North America, killing millions of the stately elm trees, which were once common in the UMRS floodplains. Dutch elm disease has effectively eliminated American elms (*Ulmus americana*) from the UMRS floodplain forests. The floodplain forests are presently responding to the loss of elms. The many dead elms provided habitat for cavity nesting birds such as woodpeckers and wood ducks, but the elm snags are rapidly falling and becoming scarce. Many areas of the UMRS floodplain where elms died out have been invaded by Reed canary grass (*Phalaris arundinacea*), which is preventing recruitment of seedling trees. The smaller introduced Chinese elm, (*Ulmus parviflora*) is resistant to Dutch elm disease, and has colonized many UMRS floodplain areas.

4.3.11 Exotic Species Introductions

Human activity in the UMRS Basin has resulted in wholesale modification of the landscape and introductions of many species that have changed the UMRS ecosystem. Human activity has allowed some native species to increase their range and become abundant because of environmental conditions that are different than conditions before European settlement (e.g., grazing, fire, or creation of disturbed habitats).

Native Americans brought the domesticated dog with them from Asia to North America in the late Pleistocene. As Native American populations became agriculturalists in the UMRS region about 5000 years ago, they cleared land by burning, domesticated a number of native plant species, and introduced other plants such as maize, beans, and squashes native to other parts of North and Central America. Some plants probably introduced to the UMRS region by Native Americans persist in the wild today, such as several species of sunflowers (*Helianthus* spp.) and lotus (*Nelumbo lutea*).

Early European contacts introduced human pathogens that decimated the Native American populations. The greatly reduced Native American populations along the UMRS resulted in reduced incidence of fire and succession of fire-maintained prairie habitats into forest. With increased European settlement in the early 1800s, free-ranging elk and bison, which were abundant in the UMRS floodplains, were hunted nearly to extinction and replaced with cattle, horses, and other domesticated farm animals.

Nearly all prairie habitat in the UMR Basin has been converted to forest, pasture, and farmland. Nearly all of the original forests in the UMRS basin have been logged, and converted to agriculture, farm wood lots, or industrial forests. The entire landscape of the UMRS Basin has been altered by human activity. Now the landscape is dominated by and intentionally managed for non-native species such as a variety of ornamental plants in residential areas and corn and soybeans in agricultural areas. Many exotic species have invaded the basin and floodplain, ranging from trees to zooplankton. Table 6 lists a number of exotic species discussed in the USACE Cumulative Effects Study (WEST 2000).

4.4 Summary

Natural ecological disturbances are predictable events that shaped the physical and evolutionary template of the UMRS. The pre-settlement channels and landscapes developed over thousands of years of seasonal and cyclical natural disturbance. The biota evolved within the dynamic environment over millennia. Human development of the UMRS has permanently altered many important disturbance mechanisms. The river ecosystem is, in many ways, in dis-equilibrium and is responding to a new set of environmental controls. The cumulative impacts of human disturbance from basin to habitat scales have degraded habitat diversity and quality throughout the UMRS.

Table 6. Selected exotic species introduced to the UMRS.

Common Name	Scientific Name
Plants	
Black locust	*Robenia pseudoacacia*
Chinese elm	*Ulmus parviflora*
Reed canary grass (Euro. ecotype)	*Phalaris arundinacea*
Stinging nettle (Euro. ecotype)	*Utria diooica var. dioica*
Autumn olive	*Elaeganus umbrellata*
Buckthorns	*Rhammus spp.*
Bush honeysuckle	*Lonicera spp.*
Japanese honeysuckle	*Lonicera japonica*
Multiflora rose	*Rosa multiflora*
Purple loostrife	*Lythrum salicaria*
Sweet clover	*Melilotus sp.*
Curly-leaf pondweed	*Potamogeton crispis*
Eurasian milfoil	*Myriophyllum spicatum*
Aquatic Invertebrates	
Zooplankton	*Daphnia lumholtzi*
Spiny water flea	*Blethotryphes cederstroemi*
Zebra mussels	*Dreissena polymorpha*
Quagga mussel	*Dreissena bugensis*
Asian clam	*Corbicula fluminea*
Rusty crayfish	*Orconectes rusticus*
Fish	
Round goby	*Neogobuis melanostomus*
White perch	*Morone Americana*
Striped bass	*Morone saxatilis*
White catfish	*Ameiurus catus*
Black carp	*Mylopharyngodon piceus*
Bighead carp	*Hypophthalmichtys nobilis*
Silver carp	*Hypophthalmichtys molitrix*
Grass carp	*Cttenopharyngodon idella*
Goldfish	*Carassius auratus*
Common carp	*Cyprinus carpio*
Birds	
Ring-necked pheasant	*Phasianus colchicus*
Starling	*Sturnus vulgarus*
House finches	*Carpodacus mexicanus*
House sparrow	*Passer domesticus*
Mammals	
Dog	*Canis familiaris*
Common cat	*Felis catus*
Norway rat	*Rattus norvegicus*

5 Land Cover and Geomorphic Area Classification

Land cover data are widely available to natural resource managers working on the Upper Mississippi River System. The availability and resolution of land cover data, however, differ among river reaches and data formats. Land cover data sets presented in Table 7 were incorporated into the HNA Query Tool. The 1975 data set was interpreted from aerial photographs using about 40 land cover classes that were reclassified to match the 18 land cover classes developed for the HNA (Table 8 and Figure 3). The 1975 data are only available for a few pools. Satellite data collected in 1989 is the most extensive land cover data set; it covers the entire UMRS floodplain extent. Satellite data, however, are low resolution with only seven broad land cover classes mapped. Land cover data developed by the Long Term Resource Monitoring Program (LTRMP) from aerial photos collected during 1989, 1991, 1994, and 1995 are the most detailed, with over 150 plant genera, communities, or cultural features mapped. The LTRMP data are extensive for 1989, but offer only spotty coverage in other years. The 1989, 1991, and 1994 LTRMP data cover pools 1 to 26 and portions of the Open River and Illinois Waterway. There are large areas with no photo coverage in lower pooled reaches dominated by agriculture. LTRMP data were used wherever possible in assessments of existing conditions. Aquatic area coverages that define channels, backwaters, etc. were developed from the 1989 land cover data and are available for the same areas. The St. Louis District Army Corps of Engineers developed their REEGIS system GIS databases from 1994 aerial photography for the Pool 24 to Ohio River reach to help assess the effects of extreme flooding in 1993. The REEGIS data provide rather detailed classes for forest communities and broad general classes for grasses and wetlands. Data used in the existing condition analysis are highlighted in Table 7.

5.1 Land Cover

The **open water** land cover classification includes all non-vegetated aquatic area. The class is very general and may include areas from 1 to 100 feet in depth with widely varying flow. The geomorphic area classification must be used to estimate the details of open water habitat. For example, open water in a backwater is likely to be shallow to moderately deep with low current velocity and soft substrates. Conversely, open water in the main navigation channel is likely to have moderate to high current velocity, > 9 feet depth, and sandy substrates. The class is included in the terrestrial successional model to estimate the expected creation or loss of floodplain terrestrial areas.

UMRS **submersed aquatic beds** are populated by about 30 species of submersed aquatic plants. The majority of species are broad leaved or structurally complex and adapted to low flow environments (e.g., pondweeds, waterweeds), typically found in backwaters. A few species have long linear leaves that can withstand stronger currents (e.g., wild celery, sago pondweed). Most are found at depths less than 1.5 m, but their depth of occurrence decreases downstream where ambient turbidity is higher. Most species are rooted and derive nutrients from the sediment, but others (e.g., coontail) can float freely and derive nutrients from the water. Submersed aquatic plants create unique microhabitats of clear water because plants on the outer edge of a bed filter sediments as water flows through the bed. This may make beds self-sustaining, but the loss of periphery plants may ultimately lead to the degradation of the whole bed. Submersed aquatic plants are important to many UMRS animals. Macroinvertebrate communities associated with aquatic plants are typically very diverse and harbor large numbers of individuals; biomass, however, is slightly lower than in adjacent depositional communities. A few fish species feed on plants but most eat the lentic littoral macroinvertebrates found on the plants. Fish also seek refuge from predation and spawn in aquatic plants. Waterfowl feed on a variety of the plants,

Table 7. Availability of GIS data for the Upper Mississippi River System (shaded data sets were used in HNA existing condition analysis).

River Reach	Land Cover, 1975	Land Cover, 1989 Satellite	Land Cover, 1989	Aquatic Areas, 1989	Land Cover/ Aquatic	Land Cover, 1991	Land Cover, 1994	Land Cover, 1994 REEGIS	Land Cover, 1995
Upper Mississippi									
Pool 1							X		
Pool 2		X					X		
Pool 3		X					X		
Pool 4	X	X	X	X	X				
Pool 5		X	X	X	X				
Pool 5a		X	X	X	X				
Pool 6		X	X	X	X				
Pool 7		X	X	X	X		X		
Pool 8	X	X	X	X	X	X	X		X
Pool 9		X	X	X	X				
Pool 10		X	X	X	X				
Pool 11		X	X	X	X				
Pool 12		X	X	X	X				
Pool 13	X	X	X	X	X				
Pool 14		X	X	X	X				
Pool 15		X	X	X	X				
Pool 16		X	X	X	X				
Pool 17		X	X	X	X				
Pool 18		X	X	X	X				
Pool 19		X	X	X	X				
Pool 20		X	X	X	X				
Pool 21		X	X	X	X				
Pool 22		X	X	X	X			X	

Table 7. Continued.

River Reach	Land Cover, 1975	Land Cover, 1989 Satellite	Land Cover, 1989	Aquatic Areas, 1989	Land Cover/ Aquatic	Land Cover, 1991	Land Cover, 1994	Land Cover, 1994 REEGIS	Land Cover, 1995
Upper Mississippi									
Pool 24		X	X	X	X			X	
Pool 25		X	X	X	X			X	
Pool 26		X	X	X	X		X	X	
26 to Kaskaskia River		X						X	
Kas. to Grand Tower		X						X	
Gra. To Ohio River		X	X	X	X			X	
Illinois River									
Lockport		X							
Brandon		X							
Dresden		X							
Marseilles		X							
Starved Rock		X							
Peoria		X	X						
Lagrange		X		X[a]		X			
Alton		X							

a = Aquatic areas interpreted from 1991 land cover.

Table 8. HNA land cover classification.

Land Cover Classification	Land Cover Common Species
1. Open water	None
2. Submersed aquatic bed	Wild celery, coontail
3. Floating-leaved aquatic bed	Lotus, lily (often accompanied by submergents)
4. Semi-permanently flooded emergent annual	Wild rice
5. Semi-permanently flooded emergent perennial	Cattail, arrowhead, giant burreed, hardstem bulrush
6. Seasonally flooded emergent annual	Wild millet, smartweed, beggartick
7. Seasonally flooded emergent perennial	Yellow nut-sedge, sedge meadows
8. Wet meadow	Reed canary grass, rice cutgrass, prairie cord-grass
9. Grassland	Big bluestem, foxtail, roadside/levee grass
10. Scrub-shrub	Buttonbush, false indigo
11. Salix community	Willow-dominated shrubs
12. Populus community	Cottonwood-dominated floodplain forest
13. Wet floodplain forest	Silver maple, green ash, black willow
14. Mesic bottomland hardwood forest	Oaks, hickories
15. Agriculture	Cultivated fields
16. Developed	Urban, rural, residential
17. Sand-mud	Exposed sand beaches and mud flats
18. No Photo coverage-clouds	

tubers, and invertebrates in submersed aquatic beds, as do wading birds and shorebirds. Beaver and muskrats may feed on plants and tubers.

Floating–leaved aquatic beds are composed of three species of plants in the UMRS (lotus, white water lily, and yellow water lily). These plants are rooted in the substrate, and their leaves extend to the water's surface on a single stem where they spread flat. These species are restricted to low current velocity environments, usually less than 1 m deep. Lotus plants may have an emergent stage if water levels drop late in the growing season. Floating-leaved plants have simple structures and support relatively few invertebrates compared to submersed beds. The floating mats created by their leaves, however, provide feeding surfaces for insect gleaning birds and many amphibians. The shade created by the leaf mats can provide thermal refuge for fishes and turtles. Beavers and muskrats feed on the tubers and waterfowl feed on seeds.

There is only one **semi-permanently flooded emergent annual** plant – wild rice. This is an emergent species with an aquatic phase prior to the emergent phase. Species abundance is variable among years depending on hydrologic and perhaps nutrient conditions. Under favorable conditions, the seed bank responds and dense stands can develop. The emergent phase forms dense thickets of plant approaching 6 to 8 feet in height. They may occur on exposed substrates if water levels drop. Wild rice thickets provide cover for a variety of waterfowl, water birds, and marsh birds. The seeds are also a valuable food resource for many birds.

Semi-permanently flooded emergent perennials represent a wide range of plants that grow in shallow water. There are simple grass-like species of bulrushes, burreeds, and cattails; bushy multi-leaved species of water smartweeds, broadleaved arrowheads and pickerelweed; and many others. Many species are rhizominous, others grow from tubers. The community can form dense thickets at the shallow margins of stable water shorelines, but most can tolerate periods of exposure. The cover of the plants and their detritus production supports many aquatic and semi-aquatic macroinvertebrates that are fed on by small fishes and amphibians. Lentic turtles feed on emergent plants and aquatic snakes feed on the abundant small animals and fishes. Many species in this group are prolific seed producers important to dabbling ducks and other seed-eating birds and rodents. Wading birds and shorebirds feed on abundant small fishes and insects. Muskrats and beaver feed extensively on cattails and arrowhead plants and tubers. Small carnivorous mammals roam the shorelines searching for rodents and amphibians. Deer graze on and rest in the lush vegetation in the emergent plant community.

The **seasonally flooded emergent annual** community occurs on the lowest mudflats associated with backwater lakes, sloughs, and impoundments. Normally, these sites are flooded throughout much of the year and are too wet for terrestrial plant establishment. However, during brief periods of low river flow during mid to late summer, these sites are colonized by annuals such as wild millet, sedges, rice cutgrass, and (in the northern reaches) wild rice. Tree growth is restricted by saturated clayey soils. The dense, highly productive growth supported by the emergent annual community provides food, cover, and nesting habitat for reptiles and amphibians, marsh birds, and small mammals. When inundated, fish spawn in the emergent grasses and feed on insects colonizing the detritus. The detrital input is theorized to provide a significant organic energy pulse to the river. Standing vegetation may trap sand and silt during floods and help promote the development of natural levees along channel margins. Sediment accumulation above the average low water level will allow colonization by woody species, usually willow or silver maple forests.

At a slightly higher elevation above the seasonally flooded emergent annual community is the **seasonally flooded emergent perennial** community. These sites are also flooded during much of the year and are characterized by hydrophilic plants adapted to highly saturated anaerobic soil conditions. In addition to seed germination, many plants that grow on these sites persist through rhizomes and tubers. These organs allow some plants to wait out unfavorable growing conditions for several years if necessary. Characteristic plants are cattails, bulrushes, giant reed grass, arrowhead, horsetails, lotus, pickerelweed, and bur reed. Tree growth is restricted because of saturated clayey soils. The dense, highly productive growth supported by the emergent perennial community provides food, cover, and nesting habitat for reptiles and amphibians, marsh birds, and small mammals. When inundated, fish spawn in the emergent grasses and feed on insects colonizing the detritus. The detrital input is thought to provide a significant organic energy pulse to the river. Standing vegetation may trap sand and silt during floods and help promote the development of natural levees along channel margins. Sediment accumulation above the average low water level will allow colonization by woody species, usually willow or wet floodplain forests.

Wet meadow is characterized by saturated soils and standing water for brief to moderate periods during the growing season. Characteristic plants include prairie cord grass, sedges, reed canary grass, bluejoint grass, prairie dock, marsh aster, and Indian hemp. Tree growth is restricted because of saturated clayed soils and occasional fire disturbance during dry periods. A European ecotype of reed canary grass can crowd out woody species to form large monotypic meadows. The dense, highly productive growth supported by the wet meadow community provides cover and nesting habitat for reptiles and amphibians, marsh birds, and small mammals. When inundated, fish spawn in the emergent grasses and feed on insects colonizing the detritus. The detrital input is thought to provide a significant energy pulse to the river. Standing vegetation may trap sand and silt during floods and help promote the development of natural levees along channel margins. Sediment accumulation above the average low water level will allow colonization by woody species, usually willow or wet floodplain forests.

Floodplain **grasslands** are composed of mesic to xeric grasses and forbs and may occur mixed with trees as savannas. They are not frequently inundated and, if flooded post-germination, are unlikely to survive. Without disturbances of fire or mowing, the community tends to progress toward later successional woody stages. Grasslands provide forage for herbivores, abundant seeds, and cover. Some rare grasslands such as the Illinois River sand prairies support endemic species. Grassland communities have become rare because they were widely converted to agriculture and urban development on high elevation floodplains and terraces. Most former grasslands have also been leveed.

Scrub-shrub wetlands are characterized by small woody vegetation, primarily buttonbush and scattered willows that are less than 20 feet tall. Along the Upper Mississippi and Illinois Rivers, scrub-shrub wetlands represent a successional stage in the transition of an emergent wetland to a forested wetland. Buttonbush can be important to waterfowl eating nutlets and associated invertebrates. The community attracts wading birds, marsh birds, upland game birds, songbirds, beaver, and muskrats. Unless sedimentation rates are very high, this community can be relatively stable. With high rates of sedimentation, these areas are likely to convert quickly to wet floodplain forests.

Salix communities grow under full sunlight and on bare mineral soils. They are most often established on low-lying, wet, fine textured alluvium associated with backwater lakes, sloughs, side channels, inside bends of meandering tributaries, and the banks of the Illinois River. Salix communities are a pioneer stage in the development of a forested wetland. Salix stands are even-aged and short-lived. Unless disturbed, for example by active cutting from beaver and muskrat, willow stands will be replaced by silver maple and other wet floodplain forest associated species. Willow thickets attract birds, muskrats, beavers, and deer. Old relic black willows provide sites for cavity nesting and bark boring and gleaning birds. Salix communities are likely to persist 20 to 30 years and then be replaced by wet floodplain forests.

Populus communities also grow under full sunlight on bare mineral soils. They are most often established on newly formed land with better-drained sand-silt soils at the downstream ends of islands and inside bends of meandering tributaries. Like the salix community, populus communities are a pioneer stage in the development of a forested wetland. Populus stands are even-aged and may survive 50 to 100 years and achieve heights in excess of 100 feet. Populus stands regenerate naturally along the unimpounded reaches, but regeneration is poor in impounded reaches of the Upper Mississippi and Illinois Rivers. They do not provide much wildlife food beyond deer grazing saplings, but the leaf fall promotes secondary aquatic production and soil development. Communal nesting wading birds (e.g., great blue herons and great egrets) often nest in the top branches of mature cottonwood stands. This community is regularly harvested for pulpwood in some river reaches. Populus stands are likely to persist about 50 years before being overtaken by wet floodplain forests. Individual trees may survive much longer.

Wet floodplain forests occur at intermediate floodplain elevations on poorly drained soils of silt-clay on islands, riverbanks, floodplains, tributary deltas, inside bends of tributaries, and abandoned agricultural fields. The community is flood tolerant up to a few weeks each year, but can be killed if inundated for long periods during the growing season. The wet floodplain forest is the most common forest type occurring along the Upper Mississippi and Illinois Rivers. While the individual species of this association are relatively short-lived, this successional stage is long-duration because of its self-replacing nature. River impoundments, increased flood frequencies and durations, and increased sedimentation of silts and clays are suspected to have benefited the wet floodplain forest type. Mixed maple communities do not provide much wildlife food beyond deer grazing on saplings, but the leaf fall promotes secondary aquatic production and soil development. Many neotropical migrant birds feed on insects and nest in the forest canopy, branches, bark, and snags. There are several groups of reptiles and amphibians adapted to moist woodland conditions. The modern wet floodplain forest is the product of extensive harvest and, in pooled reaches, water table manipulation. Logging and inundation killed off many trees. The remaining forests are mostly even aged stands.

Mesic bottomland hardwood forests occur on high elevation floodplains with better-drained sandy and loess-derived soils on natural levees, ridges, terraces, and outside bends of tributaries. The mesic bottomland hardwood forest was once much more extensive along the Upper Mississippi and Illinois Rivers than its current limited status suggests. Natural regeneration of this type has been poor because of river impoundments, the great floods of 1973 and 1993, intensive logging, conversion to agriculture, limited seed source, elimination of associated prairies, and fire disturbance. Mast producing species are valuable to many wildlife species (e.g., squirrels and deer). Many neotropical migrant birds feed on insects and nest in the forest canopy, branches, bark, and snags. There are several groups of reptiles and amphibians adapted to moist woodland conditions. The modern wet floodplain forest is the product of extensive harvest and, in pooled reaches, water table manipulation. Logging and inundation killed off many trees. The remaining forests are mostly even aged stands. Regeneration of mesic bottomland hardwood floodplain forests is an important management concern.

Agriculture is a highly controlled and monotypic land cover class protected by levees in most floodplain areas on the lower Illinois River and south of Rock Island, Illinois, on the Mississippi River. Most floodplain agricultural areas are planted to row crops, corn or soybeans. Livestock and hayfields are also present. Interspersed with agriculture is an entire agricultural infrastructure of roads, small towns, pipelines, and railroads. Many wildlife species occur in agricultural areas and feed on crops. Some crops are planted on public lands to feed wildlife.

Developed areas include cultural features such as roads and railroads as well as small towns and large cities. The impact of small towns may be relatively benign, but large industrial cities claim large amounts of habitat, affect run-off rates, and increase pollutant loads.

Sand and mud land cover classes are primarily exposed sand bars and marginal mud flats. In upper river reaches, the class may represent large dredged material disposal sites. Natural sand bars are created through movement of sediments (e.g., point bars, sand spits, and sand bars) within river bends and around obstructions in the channel. Mud flats are typically exposed at the river’s edge and backwater margins as floods recede and backwaters evaporate. These areas are likely to be quickly colonized by pioneering trees and emergent grasses. Some fishes are associated with gradually sloping sand bars, lotic turtles nest on sand bars, and many shorebirds, gulls and terns use these areas. The endangered least tern is a sandbar nester.

5.2 Geomorphic Area

The **main navigation channel** is the designated navigation corridor marked by channel buoys and other aids to navigation. The navigation channel in most of the UMRS is 91.4 m (300 feet) wide in straight reaches and 152.4 m (500 feet) wide in bends. The main navigation channel in the upper river reaches and tributaries may be narrower. The prescribed depth of at least 2.7 m (9 feet) is maintained by navigation dams, channel training structures, and dredging. The main navigation channel extends through locks where present. The main navigation channel is usually the main channel of the river, but in some locations it is located in large secondary channels. The main navigation channel is a high current velocity environment with shifting sand substrates. The main channel usually has abundant dissolved oxygen, but winter water temperatures may be too extreme for some fish species.

Tailwaters are the areas directly downstream of the navigation dams. They have deep scour holes, high velocity, and turbulent flow. Boundaries of tailwater areas are the navigation dam upstream, the apparent shorelines, and a straight line across the channel 500 m downstream of the dam. This is a hydraulically severe environment with boulder, cobble, gravel, and shifting sand substrates. Tailwaters are also hydrologically variable. Water quality is generally good in tailwaters, although winter water temperature may be too extreme for some fish species.

Channel borders are the areas between the navigation channel and the riverbanks. Boundaries of the channel border areas are the apparent shorelines, the navigation channel buoy line, straight lines across the mouths of secondary and tertiary channels, and the inundated portions of the natural bank lines. Channel borders are narrow in upstream portions of the pools, where bank lines are steep and the main channel is narrow. Channel borders are widest in the lower reaches of the pools where the dams impound water and many former floodplains are inundated. Submerged channels can be detected with bathymetric data, but most are masked by the water's surface. Substrates vary with current velocity but include sand, mixed sand, silt, or clay, or fine silts and clays. Submersed aquatic plants, submerged logs, riprap, and wing dams (where present) provide habitat for many aquatic animals. Current velocity is generally lower than in the main channel, but water quality is usually similar to the main channel. Winter water temperatures can be extreme.

Secondary channels are large channels that carry less flow than the main channel. In some reaches, the navigation channel is located in secondary channels. Boundaries of secondary channel areas are the apparent shorelines, straight lines across the mouths of tertiary and tributary channels, and straight lines at the upstream and downstream limits of the apparent shorelines where the secondary channel connects with the main channel. Some may be obstructed at their upstream ends by closing dams or log jams that made lead to rapid filling with sediment. Secondary channel habitats can be quite variable depending on their connectivity with the main channel, age, size, and substrate. Large, highly connected secondary channels provide habitats and water quality characteristics similar to the main channel. Smaller less connected secondary channels provide lower current velocity, finer sediments, and may have more log jams and aquatic plants. Water quality declines rapidly in some Open River secondary channels when they are isolated from the river.

Tertiary channels are small channels (<30 m wide) splitting off secondary channels in island braided river reaches. The landward boundaries of tertiary channels are the apparent shorelines or inundated natural bank lines. The upstream and downstream limits of tertiary channels are straight lines between the upstream and downstream limits of the apparent shorelines where they merge with secondary channels or other aquatic features. Many tertiary channels were formed when navigation dams increased and stabilized river stages, others were inundated and can only be detected with bathymetric data. Tertiary channel habitat and water quality can be quite variable depending on their connectivity with other aquatic areas and tree cover. High current velocity tertiary channels are likely to have sand and gravel substrates and few plants. Low current velocity tertiary channels may be quite "backwater-like," with silt-clay substrates. Plants may be present if light filters through riparian forests.

Tributary channels are channels of tributary streams and rivers. The landward boundary is the line where the tributary crosses the study area boundary. The lateral boundaries are the apparent shorelines and any inundated natural bank lines. The riverward limit of the tributary channel is a line drawn across the downstream limits of the apparent shoreline where it meets another aquatic area, or where the inundated natural bank lines of tributary channels merge with another aquatic area (detected with bathymetric data). Tributary channel habitats differ with size of the stream or river. Larger streams and rivers may be important for certain migratory fishes, while small bluff line distributaries provide little habitat for river species. Tributary delta regions are sometimes highly dissected with abandoned channels, scour holes, and natural levee ridges created by the meandering of high gradient tributary channels across the erosive floodplain. The diverse physical structure of tributary deltas promotes high biological diversity. Tributary channels provide fish refuges from harsh conditions in the main channel. Many tributaries have been degraded by fine sediment and sand eroded from agriculturally developed or clear-cut watersheds. Tributary channels in leveed areas are highly controlled and channelized.

Excavated channels are constructed channels with flowing water. They may be small, connecting marinas to the river, or large enough to pass commercial traffic. The uppermost portions of the Illinois Waterway (IWW) are excavated channels dug to connect the UMRS with Lake Michigan. The IWW canal transported extreme amounts of pollution to the Illinois River and also permits exotic species introductions. A significant canal was constructed to by-pass the Chain of Rocks Rapids north of St. Louis. Habitat can be variable depending on the amount of pollution and boat activity, but the area affected is quite small.

Contiguous impounded areas are large, mostly open water areas located in the downstream portions of the navigation pools. The downstream boundaries of impounded areas are the navigation dam and connecting dikes. Landward boundaries are the apparent shorelines or the boundaries of other aquatic areas. Upstream boundaries are formed by islands and floodplain shallow aquatic zones. Riverward boundaries are channel border zones. Impounded areas vary in size and proportion of aquatic area within a pool. Pools 8 through 13 have particularly pronounced impounded areas because of their relatively long length and steep bed gradient. Southern pools and the Lower Illinois Waterway pools had relatively small or no impounded area. Upper Illinois Waterway pools and Pool 19 differ in that they are relatively deep and reservoir-like. The open river does not contain impounded areas because of the lack of dams. Impounded area habitat is variable, resulting from their size and orientation to the wind. Several pools have lost islands to erosion and do not support plants because of deep water or turbid conditions. Sediment from island erosion and upstream sources has leveled the formerly diverse topography of the now inundated floodplain. Dissolved oxygen is typically adequate for most fishes, though winter water temperatures and current velocity may be too extreme for some fishes.

Contiguous backwater floodplain lakes are hydraulically connected by surface water at low flow. The geologic processes by which they were created can be used to define many categories of backwater lakes (Wilcox 1993), but all provide similar low current velocity habitat and year-around connectivity to channel areas. Their apparent shorelines, and the point(s) at which they join other aquatic areas define contiguous backwater floodplain lake boundaries. These lakes can vary greatly in size and degree of connectivity with other aquatic areas. Sediments are variable, but are most likely to be silt, clay, or mixed sand, silt and clay. Contiguous backwater lakes provide habitat to a wide variety of plants and animals adapted to low flow conditions. Most submersed and emergent aquatic plants are adapted to the shallow, relatively clear water of UMRS backwaters. Many game fish, waterfowl, and wetland bird species live and feed on and among aquatic plants. In southern pools and the Lower Illinois Waterway fine sediments are frequently resuspended by waves, thus creating constant high turbidity that prevents aquatic plant growth. Accumulated organic matter and nutrients may lead to periods of low dissolved oxygen in stagnant water during hot summers or under ice. Water depth and depth variability are important determinants of backwater habitat quality. Low current velocity and warmer winter water temperatures make contiguous backwaters important fish overwintering habitat.

Isolated backwater floodplain lakes are floodplain water bodies that do not connect with the river at low flow. They are, however, frequently inundated during floods during which time exchanges of sediment, nutrients, plants, and animals occur. The fluvial processes by which they were created can be used to define many categories of backwater lakes (Wilcox 1993), but all provide similar habitat with no current during low river stages. Water quality (dissolved oxygen, turbidity, nutrients, etc) varies based on the water source, i.e., spring fed lakes may be quite clear and oligotrophic, while flood fed lakes may be quite turbid and eutrophic. Isolated backwater floodplain lake boundaries are defined by their apparent shoreline. Isolated backwater lakes provide habitat to a wide variety of plants and animals adapted to low flow conditions. Most submersed and emergent aquatic plants are adapted to the shallow, relatively clear water of UMRS isolated backwaters. Many game fish, waterfowl, and wetland bird species live and feed on and among aquatic plants. In southern pools and the Lower Illinois Waterway fine sediments in large lakes are frequently resuspended by waves, thus creating constant high turbidity that prevents aquatic plant growth. Small, fishless, isolated backwaters are important breeding habitats for amphibians.

Islands are landmasses completely surrounded by water. They are especially numerous in geomorphic reaches 1 through 4 and in mid-pool reaches of other pools. Islands and sand bars were once numerous in the Open River reach, but channel training and dredging has destroyed most islands since improvements for commercial navigation were initiated. Islands are generally small and numerous in northern river reaches, where small secondary and tertiary channels are common. Island size and stability generally increases as island number and channel complexity decreases in a downstream direction. Many islands in contiguous backwater impounded areas have been eroded by waves. Islands are typically sand based and capped with fine silts and clays deposited during floods. Islands are typically wooded with wet mesic floodplain forests, salix and populus communities, and colonizing herbaceous plants on point bars at their downstream ends. Islands create habitat diversity for aquatic species allowing submersed aquatic plants to grow in their “flow shadow.” Islands also provide flow refuges for fish and predator free nesting areas for birds.

Contiguous floodplain areas include all non-island terrestrial habitats subject to flooding. Small differences in contiguous floodplain physiography are poorly defined in this analysis. This is caused by a lack of high-resolution topographic data to delineate important features of floodplain terrestrial areas. Much of the contiguous floodplain is inundated each year, but the distribution of floodwaters is impossible to predict given current terrestrial elevation data. Contiguous floodplain soils are generally silt, clay or loam, but abandoned channels, ridges, and sand splays provide well-drained soils in which less flood tolerant plant species can occur. Terraces at the lateral margins of contiguous floodplains are inundated less frequently and subsequently have dryer soils. Wet mesic floodplain forests dominate the lowest elevation contiguous floodplain areas (i.e., most frequently flooded), and mesic bottomland hardwood floodplain forests occur in the higher elevation or better-drained areas. Although terraces can support savanna and grassland habitats, most have been converted to agriculture.

Isolated floodplain areas are protected from moderate flooding by constructed levees. Most of the land area protected by levees has been converted to agriculture, but urban areas and small towns are also protected. Much of the land in leveed areas has been leveled to facilitate farming, thus filling small wetlands and backwaters. Tributaries and former channels are highly channelized and water levels are often controlled with pumping stations. Soils are generally highly fertile clay and loam. Native plants communities composed of oak groves, savannas, and grasslands are largely absent since the conversion of hundreds of thousand of acres to agricultural use. Large communities of prairie birds, reptiles, and large herbivores have been either extirpated or suffer from lack of habitat.

Aquatic geomorphic areas have also been attributed with habitat modifiers, features known to affect habitat quality. **Shorelines** are difficult to define without bathymetric data, but a default buffer of 15 m was established to display the shore zone. Fish are known to congregate in structured (e.g., snags and plants) shoreline areas. **Wing dams** are rock structures usually constructed perpendicular to the flow to constrict river flow in the main channel. Wing dams create unique hydraulic eddies and scour holes in their downstream shadow that are often used by fish. Wing dams can also have negative effects where the area between wing dams becomes filled with sediment and converts to terrestrial floodplain area. **Rip rapped shorelines** are covered with large grade limestone to prevent bank line erosion and river meandering. The banks are cleared of vegetation, graded to a stable slope, and covered with rock. The rock substrate provides stable habitat for lotic erosional macroinvertebrates that frequently colonize the rock in very high densities. Fish of many types live in or in proximity to the rock structure.

5.3 Summary

The HNA land cover and geomorphic area classification system provides a hierarchical framework to define river floodplain landscapes. The 18 land cover classes contain 3 categories of aquatic habitat, 4 types of emergent marsh habitat, 2 grassland categories, 5 woody plant classes, a sand-mud class, and 2 categories reflecting cultural development. The distribution of the 18 classes can help identify average hydrologic influences and other disturbances. The 15 geomorphic classes contain 7 channel classes, 4 backwater classes, and 3 terrestrial classes. The degree of connectivity with the main channel or frequency of inundation helps identify the general habitat characteristics in terms of flow, sediment type, water quality, and potential plant communities. The HNA classification system allows for coarse modeling of potential species occurrence. Incorporating more detailed habitat attributes in GIS data layers, such as bathymetry, hydraulic models, terrestrial elevation, and water quality allows more refined habitat characterization and will provide more powerful modeling capabilities.

6 HNA Guild/Species Query Tool Development

6.1 HNA Habitat Areas Classification and GIS Database

6.1.1 Approach

UMRS GIS data were inventoried and their various attribute classifications were reviewed for use in the HNA. None of the available databases provided all the information necessary for systemic habitat analysis.

A systemic HNA Areas GIS database was developed from existing data to standardize geomorphic area (location in the river system) and land cover (plant communities and land use) classification systems. The GIS database incorporates information from existing LTRMP aquatic areas, land-water, and levee coverages to define various aquatic areas, islands, and contiguous and isolated floodplain areas (Table 9). Other fields in the database define the HNA land cover classification by re-classifying existing LTRMP land cover-land use data into units that are ecologically relevant and understandable by a wide range of users (Table 9). Common species are included in Table 9 to characterize the HNA land cover classes. The HNA habitat areas classification is compatible with, but not identical to, the Lower Mississippi River (LMR) aquatic habitat classification system because some UMRS floodplain features are not present in the LMR and vice versa. The hydrologic regime (i.e., permanently flooded, semi-permanently flooded, high frequency of flooding, moderate frequency of flooding, and low frequency of flooding) can be inferred from the HNA land cover database based on flood tolerance of plant communities. True floodplain elevation data at ecologically relevant scales are lacking for most of the UMRS.

The LTRMP 1989 land use/land cover GIS database does not precisely represent current conditions because of changes over the last ten years, but it does provide the most extensive high-resolution GIS coverage available. The HNA technical team expressed a need for more recent data, but accepted the 1989 coverage as a reasonable representation of river habitats. Updated data sets are available from the LTRMP for some locations on the river (See Table 7). Land cover-land use data developed from 1994 aerial photography is also available from the U.S. Army Corps of Engineers, St. Louis District (See Table 7). These data were converted from Intergraph GIS software to Arc Info format and reclassified to match the HNA land cover classification.

The 1989 HNA land cover GIS database was also updated to include project boundaries for HREP project areas. Updated land cover data for HREP areas were not created, but links to the HREP database provide information on project goals and objectives.

Spatial data are formatted as Arc Info and Arc View compatible files stored at the UMESC. Metadata were prepared to meet US Department of Interior and Corps of Engineers standards. The data are distributed on CD with the HNA query tool.

6.1.2 GIS Database

The LTRMP data inventory is summarized in Table 7. Land cover data interpreted from 1:15,000 color infrared aerial photography collected during late summer 1989 are available for pools 4 to 26, Peoria, and the Cape Girardeau reach (river miles 0 to 80). Additional land cover data are available for a subset of pools for 1975, 1991, 1992, 1994, and 1995. In addition to LTRMP, the Corps of Engineers, St. Louis District supplied 1994 land

Table 9. HNA Geomorphic areas and land cover classification.

Geomorphic Area	Land Cover Classification	Land Cover Common Species
Main navigation channel	Open water	None
Channel border	Submersed aquatic bed	Wild celery, coontail
Tailwater	Floating-leaved aquatic bed	Lotus, lily (often accompanied by submergents)
Secondary channel	Semi-permanently flooded emergent annual	Wild rice
Tertiary channel	Semi-permanently flooded emergent perennial	Cattail, arrowhead, giant burreed, hardstem bulrush
Tributary channel	Seasonally flooded emergent annual	Wild millet, smartweed, beggartick
Excavated channel	Seasonally flooded emergent perennial	Yellow nut-sedge, sedge meadows
Contiguous backwater floodplain lake	Wet meadow	Reed canary grass, rice cutgrass, prairie cord-grass
Backwater shallow aquatic area	Grassland	Big bluestem, foxtail, roadside/levee grass
Backwater impounded area	Scrub-shrub	Buttonbush, false indigo, swamp privet
Isolated backwater	Salix community	Willow-dominated shrubs
Island	Populus community	Cottonwood-dominated floodplain forest
Contiguous floodplain	Wet floodplain forest	Silver maple, green ash, black willow
Isolated floodplain	Mesic bottomland hardwood forest	Oaks, hickories
	Agriculture	Cultivated fields
Habitat modifiers – shoreline	Developed	Urban, rural, residential
wing dam	Sand-mud	Exposed sand beaches and mud flats
rip-rap	No Photo coverage/clouds	

cover data for the Mississippi River portion of the District. These data were classified differently than the LTRMP data and were thus reclassified to match the HNA areas. There was similar resolution of woody plant classes, but herbaceous classes were much less refined in the St. Louis District data. In addition to detailed land cover data, Landsat satellite imagery collected during summer 1989 is available for the entire UMRS (except Pool 1). Aquatic areas were defined using the 1989 land cover data (or 1991 for La Grange pool) for the pooled reaches 4 through 26, La Grange Pool, and the Cape Girardeau reach. The land cover and aquatic areas coverages, where available, were merged to create the HNA coverages used in the query tool.

The land cover portion of the systemic HNA habitat areas GIS database was created by reclassifying existing 1989 data using the look-up table in Appendix A. Aerial photography data were available for most of the river, except pools 1 through 3, Mississippi River miles 80 to 201, Illinois River miles 0 to 80, and the Upper Illinois River (see Table 7). Lower resolution satellite data will be used where aerial photography data are lacking to provide systemic land cover coverage. Users will be able to select from several types of data in some locations including satellite data and aerial photograph data from multiple years. The geomorphic areas of the HNA systemic habitat areas were compiled from aquatic areas obtained from the LTRMP databases and existing coverages of leveed areas. Aquatic area maps were available for about the same range as the aerial photography data. Aquatic area habitat attributes were enhanced by including wing dams, closing dams, rip rapped shorelines, and 15-meter shoreline-wing dam buffers. Islands were identified through a GIS routine that isolated all landmasses surrounded by water. Contiguous and isolated (by levees) floodplain areas were identified and isolated using existing maps of levees obtained from the Scientific Assessment and Strategy Team formed following extreme flooding in 1993 (IFMRC 1994). Analysis of the coverages is presented in the Existing Conditions analysis (see Chapter 7).

The 1989 data do not reflect current conditions, but were deemed acceptable for most of this analysis. Forests in the USACE St. Louis District, however, were greatly affected by flooding in 1993 (adult tree mortality up to 30%; Yin 1999), so 1994 data available from the St. Louis District were converted from Intergraph GIS software format to Arc View format to update the database.

Spatial data used for this analysis are storeed at the U.S. Geological Survey – Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. Metadata conforming to Federal government reporting standards are available and the query tool automatically creates a record of all queries. The spatial data used in this analysis will be distributed on CD along with the computer program to use the HNA query tool with Arcview GIS software.

6.2 HNA Species and Guild Approach

A literature search was conducted to review previously developed ecological guild classifications and to relate UMRS species and guilds to HNA habitat area classes. A list of species occurring on the UMRS was developed with some groups of organisms (plants, aquatic macroinvertebrates, freshwater mussels, fish and reptiles and amphibians) being assigned to guilds, or groups of organisms that use environmental resources in a similar way (Root 1967, Balon 1975, Simberloff and Dayan 1991, Austen et al. 1994). Each guild was described in narrative form. Adult stage habitat needs (except aquatic insects) were associated with HNA geomorphic areas and land cover classes in matrices. All associations were based on describing the summertime distribution of adult animals (except aquatic insects). The limitations of the data (i.e., old data, single season, few data layers, etc.) make precise predictions of potential habitat difficult consequently, query tool results must be considered as overestimates of potential species/guild occurrence. Many aquatic organisms require unique habitat characteristics that are not easily mapped without bathymetric, flow, and water quality data layers. In the terrestrial realm, elevation, forest composition, and forest understory data would improve habitat modeling capabilities.

In addition to scientific names for individual species, common names were assigned to aid public understanding. Representative species and species with high commercial, recreational, or cultural value were identified for each guild (Appendices B through H). Known and suspected ecological bottlenecks (i.e., factors influencing survival from younger to older developmental stages) and specific habitat needs that cannot be queried will be identified for each species or guild and displayed as warnings in the model ("pop-up window", see Query Tool Users Manual; Appendices B through H). The warnings emphasize limitations of the systemic GIS query tool.

Some species are not naturally distributed throughout the river system and dams restrict the distribution of other species. For example, cypress swamps are naturally restricted to the southern tip of the UMRS and skipjack herring are not abundant north of Pool 19 because the dam creates a barrier to migration. Where species distributions are not systemic, flags are displayed and users are alerted to carefully interpret query results. Because the distribution of many species is not well known, we selected arbitrary lines of demarcation to separate pools 1 to 13, pools 14 to 26, the Open River reach, and the Illinois River. Most species are widely distributed or their distribution is unknown.

6.3 HNA Guild Classifications

The UMR supports a large number of species including the following: over 200 aquatic macroinvertebrate species, 30 mussel species, 150 fish species, 73 reptile and amphibian species, over 300 bird species, and over 50 mammal species (Appendices B through H), not to mention the vast number (>600) of plant species. This large number of species was organized by developing separate guilds of aquatic macroinvertebrate, mussel, fish, and herpetofauna species that exhibit similar life history requirements. Birds, mammals, herpetofauna, and some fish are considered at species level because much is known of their life history. The guilds selected for this study, listed in Table 10, are described individually below. Species are not described here. Readers are referred to appropriate field guides and texts describing species' life histories at the beginning of each appendix.

6.3.1 Lotic Erosional Macroinvertebrates

Lotic erosional macroinvertebrates are found in main channel, channel border, and swift flowing secondary and tertiary channels. They are most abundant clinging to structures such as snags, riprap, and wing dams. However, some species are adapted to life in the shifting sands at the bottom of the channel. Many life history strategies have evolved to permit existence in this high flow environment.

Tube building and net spinning are common adaptations that macroinvertebrates employ to survive in high flows. The net spinning caddis flies (Hydropsychidae) construct fine meshed nets on rock, wood, or animal substrates to provide flow refuge and to filter fine organic material as water flows through the net. They are frequently the most abundant taxa in lotic environments.

Table 10. Biological guilds used in the HNA query tool. References refer to papers that present well-defined guilds for plants, aquatic macroinvertebrates, and fish. Mussel and herpetofauna guilds were developed for this project and species were assigned with information in the listed reference. UMRS fish species were assigned to aquatic habitat guilds by Robert Hrabik, Missouri Department of Conservation, Cape Girardeau, Missouri.

Biological Guild	Reference
Macroinvertebrates	Merritt and Cummins 1996; Pennak 1978
Lotic-Erosional)	
Lotic Depositional	
Lentic Limnetic	
Lentic-Littoral	
Lentic Profundal	
Freshwater Mussels	Cummings and Mayer 1992
Lotic erosional	
Lotic depositional	
Lentic	
Fish	Poddubny and Galat 1995
Limnophil	
Limno-Rheophil	
Pelagic Limno-Rheophil	
Rheo-Limnophil	
Rheophil	
Amphibians and Reptiles	Tucker and Theiling (this study)
Aquatic Salamanders	
Terrestrial Salamanders	
Terrestrial Frogs and Toads	
Aquatic Frogs	
Arboreal Frogs	
Lentic Turtles	
Lotic Turtles	
Terrestrial Turtles	
Woodland Lizards	
Prairie Lizards	
Woodland Snakes	
Prairie Snakes	
Aquatic Snakes	

Many chironomid species (Chironomidae) construct tubes from particulates in their environment to shelter themselves from high flows. Other adaptations include dorso-ventral flattening (mayflies and stoneflies) that permit organisms to shelter themselves in a hydraulic boundary layer near rock surfaces where flow is low, or secretive behaviors that keep organisms secluded in gaps and crevices in their environment. A final adaptation is exclusive to an exotic invader – the zebra mussel (*Dreissena polymorpha*). Zebra mussels secrete byssal threads that tightly bond the organisms to their substrate.

This guild is preyed upon by a variety of fishes. These macroinvertebrates are frequently dislodged and drift in the current to the benefit of filter feeding fishes such as paddlefish. Most drift until they settle on suitable substrate. Mass emergences are common and attract swarms of swallows and other aerial foraging birds. Many species are indicators of good water quality.

Representative species include the following the following: Diptera (Chironomidae; *Polypedilum convictum, Rheotanytarsus* sp.), Ephemeroptera (Heptageniidae, Heptageniidae), and Trichoptera (Hydropsychidae). The recently arrived zebra mussel is also an inhabitant of this environment. A species list (not comprehensive) compiled from several UMRS macroinvertebrate studies is included in Appendix B.

6.3.2 Lotic Depositional Macroinvertebrates

Lotic depositional macroinvertebrates are found in the soft substrates of low current velocity channel habitats. They include a variety of worms (Annelida), midges (Diptera; Chironomidae), burrowing mayflies (Ephemeridae), and fingernail clams (Sphaeriidae). Under proper conditions, high population density is possible.

Most members of this guild burrow in the substrate where they feed and seek refuge from predation. The economically important mayflies and fingernail clams are filter feeders that derive energy from interstitial and overlying waters. Midges and worms feed primarily on algae and detritus in the sediment, but many feeding strategies may be exhibited.

This guild is of great food value to many bottom foraging fishes, shorebirds, waterfowl, and aerial foraging birds and bats. Many species are indicators of good water quality. When population density is high, mass emergences can be a nuisance.

Representative species include the following the following: Chironomids (midges), burrowing mayflies, and fingernail clams. A species list (not comprehensive) compiled from several UMRS macroinvertebrate studies is included in Appendix B.

6.3.3 Lentic Limnetic Macroinvertebrates

Lentic limnetic macroinvertebrates include the group of invertebrates that float or swim in the water column. Though a little small to be classified as macroinvertebrates, pelagic zooplankton can be considered in this group along with a common Dipteran *Chaoborus* sp., the phantom midge, which migrates from the bottom up into the water column at night.

Guild members inhabit non-flowing, contiguous and isolated backwaters where they feed on algae suspended in the water column. They are likely to be swept into channel areas during high flow periods and may be transported from contiguous backwaters to the river by convection currents during low flow periods (Schaeffer and Nickum 1986).

This group of invertebrates makes up an important part of the diet of planktivorous, filter feeding fishes, and the young of many fish species. Waterfowl that filter feed in open water also benefit from this macroinvertebrate guild.

Representative species include the following: phantom midges (*Chaoborus* spp.), and pelagic zooplankton. A species list (not comprehensive) compiled from several UMRS macroinvertebrate studies is included in Appendix B.

6.3.4 Lentic Littoral Macroinvertebrates

Lentic littoral macroinvertebrates are found among the vegetation in shallow backwaters and channel border habitats. This is a complex guild that supports very high densities of invertebrates ranging from the very small zooplankton to large predaceous beetles. Generally, the community consists of herbivores that feed on the algae growing on plant leaves (mayflies, caddis flies), detritivores consuming decomposing plant material (amphipods, chironomids), and a group of primary predators (beetles, dragonflies, damselflies, true bugs) that feed on the smaller species.

Organisms in this guild are found primarily in shallow, vegetated, contiguous and isolated backwaters. They may occur in plant beds in channel habitats, but would be susceptible to being dislodged by current and swept up in the drift. Some species are likely to be swept into channel areas during high flow periods. Many species migrate along the rising edge of the floodwaters and feed on decaying terrestrial vegetation.

Fish, waterfowl, and shorebirds feed on many types of lentic littoral macroinvertebrates.

Representative species include the following: Odonata (dragonflies and damselflies), Trichoptera (case building caddisflies), amphipods (scuds), Ephemeroptera (caenid mayflies), Diptera, and worms. A species list (not comprehensive) compiled from several UMRS macroinvertebrate studies is included in Appendix B.

6.3.5 Lentic Profundal Macroinvertebrates

Lentic profundal macroinvertebrates are typically found in the deep open water of backwater lakes. They are generally detritivores that burrow in soft, silty clay. The most common organisms are worms and large chironomids, but predaceous Diptera (Ceratopoginidae, biting midges) are also common. Many species are adapted to survive periods of low dissolved oxygen concentrations.

This guild is found primarily in deep backwaters, but can also be found in shallow areas where aquatic vegetation is lacking. In some Mississippi and Illinois River backwaters where vegetation is lacking, this is the most abundant guild.

The animals may occur too deep for diving waterfowl and shorebirds, but they are an important part of the diet of many bottom foraging fishes.

Representative species include the following: Worms, Diptera (*Chironomus* sp., *Ceratopogonidae* sp., *Chaoborus* sp.). A species list (not comprehensive) compiled from several UMRS macroinvertebrate studies is included in Appendix B.

6.3.6 Lotic Erosional Freshwater Mussels

Most freshwater mussels (Unionidae) are found in flowing water habitats where they bury their posterior end about two-thirds into the substrate. They are filter feeders that take river water in through a siphon, absorb organic particles, coagulate and expel inorganic material, and expel the water. A single mussel can filter several gallons of water each day. They are typically found in large concentrations (beds). Freshwater mussels require a fish host to complete their life cycle.

This guild is found primarily in swift flowing channel habitats, with cobble, gravel, or sand/gravel substrates. High dissolved oxygen concentrations and river currents are necessary for this guild.

Muskrats eat adult mussels and bottom foraging fish eat juveniles. Mussels also provide substrate for lotic erosional macroinvertebrates and their beds attract fishes necessary to host broods of glochidia. Mussels are commercially harvested to support the cultured pearl industry.

Representative species include the following: deer toe, pink heelsplitter, spike, sandshells, and papershells. A comprehensive list and scientific names are listed in Appendix C.

6.3.7 Lotic Depositional Freshwater Mussels

This guild is found primarily in moderate flow channel habitats, with sand-clay or silt-clay substrates with some species being more tolerant of silt than others. This guild is somewhat more tolerant of lower dissolved oxygen concentrations and more silt than the lotic erosional guild, but other characteristics are similar.

Representative species include the following: Threeridge, washboard, muckets. A comprehensive list and scientific names are listed in Appendix C.

6.3.8 Lentic Freshwater Mussels

There is one group of mussels, floaters, adapted to life in backwater habitats. They have life histories similar to other freshwater mussels but have a special adaptation to accumulate air and float from one spot to another. They are also more tolerant of silt substrates. This guild is found most often in contiguous backwaters and permanent isolated backwaters.

Representative species include the following: floaters. A comprehensive list and scientific names are listed in Appendix C.

6.3.9 Rheophilic Fish

Rheophilic fishes are found in swift-flowing main and secondary channel habitats. They have physical and behavioral adaptations that allow them to survive in the high-flow environment. Species adaptations include living at the bottom of the river where currents are slower and seeking shelter in flow refugia such as dike fields and snags.

Shovelnose sturgeon are commercially fished in some areas, however other sturgeon species require protection from commercial harvest. Catfish species are common in both the commercial and recreational catch. The minnows and suckers may be preyed upon by a variety of channel dwelling picivorous fishes and fish-eating birds. Several of the chubs and darters are rare. The blue sucker was once a predominant species in the commercial catch, but the abundance has declined since large riffles and rapids were inundated by the navigation system.

Representative species include the following: Shovelnose sturgeon, pallid sturgeon, lake sturgeon, blue catfish, channel catfish, speckled chub, flathead chub, sicklefin chub, silver chub, blue sucker, stonecat, freckled madtom, western sand darter, plains minnow, and crystal darter. A comprehensive list and scientific names are listed in Appendix D.

6.3.10 Rheo-Limnophilic Fish

This guild is similar to the Rheophils in that they too have behavioral and physical adaptations to moderate flow. In addition to bottom dwelling, some species show streamlined shapes that ease swimming in high velocity current. While adapted for life in channel habitats, members of this guild may also occur in backwaters. Some species may use or require inundated floodplains.

The American eel, catastomids, and catfish species are important in the commercial catch in many parts of the UMRS. Recreational fishers seek flathead catfish and sauger. The minnow and herring species are preyed upon by picivorous fishes and fish-eating birds.

Representative species include the following: Chestnut lamprey, longnose gar, shortnose gar, American eel, skipjack herring, goldeye, mooneye, Mississippi silvery minnow, emerald shiner, ghost shiner, river shiner, red shiner, silverband shiner, sand shiner, blacktail shiner, channel shiner, bullhead minnow, black buffalo, shorthead redhorse, river redhorse, flathead catfish, brook silverside, river darter, and sauger. A comprehensive list and scientific names are listed in Appendix D.

6.3.11 Limno-Rheophilic Fish

Limno-Rheophilic fishes are species that are primarily adapted for low current velocity, backwater habitats. They can tolerate moderate current velocity for short periods or may seek areas in channel habitats where they can find adequate refuge from strong currents. They can be found in both channel and backwater habitats. Many species are also likely to occur in inundated floodplains.

Common carp and the catastomid species are major components of the commercial fishery. Smallmouth bass, yellow perch, and walleye are among the most popular game fish on the UMRS. The shiner species are prey for piscivorous fish and birds.

Representative species include the following: Spotted gar, common carp, pugnose shiner, spottail shiner, weed shiner, quillback, river carpsucker, highfin carpsucker, spotted sucker, silver redhorse, golden redhorse, smallmouth bass, mud darter, bluntnose darter, johnny darter, yellow perch, and walleye. A comprehensive list and scientific names are listed in Appendix D.

6.3.12 Pelagic Limno-Rheophilic Fish

This guild of fishes is found in low current velocity portions of the water column in backwaters and channel habitats. They may tolerate higher current velocity, but will seek refuge from high current velocities.

The paddlefish (*Polyodon spathula*) is a species known to make seasonal longitudinal migrations. It is a component of the recreational and commercial fishery in some UMRS reaches, but restricted in others. The buffalo, which spawn in inundated floodplains, are also commonly caught commercial fishes. The species feed on drift in the water column or may scour the bottom dislodging benthos.

Representative species include the following: Paddlefish, bigmouth buffalo, and smallmouth buffalo. A comprehensive list and scientific names are listed in Appendix D.

6.3.13 Limnophilic Fish

Limnophilic fish are those species common to lakes and backwaters. They are not strong swimmers and do not tolerate high current velocity for long periods. They may also be strongly oriented toward vegetated habitats where they feed on invertebrates living among the vegetation. Most species are likely to be found in inundated terrestrial areas. Many species are opportunistic feeders, some are specialized insectivores, and others are piscivores.

Many centrarchids and northern pike are popular game fish whose management is an important goal of natural resource agencies. The gizzard shad is highly abundant and is preyed upon by many fishes and birds.

Representative species include the following: Gizzard shad, threadfin shad, black bullhead, yellow bullhead, tadpole madtom, northern pike, central mudminnow, green sunfish, warmouth, orangespotted sunfish, bluegill, largemouth bass, white crappie, and black crappie. A comprehensive list and scientific names are listed in Appendix D.

6.3.14 Aquatic Salamanders

Aquatic salamanders are found in mostly lentic environments, though the larger hellbender and sirens may seek low current velocity refuge in channel habitat. Smaller individuals consume crayfish, insects, snails and worms, while larger individuals may eat small fish. The central newt has a terrestrial eft stage, the others are fully aquatic.

The mud snake preys on sirens and amphiuma. Fishes may prey on other species' eggs and young. Newts may be preyed on by wading birds.

Representative species include the following: hellbenders, sirens, newts, amphiuma, and mudpuppies. A comprehensive list and scientific names are listed in Appendix E.

6.3.15 Terrestrial Salamanders

Terrestrial salamanders include many species adapted to the moist forest floor environment and wet caves. They are secretive creatures that hide under logs, rocks, and moss. Most terrestrial salamanders feed on insects, snails and worms. Breeding occurs primarily in fishless woodland ponds and moist areas under logs on the forest floor.

If present in breeding areas, fish will eat salamander eggs and young. Snakes and small mammals may hunt them out also, but their secretive behavior largely protects them from predation.

Representative species include the following: eastern tiger salamander, smallmouth salamander, and spotted salamander. A comprehensive list and scientific names are listed in Appendix E.

6.3.16 Terrestrial Frogs and Toads

Terrestrial anurans include spadefoots, toads, and true frogs. The spadefoots, Fowler's toad, and chorus frogs are likely to be found in sandy grassy or rocky areas. The American toad is more common in wooded areas. Most are nocturnal and prefer warm wet nights. The eastern narrowmouth toad and wood frog are found in wooded areas. The northern crawfish and green frogs are likely to be found in wooded riparian areas.

Terrestrial anurans are preyed upon by a variety of snakes, birds, and small mammals. If present in breeding areas, fish will eat frog eggs and young.

Representative species include the following: spadefoots, Fowler's toad, chorus frogs, American toad, eastern narrowmouth toad, wood frog, northern crawfish, and green frogs. A comprehensive list and scientific names are listed in Appendix E.

6.3.17 Semi-Aquatic Frogs

The semi-aquatic frogs are true frogs with a high affinity for water bodies. Cricket frogs are found along the shorelines of lakes and ponds. Leopard frogs are found near water but venture into grassy areas to feed. The pickerel frog is restricted to cool tributary streams. The bullfrog is the most highly aquatic, found in backwater lakes and slow-moving channels.

Semi-aquatic anurans are preyed upon by a variety of snakes, birds, and small mammals. If present in breeding areas, fish will eat frog eggs and young.

Representative species include the following: true frogs (*Rana* spp.). A comprehensive list and scientific names are listed in Appendix E.

6.3.18 Aquatic Frogs

The aquatic frogs are true frogs that spend the majority of the time in water. The bullfrog is the most highly aquatic, found in backwater lakes and slow-moving channels.

Aquatic anurans are preyed upon by a variety of snakes, birds, and small mammals. If present in breeding areas, fish will eat frog eggs and young.

Representative species include the following: bullfrog and northern Blanchard's cricket frog. A comprehensive list and scientific names are listed in Appendix E.

6.3.19 Arboreal Frogs

Tree frogs can be found in most areas where there are trees in proximity to water. Green tree frogs are associated with swamps and cattails in southern Missouri. Other tree frogs and spring peepers are widespread and common in forests with isolated ponds, along wooded lake shorelines, and in riparian buffer forests. Most frogs in this guild are nocturnal.

Representative species include the following: tree frogs (*Hyla* spp.) and spring peeper (*Pseudacris crucifer*). A comprehensive list and scientific names are listed in Appendix E.

6.3.20 Lentic Turtles

Lentic turtles include snapping, mud, musk, and basking and marsh turtles. Most can be found in a variety of low flow UMRS environments. Blanding's, chicken, and stinkpot turtles are common on land, but the remainder remain under water or bask on objects near water. The map turtles and cooters have a slightly higher affinity for flowing water. The snapping turtles are almost entirely aquatic.

Representative species include the following: snapping, map, mud, painted, and red-eared slider turtles. A comprehensive list and scientific names are listed in Appendix E.

6.3.21 Lotic Turtles

Softshell turtles represent the lotic turtle guild. These are dorso-ventrally flattened species that prefer sandbar and mudflat habitats. They are frequently buried in the substrate with only their heads exposed.

Species include: smooth softshell turtle and spiny softshell turtle. Scientific names are listed in Appendix E.

6.3.22 Terrestrial Turtles

Box turtles and wood turtles comprise the terrestrial turtles found in the UMRS. The ornate box turtle exhibits a preference for grassy areas and open woodlands. The eastern box turtle and wood turtle prefer moist wooded areas and open wooded areas.

Species include: ornate box turtle, eastern box turtle, and wood turtle. Scientific names are listed in Appendix E.

6.3.23 Woodland Lizards

Woodland lizards include species that prefer open woods and forest edges. The guild includes most skinks and fence lizards. Most species prefer rocky, craggy areas with leaf litter and snags where they can quickly find refuge from predators.

Representative species include the following: fence lizard, five-lined skink, and broadhead skink. A comprehensive list and scientific names are listed in Appendix E.

6.3.24 Prairie Lizards

Prairie lizards include the prairie skink, the six-lined racerunner, and the legless slender glass lizard. All members of the guild prefer open grassy areas with loose or gravelly soils. They are likely to be found in open woods also.

Species include: prairie skink, six-lined racerunner, and slender glass lizard. Scientific names are listed in Appendix E.

6.3.25 Woodland Snakes

Many snake species occur in the UMRS. Most use open wooded hillsides during the spring and can be found along forest edges during the summer. Species included in this guild prefer forested areas and scrub-shrub habitat, some may be considered arboreal.

Common species include: eastern garter snake, timber rattlesnake, and black rat snake. A comprehensive list and scientific names are listed in Appendix E.

6.3.26 Prairie Snakes

There are many species included in the prairie snake guild, but their habits and habitats are varied. Many will use open wooded areas and wooded hillsides during some parts of the year. Many will also prefer gravel splays and rock outcrops. Most will usually be found in open grassy and wet meadow areas.

Representative species include the following: plains garter snake, hognose snakes, and kingsnakes. A comprehensive list and scientific names are listed in Appendix E.

6.3.27 Aquatic Snakes

There are seven true aquatic species in the aquatic snake guild. Most are associated with backwater edges and marshy habitats. They are likely to be found in all low current velocity channel areas and backwaters.

Representative species include the following: diamondback water snake, northern water snake, and Graham's crayfish snake. A comprehensive list and scientific names are listed in Appendix E.

6.3.28 Birds and Mammals

Birds and mammals were not assigned to guilds. Species lists are presented in appendix F and G.

6.4 Task 1.3 HNA Area and Species/Guild Matrices

6.4.1 Approach

A series of tables were developed to link species and guilds with habitat areas (Table 11; Appendices H and I). Overestimates of potential species/guild occurrence are very likely because many species prefer very distinct microhabitats that could not be defined at the scale of the HNA areas data. All species and guilds were associated with the HNA areas classes that encompass the entire UMRS. The likely potential occurrence for species and guilds was rated using a scale from 0 to 3:

0 = no potential occurrence,
1 = low potential occurrence,
2 = moderate potential occurrence,
3 = high potential occurrence.

Potential species occurrence scores were based on adult stage, summertime life history requirements. References used to assign scores are listed at the beginning of Appendices B through E.

Selected habitat/guild associations (e.g., soft-substrate benthic macroinvertebrates, fish, breeding birds) should be examined and verified if possible using existing spatial data on organism distributions from the LTRMP, States, and other agencies. The certainty of habitat/guild associations will be estimated for fish, macroinvertebrates, and breeding birds when advanced query tools are developed. Information needed for more complete habitat assignments for each guild or species will be identified.

6.4.2 Matrix Development

The HNA area and species/guild matrices were scored 0 to 3 as described above using life history information in published reports and in consultation with regional experts (Appendices H and I; see Table 11). The guild approach was most useful where there are large numbers of species in a class of organisms, where life histories are not well known, and where many habitat generalists occur. Guilds, except birds and mammals because of their wide-ranging habits, were scored for both the geomorphic areas and land cover databases. Birds and mammals were only scored for land cover data.

Aquatic macroinvertebrate species were classified by Chuck Theiling (U.S. Geological Survey, Upper Midwest Environmental Science Center, La Crosse, Wisconsin) according to guilds presented by Merritt and Cummins (1996). Life history information was supplemented with additional texts listed in Appendix B. The specific life histories of most species are not well known so the guild approach was quite useful for the large number of species in this group. Scoring was accomplished by relating general habitat attributes of the HNA areas to the habitat requirements of broadly defined aquatic macroinvertebrate guilds. Overestimates of potential habitat are very likely because many species of macroinvertebrates prefer very distinct microhabitats that could not be defined at the scale of the HNA areas data.

Freshwater mussel species were scored by Chuck Theiling (U.S. Geological Survey, Upper Midwest Environmental Science Center, La Crosse, Wisconsin) using information in Cummings and Mayer (1992). Because either the needs of individual mussel species habitat are not well known, or habitat needs are similar among species, the guild approach was used. Basing mussel distribution on the limited information provided by the HNA areas will lead to gross overestimates of habitat. Detailed bathymetry, current velocity, and substrate data are needed to improve estimates of potential mussel habitat.

Table 11. HNA reptile and amphibian guild geomorphic area and land cover matrices.

	Habitat Modifiers (1 or 0)			**Aquatic**											**Terrestrial**		
				Channel Areas							Backwater Areas				Islands	Floodplain	
				main			secondary	tertiary	tributary	excavated	contiguous			isolated		contiguous	isolated
Guild	shoreline	wing dam	rip-rap	nav. Channel	channel border	tailwater					FP lake	shallow AQ	impounded				
Lotic Aquatic Salamanders	0	1	1	0	2	3	2	1	2	0	0	0	1	0	0	0	0
Lentic Aquatic Salamanders	1	0	0	0	0	0	0	0	1	0	1	3	1	3	2	3	1
Terrestrial Salamanders	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	1
Terrestrial Frogs and Toads	1	0	0	0	1	0	1	1	2	1	2	3	2	3	0	3	2
Semi-Aquatic Frogs	1	0	1	0	2	1	2	2	1	2	3	3	2	3	1	3	3
Aquatic Frogs	1	0	1	0	2	2	3	3	3	3	3	1	3	2	2	3	3
Arboreal Frogs	1	0	0	0	0	0	0	0	0	0	1	1	1	3	0	1	2
Lentic Turtles	1	1	1	1	2	1	3	1	2	2	3	1	3	2	3	3	2
Lotic Turtles	1	1	1	1	3	2	3	1	2	1	3	1	2	0	2	2	0
Terrestrial Turtles	1	0	0	0	1	0	0	0	1	0	1	1	1	1	0	3	3
Woodland Lizards	1	0	0	0	2	0	2	2	2	0	1	0	2	2	0	2	3
Prairie Lizards	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	2	3
Woodland Snakes	1	0	0	0	1	0	1	0	2	0	1	1	1	1	0	2	1
Prairie Snakes	1	0	1	0	1	0	1	1	2	1	2	3	3	3	0	3	3
Aquatic Snakes	1	1	1	0	3	1	3	1	2	1	3	1	2	2	1	3	1

0 = no potential occurrence,
1 = low potential occurrence,
2 = moderate potential occurrence,
3 = high potential occurrence.

Table 11. Continued.

	Open Water	Submersed Aquatic Bed	Floating-Leaved Aquatic Bed	Semi-Permanently Flooded Emergent Annual	Semi-Permanently Flooded Emergent Perennial	Seasonally Flooded Emergent Annual	Seasonally Flooded Emergent Perennial	Wet Meadow	Grassland	Scrub/Shrub	Salix Community	Populus Community	Wet Floodplain Forest	Mesic Bottomland Hardwood Floodplain Forest	Agriculture	Developed	Sand/Mud
Lotic Aquatic Salamanders	3	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Lentic Aquatic Salamanders	1	3	3	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Terrestrial Salamanders	0	1	1	1	1	1	1	3	1	0	0	0	2	3	0	0	0
Terrestrial Frogs and Toads	0	0	0	0	2	2	3	2	3	0	0	0	1	1	2	1	0
Semi-Aquatic Frogs	1	1	2	0	2	2	2	2	1	1	1	1	1	1	1	1	1
Aquatic Frogs	1	1	3	1	3	1	1	1	0	0	0	0	0	0	2	1	2
Arboreal Frogs	0	0	1	0	1	2	2	2	0	1	1	1	3	2	1	1	0
Lentic Turtles	1	3	3	1	2	1	1	0	0	0	0	0	1	1	2	2	1
Lotic Turtles	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Terrestrial Turtles	0	0	0	0	1	0	1	3	1	1	0	0	3	3	1	1	0
Woodland Lizards	0	0	0	0	0	0	0	1	1	1	0	1	3	3	1	2	0
Prairie Lizards	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0
Woodland Snakes	0	0	0	0	0	0	0	1	0	0	0	1	3	3	0	0	0
Prairie Snakes	0	0	1	1	1	2	2	3	1	1	1	1	2	1	2	1	1
Aquatic Snakes	2	2	2	1	1	1	1	0	0	1	1	1	0	0	0	0	0

0 = no potential occurrence,
1 = low potential occurrence,
2 = moderate potential occurrence,
3 = high potential occurrence.

Fish matrices (common species and guilds) were scored by regional experts using regional texts and local knowledge. Mr. Robert Hrabik (Missouri Department of Conservation, Cape Girardeau, Missouri) and Mr. John Pitlo (Iowa Department of Natural Resources, Bellevue, Iowa) each scored the matrices individually. They scored the matricies considering potential species occurrence through the whole year rather than just summer. Their scores were then compared and the highest score was applied to the matrix. This approach increases the already apparent overestimates of habitat imposed by lack of sufficient data describing habitat. Detailed habitat data including bathymetry, current velocity, aquatic plant, and substrate data are needed to refine GIS queries of potential habitat. Also, many fish species have different seasonal habitat needs for spawning, rearing, feeding, and overwintering that are not incorporated into this version of the GIS query tool.

The reptile and amphibian species and guilds matrices were scored by Mr. John Tucker (Illinois Natural History Survey, Great Rivers Field Station, Brighton, Illinois). The scores were applied in consultation with regional texts and local knowledge. Overestimates of potential habitat are likely to occur because of the limited information on microhabitat availability. Terrestrial soils and forest understory plant data would greatly improve microhabitat definition. Also, identification of woodland pools and ephemeral water bodies throughout the floodplain would help refine estimates of potential breeding habitat.

Regional experts using regional texts and local knowledge scored the bird-by-land cover matrix. Dr. Eileen Kirsch, Ms. Jenny Sauer, Mr. Tim Fox, and Dr. Carl Korschgen (all, U.S. Geological Survey, Upper Midwest Environmental Science Center, La Crosse, Wisconsin) scored the matrix in a group setting with individual review. Overestimates of potential bird habitat are likely because of the resolution of the HNA area data. Many bird species use specific forest types, specific understory plant communities, require forests of different ages, or use edge habitats that are not defined in the HNA GIS database. Aquatic birds usually require specific depths, rather than specific aquatic areas, so databases that do not include water depth and velocity (i.e., HNA geomorphic areas database) do not provide sufficient resolution to model water bird habitat. Also, many birds may use specific habitats seasonally or diurnally.

Dr. Eileen Kirsch (U.S. Geological Survey, Upper Midwest Environmental Science Center, La Crosse, Wisconsin) scored the mammal matrix. Large mammal potential habitat estimates are probably valid because they are wide ranging and may occupy the entire floodplain. Estimates of small mammal potential habitat may exceed their true distribution because their life histories and population sizes are not well understood in the UMRS floodplain. Factors such as forest type, understory vegetation, availability of winter cover, and others are not represented in the HNA GIS database but may be important factors in the distribution of small rodents. In the case of small mammals, better life history information, as well as more refined GIS data, is necessary.

6.5 Summary

The HNA Query Tool was developed to provide natural resource managers easy access to the vast amount of GIS and other data available for the Upper Mississippi River. The HNA Query Tool provides a user-friendly interface to access the power of ArcView GIS software. In addition to providing easy access to data, the HNA Query Tool provides modeling capability to estimate the area of potential species/guild occurrence for user selected river reaches. Potential species/guild occurrence is calculated by relating a matrix ranking likely occurrence among HNA land cover and geomorphic area with GIS data layers. Queries are bi-directional in that users can query to find the distribution of a species/guild or they can query a location and obtain list of species/guilds likely to be present. Users can select the level of likelihood of occurrence by defining one or more potential occurrence rankings. Additional attributes of habitat, including shorelines, wing dams, and riprapped shorelines are available on the current version of the query tool. Land cover and geomorphic area coverages have also been merged to allow user defined queries involving both data layers. The current version of the query tool overestimates potential species/guild occurrence because fine attributes of habitat cannot be modeled with the current resolution of the data. An advanced tool is in development to access bathymetric, hydraulic model results (i.e., current velocity), water quality, and terrestrial elevation data. The advanced tool will also access spatially randomized monitoring data for macroinvertebrates, fish, and birds to help validate query tool results. Users will be able to incorporate their own data. The advanced tool will require a higher level of technical skill in the use of ArcView.

7 Existing Conditions

Existing conditions were assessed at systemic, river, geomorphic reach, and pool scales. HNA land cover and geomorphic areas were assessed separately from query tool estimates of potential species/guild occurrence. The HNA land cover and geomorphic areas database was the source for acreage estimates (see Table 7). Data for pools 1 through 3 were obtained from 1994 aerial photographs. Data covering pools 4 through 26 were obtained from 1989 aerial photographs. The data for the most of the Illinois River and Mississippi River south of Pool 26 were obtained from 1989 satellite images. Higher resolution data for the La Grange Pool, Peoria Pool, and Cape Girardeau reach are available from the LTRMP. The St. Louis District USACE maintains finer resolution data for pool 24 to the Ohio River in their REEGIS database. Potential guild and species habitat area estimates were based on the same GIS data using the species-habitat matrices developed for the HNA query tool.

Land cover and geomorphic area abundance and distribution are presented in detail in the tables and Figure s below. Systemic and river scale results are also presented here briefly. Appendices J and K present the results at the geomorphic reach scale, appendices L and M present pool scale results. Habitat richness and Simpson's diversity index calculated by the query tool are presented at the reach and pool scale below. Habitat fragmentation is discussed in general terms as it relates to patterns in land cover class distribution throughout the river system. Habitat connectivity is also discussed in general terms related to the distribution of natural and constructed barriers to migration and material transport throughout the river system. Lastly, the systemic distribution of former landscapes are, contrasted, where possible, with their existing distribution to assess the potential for restoring them. Potential species/guild occurrence results are discussed in general terms to outline strengths and weaknesses of the methodology. The results are very extensive given the large number of species considered. Results at the reach scale are presented in Appendix N. The query tool should be used to obtain habitat estimates at pool or river mile increments.

7.1 Systemic and River Summaries

The Upper Mississippi River System floodplain area encompasses 2,643,376 acres (Table 12, Figure 8 and 9). Agriculture is the dominant land cover class occupying 44% of the floodplain. Open water is the second dominant land cover class covering 17% of the floodplain. Wet mesic forests follow closely occupying 14% of the floodplain. None of the other classes exceed 10% of the floodplain area. Only developed land areas exceed 5%. There is a lack of photo coverage for about 8% of the area, mostly between geomorphic reaches 5 and 8. Analysis of the satellite coverage of the areas lacking photo coverage revealed the areas were dominated by agriculture (over 75%).

The geomorphic class data is limited to Upper Mississippi River Pools 4 through 26, the La Grange Pool, and the Cape Girardeau LTRMP study reach. The summary of geomorphic reaches 2 through 8 shows 26% of the floodplain area leveed (Tables 13 - 15, Figure 10 and 11). The no photo coverage area that occurs in reaches 5 to 8 is mostly leveed, so the 15% of the floodplain lacking coverage can be added to the measured leveed area to bring the total to about 40% of the floodplain. This Figure closely approximates the amount of agriculture in the floodplain. Contiguous floodplain susceptible to seasonal flooding was about 23% of the floodplain area. Islands were about 8% of the floodplain area bringing the total floodplain terrestrial area to 73% of geomorphic reaches 2 through 8. The range of the proportional contribution of aquatic area types was 10 to 70% of the floodplain area, which indicates their skewed distribution. Backwater aquatic area classes are more prominent in the northern pooled reaches (reaches 1 to 4), while channel habitats are more prominent in the southern pooled reaches (reaches 5 to 8).

Table 12. HNA land cover class distribution (in acres) in the Upper Mississippi River System (* = satellite data used).

Reach	Open Water	Submersed Aquatic Bed	Floating-leaved Aquatic Bed	Permanently Flooded Emergent Annual	Permanently Flooded Emergent Perennial	Seasonally Flooded Emergent Annual	Seasonally Flooded Emergent Perennial	Wet Meadow	Grassland	Scrub/ Shrub Wetland	Salix Community	Populus Community	Wet Floodplain Forest	Mesic Bottomland Hardwood Forest	Agriculture	Developed	Sand/ mud	No Photo Coverage	Total
Pool 1	847	0	0	0	0	0	0	13	0	57	0	0	341	0	0	2,463	15	0	3,736
Pool 2	9,039	734	133	0	320	0	16	1,363	0	525	14	0	5,222	6	558	4,920	301	0	23,152
Pool 3	5,557	1,164	189	276	1,232	0	5	1,902	0	1,155	0	0	9,410	0	1,342	1,022	404	0	23,660
Pool 4	29,275	4,190	1,486	0	4,177	0	48	1,791	519	791	436	5	11,486	1,122	3,526	3,082	225	0	62,157
Pool 5	6,135	2,677	1,549	176	1,537	0	138	1,582	1,467	802	361	1	3,990	1,372	4,860	1,390	129	0	28,165
Pool 5a	3,753	1,034	1,317	45	2,098	0	112	348	68	408	320	2	5,400	379	1,450	934	65	0	17,733
Pool 6	5,735	1,202	1,848	620	1,544	0	382	553	373	609	181	0	3,055	1,783	293	3,547	18	76	21,817
Pool 7	8,966	1,375	1,270	0	3,029	0	0	898	5	323	300	71	3,249	235	1,877	1,842	78	0	23,519
Pool 8	13,871	2,304	4,059	0	3,408	0	40	2,885	368	608	572	0	5,443	275	279	3,886	76	0	38,074
Pool 9	17,558	2,652	6,319	4	6,110	0	433	2,964	3	510	1,039	155	11,532	16	953	400	66	314	51,027
Pool 10	11,320	1,914	2,131	113	3,511	0	564	2,069	40	715	316	58	9,508	263	2,586	3,211	32	606	38,958
Pool 11	14,111	2,157	2,675	61	1,342	0	152	885	10	269	144	113	6,136	82	500	562	73	0	29,273
Pool 12	8,234	1,435	1,297	8	874	0	219	1,283	27	383	108	9	4,517	230	196	1,598	15	0	20,431
Pool 13	15,238	6,183	4,449	0	3,329	0	785	3,149	328	1,009	302	3	11,159	1,756	4,353	7,075	100	0	59,217
Pool 14	8,769	877	111	0	573	0	214	913	154	719	167	17	6,664	643	1,951	3,656	18	492	25,936
Pool 15	3,250	276	7	0	24	0	5	118	43	155	7	0	284	67	413	4,426	1	148	9,223
Pool 16	9,604	1,100	452	0	653	0	122	792	20	732	400	89	5,505	274	2,247	3,178	25	1,629	26,821
Pool 17	6,161	479	88	0	212	0	56	691	92	1,116	99	0	6,404	491	9,237	1,747	12	45,478	72,362
Pool 18	12,311	890	739	0	840	0	201	2,625	174	3,619	383	67	13,337	5,439	56,915	3,221	193	33,503	134,457
Pool 19	24,583	1,952	2,223	0	1,593	0	19	2,550	150	3,296	227	250	13,329	1,830	45,713	7,032	101	14,083	118,929
Pool 20	8,119	82	24	0	59	0	7	1,152	0	2,903	40	144	6,645	59	43,819	953	246	11,032	75,283
Pool 21	8,149	44	13	0	171	0	43	673	9	2,823	149	228	9,275	227	43,100	1,595	118	0	66,617
Pool 22	8,516	79	8	0	97	0	12	886	32	3,064	84	341	9,654	31	42,385	966	66	18,084	84,305
Pool 24	11,043	522	287	0	612	0	59	2,045	39	2,924	210	914	11,449	12	26,177	444	48	38,327	95,111
Pool 25	14,968	882	157	0	731	0	112	2,668	11	3,372	314	369	16,867	57	43,455	1,093	183	2,292	87,530
Pool 26	16,024	761	368	0	803	0	6	1,650	134	1,506	185	459	14,876	1,341	40,169	3,528	230	37,722	119,762

Table 12. Continued.

Reach	Open Water	Submersed Aquatic Bed	Floating-leaved Aquatic Bed	Permanently Flooded Emergent Annual	Permanently Flooded Emergent Perennial	Seasonally Flooded Emergent Annual	Seasonally Flooded Emergent Perennial	Wet Meadow	Grassland	Scrub/ Shrub Wetland	Salix Community	Populus Community	Wet Floodplain Forest	Mesic Bottomland Hardwood Forest	Agriculture	Developed	Sand/ mud	No Photo Coverage	Total
L+D 26 to Kaskaskia R.*	29,585	0	0	0	953	0	0	0	14,965	0	0	0	22,618	0	160,797	47,850	1,820	1	278,588
Kaskaskia R. to Grand Tower*	11,441	0	0	0	22	0	0	0	3,211	0	0	0	22,737	0	92,030	538	396	0	130,374
Grand Tower to Ohio R.*	25,900	0	0	0	1,613	0	0	0	4,501	0	0	0	36,864	0	186,375	4,377	1,105	4,015	264,749
Lockport*	4,045	0	0	0	1	0	0	0	3,054	0	0	0	3,832	0	4	4,491	0	1	15,429
Brandon*	331	0	0	0	1	0	0	0	218	0	0	0	237	0	0	1,072	0	0	1,859
Dresdon*	2,370	0	0	0	26	0	0	0	1,194	0	0	0	1,725	0	108	627	36	0	6,086
Marseilles*	4,623	0	0	0	131	0	0	0	2,101	0	0	0	4,735	0	11,380	2,545	7	4	25,525
Starved Rock*	3,092	0	0	0	416	0	0	0	1,046	0	0	0	2,392	0	3,343	3,644	2	0	13,935
Peoria*	40,070	0	0	0	5,416	0	0	0	7,292	0	0	0	19,501	0	49,153	9,832	52	0	131,317
Lagrange*	34,660	0	0	0	4,806	0	0	0	8,294	0	0	0	38,097	0	131,803	3,511	55	1	221,227
Alton*	15,337	0	0	0	2,009	0	0	0	4,516	0	0	0	20,809	0	153,345	1,017	0	1	197,034
Total	452,587	36,964	33,197	1,304	54,272	0	3,750	38,449	54,454	34,393	6,357	3,294	378,282	17,989	1,166,691	147,277	6,308	207,808	2,643,376
Percent	17	1	1	0	2	0	0	1	2	1	0	0	14	1	44	6	0	8	100

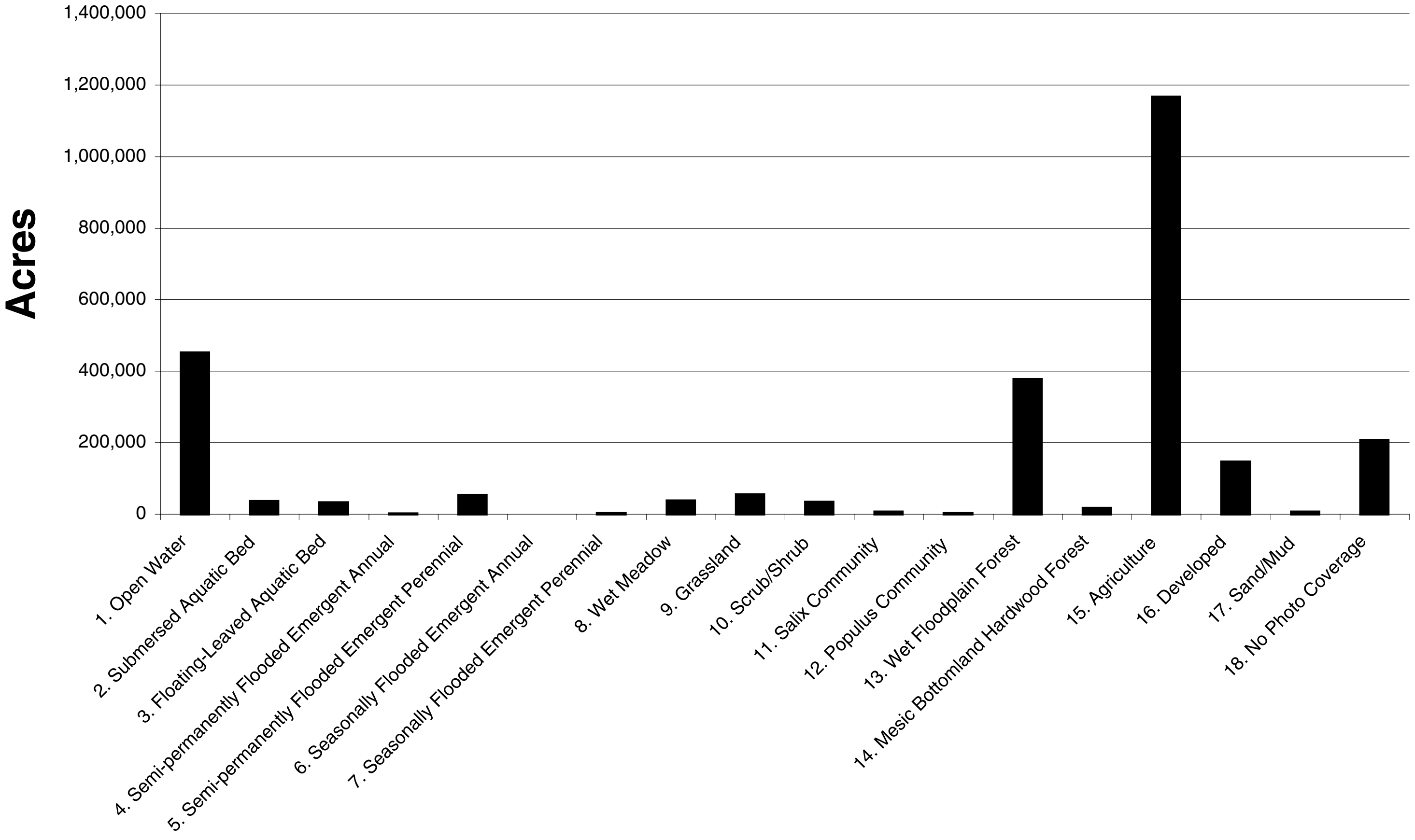

Figure 8. Systemic abundance of HNA land cover classes.

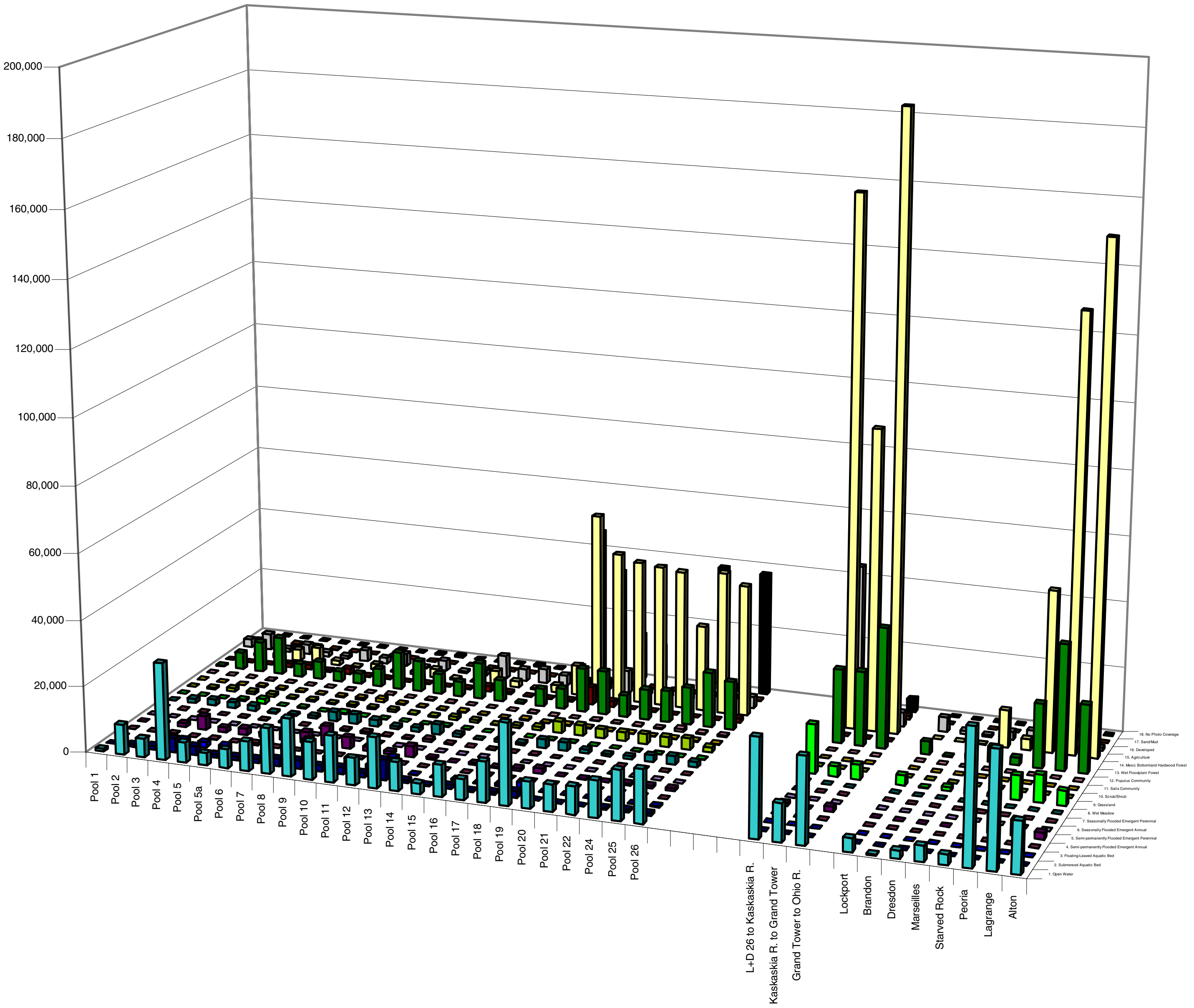

Figure 9. Systemic distribution of HNA land cover classes (* = satellite data used).

Table 13. HNA geomorphic area distribution and abundance in Upper Mississippi River pools 4 to 26 (* = satellite data used).

	Acres															
	Aquatic											**Terrestrial**				
	Channel Areas							Backwater Areas				Islands	Floodplain		No	
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated		Contiguous	Isolated	Photo	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded					Coverage	Total
Pool 4	2,700.4	1,107.2	28.7	1,142.8	5.8	238.9	0.0	25,501.8	3,873.2	1,007.2	978.2	4,566.3	20,850.9	155.3	0.0	62,156.7
Pool 5	831.7	1,324.6	54.9	686.0	0.0	145.5	0.0	383.2	1,810.9	5,382.8	442.0	2,132.7	14,889.3	81.4	0.0	28,165.0
Pool 5a	536.5	625.5	75.8	366.7	27.3	67.9	0.0	199.4	2,891.9	771.2	1,046.1	3,926.7	6,013.5	1,184.8	0.0	17,733.3
Pool 6	754.1	1,375.0	40.1	2,394.2	1.8	90.0	0.0	504.1	259.3	0.0	4,539.5	1,641.0	6,266.2	3,876.7	75.5	21,817.5
Pool 7	563.8	1,500.2	49.4	1,323.9	1.1	80.4	0.0	1,124.4	862.2	7,231.2	337.4	3,857.6	6,587.0	0.0	0.0	23,518.6
Pool 8	1,548.9	1,491.2	50.5	1,258.7	1.8	74.3	0.0	2,778.9	3,888.3	9,944.4	832.3	7,330.1	8,593.2	281.1	0.0	38,073.7
Pool 9	1,605.2	2,771.0	51.4	926.2	1,028.8	57.9	0.0	1,806.6	8,091.1	12,777.6	1,037.8	9,462.4	11,097.2	0.0	313.8	51,027.0
Pool 10	1,650.5	4,039.9	46.2	3,814.8	157.8	364.3	0.0	4,141.8	1,278.7	2,253.6	815.3	8,204.8	11,359.4	224.9	606.2	38,958.2
Pool 11	2,034.0	5,755.0	43.0	1,583.2	23.2	34.0	0.0	1,124.7	3,168.9	5,659.2	440.8	4,074.7	5,129.8	201.3	0.0	29,271.8
Pool 12	1,472.3	3,722.3	64.3	1,828.2	49.4	11.2	0.0	991.9	1,346.8	2,135.7	435.0	3,573.1	4,064.1	737.0	0.0	20,431.3
Pool 13	3,875.6	2,819.1	49.1	1,949.9	259.9	77.9	0.0	3,068.6	4,700.5	8,785.5	1,764.2	5,963.9	20,988.3	4,913.8	0.0	59,216.3
Pool 14	1,385.5	5,254.9	54.9	1,481.1	11.0	59.1	0.0	1,651.4	0.0	0.0	520.0	3,353.1	7,677.6	3,996.9	491.7	25,937.2
Pool 15	584.1	2,422.1	90.9	408.6	0.0	7.9	0.0	17.2	0.0	0.0	22.2	444.6	3,108.8	1,969.2	147.5	9,223.1
Pool 16	1,593.3	4,459.1	61.0	3,935.2	93.3	56.3	0.0	484.0	608.7	0.0	486.8	3,003.2	9,232.1	1,178.9	1,629.4	26,821.3
Pool 17	1,914.3	1,925.6	60.3	1,992.2	1.1	0.3	0.0	593.8	0.0	0.0	368.4	2,837.2	2,870.9	14,320.1	45,478.0	72,362.2
Pool 18	2,074.3	4,582.8	50.3	3,800.4	92.8	309.9	0.0	873.4	0.0	0.0	2,924.4	4,846.6	32,923.0	48,476.1	33,503.0	134,457.0
Pool 19	3,335.2	13,030.2	74.7	3,773.5	2.0	229.3	0.0	2,143.8	3,169.1	2,641.6	1,537.1	5,677.1	34,674.7	34,557.9	14,083.0	118,929.2
Pool 20	1,417.6	4,269.5	96.2	1,345.8	11.0	492.7	0.0	57.4	0.0	0.0	547.3	1,940.7	11,933.1	42,140.0	11,031.5	75,282.8
Pool 21	1,670.7	2,679.2	75.5	1,878.9	9.5	34.9	0.0	813.9	0.0	0.0	1,156.4	6,049.1	8,229.6	44,019.9	0.0	66,617.6
Pool 22	1,958.7	4,133.5	58.7	1,275.0	3.6	49.5	0.0	168.1	0.0	0.0	1,025.1	1,938.7	8,069.8	47,540.8	18,083.5	84,305.0
Pool 24	2,272.4	4,498.3	79.5	2,915.0	149.2	244.0	0.0	310.7	0.0	0.0	1,696.5	3,765.7	8,161.4	32,691.2	38,327.1	95,111.0
Pool 25	2,709.0	5,122.9	71.9	3,975.1	78.0	102.4	0.0	1,385.1	818.5	416.5	1,853.5	6,677.6	15,996.3	46,030.7	2,292.3	87,529.8
Pool 26	3,626.3	7,102.9	67.8	3,664.3	34.0	124.7	0.0	1,010.7	0.0	604.7	1,407.2	6,251.2	46,117.7	12,022.9	37,721.6	119,756.0
Total	42,114.4	86,012.0	1,395.1	47,719.7	2,042.4	2,953.3	0.0	51,134.9	36,768.1	59,611.2	26,213.5	101,518.1	304,833.9	340,600.9	203,784.1	1,306,701.6
Percent	3.2	6.6	0.1	3.7	0.2	0.2	0.0	3.9	2.8	4.6	2.0	7.8	23.3	26.1	15.6	100.0

Table 13. Continued.

	Acres															
	Aquatic											**Terrestrial**				
	Channel Areas							Backwater Areas				Islands	Floodplain		No	
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated		Contiguous	Isolated	Photo	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded					Coverage	Total
Cape Girardeau	3,727.6	6,987.5	0.0	646.5	0.0	164.8	0.0	254.0	0.0	0.0	2,030.7	1,113.8	36,769.8	46,567.9	17,528.0	115,790.6
La Grange Pool	5,828.5	0.0	0.0	441.3	7.1	686.0	482.8	13,772.3	255.3	0.1	7,026.2	2,747.9	48,688.5	64,555.6	56,670.3	201,161.9

Table 14. HNA geomorphic area percent distribution and abundance in selected Upper Mississippi River System Reaches.

	Percent															
	Aquatic											**Terrestrial**				
	Channel Areas							Backwater Areas				Islands	Floodplain		No	
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated		Contiguous	Isolated	Photo	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded					Coverage	Total
Pool 4	4.3	1.8	0.0	1.8	0.0	0.4	0.0	41.0	6.2	1.6	1.6	7.3	33.5	0.2	0.0	100.0
Pool 5	3.0	4.7	0.2	2.4	0.0	0.5	0.0	1.4	6.4	19.1	1.6	7.6	52.9	0.3	0.0	100.0
Pool 5a	3.0	3.5	0.4	2.1	0.2	0.4	0.0	1.1	16.3	4.3	5.9	22.1	33.9	6.7	0.0	100.0
Pool 6	3.5	6.3	0.2	11.0	0.0	0.4	0.0	2.3	1.2	0.0	20.8	7.5	28.7	17.8	0.3	100.0
Pool 7	2.4	6.4	0.2	5.6	0.0	0.3	0.0	4.8	3.7	30.7	1.4	16.4	28.0	0.0	0.0	100.0
Pool 8	4.1	3.9	0.1	3.3	0.0	0.2	0.0	7.3	10.2	26.1	2.2	19.3	22.6	0.7	0.0	100.0
Pool 9	3.1	5.4	0.1	1.8	2.0	0.1	0.0	3.5	15.9	25.0	2.0	18.5	21.7	0.0	0.6	100.0
Pool 10	4.2	10.4	0.1	9.8	0.4	0.9	0.0	10.6	3.3	5.8	2.1	21.1	29.2	0.6	1.6	100.0
Pool 11	6.9	19.7	0.1	5.4	0.1	0.1	0.0	3.8	10.8	19.3	1.5	13.9	17.5	0.7	0.0	100.0
Pool 12	7.2	18.2	0.3	8.9	0.2	0.1	0.0	4.9	6.6	10.5	2.1	17.5	19.9	3.6	0.0	100.0
Pool 13	6.5	4.8	0.1	3.3	0.4	0.1	0.0	5.2	7.9	14.8	3.0	10.1	35.4	8.3	0.0	100.0
Pool 14	5.3	20.3	0.2	5.7	0.0	0.2	0.0	6.4	0.0	0.0	2.0	12.9	29.6	15.4	1.9	100.0
Pool 15	6.3	26.3	1.0	4.4	0.0	0.1	0.0	0.2	0.0	0.0	0.2	4.8	33.7	21.4	1.6	100.0
Pool 16	5.9	16.6	0.2	14.7	0.3	0.2	0.0	1.8	2.3	0.0	1.8	11.2	34.4	4.4	6.1	100.0
Pool 17	2.6	2.7	0.1	2.8	0.0	0.0	0.0	0.8	0.0	0.0	0.5	3.9	4.0	19.8	62.8	100.0
Pool 18	1.5	3.4	0.0	2.8	0.1	0.2	0.0	0.6	0.0	0.0	2.2	3.6	24.5	36.1	24.9	100.0
Pool 19	2.8	11.0	0.1	3.2	0.0	0.2	0.0	1.8	2.7	2.2	1.3	4.8	29.2	29.1	11.8	100.0
Pool 20	1.9	5.7	0.1	1.8	0.0	0.7	0.0	0.1	0.0	0.0	0.7	2.6	15.9	56.0	14.7	100.0
Pool 21	2.5	4.0	0.1	2.8	0.0	0.1	0.0	1.2	0.0	0.0	1.7	9.1	12.4	66.1	0.0	100.0
Pool 22	2.3	4.9	0.1	1.5	0.0	0.1	0.0	0.2	0.0	0.0	1.2	2.3	9.6	56.4	21.5	100.0
Pool 24	2.4	4.7	0.1	3.1	0.2	0.3	0.0	0.3	0.0	0.0	1.8	4.0	8.6	34.4	40.3	100.0
Pool 25	3.1	5.9	0.1	4.5	0.1	0.1	0.0	1.6	0.9	0.5	2.1	7.6	18.3	52.6	2.6	100.0
Pool 26	3.0	5.9	0.1	3.1	0.0	0.1	0.0	0.8	0.0	0.5	1.2	5.2	38.5	10.0	31.5	100.0
Pools 4 - 25	3.2	6.6	0.1	3.7	0.2	0.2	0.0	3.9	2.8	4.6	2.0	7.8	23.3	26.1	15.6	100.0

Table 14. Continued

	Percent															
	Aquatic											**Terrestrial**				
	Channel Areas							Backwater Areas				Islands	Floodplain		No	
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated		Contiguous	Isolated	Photo	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded					Coverage	Total
Cape Girardeau	3.2	6.0	0.0	0.6	0.0	0.1	0.0	0.2	0.0	0.0	1.8	1.0	31.8	40.2	15.1	100.0
La Grange Pool	2.9	0.0	0.0	0.2	0.0	0.3	0.2	6.8	0.1	0.0	3.5	1.4	24.2	32.1	28.2	100.0

Table 15. HNA aquatic area percent distribution and abundance in Upper Mississippi River pools 4 to 26.

	Percent											
	Channel Areas							Backwater Areas				
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded		Total Aquatic
Pool 4	7.4	3.0	0.1	3.1	0.0	0.7	0.0	69.7	10.6	2.8	2.7	100.0
Pool 5	7.5	12.0	0.5	6.2	0.0	1.3	0.0	3.5	16.4	48.7	4.0	100.0
Pool 5a	8.1	9.5	1.1	5.5	0.4	1.0	0.0	3.0	43.8	11.7	15.8	100.0
Pool 6	7.6	13.8	0.4	24.0	0.0	0.9	0.0	5.1	2.6	0.0	45.6	100.0
Pool 7	4.3	11.5	0.4	10.1	0.0	0.6	0.0	8.6	6.6	55.3	2.6	100.0
Pool 8	7.1	6.8	0.2	5.8	0.0	0.3	0.0	12.7	17.8	45.5	3.8	100.0
Pool 9	5.3	9.2	0.2	3.1	3.4	0.2	0.0	6.0	26.8	42.4	3.4	100.0
Pool 10	8.9	21.8	0.2	20.6	0.9	2.0	0.0	22.3	6.9	12.1	4.4	100.0
Pool 11	10.2	29.0	0.2	8.0	0.1	0.2	0.0	5.7	16.0	28.5	2.2	100.0
Pool 12	12.2	30.9	0.5	15.2	0.4	0.1	0.0	8.2	11.2	17.7	3.6	100.0
Pool 13	14.2	10.3	0.2	7.1	1.0	0.3	0.0	11.2	17.2	32.1	6.5	100.0
Pool 14	13.3	50.4	0.5	14.2	0.1	0.6	0.0	15.9	0.0	0.0	5.0	100.0
Pool 15	16.4	68.2	2.6	11.5	0.0	0.2	0.0	0.5	0.0	0.0	0.6	100.0
Pool 16	13.5	37.9	0.5	33.4	0.8	0.5	0.0	4.1	5.2	0.0	4.1	100.0
Pool 17	27.9	28.1	0.9	29.1	0.0	0.0	0.0	8.7	0.0	0.0	5.4	100.0
Pool 18	14.1	31.2	0.3	25.8	0.6	2.1	0.0	5.9	0.0	0.0	19.9	100.0
Pool 19	11.1	43.5	0.2	12.6	0.0	0.8	0.0	7.2	10.6	8.8	5.1	100.0
Pool 20	17.2	51.8	1.2	16.3	0.1	6.0	0.0	0.7	0.0	0.0	6.6	100.0
Pool 21	20.1	32.2	0.9	22.6	0.1	0.4	0.0	9.8	0.0	0.0	13.9	100.0
Pool 22	22.6	47.7	0.7	14.7	0.0	0.6	0.0	1.9	0.0	0.0	11.8	100.0
Pool 24	18.7	37.0	0.7	24.0	1.2	2.0	0.0	2.6	0.0	0.0	13.9	100.0
Pool 25	16.4	31.0	0.4	24.0	0.5	0.6	0.0	8.4	5.0	2.5	11.2	100.0
Pool 26	20.6	40.3	0.4	20.8	0.2	0.7	0.0	5.7	0.0	3.4	8.0	100.0
Total	11.8	24.2	0.4	13.4	0.6	0.8	0.0	14.4	10.3	16.7	7.4	100.0
Cape Girardeau	27.0	50.6	0.0	4.7	0.0	1.2	0.0	1.8	0.0	0.0	14.7	100.0
La Grange Pool	20.5	0.0	0.0	1.5	0.0	2.4	1.7	48.3	0.9	0.0	24.7	100.0

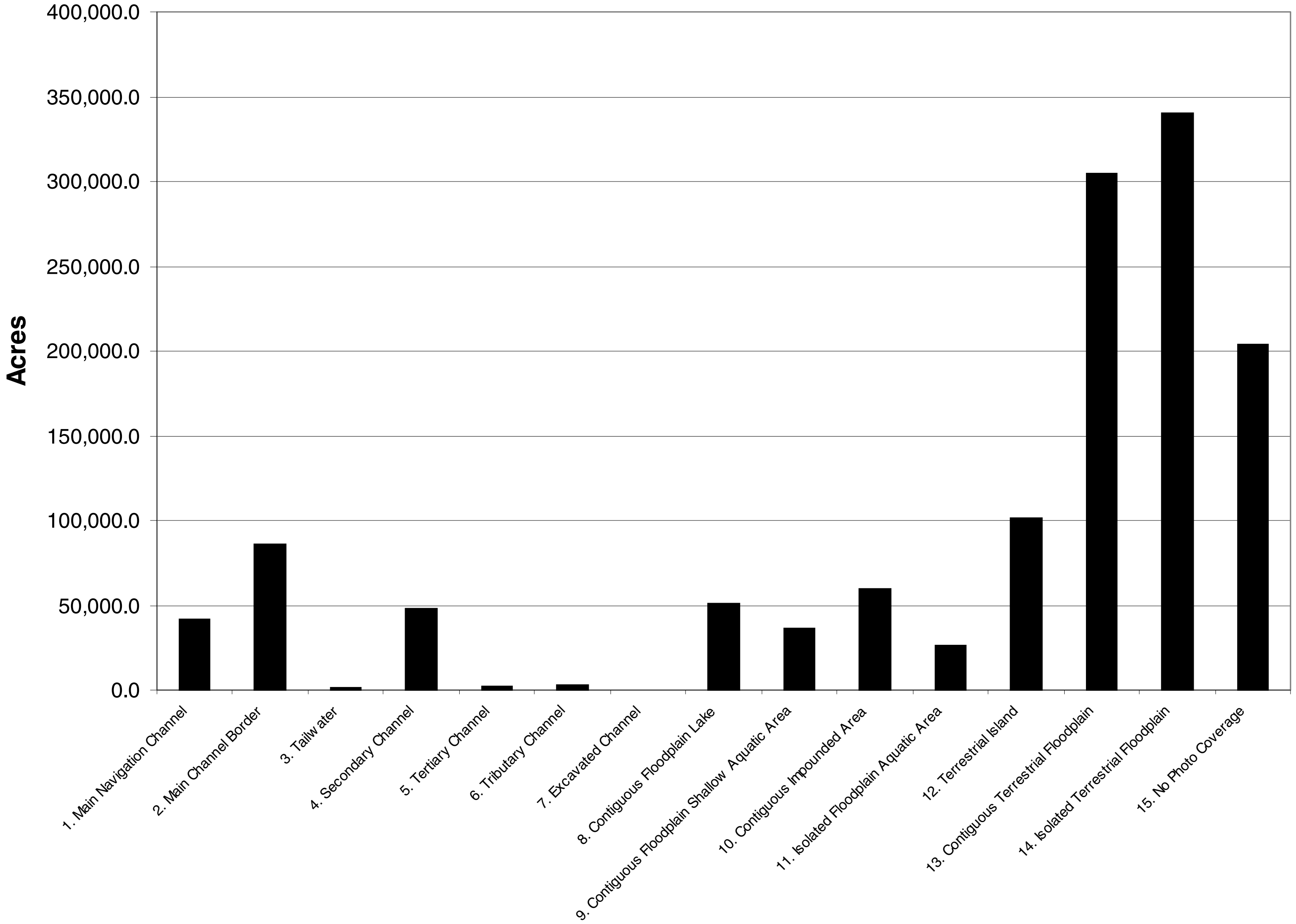

Figure 10. Systemic abundance of HNA geomorphic areas.

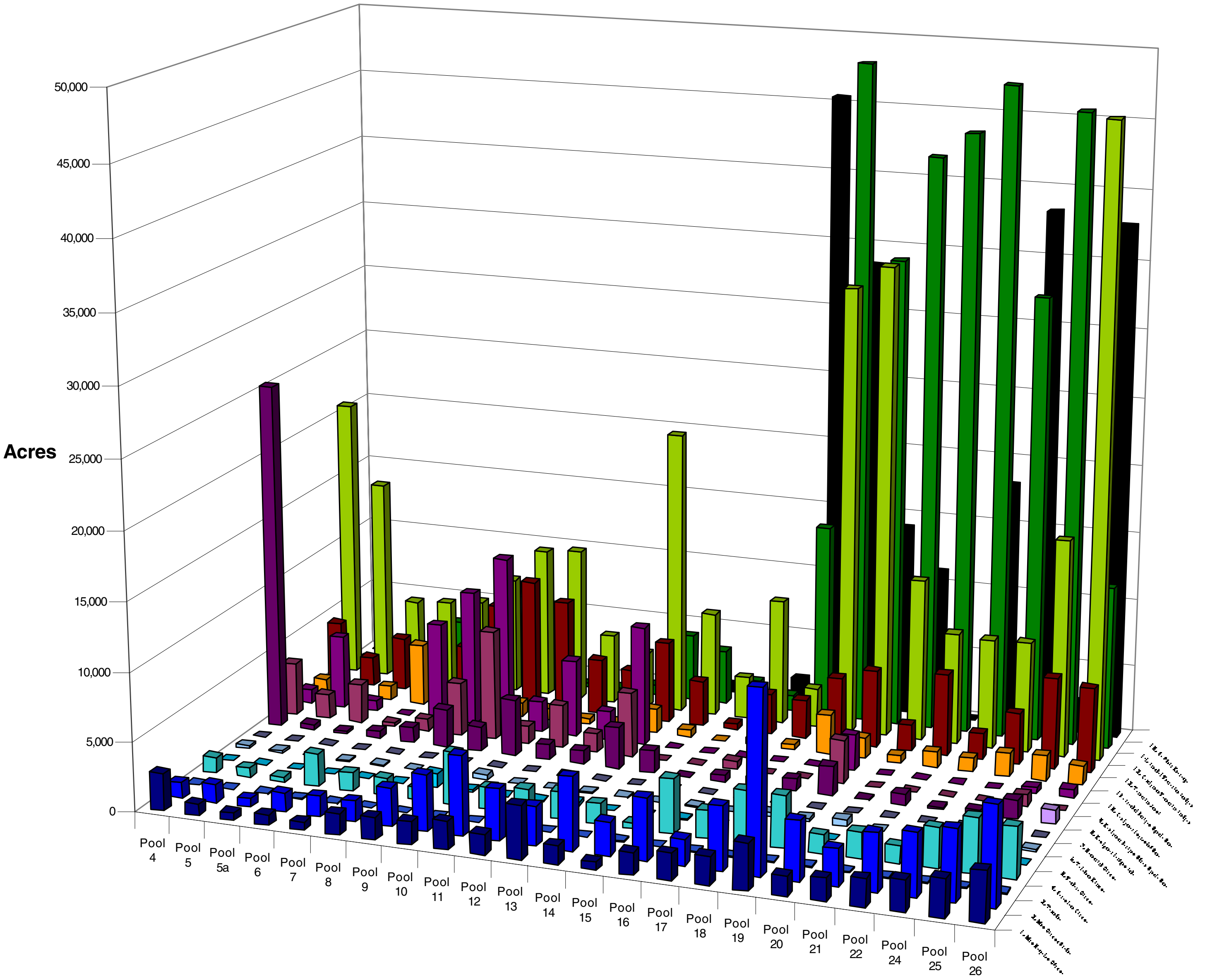

Figure 11. Systemic distribution and abundance of HNA geomorphic areas.

Overall, channel border was 6.6% of the floodplain area, impounded area was 4.6%, contiguous backwaters were 3.9%, secondary channels were 3.7%, navigation channel was 3.2%, shallow aquatic area was 2.8%, and isolated backwaters were 2.0%. Tailwaters, tertiary channels, tributary channels, and excavated channels were 0.2% or less of the floodplain area, respectively. Aquatic area class distribution is discussed below.

The proportion of land cover classes on the two individual rivers is very similar to the proportions on the systemic scale. Although differing in the total amount of acreage, the two rivers are in general also quite similar in the proportion of land cover classes. The Upper Mississippi River floodplain area encompasses 2,030,965 acres (Table 16, Figure 12). Agriculture, the dominant land cover class, measured 40% of the floodplain. Considering that approximately 75% of the area lacking photo coverage (10% of floodplain) is agriculture, the actual proportion of the floodplain developed for agriculture is closer to 50% of the floodplain area. Open water is the next most abundant land cover class, occupying 17% of the floodplain. Wet mesic forests occupy 14% of the floodplain. The contribution of other woody plant classes brings forested and scrub-shrub area up to about 17% of the floodplain area. The developed class covers 6% of the floodplain area. The four emergent marsh and wet meadow classes combined occupy less than 5% of the floodplain. Submersed and floating-leaved aquatic plants occur in about 4% of the total floodplain area. Grasslands occur in only 1% of the floodplain.

The entire Illinois Waterway floodplain area mapped by satellite encompasses 612,411 acres (Tables 17, Figure 13). Agriculture is the dominant land cover class covering 57% of the floodplain. Open water is the next most abundant land cover class, occupying 17% of the floodplain. Wet mesic forests, converted from the woody terrestrial class on the satellite derived GIS coverage, occupy 15% of the floodplain. The developed class covers 4% of the floodplain area. The four emergent marsh classes, combined as marsh on the satellite coverage, occupy about 2% of the floodplain. Submersed and floating-leaved aquatic plants do not map well from the satellite, but they are rare in the Illinois River. Grasslands occur in 5% of the floodplain. More detailed land cover data interpreted from photographs are available for the La Grange and Peoria Pools, but land cover in the two pools differs considerably and they are not reflective of conditions in other Illinois River reaches. The Illinois River north of Peoria Pool occupies little total floodplain area and much of it is developed. The floodplain south of La Grange Pool is almost entirely leveed.

Geomorphic areas are not directly comparable among all river reaches for lack of data for most of the Illinois River and the Mississippi River south of St. Louis. The pooled Mississippi reaches will be discussed in detail below, but data available for the Illinois River La Grange Pool and the Mississippi River Cape Girardeau will be presented briefly here. The Cape Girardeau LTRMP study reach spans parts of geomorphic reaches 9 and 10. Forty% of the reach is leveed on the available GIS coverage, but it appears that not all levees were included in the database. Other estimates indicate the reach is closer to 70% leveed. The channel has been highly modified by training structures and dredging (see Table 13). Aquatic area is only 3% of the floodplain area and main channel and channel border area account for 78% of the aquatic area. Secondary channels account for about 5% of the aquatic area. Contiguous backwaters are only 2% of the aquatic area, but isolated backwaters account for 15%. Throughout the Open River reach there are about 25 secondary channels that vary in their degree of connectivity with the main channel. Many secondary channels have filled over the period since channel maintenance activities were initiated.

Table 16. HNA land cover class distribution (in acres) in the Upper Mississippi River (* = satellite data used).

Reach	Open Water	Submersed Aquatic Bed	Floating-leaved Aquatic Bed	Permanently Flooded Emergent Annual	Permanently Flooded Emergent Perennial	Seasonally Flooded Emergent Annual	Seasonally Flooded Emergent Perennial	Wet Meadow	Grassland	Scrub/ Shrub Wetland	Salix Community	Populus Community	Wet Floodplain Forest	Mesic Bottomland Hardwood Forest	Agriculture	Developed	Sand/ mud	No Photo Coverage	Total
Pool 1	847	0	0	0	0	0	0	13	0	57	0	0	341	0	0	2,463	15	0	3,736
Pool 2	9,039	734	133	0	320	0	16	1,363	0	525	14	0	5,222	6	558	4,920	301	0	23,152
Pool 3	5,557	1,164	189	276	1,232	0	5	1,902	0	1,155	0	0	9,410	0	1,342	1,022	404	0	23,660
Pool 4	29,275	4,190	1,486	0	4,177	0	48	1,791	519	791	436	5	11,486	1,122	3,526	3,082	225	0	62,157
Pool 5	6,135	2,677	1,549	176	1,537	0	138	1,582	1,467	802	361	1	3,990	1,372	4,860	1,390	129	0	28,165
Pool 5a	3,753	1,034	1,317	45	2,098	0	112	348	68	408	320	2	5,400	379	1,450	934	65	0	17,733
Pool 6	5,735	1,202	1,848	620	1,544	0	382	553	373	609	181	0	3,055	1,783	293	3,547	18	76	21,817
Pool 7	8,966	1,375	1,270	0	3,029	0	0	898	5	323	300	71	3,249	235	1,877	1,842	78	0	23,519
Pool 8	13,871	2,304	4,059	0	3,408	0	40	2,885	368	608	572	0	5,443	275	279	3,886	76	0	38,074
Pool 9	17,558	2,652	6,319	4	6,110	0	433	2,964	3	510	1,039	155	11,532	16	953	400	66	314	51,027
Pool 10	11,320	1,914	2,131	113	3,511	0	564	2,069	40	715	316	58	9,508	263	2,586	3,211	32	606	38,958
Pool 11	14,111	2,157	2,675	61	1,342	0	152	885	10	269	144	113	6,136	82	500	562	73	0	29,273
Pool 12	8,234	1,435	1,297	8	874	0	219	1,283	27	383	108	9	4,517	230	196	1,598	15	0	20,431
Pool 13	15,238	6,183	4,449	0	3,329	0	785	3,149	328	1,009	302	3	11,159	1,756	4,353	7,075	100	0	59,217
Pool 14	8,769	877	111	0	573	0	214	913	154	719	167	17	6,664	643	1,951	3,656	18	492	25,936
Pool 15	3,250	276	7	0	24	0	5	118	43	155	7	0	284	67	413	4,426	1	148	9,223
Pool 16	9,604	1,100	452	0	653	0	122	792	20	732	400	89	5,505	274	2,247	3,178	25	1,629	26,821
Pool 17	6,161	479	88	0	212	0	56	691	92	1,116	99	0	6,404	491	9,237	1,747	12	45,478	72,362
Pool 18	12,311	890	739	0	840	0	201	2,625	174	3,619	383	67	13,337	5,439	56,915	3,221	193	33,503	134,457
Pool 19	24,583	1,952	2,223	0	1,593	0	19	2,550	150	3,296	227	250	13,329	1,830	45,713	7,032	101	14,083	118,929
Pool 20	8,119	82	24	0	59	0	7	1,152	0	2,903	40	144	6,645	59	43,819	953	246	11,032	75,283
Pool 21	8,149	44	13	0	171	0	43	673	9	2,823	149	228	9,275	227	43,100	1,595	118	0	66,617
Pool 22	8,516	79	8	0	97	0	12	886	32	3,064	84	341	9,654	31	42,385	966	66	18,084	84,305
Pool 24	11,043	522	287	0	612	0	59	2,045	39	2,924	210	914	11,449	12	26,177	444	48	38,327	95,111
Pool 25	14,968	882	157	0	731	0	112	2,668	11	3,372	314	369	16,867	57	43,455	1,093	183	2,292	87,530
Pool 26	16,024	761	368	0	803	0	6	1,650	134	1,506	185	459	14,876	1,341	40,169	3,528	230	37,722	119,762

Table 16. Continued.

Reach	Open Water	Submersed Aquatic Bed	Floating-leaved Aquatic Bed	Permanently Flooded Emergent Annual	Permanently Flooded Emergent Perennial	Seasonally Flooded Emergent Annual	Seasonally Flooded Emergent Perennial	Wet Meadow	Grassland	Scrub/ Shrub Wetland	Salix Community	Populus Community	Wet Floodplain Forest	Mesic Bottomland Hardwood Forest	Agriculture	Developed	Sand/ mud	No Photo Coverage	Total
L+D 26 to Kaskaskia R.*	29,585	0	0	0	953	0	0	0	14,965	0	0	0	22,618	0	160,797	47,850	1,820	1	278,588
Kaskaskia R. to Grand Tower*	11,441	0	0	0	22	0	0	0	3,211	0	0	0	22,737	0	92,030	538	396	0	130,374
Grand Tower to Ohio R.*	25,900	0	0	0	1,613	0	0	0	4,501	0	0	0	36,864	0	186,375	4,377	1,105	4,015	264,749
Total	348,057	36,964	33,197	1,304	41,467	0	3,750	38,449	26,741	34,393	6,357	3,294	286,956	17,989	817,554	120,538	6,155	207,800	2,030,965
Percent	17	2	2	0	2	0	0	2	1	2	0	0	14	1	40	6	0	10	100

Table 17. HNA land cover class distribution (in acres) in the Illinois River (* = satellite data used).

Reach	Open Water	Submersed Aquatic Bed	Floating-leaved Aquatic Bed	Permanently Flooded Emergent Annual	Permanently Flooded Emergent Perennial	Seasonally Flooded Emergent Annual	Seasonally Flooded Emergent Perennial	Wet Meadow	Grassland	Scrub/ Shrub Wetland	Salix Community	Populus Community	Wet Floodplain Forest	Mesic Bottomland Hardwood Forest	Agriculture	Developed	Sand/ mud	No Photo Coverage	Total
Lockport*	4,045	0	0	0	1	0	0	0	3,054	0	0	0	3,832	0	4	4,491	0	1	15,429
Brandon*	331	0	0	0	1	0	0	0	218	0	0	0	237	0	0	1,072	0	0	1,859
Dresdon*	2,370	0	0	0	26	0	0	0	1,194	0	0	0	1,725	0	108	627	36	0	6,086
Marseilles*	4,623	0	0	0	131	0	0	0	2,101	0	0	0	4,735	0	11,380	2,545	7	4	25,525
Starved Rock*	3,092	0	0	0	416	0	0	0	1,046	0	0	0	2,392	0	3,343	3,644	2	0	13,935
Peoria*	40,070	0	0	0	5,416	0	0	0	7,292	0	0	0	19,501	0	49,153	9,832	52	0	131,317
Lagrange*	34,660	0	0	0	4,806	0	0	0	8,294	0	0	0	38,097	0	131,803	3,511	55	1	221,227
Alton*	15,337	0	0	0	2,009	0	0	0	4,516	0	0	0	20,809	0	153,345	1,017	0	1	197,034
Total	104,529	0	0	0	12,805	0	0	0	27,713	0	0	0	91,326	0	349,136	26,740	153	8	612,411
Percent	17	0	0	0	2	0	0	0	5	0	0	0	15	0	57	4	0	0	100

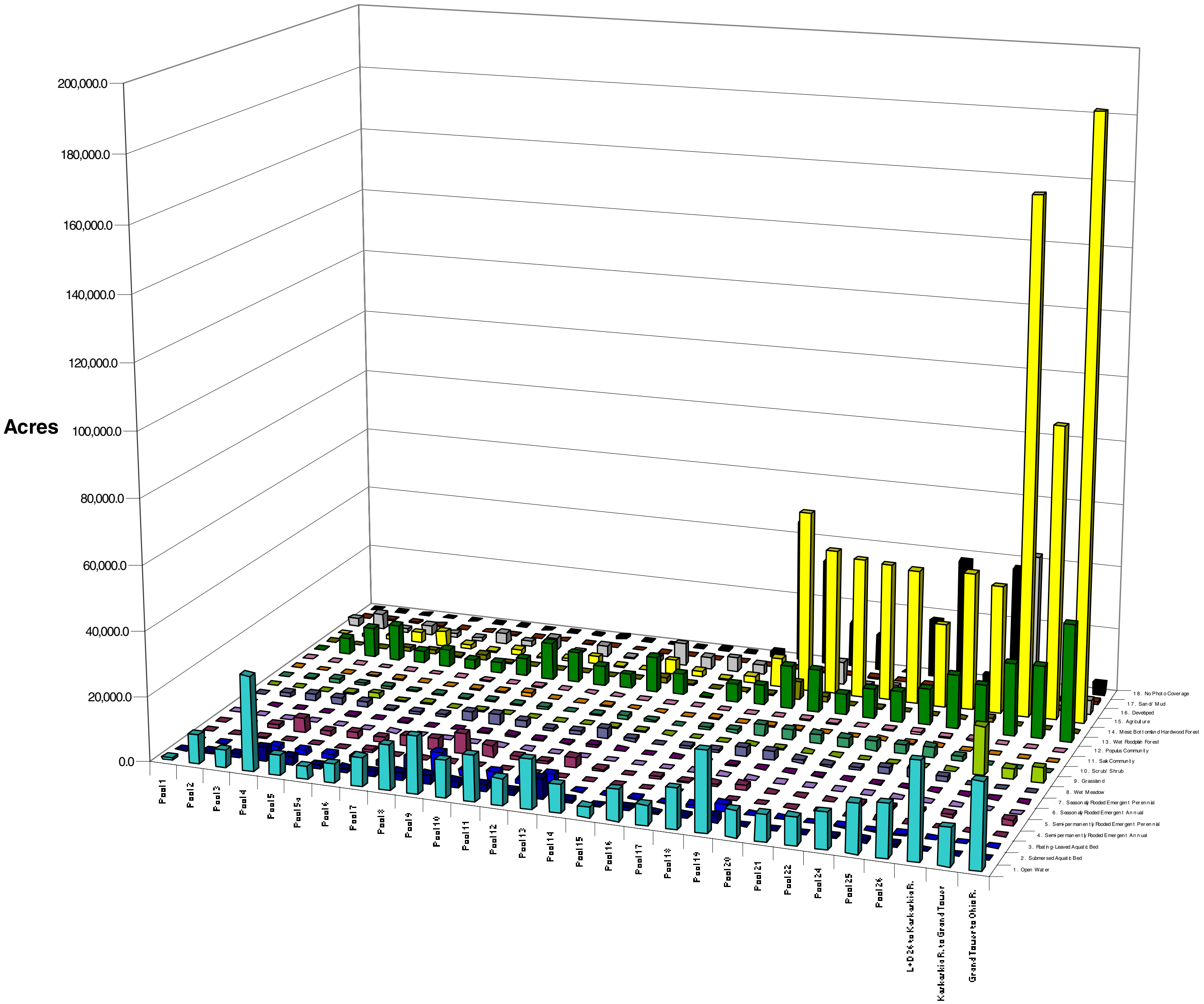

Figure 12. HNA land cover class distribution in the Upper Mississippi River (* = satellite data used).

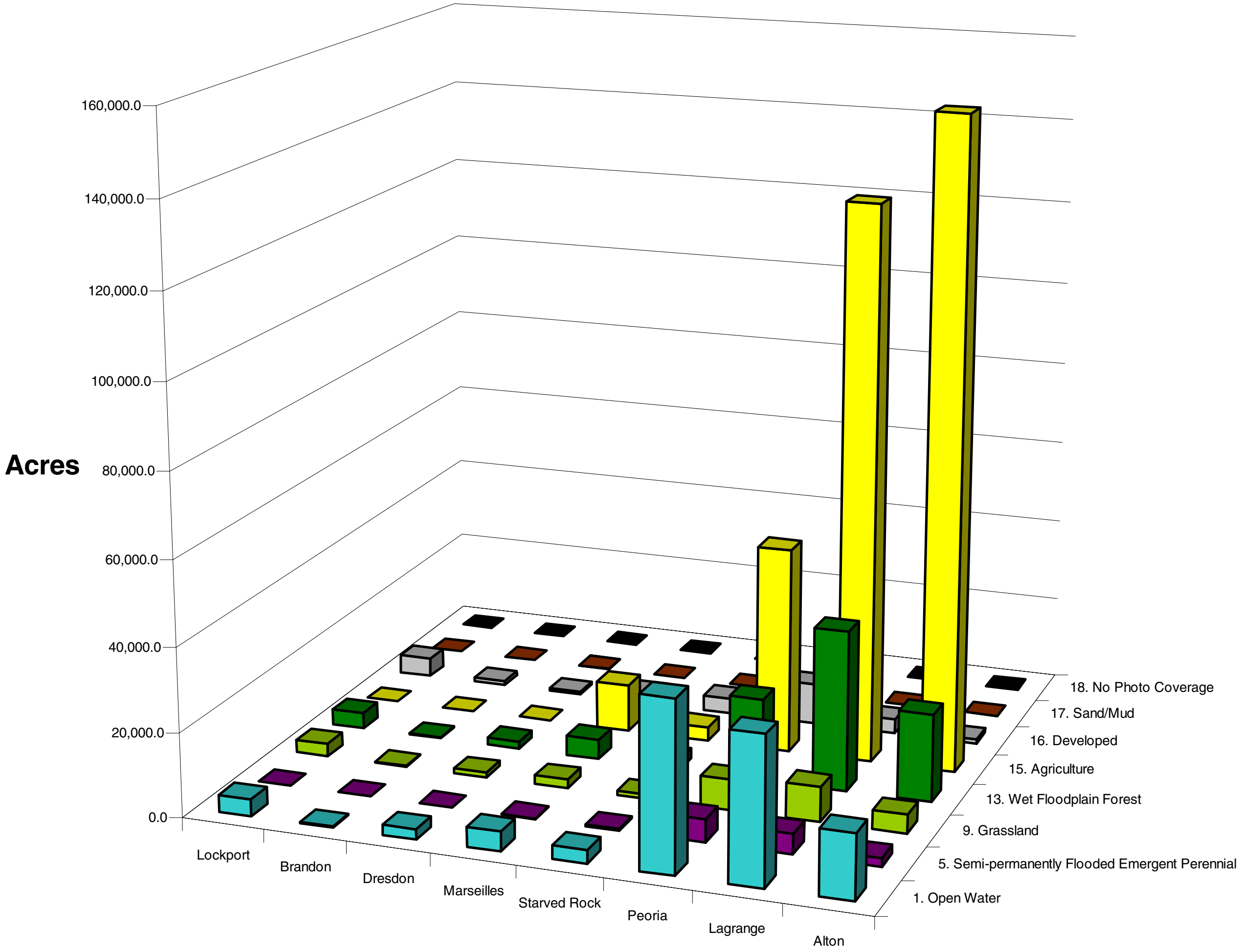

Figure 13. HNA land cover area distribution in the Illinois Waterway (satellite data used).

HNA Geomorphic data on the Illinois River is limited to the La Grange Pool, which is not representative of the rest of the river. The upper reach of the Illinois Waterway (Lockport to Starved Rock) is controlled with high dams that impound water in a narrow river valley. The main stem Peoria Lakes dominate the Peoria Pool. The Alton Pool floodplain is almost 70% leveed on both banks, the floodplain has been drained, and backwaters only occur at the upper and lower ends of the reach. The La Grange Pool, however, has less leveed area and abundant backwaters. The La Grange reach is 54% leveed and developed for agriculture. Contiguous floodplain is about 25% of the floodplain area and islands are only 1.4% (see Table 13). Aquatic area is 14% of the total floodplain. Contiguous backwaters, isolated backwaters, and the main navigation channel account for 13% of floodplain area. Contiguous backwaters alone account for 7%. Contiguous backwaters account for almost 50% of aquatic area, which is only exceeded by Pool 4 (Lake Pepin) and doubles the next closest reach. It is many times higher than most pooled Mississippi reaches.

7.2 HNA Land Cover Areas Distribution/Abundance/Scarcity

7.2.1 Open Water

The open water land cover class occurs in all geomorphic reaches, but it is unevenly distributed with respect to its total acreage and the proportion of the floodplain that it occupies (Table 18, Figure s14 and 15). The greatest amount of open water (90,068 acres) occurs in the lower Illinois River reach (IR2), but this is an exceptionally long reach that includes Peoria Lake and numerous large backwater lakes in the La Grange Pool. Geomorphic reaches 3, 9, 4, and 8 have the next highest total open water acreages, ranging from 56,000 acres to 42,000 acres, respectively. Navigation pools in Reaches 3 and 4 are relatively long, and water level regulation created large open water impoundments in lower pool areas. Geomorphic reach 8 has large amounts of open water primarily because of the length of the pools. Impoundment effects are not pronounced in the reach. Geomorphic reach 9 has a large amount of open water primarily because of the length of the reach; most open water is confined to channel habitats. Geomorphic reach 6 has almost 37,000 acres of open water, much of it because of the large impoundment created by Lock and Dam 19. Geomorphic reach 2 has over 29,000 acres of open water, with much of it occurring naturally in Lake Pepin. Geomorphic reaches 5 and 7 have about 28,000 and 25,000 acres, respectively, but do not show large effects from impoundment. Geomorphic reaches 1, 10, and IR1 have the smallest amounts of open water, primarily because of their short lengths, and in reach 1 and IR1 because of the smaller stream size.

The proportional contribution of open water to total floodplain area differs considerably among reaches though absolute acreages may be similar (Table 18). The importance of water in the floodplain is related to the geomorphology of the rivers and the effects of impoundment. The highest proportion of open water in the floodplain is in geomorphic reach 2 where Lake Pepin and other open water features occupy about 47% of the floodplain area. The proportion of open water in geomorphic reaches 1, 3, and 4 ranges from 31 to 33% because dams impound considerable open water areas in the lower portions of the pools. Geomorphic reach 5 has about 20% open water, but the distribution of water differs among pools. Open water occupies much of pools 14 and 15 where bluffs constrict the river valley, but it occupies a smaller proportion of the pools 16 and 17 floodplain where the valley widens below the rock gorge. Geomorphic reaches 6 through 10 are similar in that open water occupies less than 15% of the floodplain. The floodplain south of the Rock Island gorge widens greatly and gets progressively wider downstream. Impoundment effects are not pronounced in reaches 6, 7, or 8, except for Pool 19. No impoundment effects are evident in reach 9 and 10, but open water area has been lost over time because of channelization.

Table 18. HNA land cover class distribution (acres) and proportional coverage of Upper Mississippi River System geomorphic reaches (* = satellite data used).

Acres

Reach	Open Water	Submersed Aquatic Bed	Floating leaved Aquatic Bed	Permanently Flooded Emergent Annual	Permanently Flooded Emergent Perennial	Seasonally Flooded Emergent Annual	Seasonally Flooded Emergent Perennial	Wet Meadow	Grassland	Scrub/ Shrub Wetland	Salix Community	Populus Community	Wet Floodplain Forest	Mesic Bottomland Hardwood Forest	Agriculture	Developed	Sand/ mud	No Photo Coverage	Total
Reach 1	15,443	1,898	323	276	1,553	0	21	3,278	0	1,737	14	0	14,973	6	1,900	8,405	720	0	50,547
Reach 2	29,275	4,190	1,486	0	4,177	0	48	1,791	519	791	436	5	11,486	1,122	3,526	3,082	225	0	62,157
Reach 3	56,018	11,244	16,362	845	17,727	0	1,105	9,230	2,283	3,260	2,773	229	32,669	4,059	9,711	12,000	431	389	180,335
Reach 4	48,902	11,690	10,552	182	9,056	0	1,721	7,386	404	2,376	869	183	31,320	2,331	7,635	12,446	219	606	147,879
Reach 5	27,784	2,731	657	0	1,461	0	397	2,515	309	2,722	673	106	18,857	1,475	13,848	13,006	55	47,747	134,343
Reach 6	36,894	2,842	2,962	0	2,433	0	220	5,175	325	6,916	610	317	26,666	7,269	102,627	10,253	293	47,586	253,386
Reach 7	24,784	205	45	0	328	0	62	2,711	41	8,790	273	713	25,574	317	129,305	3,515	430	29,115	226,205
Reach 8	42,034	2,165	811	0	2,146	0	177	6,363	184	7,802	709	1,741	43,193	1,410	109,802	5,065	461	78,341	302,403
Reach 9*	53,132	0	0	0	1,810	0	0	0	20,685	0	0	0	62,845	0	309,866	49,697	2,862	515	501,413
Reach 10*	13,793	0	0	0	777	0	0	0	1,992	0	0	0	19,374	0	129,335	3,068	458	3,501	172,298
Reach IR1*	14,461	0	0	0	574	0	0	0	7,612	0	0	0	12,920	0	14,835	12,380	46	5	62,834
Reach IR2*	90,068	0	0	0	12,231	0	0	0	20,101	0	0	0	78,407	0	334,301	14,359	108	3	549,577
Total	452,587	36,964	33,197	1,304	54,272	0	3,750	38,449	54,454	34,393	6,357	3,294	378,282	17,989	1,166,691	147,277	6,308	207,808	2,643,376

Table 18. Continued.

Percent

Reach	Open Water	Submersed Aquatic Bed	Floating leaved Aquatic Bed	Permanently Flooded Emergent Annual	Permanently Flooded Emergent Perennial	Seasonally Flooded Emergent Annual	Seasonally Flooded Emergent Perennial	Wet Meadow	Grassland	Scrub/ Shrub Wetland	Salix Community	Populus Community	Wet Floodplain Forest	Mesic Bottomland Hardwood Forest	Agriculture	Developed	Sand/ mud	No Photo Coverage	Total
Reach 1	30.6	3.8	0.6	0.5	3.1	0.0	0.0	6.5	0.0	3.4	0.0	0.0	29.6	0.0	3.8	16.6	1.4	0.0	100.0
Reach 2	47.1	6.7	2.4	0.0	6.7	0.0	0.1	2.9	0.8	1.3	0.7	0.0	18.5	1.8	5.7	5.0	0.4	0.0	100.0
Reach 3	31.1	6.2	9.1	0.5	9.8	0.0	0.6	5.1	1.3	1.8	1.5	0.1	18.1	2.3	5.4	6.7	0.2	0.2	100.0
Reach 4	33.1	7.9	7.1	0.1	6.1	0.0	1.2	5.0	0.3	1.6	0.6	0.1	21.2	1.6	5.2	8.4	0.1	0.4	100.0
Reach 5	20.7	2.0	0.5	0.0	1.1	0.0	0.3	1.9	0.2	2.0	0.5	0.1	14.0	1.1	10.3	9.7	0.0	35.5	100.0
Reach 6	14.6	1.1	1.2	0.0	1.0	0.0	0.1	2.0	0.1	2.7	0.2	0.1	10.5	2.9	40.5	4.0	0.1	18.8	100.0
Reach 7	11.0	0.1	0.0	0.0	0.1	0.0	0.0	1.2	0.0	3.9	0.1	0.3	11.3	0.1	57.2	1.6	0.2	12.9	100.0
Reach 8	13.9	0.7	0.3	0.0	0.7	0.0	0.1	2.1	0.1	2.6	0.2	0.6	14.3	0.5	36.3	1.7	0.2	25.9	100.0
Reach 9*	10.6	0.0	0.0	0.0	0.4	0.0	0.0	0.0	4.1	0.0	0.0	0.0	12.5	0.0	61.8	9.9	0.6	0.1	100.0
Reach 10*	8.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	1.2	0.0	0.0	0.0	11.2	0.0	75.1	1.8	0.3	2.0	100.0
Reach IR1*	23.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	12.1	0.0	0.0	0.0	20.6	0.0	23.6	19.7	0.1	0.0	100.0
Reach IR2*	16.4	0.0	0.0	0.0	2.2	0.0	0.0	0.0	3.7	0.0	0.0	0.0	14.3	0.0	60.8	2.6	0.0	0.0	100.0
Total	17.1	1.4	1.3	0.0	2.1	0.0	0.1	1.5	2.1	1.3	0.2	0.1	14.3	0.7	44.1	5.6	0.2	7.9	100.0

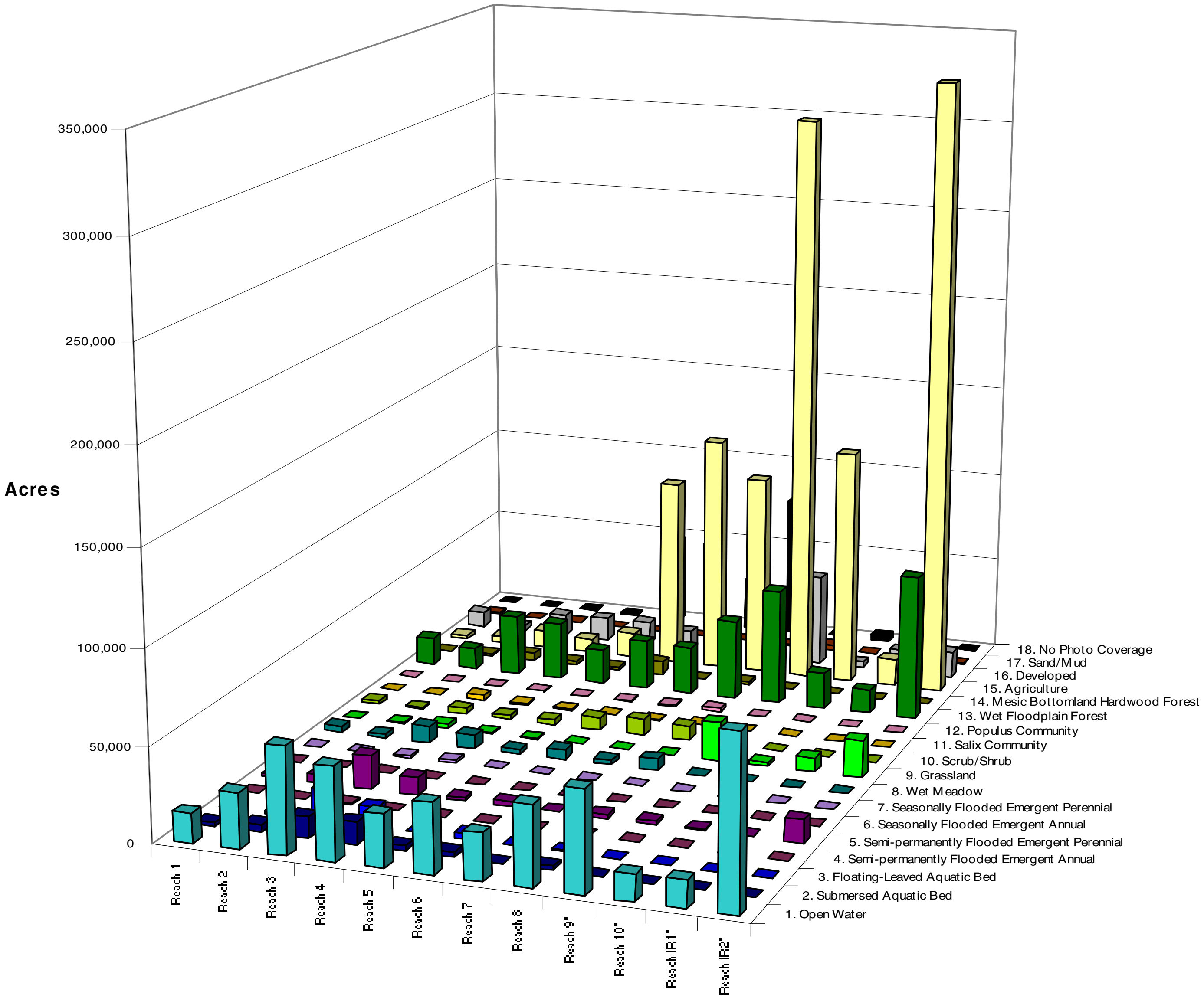

Figure 14. HNA land cover distribution among UMRS geomorphic reaches (* = satellite data used).

In the Illinois River, open water occupies 23% of the floodplain of the upper reach and 16% of the lower reach. The upper reach is maintained with relatively high dams that create short deep pools. The lower reach has very long pools that do not form large impounded areas. Impoundment and water diversions did, however, create large open water backwaters on the floodplain.

7.2.2 Submersed Aquatic Bed

Submersed aquatic vegetation is among the least abundant land cover types in the HNA GIS database (Table 18, Figure s14 and 16). The estimate presented here may not necessarily reflect current conditions because submersed aquatic plant populations are very dynamic and remote sensing tends to underestimate their abundance. Because satellites do not detect submersed aquatic plants, no estimates are provided for reaches 9, 10, IR1, and IR2. The inability to detect this vegetation class is considered minor because these reaches do not typically support submersed aquatic plants. Although the acreage estimates and percent composition of the floodplain estimates may be incorrect, the overall pattern is accurate.

The greatest acreage of the submersed aquatic bed land cover class occurs in geomorphic reaches 3 and 4, each having over 11,000 acres (Table 18, Figure s14 and 16). Geomorphic reach 2 (Pool 4) had over 4,000 acres of submersed aquatic bed. The amount of submersed aquatic bed in geomorphic reaches 1, 5, 6, and 8 ranged from 1,900 to 2,800 acres. Only 200 acres of submersed aquatic bed occurred in geomorphic reach 7. The amount of submersed aquatic bed in reaches 5 through 8 is likely to be greater than the amount typically found because the 1989 photographs were taken during an extreme drought. The drought conditions enabled plants to grow in areas where they usually are not found during normal water years. The amount of submersed aquatic bed in the upper reaches may be lower than typical because submersed aquatic beds in the north were negatively affected by the drought. In most years, the abundance of aquatic plants declines south of Pool 13 because of increases in ambient turbidity.

The proportion of submersed aquatic bed in the floodplain is greatest in reaches 2 through 4 where it ranges from about 6 to 8% of the floodplain (Table 18). The proportion of submersed aquatic bed in reach 1 is intermediate at about 4% of the floodplain area. The proportion of submersed aquatic bed in reaches 6 through 8 is 2% or less of the total floodplain area. Examining the proportion of the submersed aquatic bed class to the open water class, the amount of submersed aquatic bed is 20 and 24% of the open water class in reaches 3 and 5, respectively. The amount of submersed aquatic bed ranges between 10 and 14% of the amount of open water class in reaches 1, 2, and 5. The amount of submersed aquatic bed in geomorphic reaches 6 through 8 is 8% or less of the open water class. The trend reflects a decreasing capacity to support submersed aquatic beds in southern river reaches. The Illinois River and Mississippi River reaches 9 and 10 do not typically support submersed aquatic beds.

7.2.3 Floating-Leaved Aquatic Bed

Floating-leaved aquatic beds are generally distributed similarly to submersed aquatic beds. Although this class of aquatic plants can be detected by remote sensing, they occur as the permanently flooded emergent perennial class in the satellite derived GIS coverages (i.e., reaches 9, 10, IR1, and IR2). The greatest acreage of floating-leaved aquatic bed occurred in geomorphic reach 3, where the class covered over 16,000 acres (Table 18, Figure s14 and 17). Geomorphic reach 4 had over 10,500 acres of floating-leaved aquatic bed. The amount of floating-leaved aquatic bed was almost 3,000 acres in reach 6. Floating-leaved aquatic bed covered almost 1,500 acres in geomorphic reach 2, but it accounted for about 800 acres or less in reaches 1, 7, and 8.

The proportion of the floodplain covered by floating-leaved aquatic bed was 9 and 7% in reaches 3 and 4, but it was less than 2.5% in all the other reaches (Table 18).

7.2.4 Semi-Permanently Flooded Emergent Annual

The semi-permanently flooded emergent annual class represents wild rice. Geomorphic reach 3 supported about 850 acres of the semi-permanently flooded emergent annual class. This was almost twice as much as was mapped in the rest of the river (Table 18, Figure s14 and 18). Semi-permanently flooded emergent annual plants covered 275 and 182 acres in reaches 1 and 4, respectively. The proportion of the floodplain occupied by semi-permanently flooded emergent annual plants was very minor. Water level regulation has resulted in a systemic decline in wild rice because it requires dynamic water levels.

7.2.5 Semi-Permanently Flooded Emergent Perennial

The greatest amount of the semi-permanently flooded emergent perennial class occurs in geomorphic reach 3 where almost 18,000 acres occurred in 1989 (Table 18, Figure s14 and 19). The lower Illinois River reach (IR2) had over 12,000 acres of the semi-permanently flooded emergent perennial class in 1991. The distribution of the class in other Mississippi River reaches paralleled other aquatic plant classes. Geomorphic reach 4 had over 9,000 acres, and geomorphic reach 2 had almost 4,200 acres of the semi-permanently flooded emergent perennial class. Geomorphic reaches 6 and 8 had between 2,000 and 2,500 acres of the semi-permanently flooded emergent perennial class. Geomorphic reaches 1 and 9 had about 1,500 and 1,800 acres of the semi-permanently flooded emergent perennial class, respectively, and the remaining reaches (i.e., reaches 7, 10, and IR1) all had less than 1,000 acres. The abundance of this class parallels the distribution of backwaters.

The proportion of the floodplain covered by the semi-permanently flooded emergent perennial class was greatest in reaches 1 through 4 and IR 2. The percentage was 10, 7, 6, and 3% in Upper Mississippi River reaches 3, 2, 4, and 1 respectively. The class occupied a little more than 2% of the Illinois River floodplain. The proportion of this class barely exceeded or did not exceed 1% of the remaining river reaches.

7.2.6 Seasonally Flooded Emergent Annual

The seasonally flooded emergent annual land cover class includes wild millet, smartweed, and beggartick among others. These species did not occur in large enough areas to be mapped separately or occurred in mixed association with other emergent aquatic plant classes and did not account for any acreage in the entire UMRS (Table 18, Figure 14).

7.2.7 Seasonally flooded emergent perennial

The seasonally flooded emergent perennial class does not map separately in satellite derived data. The class is likely to be incorporated as marsh (i.e., semi-permanently flooded emergent perennial) or grassland categories in reaches 9, 10, IR1, and IR2. In the reaches where higher resolution data are available, the greatest amount of seasonally flooded emergent perennial land cover occurred in geomorphic reaches 3 and 4 (Table 18, Figure s14 and 20). Reach 4 had the most with over 1,700 acres; reach 3 had a little more than 1,100 acres. The seasonally flooded emergent perennial land cover class did not exceed 400 acres in any other reach. The class was a minor component in the floodplain land cover, occupying 1.2% or less of the floodplain in all the reaches. Water level regulation has resulted in a systemic decline in seasonally flooded emergent perennials because they require dynamic water levels. The abundance of the seasonally flooded emergent perennial class parallels the distribution of backwaters where this community thrives.

7.2.8 Wet Meadow

The wet meadow class does not map separately in satellite derived data. The class is likely to be incorporated as grassland or marsh (i.e., permanently flooded emergent perennial) categories in reaches 9, 10, IR1, and IR2. Wet meadow includes species such as reed canary grass, rice cutgrass, and prairie cord grass. An imported variant of reed canary grass is out competing and replacing woody classes in northern river reaches. The greatest amount of the wet meadow land cover class occurs in geomorphic reach 3 (9,200 acres) followed by reaches 4, 8, and 6 that range from about 5,000 to 7,400 acres (Table 18, Figure 14 and 21). The acreage of wet meadow in geomorphic reaches 1, 2, 5, and 8 is the lowest, ranging from about 3,300 to 1,800 acres. The absolute acreage appears to be related to the length and geomorphology of the reaches. The wet meadow class appears to be widely distributed throughout the system.

The proportion of the wet meadow class in the floodplain reveals the influence of reach lengths and geomorphology. Geomorphic reach 1 has the highest proportion of wet meadow, 6.5% of the floodplain. Reaches 3 and 4 have the next highest proportion (about 5%), which ranks similarly to their total amount among reaches. Wet meadow occupies between 1 and 2% of the floodplain in reaches 5 through 8. Much of the area mapped as grasslands by satellites would likely fall into this class under closer inspection.

7.2.9 Grassland

Grassland, although a major component of the pre-settlement floodplain landscape, is uncommon in the modern floodplain. The greatest acreage of grassland occurs in geomorphic reaches 9, IR2, and IR1, with about 21,000, 20,000 and 7,600 acres, respectively (Table 18, Fig 14 and 22). Much of the grassland area in reaches IR2 and 9 is grass growing on levees. Geomorphic reaches 3 and 10 each have about 2,000 acres, and the other reaches have about 500 acres or less. Grassland communities were prevalent in the pre-settlement landscape from at least Pool 13 in the north through the Kaskaskia River and throughout the lower Illinois Waterway reach, but crops have replaced them.

The greatest percentage of the grassland land cover class occurs in the upper Illinois River reach (geomorphic reach IR1), mostly in the lower end of the Lockport Pool and at the upper ends of the other pools. Grassland occurs on 4% of geomorphic reach 9 but it primarily occurs in patches near Horseshoe Lake State Park and on levees throughout the rest of the reach. The lower Illinois River (geomorphic reach IR2) has grassland cover of 4% and it occurred in a large patch at the Banner Marsh National Wildlife Refuge, along the margins of backwater lakes, and in other moist soil management units. The 1% of geomorphic reach 3 classed as grassland occurred primarily in the McCarthy Lake State Wildlife Refuge (Pool 5, Minnesota), at the Trempeleau National Wildlife Refuge (Pool 6, Wisconsin), and in the Root River delta (Pool 8, Minnesota).

7.2.10 Scrub Shrub Wetland

The scrub-shrub class does not map separately in satellite-derived data. The class is likely to be incorporated as wet floodplain forest categories in reaches 9, 10, IR1, and IR2. Much of the area reclassified to the HNA land cover class scrub-shrub was from the photo interpretation class of "Rdside-levee/grass/forbes/shrub", which includes railroads, roads, and levees. The classification causes difficulty separating natural communities from those resulting from development. Generally, a greater proportion of the natural scrub-shrub land cover occurs north of geomorphic reach 5 and most of the class in reaches 5 through 8 results from road and levee development (and reaches 9, 10, and IR2 if mapped).

The greatest amount of the scrub-shrub land cover class occurs in geomorphic reaches 6, 7, and 8 where the class ranges from about 7,000 to 9,000 acres (Table 18, Figure 14 and 23). The amount of scrub-shrub in geomorphic reaches 1 through 5 ranges from about 2,000 to 3,000 acres. Proportionately, geomorphic reaches 7 and 1 support the most scrub-shrub in the floodplain with 3.9 and 3.4% of the floodplain area, respectively. The percentage of the class comprising the floodplain is greater in the more developed reaches 5, 6, and 8 (>2%) than in the upper reaches 2, 3, and 4 (<2%).

7.2.11 Salix Community

The salix community class does not map separately in satellite-derived data. The class is likely to be incorporated as wet floodplain forest categories in reaches 9, 10, IR1, and IR2. The salix community class appears more often in geomorphic reach 3 (about 2,800 acres), than in any other reach (Table 18, Figure 14 and 24). The proportion of floodplain land cover in geomorphic reach 3 is about twice as much as the next closest reach. The salix community occurs in abundance along island and channel margins and surrounding floodplain lakes, which accounts for its abundance in the island-braided reach.

7.2.12 Populus Community

The populus community class does not map separately in satellite-derived data. The class is likely to be incorporated as wet floodplain forest categories in reaches 9, 10, IR1, and IR2. The inability to detect populus hinders the analysis of geomorphic reaches 9 and 10 where the community occurs more commonly than in pooled reaches. The community has not been regenerating well on the lower Illinois River or pooled reaches of the Mississippi. The class is largely restricted to islands and bank lines.

The greatest abundance of the populus community class occurs in geomorphic reaches 8 and 7, with about 1,700 and 700 acres, respectively (Table 18, Figure s14 and 25). The percent of populus occupying the floodplain is only 0.6 and 0.3% of reaches 8 and 7, respectively.

7.2.13 Wet Floodplain Forest

The wet floodplain forest class is the most abundant natural plant community remaining in the UMRS. The community grows well in floodplain areas, regenerating under its own canopy to create a self-sustaining climax community. The abundance of the wet floodplain forest is, to a large degree, dictated by human activity that has directly or indirectly modified the floodplain landscape.

The amount of the wet floodplain forest land cover class is related to the length of the geomorphic reaches. The greatest acreages occur in the longest reaches, geomorphic reaches IR2, 9, 8, and 3, and 4 in decreasing order (Table 18, Figure s14 and 26). The range is from 78,000 acres to 31,000 acres. The remaining reaches range from about 11,000 to 25,000 acres, with abundance being closely related to the length of the pool. The river reaches with the highest proportion of the floodplain occupied by wet floodplain forest may not necessarily be those with the largest absolute abundance. The three reaches with the highest abundance (IR2, 9, and 8) fall in the middle of the percent ranking. Wet floodplain forest occupied about 30% of geomorphic reach 1. The percent of wet floodplain forest in geomorphic reaches 2, 3, and 4 floodplains ranged from 18 to 21%. Reaches 5 through 10 have wet floodplain forest land cover ranging from 10 to 15% of the floodplain. The upper Illinois River reach (IR1) has about 21% wet floodplain forest land cover and the lower Illinois River reach has about 14%.

7.2.14 Mesic Bottomland Hardwood Forest

The mesic bottomland hardwood forest community class does not map separately in satellite derived data. The class is likely to be incorporated as wet floodplain forest categories in reaches 9, 10, IR1, and IR2. The class is a minor component of the modern floodplain. It was much more common in the past, especially in the middle river reaches and Illinois River. Geomorphic reaches 3 and 6 have two and three times, respectively, more mesic bottomland hardwood forest than the next highest ranked reach (Table 18, Figure s14 and 27). Geomorphic reach 6 has a concentrated area of more than 5,000 acres in the Big River State Forest (upper Pool 18, Illinois). Geomorphic reach 3 has large patches of mesic bottomland hardwood forest in pools 5 and 6, with isolated patches throughout the reach. Geomorphic reach 4 has large patches of mesic bottomland hardwood forest in the vicinity of the former Savanna Army Depot and the lower pool Potter’s Marsh area in Pool 13. Geomorphic reach 2 has patches along the Minnesota bluff and in the lower pool Chippewa delta area of pool 4. Geomorphic reach 5 has patches distributed in mostly upper pool reaches of pools 14, 15, 16, and 17. Mesic bottomland hardwood forest in geomorphic reach 8 occurs mostly in Pool 26 upstream of the Illinois River confluence.

The proportion of mesic bottomland hardwood forest in the floodplain is minor, with the maximum being 3 and 2% of reaches 6 and 3, respectively. The percent of mesic bottomland hardwood forest in reaches 2, 4, and 15 exceeded 1% of the floodplain, but the others did not.

7.2.15 Agriculture

Agriculture is the dominant land cover type in the UMRS, but its distribution is highly skewed toward southern river reaches. The amount of agriculture in geomorphic reaches 1 through 5 is an order of magnitude lower than in the other reaches (excluding IR1) (Table 18, Figure s14 and 28). The total amount of agriculture floodplain land cover in geomorphic reaches 6 though 10 and IR2 is related to the length of the reaches. Generally, most of the area between the riparian forest and bluffs has been leveed and converted to agriculture. The amount of agriculture in the lower reaches ranges from 100,000 to over 300,000 acres.

The proportion of the floodplain classed as agriculture clearly illustrates the degree of floodplain development. Agriculture occupies more than 50% of four floodplain reaches. In descending order, geomorphic reaches 10, 9, IR2, and 7 have 75%, 62%, 61%, and 57% of the floodplain developed as agriculture. Agriculture covers about 40% of geomorphic reaches 6 and 8, and about 24% of the upper Illinois River reach. Agriculture occupies 10% or less of the floodplain in geomorphic reaches 1 through 5.

7.2.16 Developed

The developed class includes small towns and cities that have been constructed in floodplain areas. They are typically protected by levees. The greatest amount of developed floodplain area occurs in geomorphic reach 9 across the river from St. Louis, Missouri. Most or all of the cities of Wood River, Granite City, East St. Louis, Centerville, and several smaller towns occur on about 50,000 floodplain acres (Table 18, Figure s14 and 29). Geomorphic reaches IR2, 5, 4, IR1, 3, and 6 follow in decreasing order and range from about 14,000 acres to 10,000 acres. Most of the acreage in these reaches occurs in small cities and towns, as opposed to the large metropolitan areas near St. Louis and Minneapolis. Geomorphic reach 1 has about 8,500 acres of Twin Cities development in the floodplain. The other reaches have less than 5,000 acres of developed area.

Proportionately, the Twin cities and Chicago suburbs have the most urban development in the floodplain. The upper Illinois River (IR1) developed area occurs in about 20% of the floodplain area, mostly in Lockport Pool. Geomorphic reach 1 has development on about 17% of the floodplain, including all of Pool 1 and much of Pool 2. Geomorphic reach 9 has only about 10% developed area on the floodplain, but the large total area of the reach skews the percentage. Geomorphic reaches 4 and 5 have about 8 and 10% developed area in the floodplain. Geomorphic reach 3 has about 7% development in the floodplain, with a large contribution from La Crosse, Wisconsin, the remaining reaches have 5% or less.

7.2.17 Sand-mud

The sand-mud class is a minor component of the floodplain landscape that is rather evenly distributed. Only two reaches, geomorphic reach 1 and 9 have more than 500 acres (Table 18, Figure s14 and 30). Geomorphic reach one had about 1.4% sand-mud in the floodplain and geomorphic reach 9 had 0.6. The other reaches had less than one-half percent. Channel maintenance has reduced the amount of sand bar habitat throughout the river system, impoundment limits mud flat development.

7.2.18 No Photo Coverage

Significant portions of reaches 5, 6, 7, and 8 did not have photo coverage or were considered too monotypic to develop high-resolution GIS maps (Table 18, Figure s14 and 31). No photo coverage areas account for almost 48,000 acres (36% of reach 5), and 78,000 acres (26% of reach 8). Geomorphic reaches 6 and 7 and are lacking photo interpreted data for about 48,000 and 30,000 acres, or 19 and 13% of the floodplain, respectively. Analysis of the satellite coverage for these areas revealed that agriculture accounts for more than 75% of the no photo coverage areas. The satellite data has been used to fill in the visuals of these floodplain reaches but the data are not incorporated into analyses.

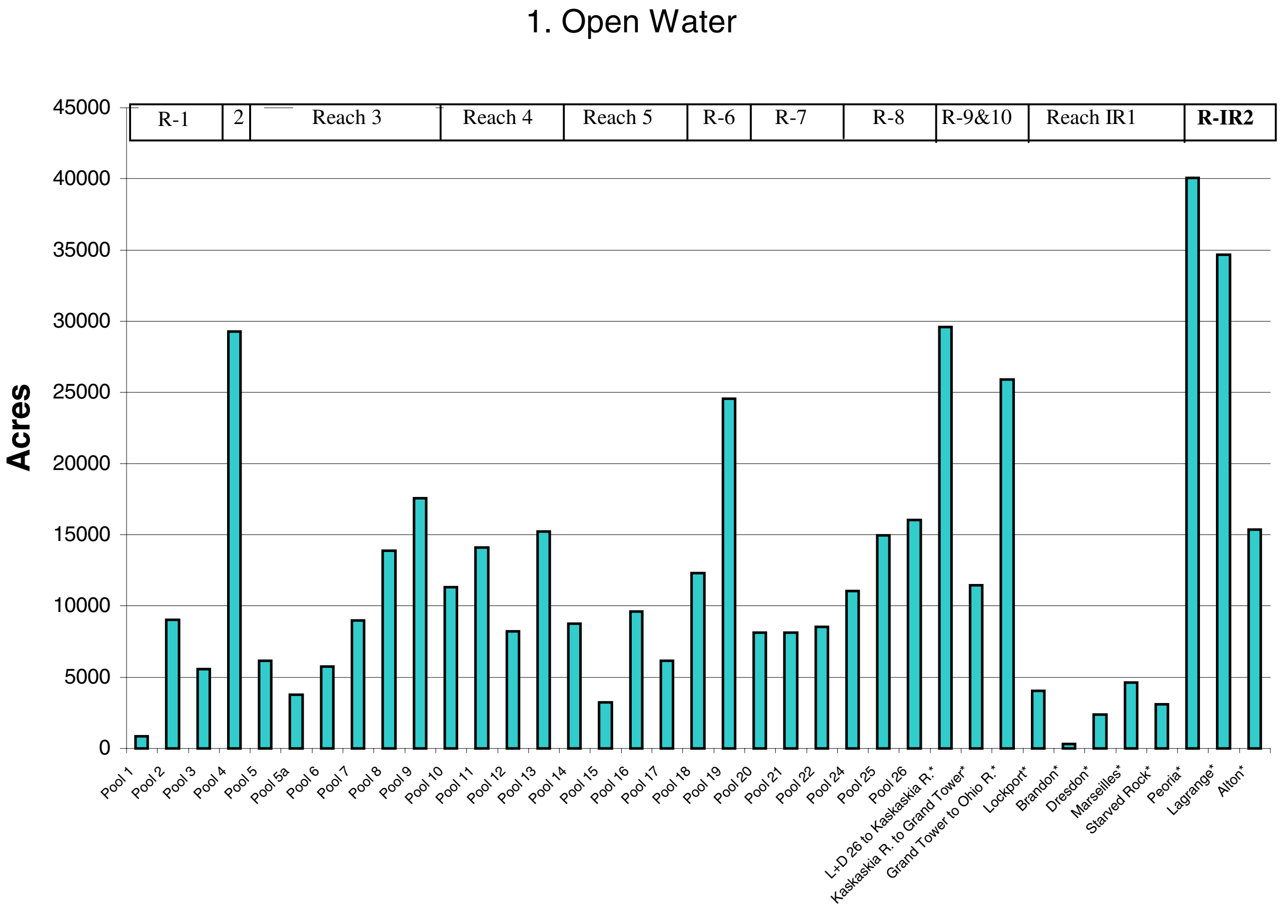

Figure 15. Open water distribution and abundance in the UMRS (* = satellite data).

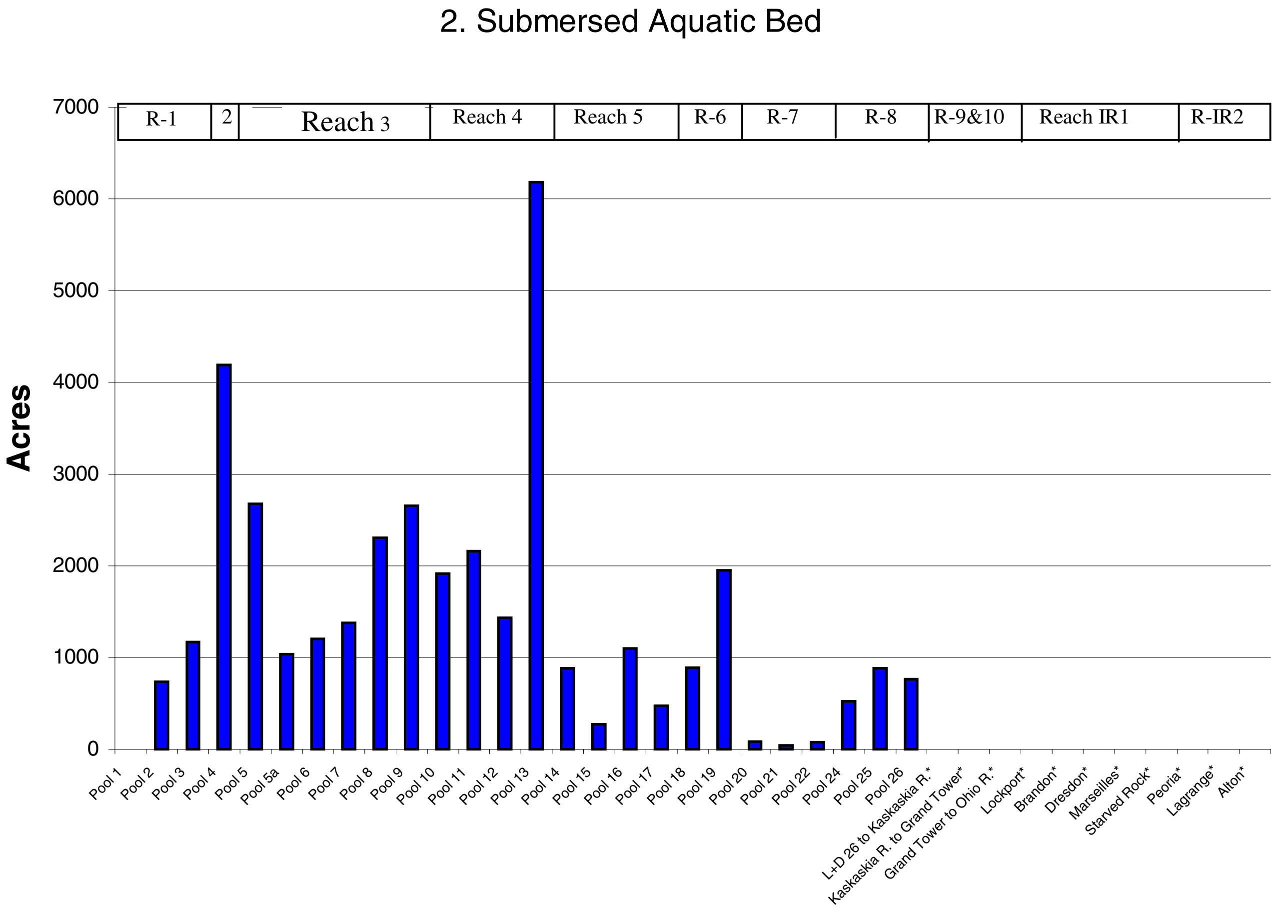

Figure 16. Submersed aquatic bed distribution and abundance in the UMRS (* = satellite data; not mapped by satellite).

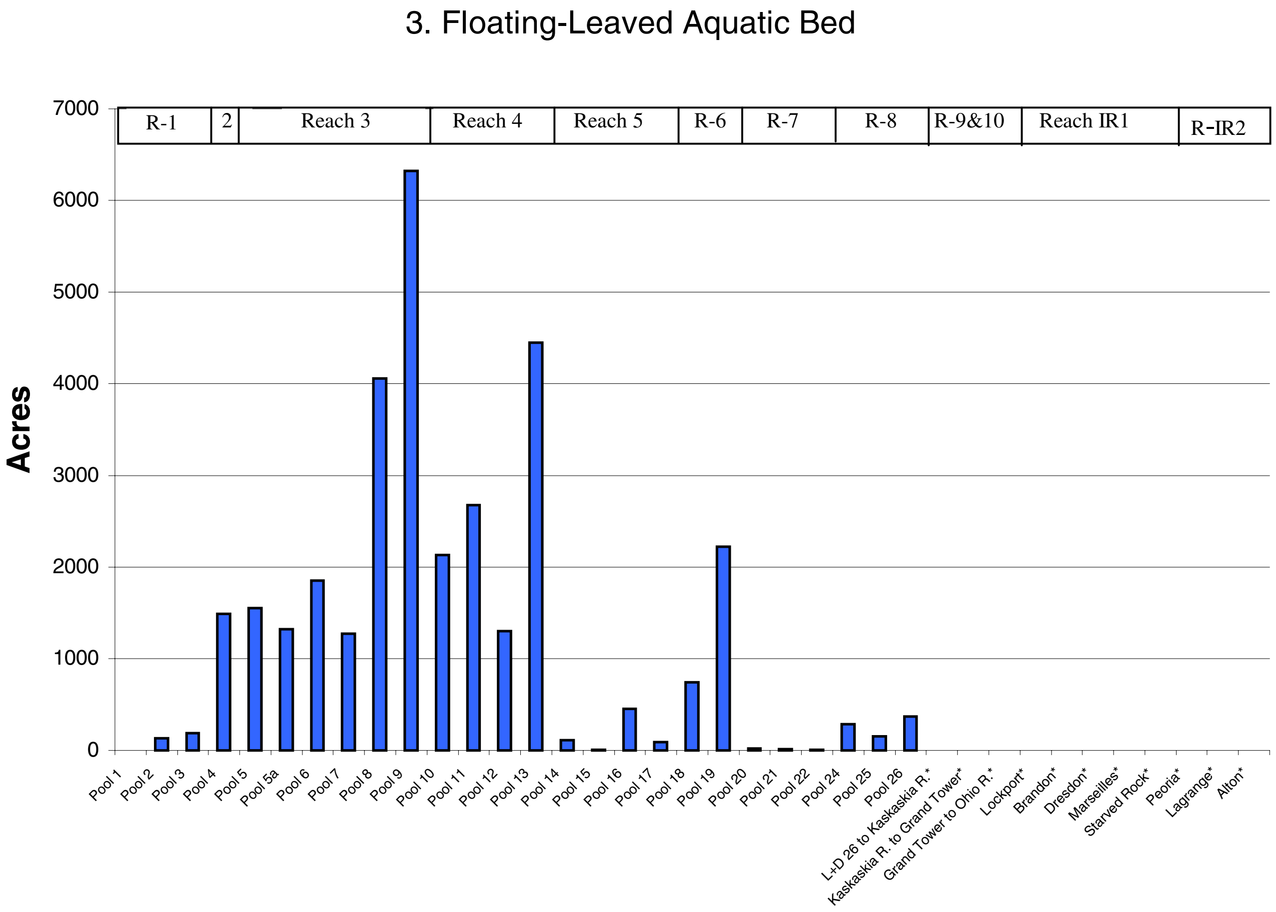

Figure 17. Floating-leaved aquatic bed distribution and abundance in the UMRS (* = satellite data).

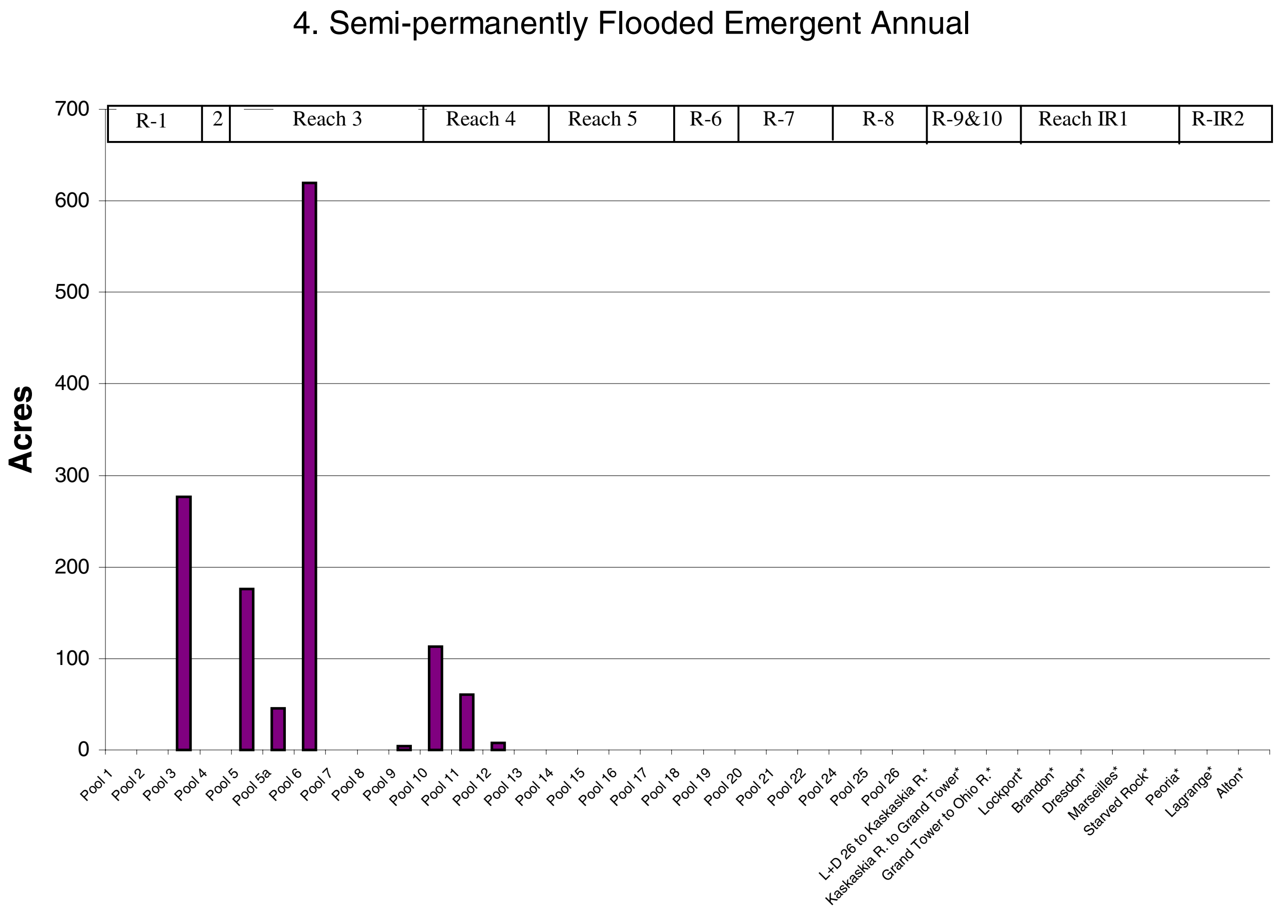

Figure 18. Semi-permanently flooded emergent annual plant distribution and abundance in the UMRS (* = satellite data).

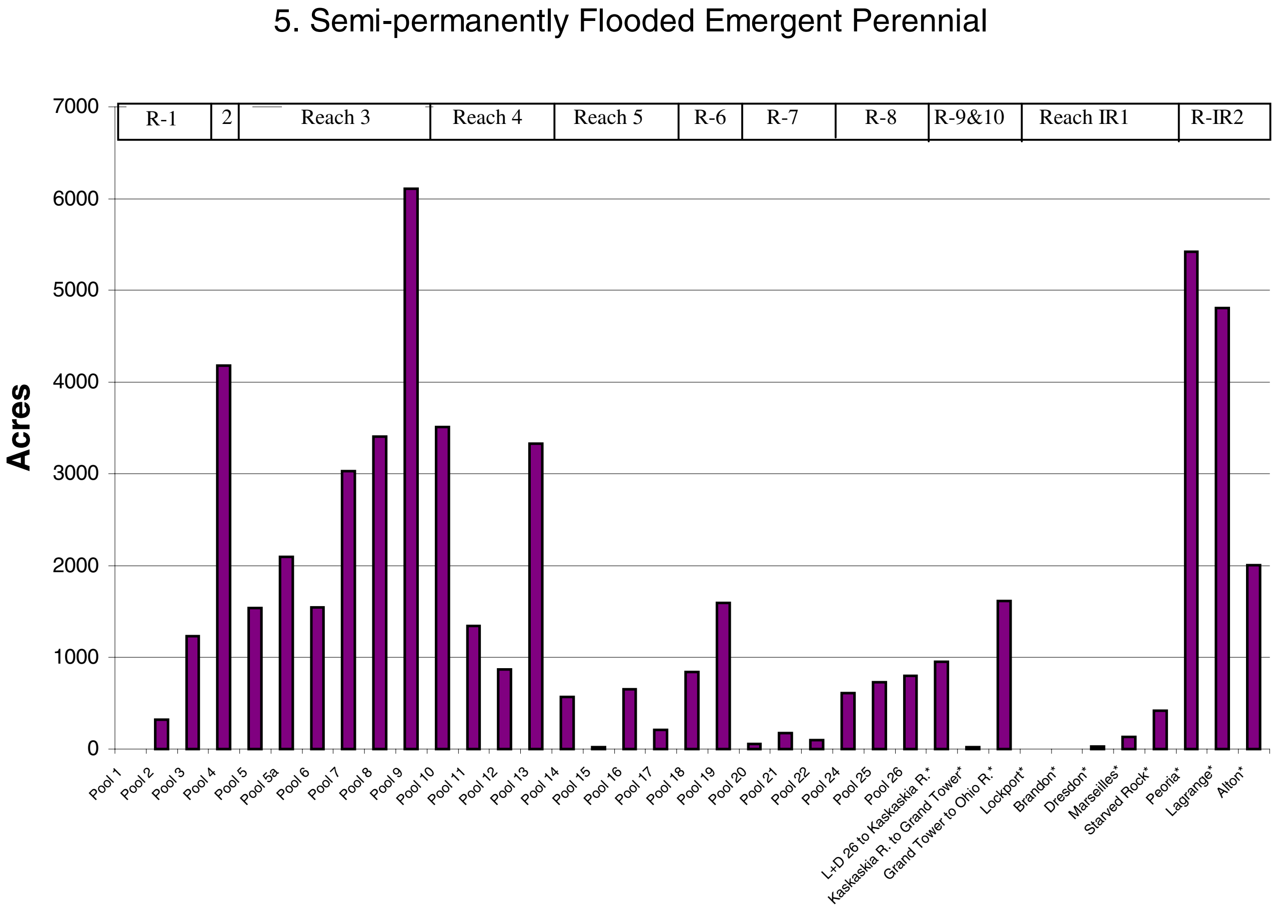

Figure 19. Semi-permanently flooded emergent perennial plant distribution and abundance in the UMRS (* = satellite data).

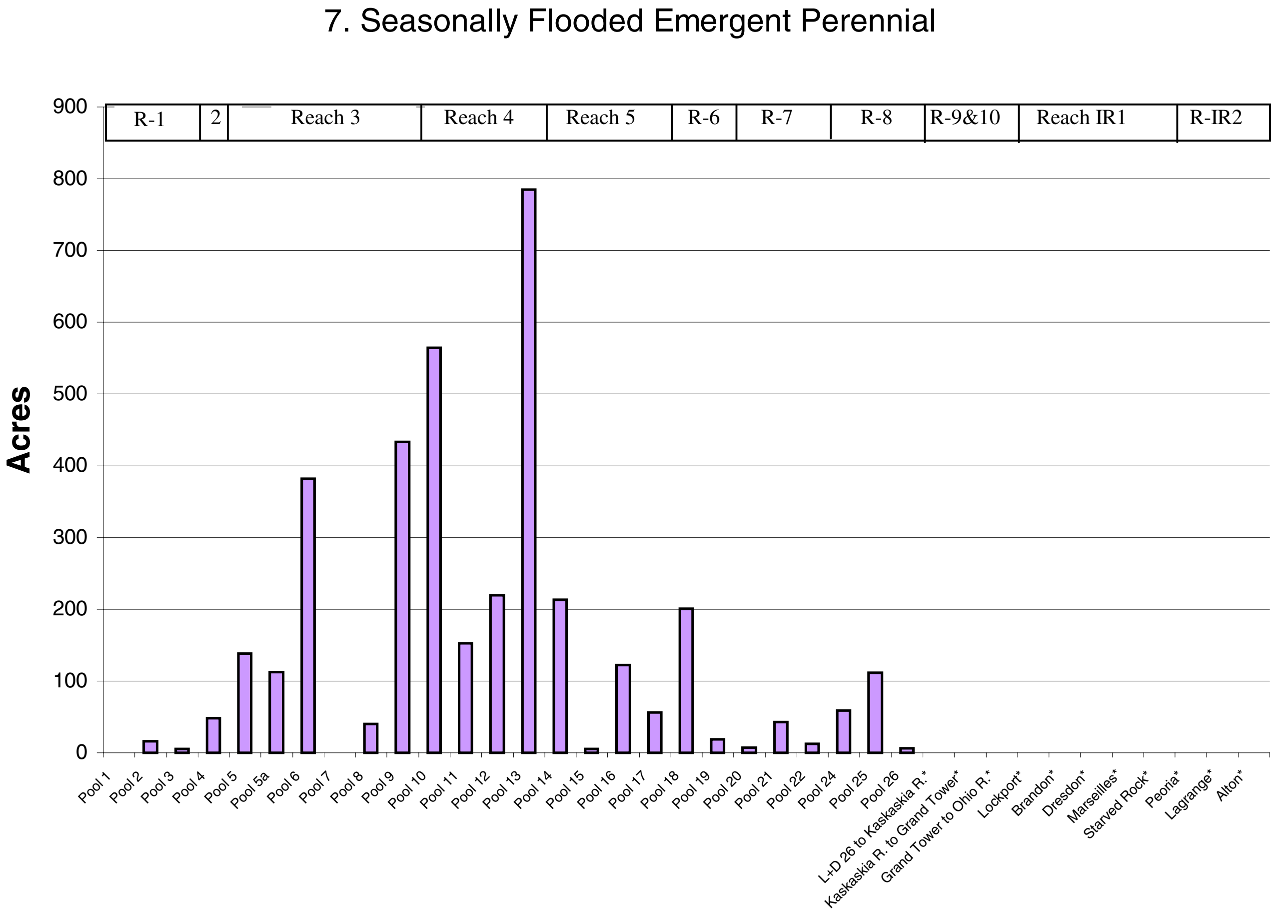

Figure 20. Seasonally flooded emergent perennial plant distribution and abundance in the UMRS (* = satellite data).

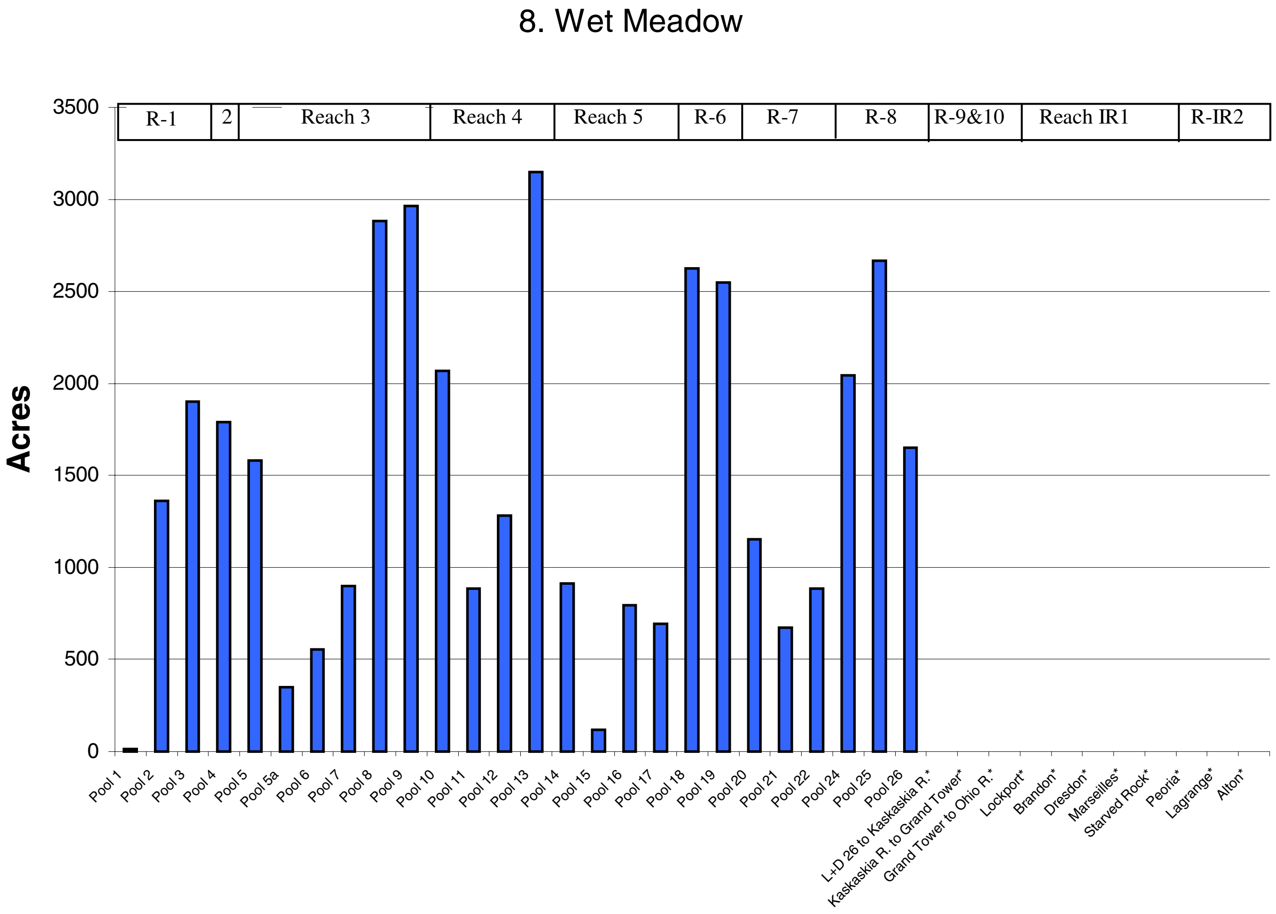

Figure 21. Wet Meadow distribution and abundance in the UMRS (* = satellite data).

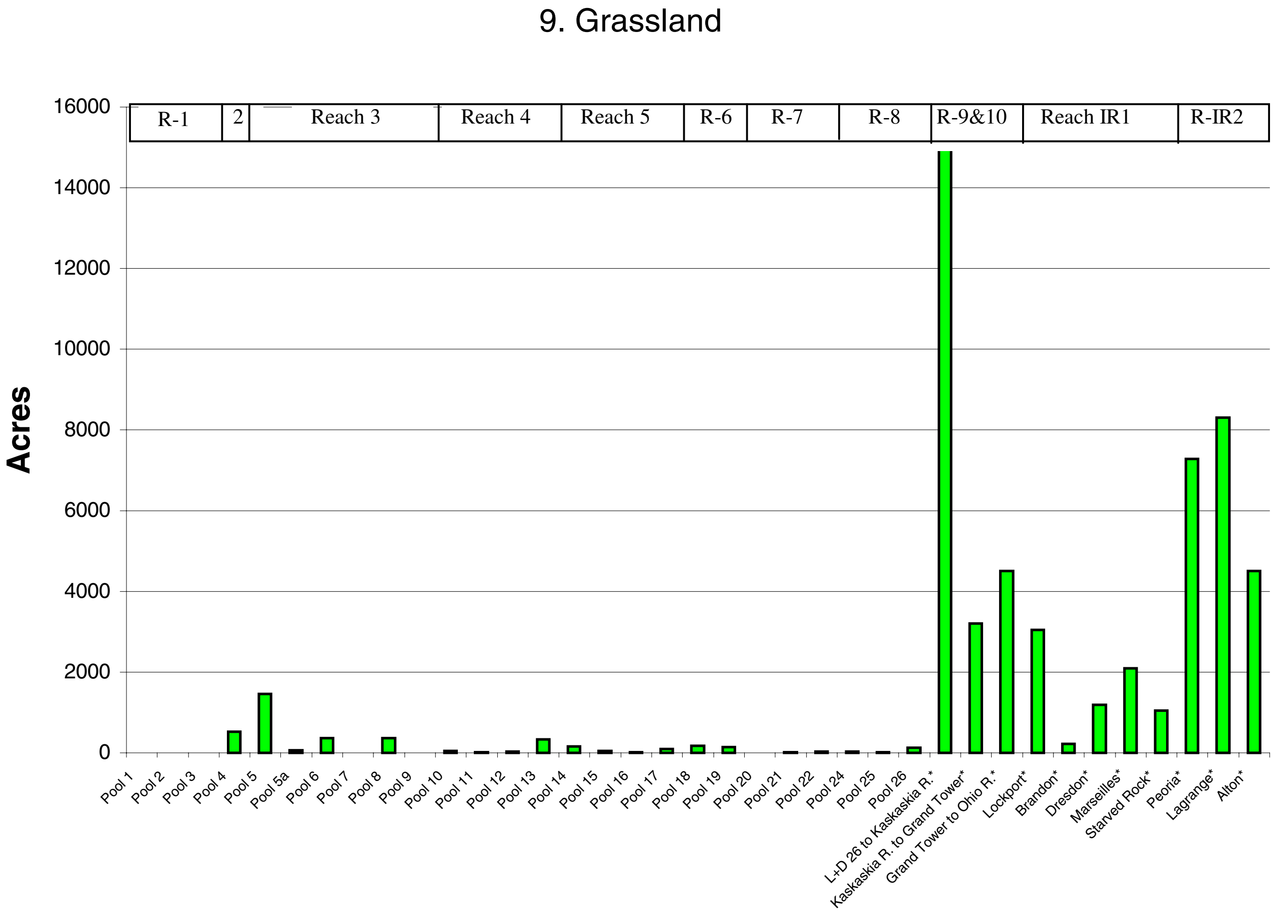

Figure 22. Grassland distribution and abundance in the UMRS (* = satellite data).

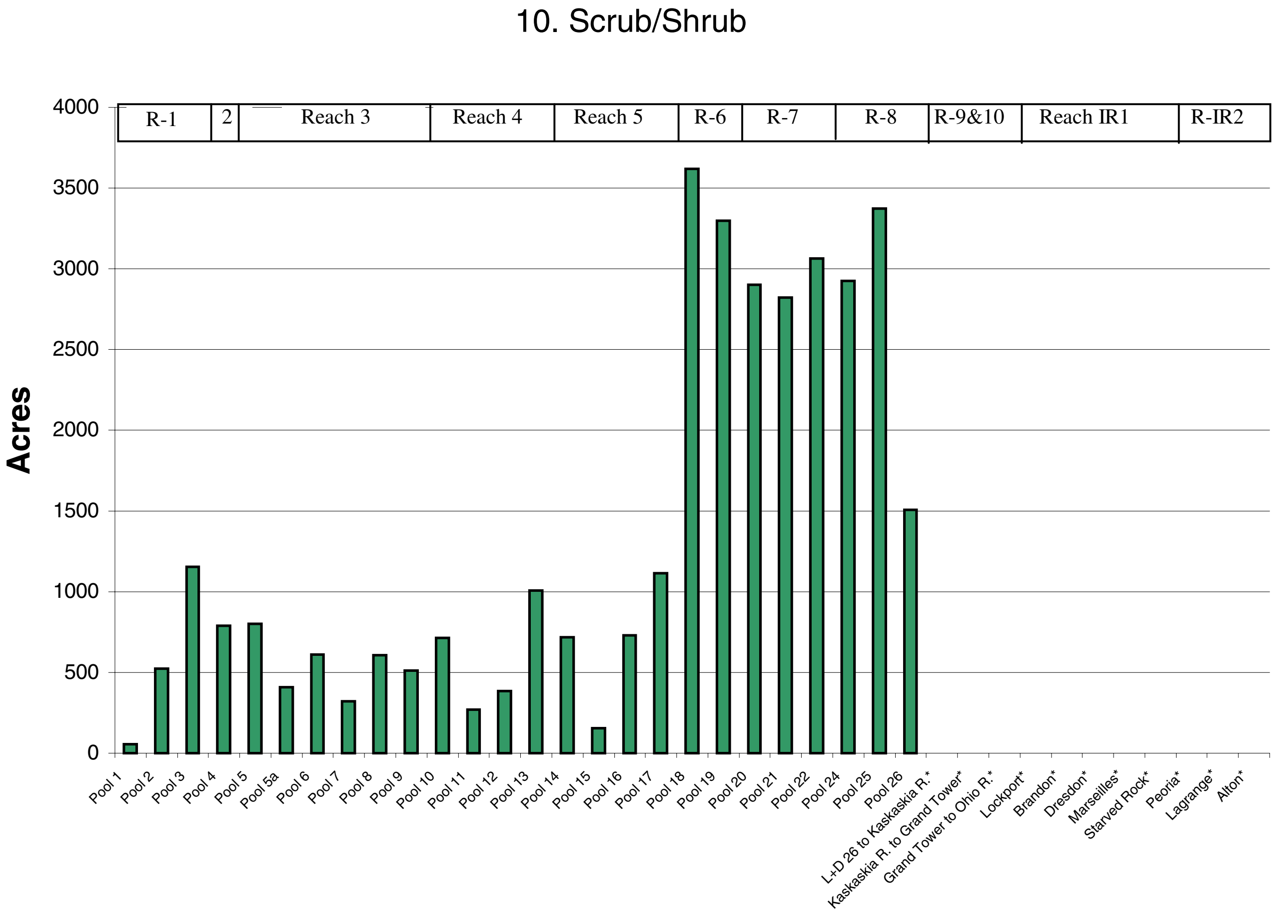

Figure 23. Scrub-shrub distribution and abundance in the UMRS (* = satellite data).

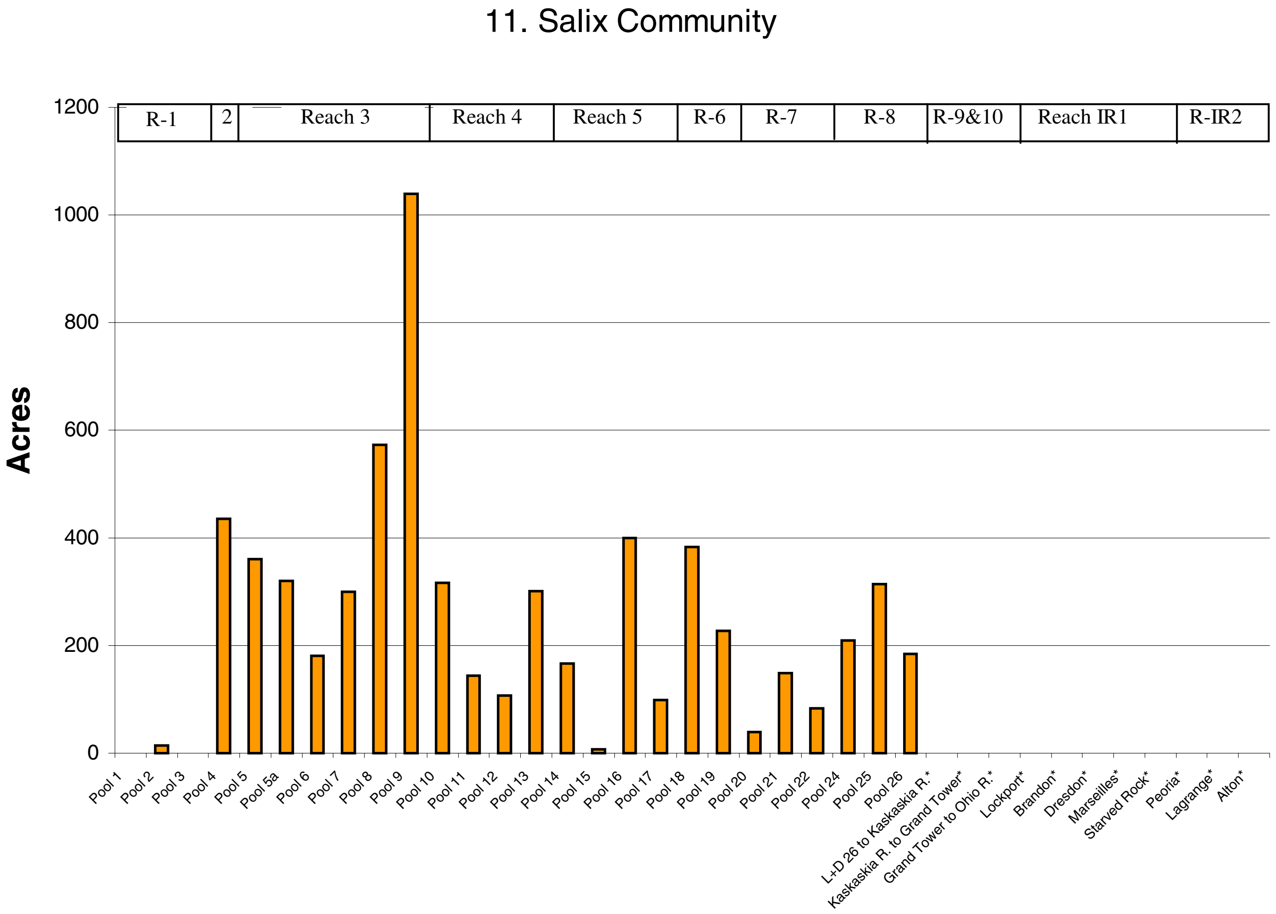

Figure 24. Salix community distribution and abundance in the UMRS (* = satellite data).

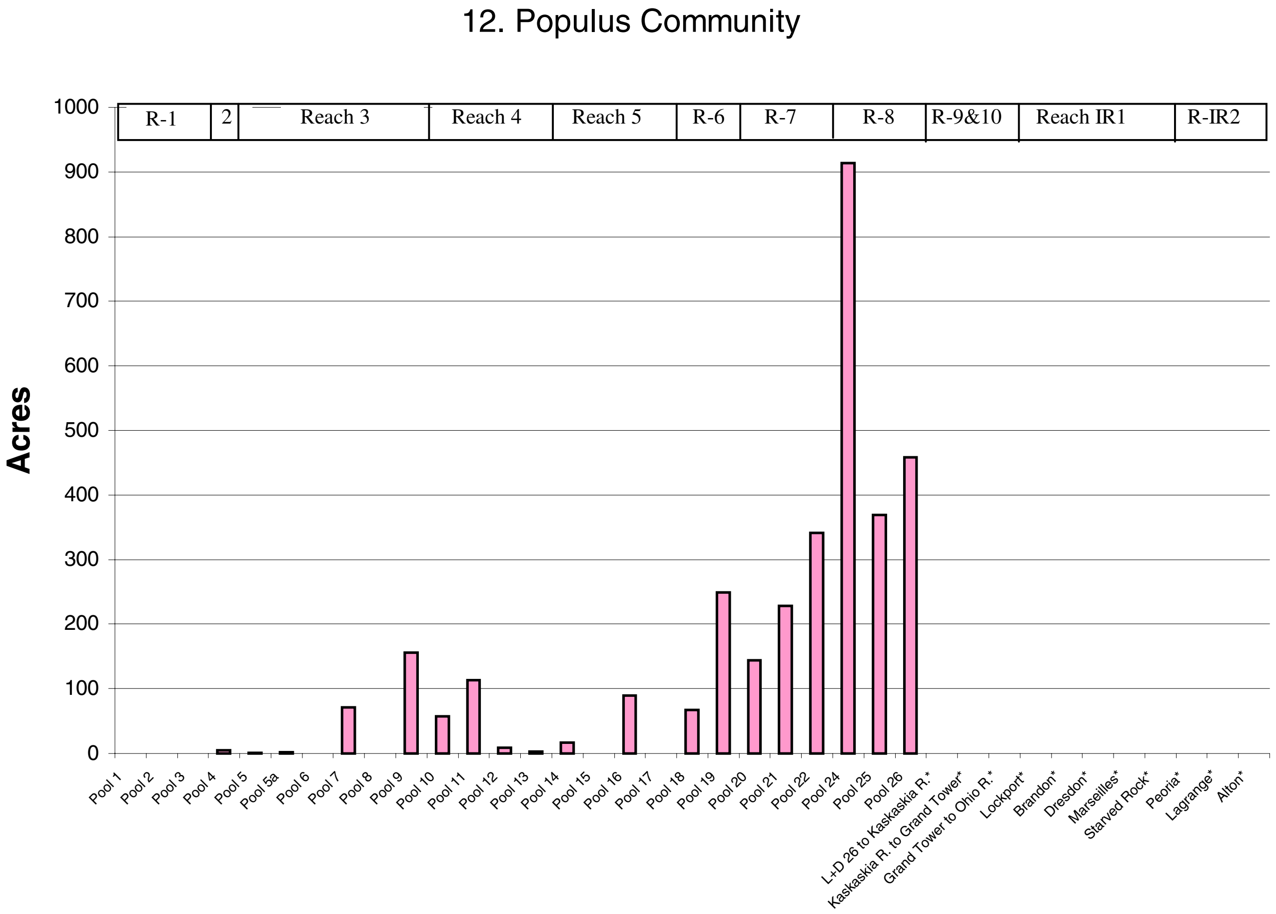

Figure 25. Populus community distribution and abundance in the UMRS (* = satellite data).

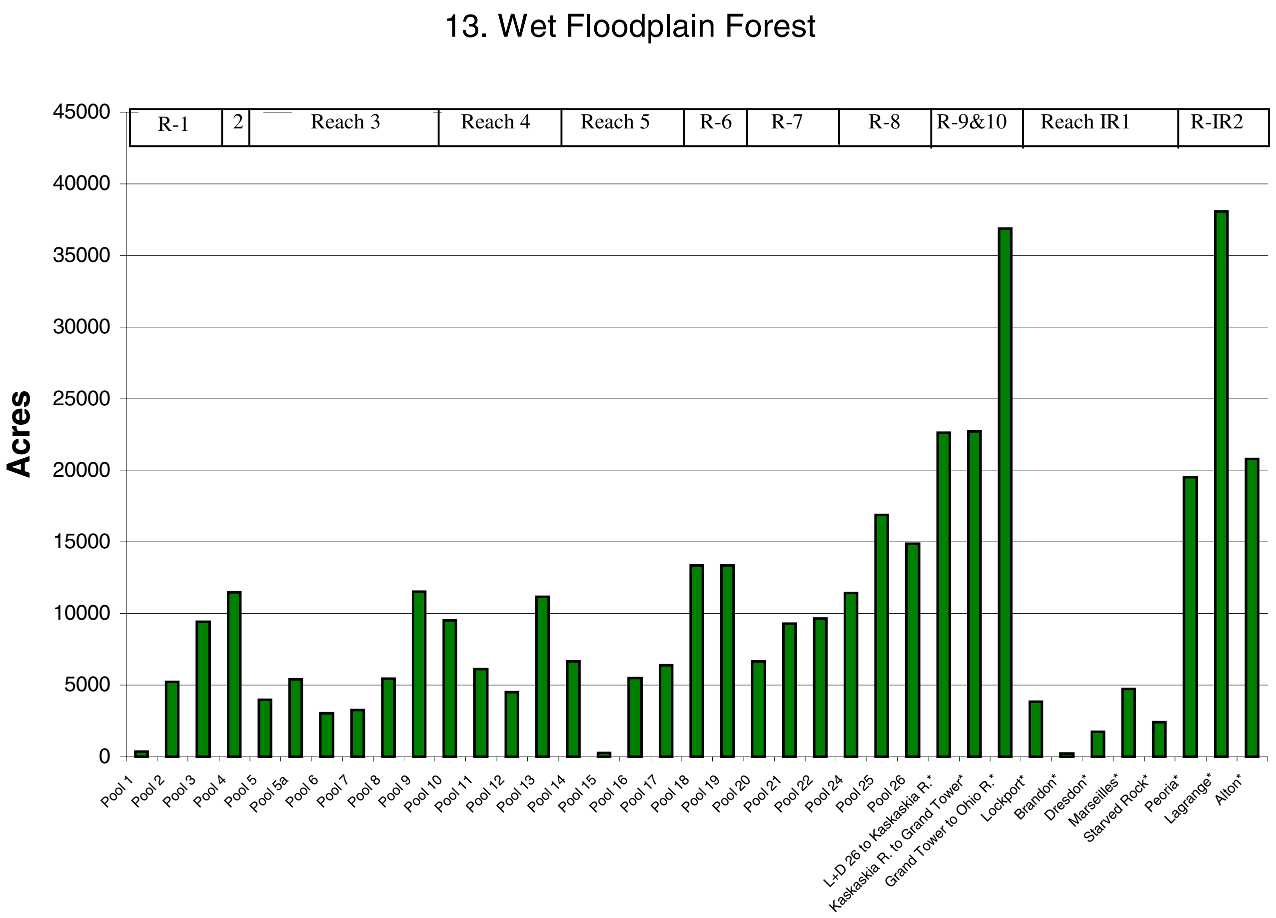

Figure 26. Wet floodplain forest distribution and abundance in the UMRS (* = satellite data).

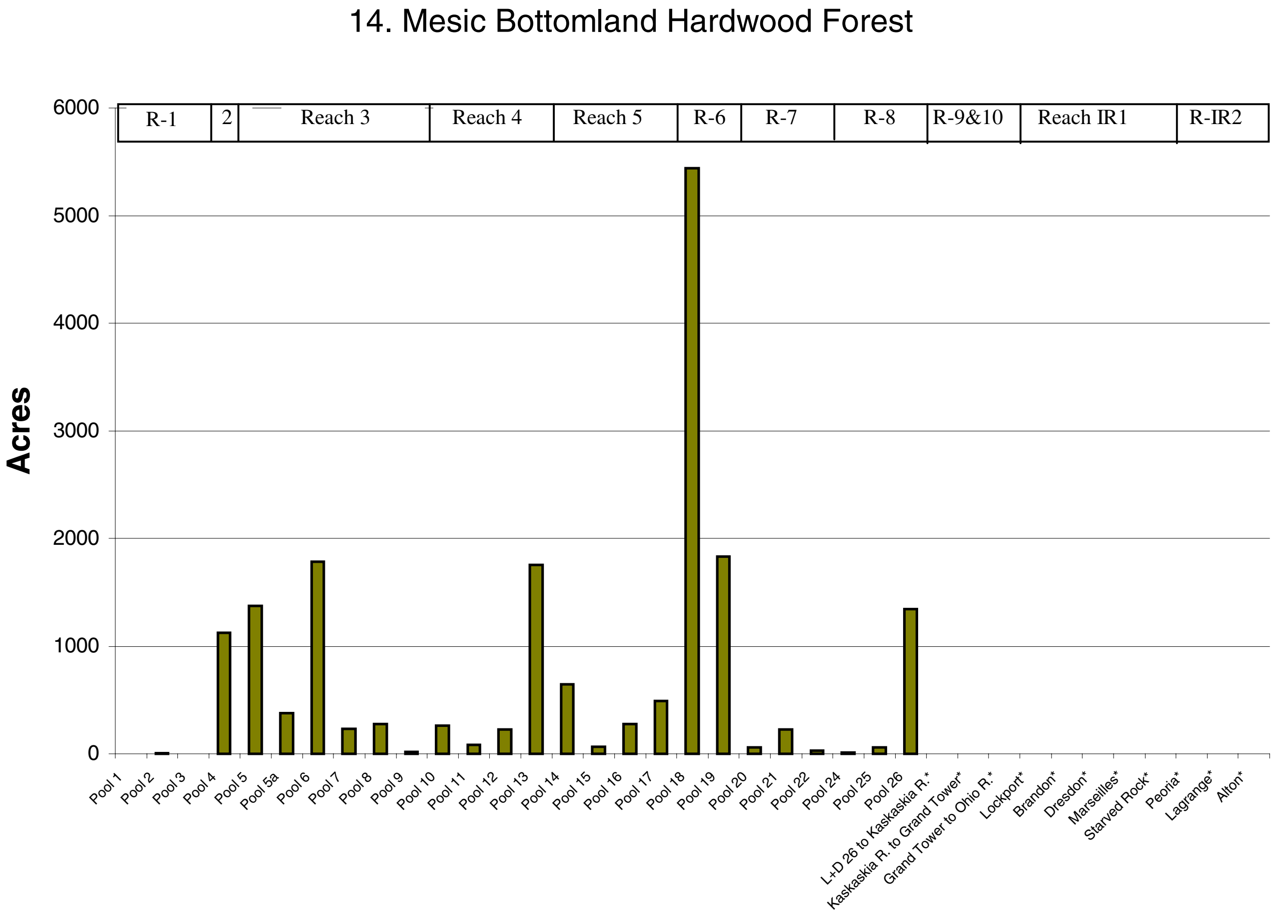

Figure 27. Mesic bottomland hardwood floodplain forest distribution and abundance in the UMRS (* = satellite data).

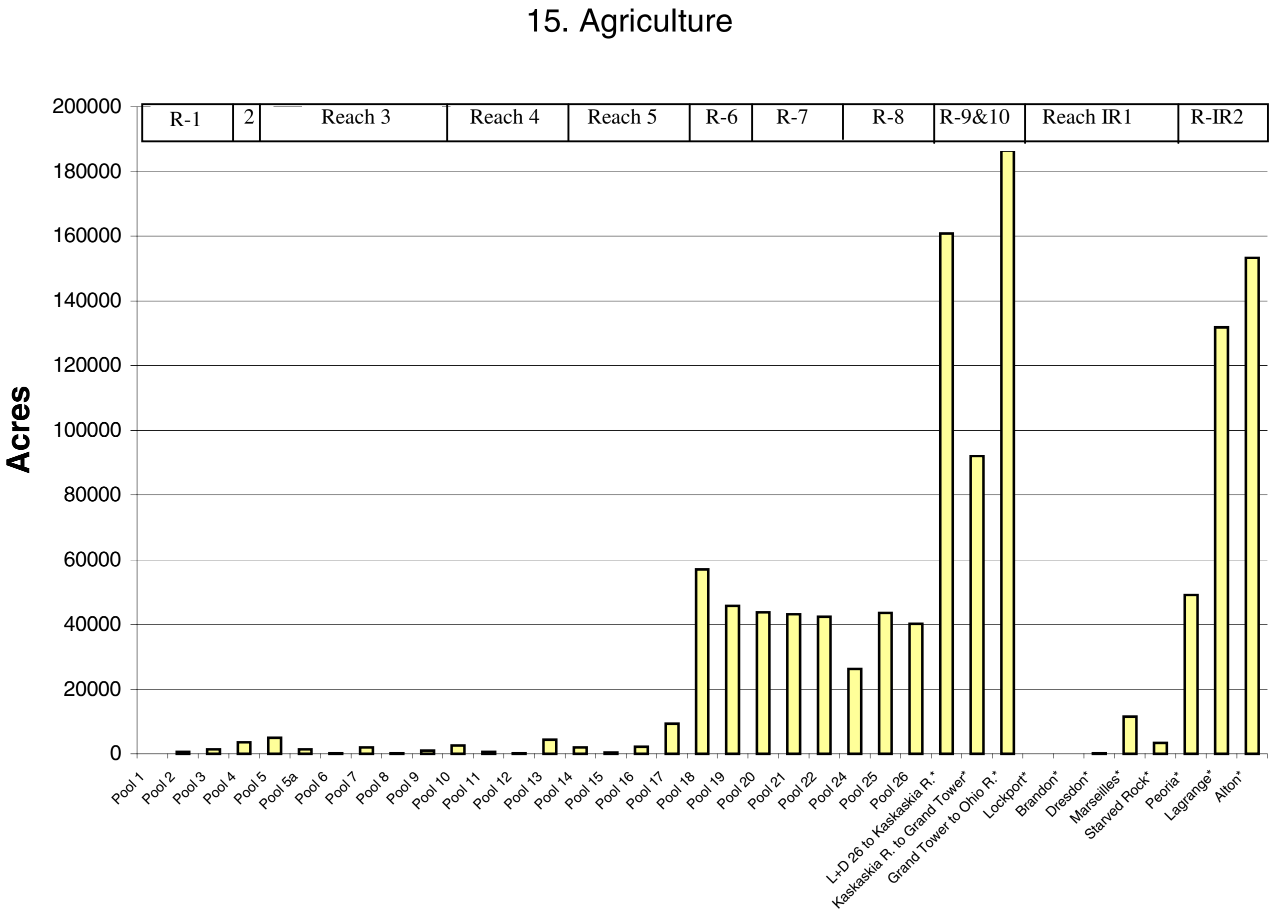

Figure 28. Agriculture distribution and abundance in the UMRS (* = satellite data).

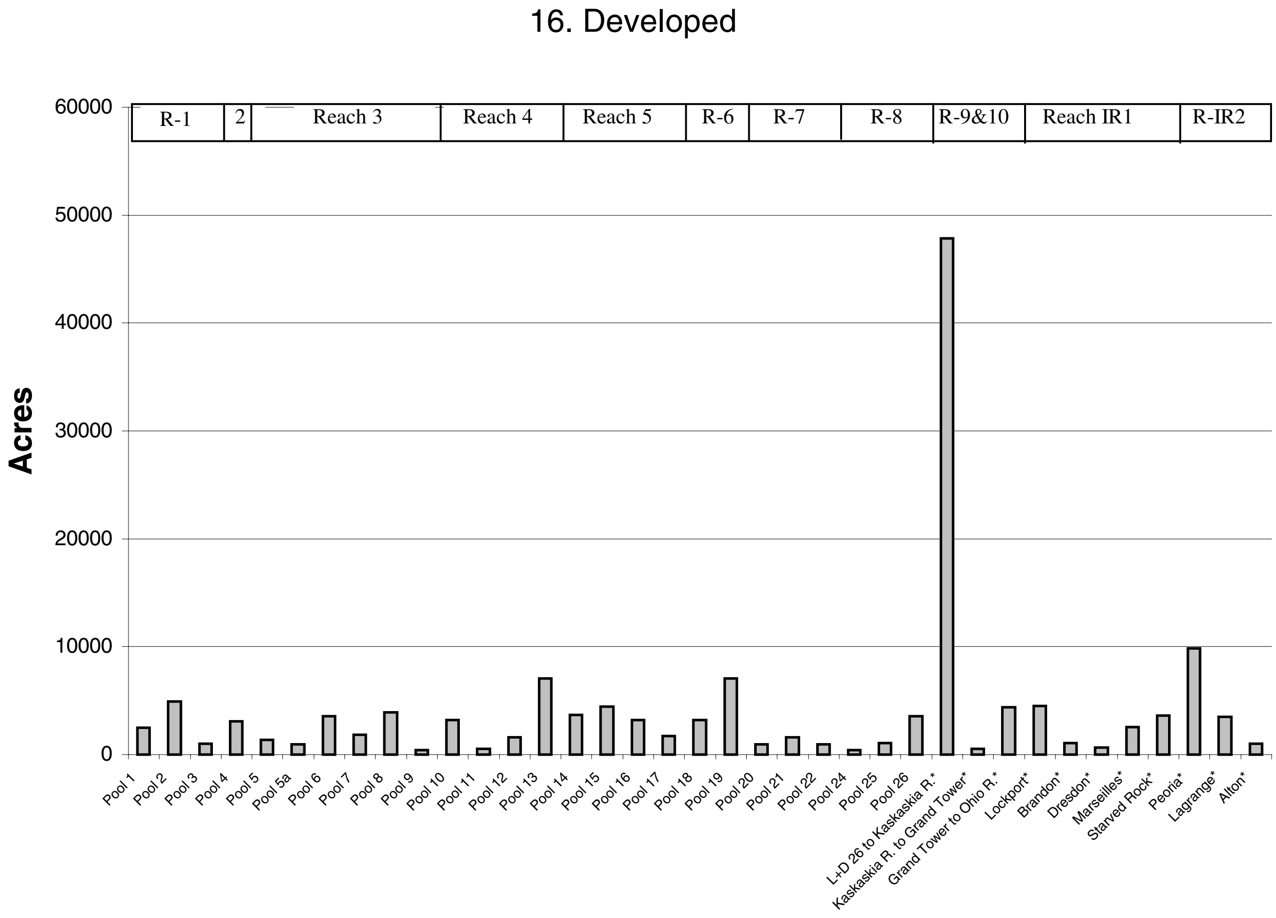

Figure 29. Developed area distribution and abundance in the UMRS (* = satellite data).

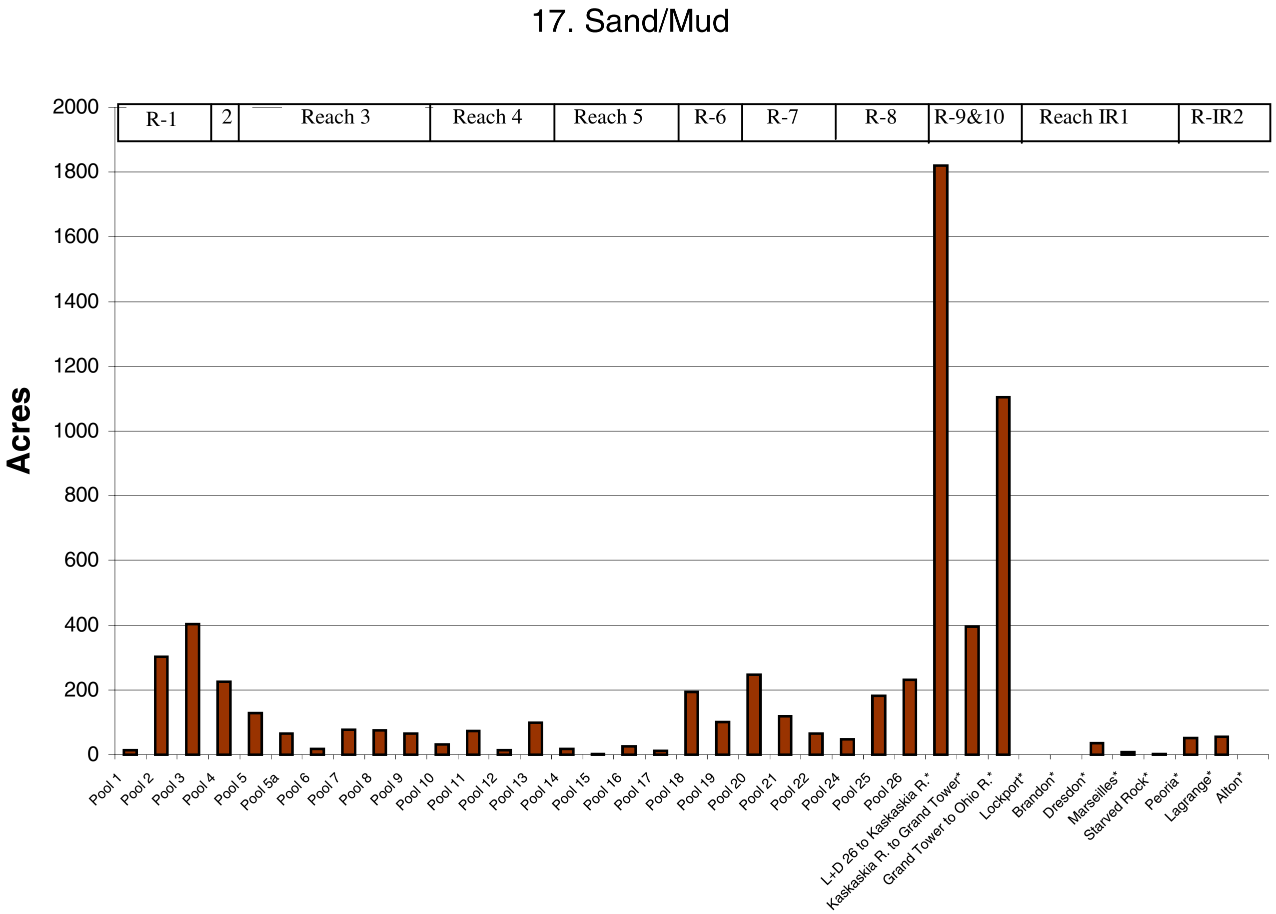

Figure 30. Sand-mud distribution and abundance in the UMRS (* = satellite data).

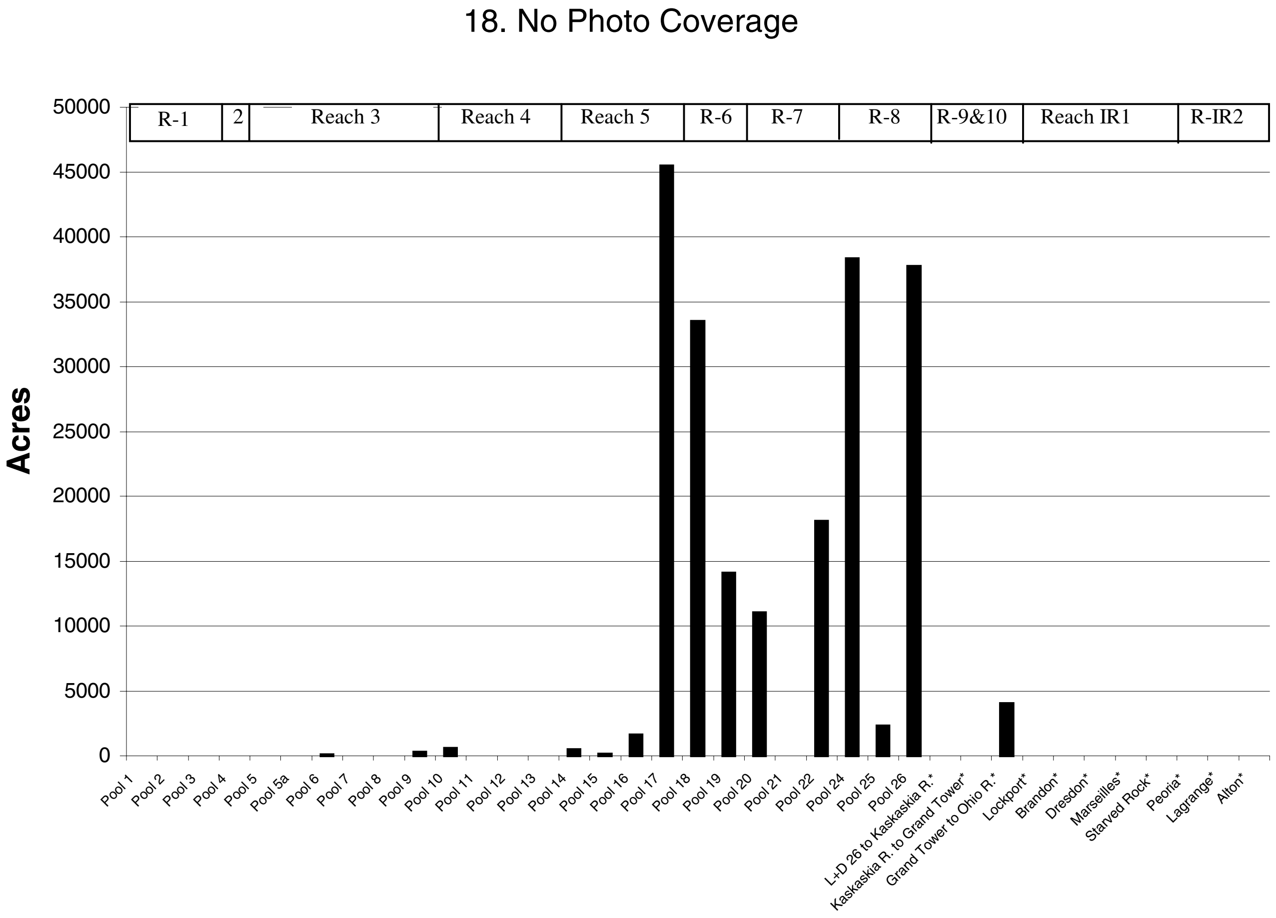

Figure 31. No photo coverage distribution and abundance in the UMRS (* = satellite data).

7.3 HNA Geomorphic Areas Distribution-Abundance-Scarcity

7.3.1 Main Navigation Channel

The amount of main channel area in each geomorphic reach is related to its length because the main channel has a defined width. Longer reaches have more main channel area than shorter reaches (Tables 19 and 20; Figs 32 and 33); the range is from 2,700 acres to 9,000 acres. The proportion of the floodplain occupied by main channel is greatest in geomorphic reaches 4, 2, and 5 (6.1, 4.3, and 4.1%, respectively; Table 19). The other reaches range from 2 to 3% of the floodplain area. The proportion of main channel to total aquatic area differs from floodplain area. Considering only aquatic areas, main channel area in geomorphic reaches 7, 8, and 5 is 20, 19, and 17%, respectively (Table 20). The main navigation channel area in the remaining reaches occupy from 7% to 12% of the total aquatic area.

7.3.2 Main Channel Border

Main channel border area varies with the width of the channel and impacts resulting from impoundment, in addition to the length of the reach. System-wide, main channel border area accounts for 6.6% of the floodplain, and 24% of the total aquatic area (Tables 19 and 20, Figure s32 and 34). The greatest amount of main channel border habitat occurs in reaches 5 through 8 where it ranges from 11,000 to 17,600 acres. The total channel width relative to the navigation channel width is much greater in the lower pooled reach, thus accounting for the high acreage in reaches 5 through 8. The proportion of main channel border in the floodplain is about 11% in geomorphic reaches 4 and 5 (Table 20). Main channel border occupies 7% of the floodplain in reach 6 and about 5% of the floodplain in reaches 3, 7, and 8. Considering only aquatic area, main channel border area is 36 to 44% of geomorphic reaches 5 through 8 (Table 20). Geomorphic reach 4 main channel border area is 21% of total aquatic area; reaches 3 and 2 are 10% and 3%, respectively.

7.3.3 Tailwater

Tailwaters are defined as the 500-foot reach of river below the dams. They are turbulent areas that attract many fish species. They occupy only 1,400 acres and less than one-half of one of total aquatic area, but they are unique habitats (Tables 19 and 20, Figure s32 and 35). The area of tailwaters range from about 100 to 300 acres among the geomorphic reaches.

7.3.4 Secondary Channel

The greatest secondary channel acreage occurs in geomorphic reaches 4 and 8 (9,200 and 10,600 acres, respectively; Tables 19 and 20, Figure s32 and 36). Reaches 3, 5, and 6 secondary channel area ranges from 7,000 to 7,800 acres. Secondary channel area is 4,500 acres in reach 7 and 1,100 in reach 2. The proportion of secondary channel in the floodplain is the greatest in reaches 4 and 5, at about 6% of total floodplain area (Table 19). The other reaches range from 2 to 4% of floodplain area. Considering only aquatic area, the proportion of side channel area is greatest in reaches 5 and 8, where side channels account for 24 and 23% of total aquatic area, respectively (Table 20). Secondary channel area is 17 and 18% of total aquatic area in reaches 6 and 7, and 8% of reach 3. Some secondary channels may have been misclassified during interpretation.

7.3.5 Tertiary Channel

Tertiary channels do not account for large amounts of area or for large proportions of either floodplain or aquatic area. There is concern, however, that tertiary channels may have been misclassified during interpretation. As mapped, they account for about 1,100 acres in reach 3, 500 acres in reach 4, and less than 300 acres in each of the other reaches (Tables 19 and 20, Figure s32 and 37). They account for 1% or less of total aquatic area in all reaches (Table 20). Tertiary channels are abundant in island braided river reaches with numerous small islands.

7.3.6 Tributary Channels

Tributary channels are also a minor, but unique, component of the floodplain landscape. They are important fish migration corridors, refugia, and spawning areas, and create highly diverse deltas. They account for less than 600 acres in each of the geomorphic reaches (Tables 19 and 20, Figure s32 and 38). Tributary channels account for 2% of the reach 7 total aquatic area, and 1% or less in the other reaches (Table 20).

7.3.7 Excavated Channels

Excavated channels are not mapped on available GIS coverages, but there are three significant canals on the UMRS. The Chicago Sanitary and Ship Canal and Cal-Sag Canal join Lake Michigan and the Upper Illinois Waterway. The Chain of Rocks Canal circumvents large rapids near the confluence with the Missouri River. The lower Kaskaskia River has been channelized by cutting off oxbows and dredging a straight channel. Other dredged channels connect marinas and harbors to the main channel.

7.3.8 Contiguous Floodplain Lake

The amount of contiguous floodplain lake area in geomorphic reach 2 greatly exceeds all the other reaches (Tables 19 and 20, Figure s32 and 39). Lake Pepin is an unusual lake formed by glacial sediment loading that impounded the Mississippi River at the Chippewa River delta. Lake Pepin accounts for most of the 25,500 acres of backwater in geomorphic reach 2 (Table 19). Geomorphic reaches 3 and 4 have large amounts of contiguous floodplain lake area with 6,800 and 9,300 acres, respectively. The amount of contiguous floodplain lake area decreases downstream. Contiguous floodplain lake area in reaches 5 through 8 ranges from 1,000 to 3,000 acres. Contiguous floodplain lake area occupies 41% of the floodplain in reach 2, 6% in reach 4, and 1 to 4% in the other reaches (Table 19). Considering aquatic area only, the distribution of contiguous floodplain lake area is a little more even. Geomorphic reach 2 contiguous floodplain lake area stands out as exceptionally high at 70% of the total aquatic area (Table 20). Contiguous floodplain lake area in reach 4 is 12% of the total aquatic area. Contiguous floodplain lake area in geomorphic reaches 3, 4, 5, and 8 ranges from 6 to 8% of the total aquatic area. Contiguous floodplain lake area accounts for only 4% of reach 7 total aquatic area.

7.3.9 Shallow Aquatic Area

Shallow aquatic areas are the transitional braided channel areas between the riverine and impounded regions of some navigation pools. They are most abundant in geomorphic reaches 3 and 4 where they account for 17,800 and 10,500 acres, respectively (Tables 19 and 20, Figure s32 and 40). Geomorphic reaches 2 and 6 have 3,900 and 3,200 acres of shallow aquatic area. The other reaches have 800 acres or less. Shallow aquatic area accounts for 10% of the total floodplain in reach 3, 7% in reach 4, and 6% in reach 2, but it is a minor component of the floodplain in the other reaches (Table 19). Considering aquatic area only, shallow aquatic area in geomorphic reaches 3, 4, and 2 accounts for 19, 14 and 11% of the floodplain (Table 20). Shallow aquatic area accounts for 7% of reach 7 total aquatic area, but it is less than 2% of the other reaches.

7.3.10 Contiguous Impounded Area

Impounded area in geomorphic reach 3 (36,100 acres) is twice as much as reach 4 (18,800 acres) and is over 15 times larger than the amount in reach 6 (2,600 acres; Tables 19 and 20, Figure s32 and 41). Geomorphic reaches 2 and 8 have about 1,000 acres of impounded area and reaches 5 and 7 have none. Impounded area accounts for 20% of the total floodplain area in geomorphic reach 2, 13% in reach 4, and 2% or less in the other reaches (Table 20). Considering aquatic area only, impounded area accounts for almost 40% of the total aquatic area in reach 2 (Table 21). Impounded area is 24% of the total aquatic area in geomorphic reach 4, 6% in reach 7, and less than 3% of the other reaches.

7.3.11 Isolated Backwater Lake

Isolated backwater lakes are most abundant in geomorphic reach 3 (8,200 acres) followed by reaches 8 and 6 with about 5,000 acres each (Tables 19 and 20, Figure s32 and 42). Geomorphic reaches 4 and 7 have about 3,500 and 2,800 acres of isolated backwaters, respectively. Geomorphic reach 5 has about 1,400 isolated backwaters acres and reach 1 has 1,000. Isolated backwater lakes account for about 5% of the total floodplain area in geomorphic reach 3, and 2% or less in the other reaches (Table 19). As percent of total aquatic area, isolated backwater lakes account for about 11% of geomorphic reaches 6, 7, and 8 (Table 20). Despite their high rank in total amount, isolated backwater lakes in geomorphic reach 3 ranks fourth in proportional abundance at 9% of total aquatic area. Isolated backwaters account for less than 5% of the land cover in other reaches.

7.3.12 Islands

The greatest amount of area occupied by islands occurs in geomorphic reach 3 where there are 28,400 acres (Table 20, Figure s32 and 43). Geomorphic reach 4 has 21,800 island acres. There are 16,700 acres of islands in geomorphic reach 8, but these are generally very large islands rather than the numerous smaller islands in the upper reaches. Geomorphic reaches 5 through 7 have about 10,000 acres of islands, and geomorphic reach 1 has about 5,000 acres. Islands account for 16 and 15% of the total floodplain area in geomorphic reaches 3 and 4, respectively (Table 19). About 7% of the total floodplain area in reaches 2 and 5 is occupied by islands. Islands account for 5% or less of reaches 6 through 8.

7.3.13 Contiguous Floodplain

There are about 70,000 acres of contiguous floodplain in geomorphic reaches 6 and 8 (Table 19, Figure s32 and 44). Geomorphic reaches 3 and 4 have about 53,500 and 41,500 acres of contiguous floodplain, respectively. The acreage of contiguous floodplain ranges from 20,000 to 28,000 acres in reaches 2, 5, and 7. Contiguous floodplain accounts for the greatest proportion of the floodplain in geomorphic reaches 2, 3, 4, and 6 where it is 34%, 30%, 28%, and 27% of total floodplain area, respectively (Table 19). In geomorphic reach 8, contiguous floodplain is 23% of the total floodplain area. It drops to 17% and 13% in reaches 5 and 7.

7.3.14 Isolated Floodplain

Geomorphic reach 7 has the greatest amount of isolated floodplain among the geomorphic reaches with 134,000 acres behind levees (Table 19, Figure s32 and 45). The other southern reaches 6, and 8 also have significant leveed area with 91,000 and 83,000 isolated floodplain acres. Geomorphic reach 5 has 21,500 acres of isolated floodplain, and the other reaches have about 6,000 leveed acres or less. If the amount of no photo coverage is included because it represents mostly leveed area, the rank of abundance of isolated floodplain changes to reach 8, 7, 6, and 5, with acreage ranging from 70,000 acres to 170,000 acres. The proportion of isolated floodplain area in the floodplain is similar to the amount of isolated area in the area with photo coverage. If the no photo coverage class is categorized with isolated floodplain, then geomorphic reach 7 is about 72% isolated. Geomorphic reach 8 is 56% isolated, and reaches 5 and 6 are about 52% isolated. Reaches 4, 3, and 2 are less than 5% isolated.

Table 19. HNA geomorphic area distribution and abundance in Upper Mississippi River geomorphic reaches 2 through 8.

Acres

	Aquatic												Terrestrial			
	Channel Areas							Backwater Areas				Islands	Floodplain		No	
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated		Contiguous	Isolated	Photo	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded					Coverage	Total
Reach 2	2,700.4	1,107.2	28.7	1,142.8	5.8	238.9	0.0	25,501.8	3,873.2	1,007.2	978.2	4,566.3	20,850.9	155.3	0.0	62,156.7
Reach 3	5,840.2	9,087.5	322.1	6,955.7	1,060.8	516.0	0.0	6,796.6	17,803.7	36,107.2	8,235.1	28,350.5	53,446.4	5,424.0	389.3	180,335.1
Reach 4	9,032.4	16,336.3	202.6	9,176.1	490.3	487.4	0.0	9,327.0	10,494.9	18,834.0	3,455.3	21,816.5	41,541.6	6,077.0	606.2	147,877.6
Reach 5	5,477.2	14,061.7	267.1	7,817.1	105.4	123.6	0.0	2,746.4	608.7	0.0	1,397.4	9,638.1	22,889.4	21,465.1	47,746.6	134,343.8
Reach 6	5,409.5	17,613.0	125.0	7,573.9	94.8	539.2	0.0	3,017.2	3,169.1	2,641.6	4,461.5	10,523.7	67,597.7	83,034.0	47,586.0	253,386.2
Reach 7	5,047.0	11,082.2	230.4	4,499.7	24.1	577.1	0.0	1,039.4	0.0	0.0	2,728.8	9,928.5	28,232.5	133,700.7	29,115.0	226,205.4
Reach 8	8,607.7	16,724.1	219.2	10,554.4	261.2	471.1	0.0	2,706.5	818.5	1,021.2	4,957.2	16,694.5	70,275.4	90,744.8	78,341.0	302,396.8
Total	42,114.4	86,012.0	1,395.1	47,719.7	2,042.4	2,953.3	0.0	51,134.9	36,768.1	59,611.2	26,213.5	101,518.1	304,833.9	340,600.9	203,784.1	1,306,701.6

Percent

	Aquatic											**Terrestrial**				
	Channel Areas							Backwater Areas				Islands	Floodplain		No	
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated		Contiguous	Isolated	Photo	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded					Coverage	Total
Reach 2	4.3	1.8	0.0	1.8	0.0	0.4	0.0	41.0	6.2	1.6	1.6	7.3	33.5	0.2	0.0	100.0
Reach 3	3.2	5.0	0.2	3.9	0.6	0.3	0.0	3.8	9.9	20.0	4.6	15.7	29.6	3.0	0.2	100.0
Reach 4	6.1	11.0	0.1	6.2	0.3	0.3	0.0	6.3	7.1	12.7	2.3	14.8	28.1	4.1	0.4	100.0
Reach 5	4.1	10.5	0.2	5.8	0.1	0.1	0.0	2.0	0.5	0.0	1.0	7.2	17.0	16.0	35.5	100.0
Reach 6	2.1	7.0	0.0	3.0	0.0	0.2	0.0	1.2	1.3	1.0	1.8	4.2	26.7	32.8	18.8	100.0
Reach 7	2.2	4.9	0.1	2.0	0.0	0.3	0.0	0.5	0.0	0.0	1.2	4.4	12.5	59.1	12.9	100.0
Reach 8	2.8	5.5	0.1	3.5	0.1	0.2	0.0	0.9	0.3	0.3	1.6	5.5	23.2	30.0	25.9	100.0
Total	3.2	6.6	0.1	3.7	0.2	0.2	0.0	3.9	2.8	4.6	2.0	7.8	23.3	26.1	15.6	100.0

Table 20. HNA aquatic area distribution and abundance in Upper Mississippi River geomorphic reaches 2 through 8.

Acres

	Aquatic											
	Channel Areas							Backwater Areas				
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded		Total
Reach 2	2,700.4	1,107.2	28.7	1,142.8	5.8	238.9	0.0	25,501.8	3,873.2	1,007.2	978.2	36,584.2
Reach 3	5,840.2	9,087.5	322.1	6,955.7	1,060.8	516.0	0.0	6,796.6	17,803.7	36,107.2	8,235.1	92,724.9
Reach 4	9,032.4	16,336.3	202.6	9,176.1	490.3	487.4	0.0	9,327.0	10,494.9	18,834.0	3,455.3	77,836.3
Reach 5	5,477.2	14,061.7	267.1	7,817.1	105.4	123.6	0.0	2,746.4	608.7	0.0	1,397.4	32,604.6
Reach 6	5,409.5	17,613.0	125.0	7,573.9	94.8	539.2	0.0	3,017.2	3,169.1	2,641.6	4,461.5	44,644.8
Reach 7	5,047.0	11,082.2	230.4	4,499.7	24.1	577.1	0.0	1,039.4	0.0	0.0	2,728.8	25,228.7
Reach 8	8,607.7	16,724.1	219.2	10,554.4	261.2	471.1	0.0	2,706.5	818.5	1,021.2	4,957.2	46,341.1
Total	42,114.4	86,012.0	1,395.1	47,719.7	2,042.4	2,953.3	0.0	51,134.9	36,768.1	59,611.2	26,213.5	355,964.6

Percent

	Aquatic											
	Channel Areas							Backwater Areas				
	Main			Secondary	Tertiary	Tributary	Excavated	Contiguous			Isolated	
Reach	Nav. Channel	Channel Border	Tailwater					FP lake	Shallow AQ	Impounded		Total
Reach 2	7.4	3.0	0.1	3.1	0.0	0.7	0.0	69.7	10.6	2.8	2.7	100.0
Reach 3	6.3	9.8	0.3	7.5	1.1	0.6	0.0	7.3	19.2	38.9	8.9	100.0
Reach 4	11.6	21.0	0.3	11.8	0.6	0.6	0.0	12.0	13.5	24.2	4.4	100.0
Reach 5	16.8	43.1	0.8	24.0	0.3	0.4	0.0	8.4	1.9	0.0	4.3	100.0
Reach 6	12.1	39.5	0.3	17.0	0.2	1.2	0.0	6.8	7.1	5.9	10.0	100.0
Reach 7	20.0	43.9	0.9	17.8	0.1	2.3	0.0	4.1	0.0	0.0	10.8	100.0
Reach 8	18.6	36.1	0.5	22.8	0.6	1.0	0.0	5.8	1.8	2.2	10.7	100.0
Total	11.8	24.2	0.4	13.4	0.6	0.8	0.0	14.4	10.3	16.7	7.4	100.0

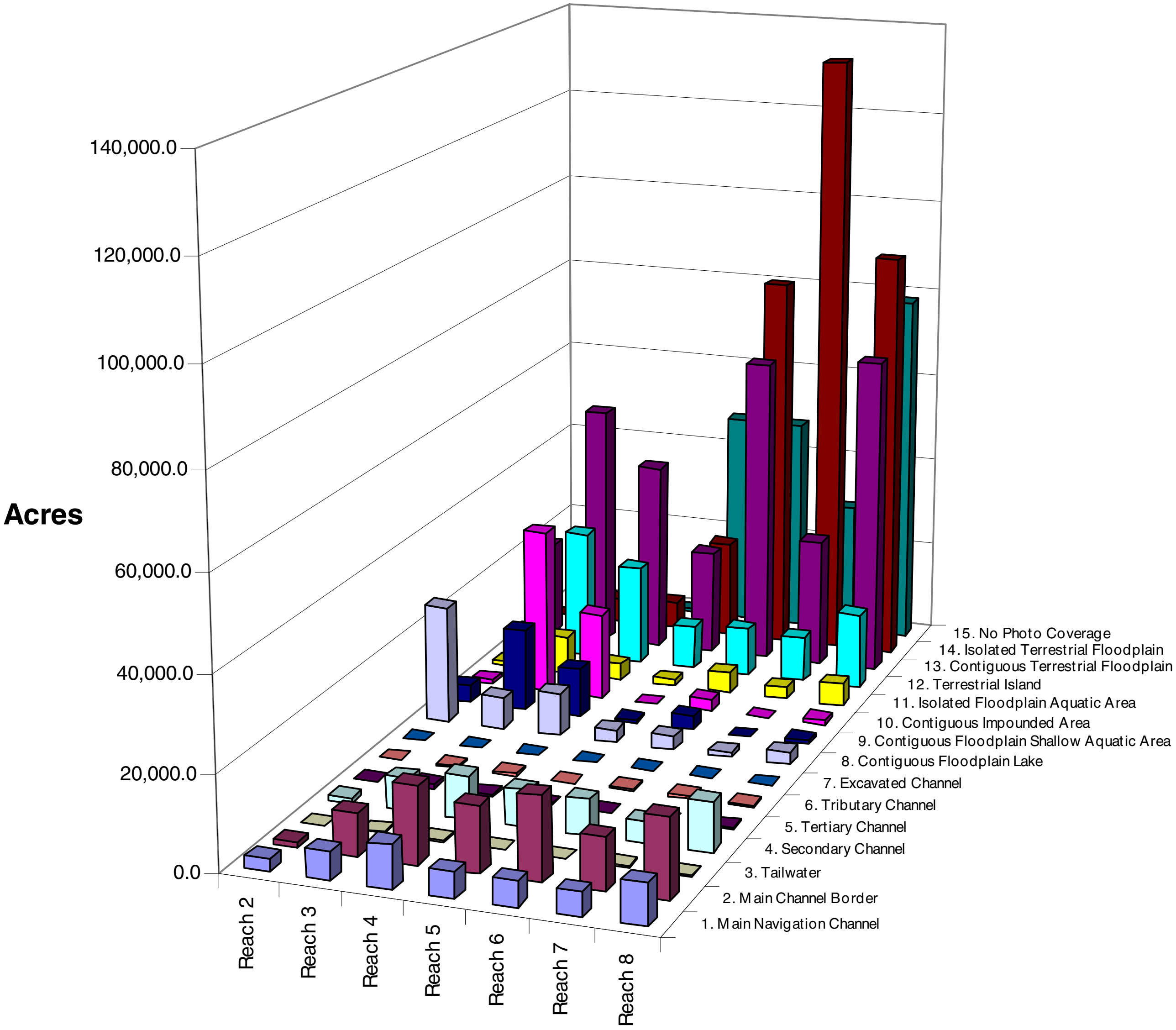

Figure 32. HNA geomorphic area distribution and abundance in the UMRS.

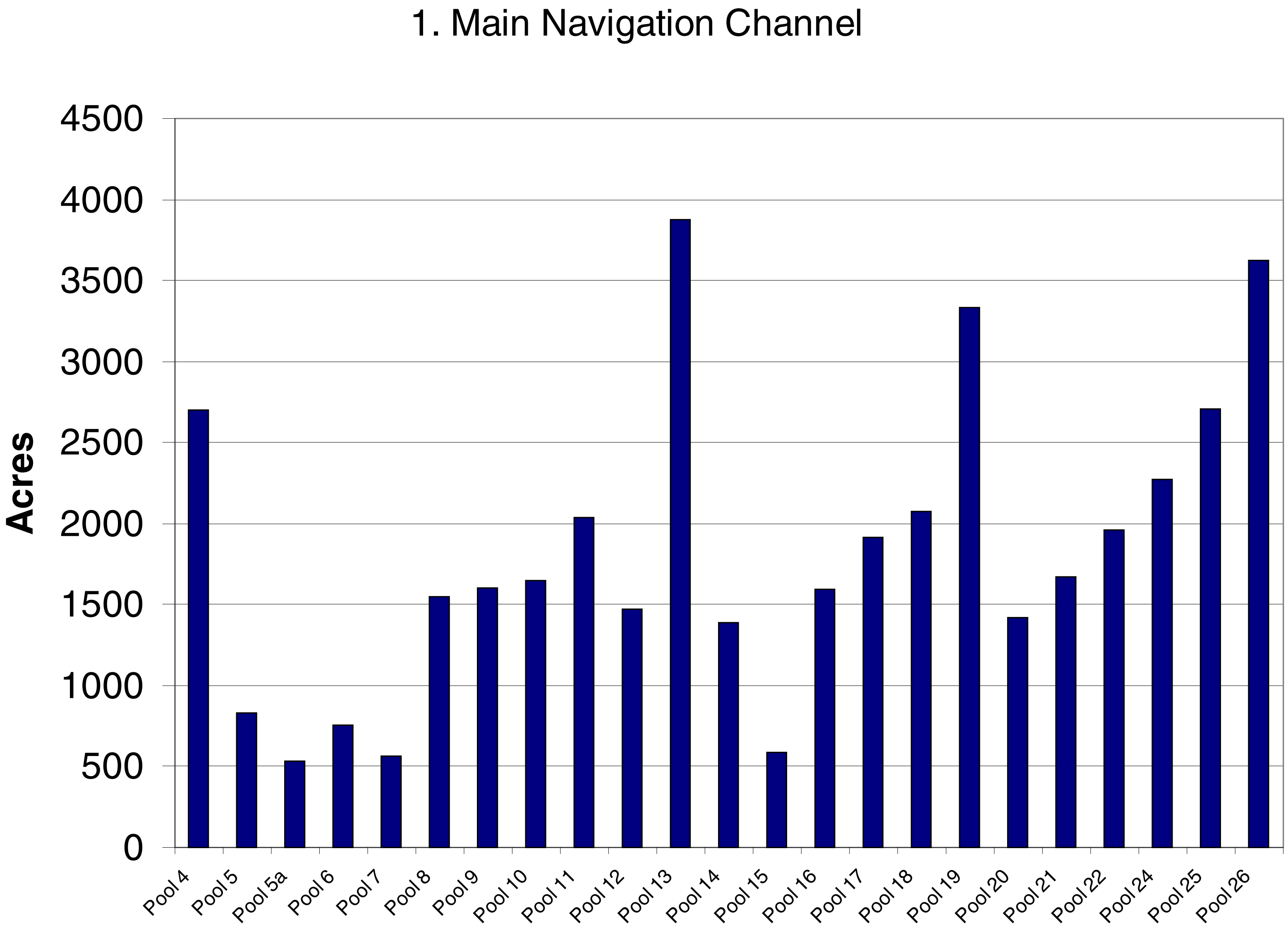

Figure 33. Main channel area distribution and abundance in the UMRS.

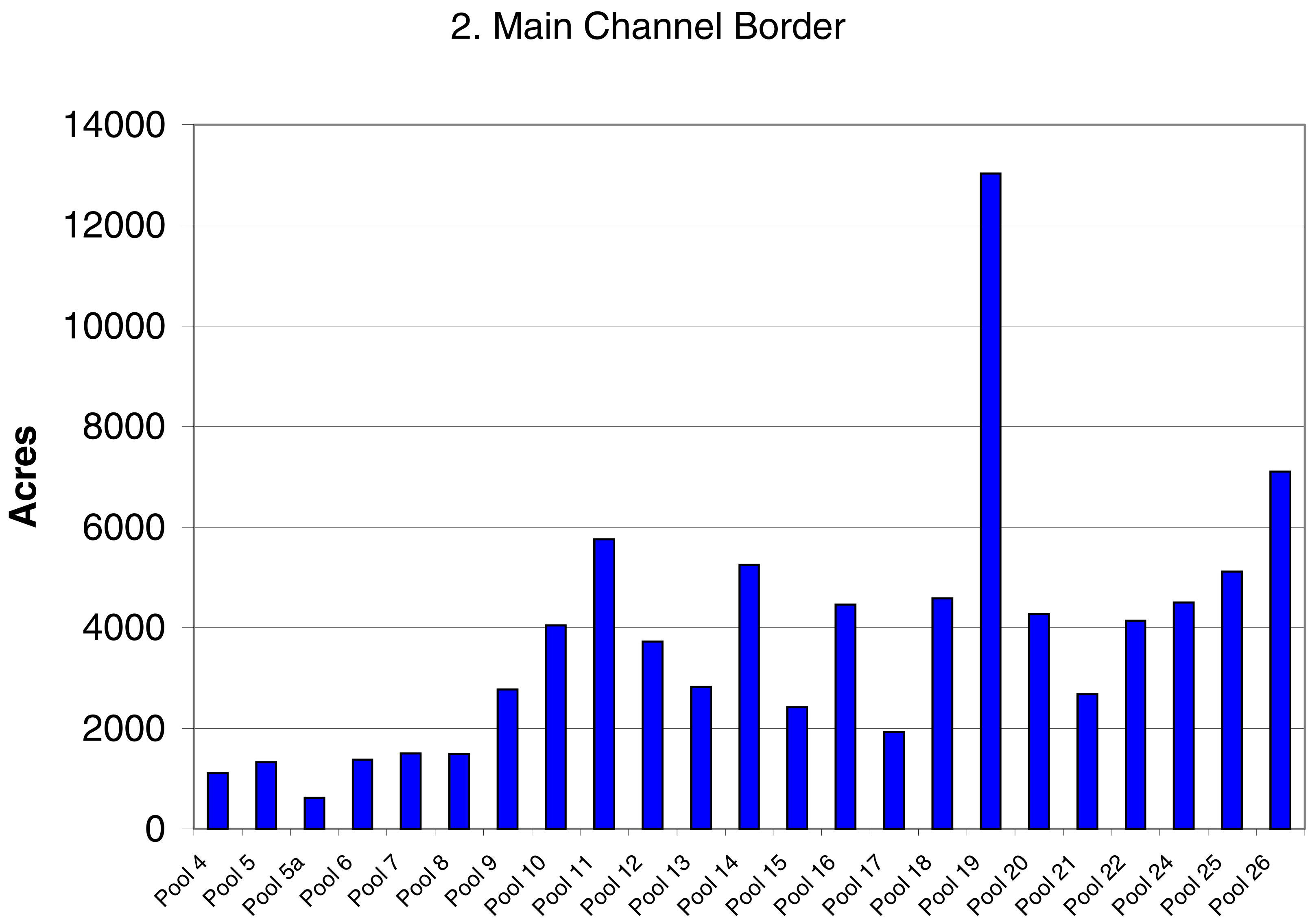

Figure 34. Main channel border area distribution and abundance in the UMRS.

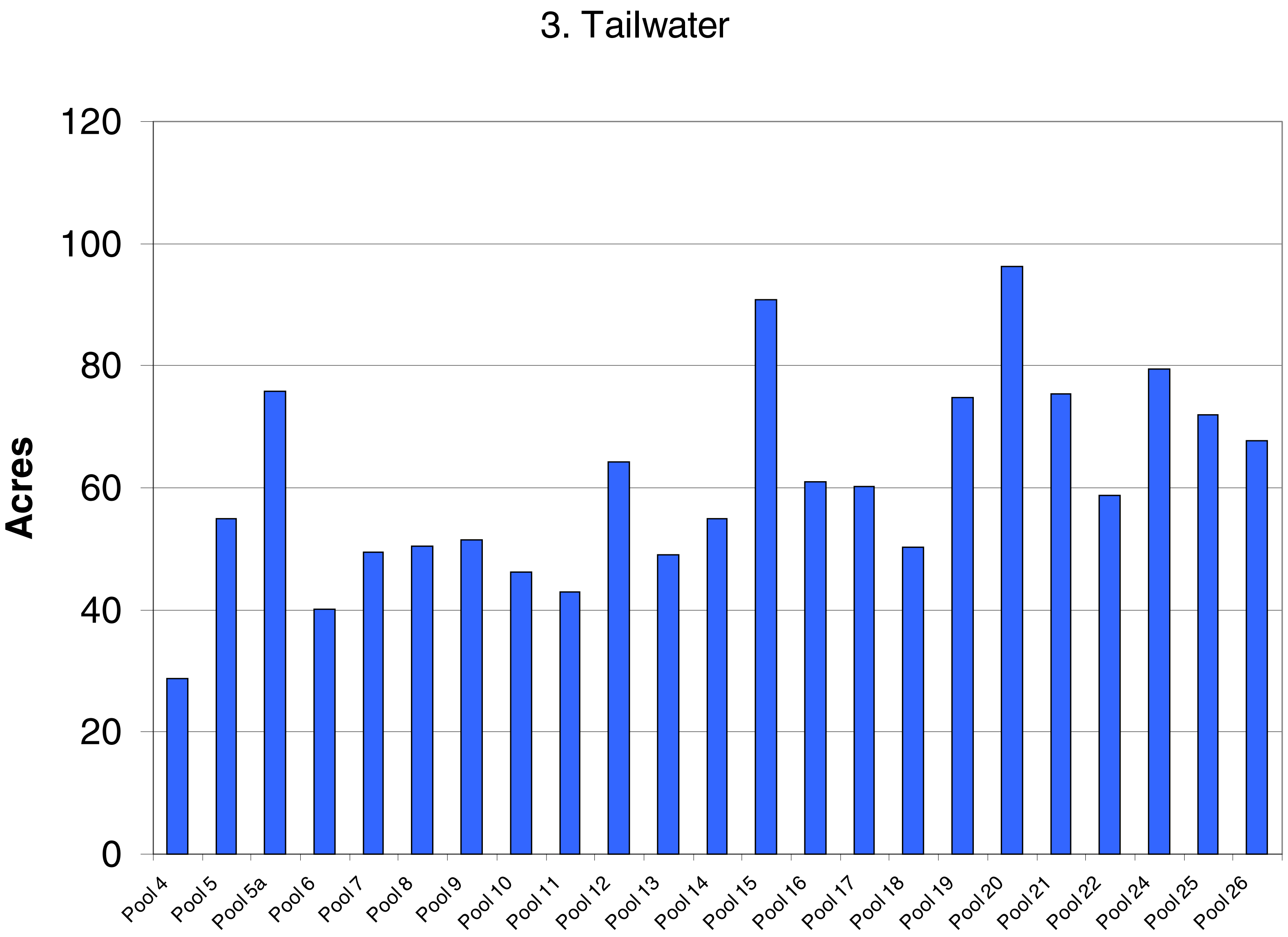

Figure 35. Tailwater area distribution and abundance in the UMRS.

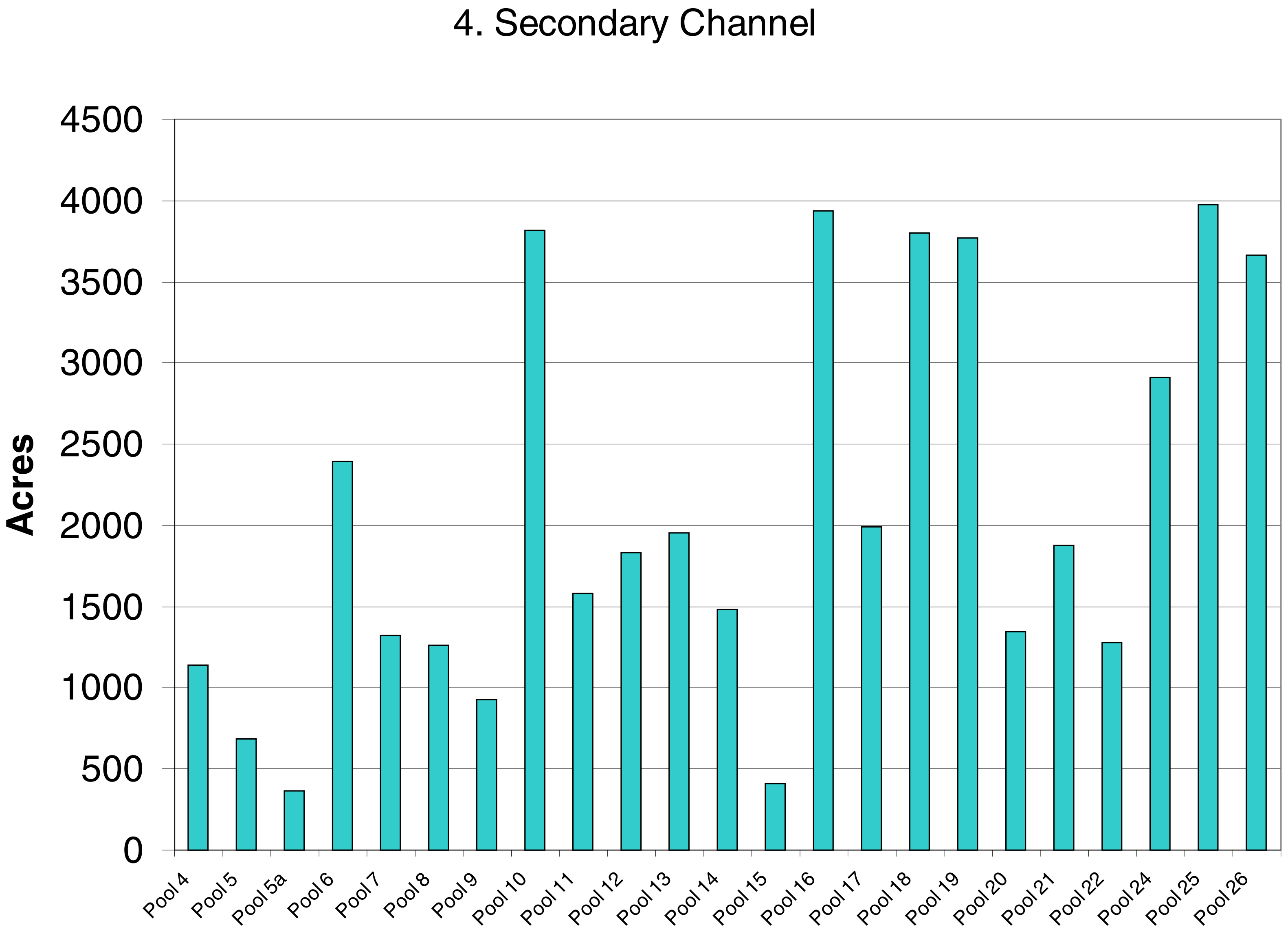

Figure 36. Secondary channel area distribution and abundance in the UMRS.

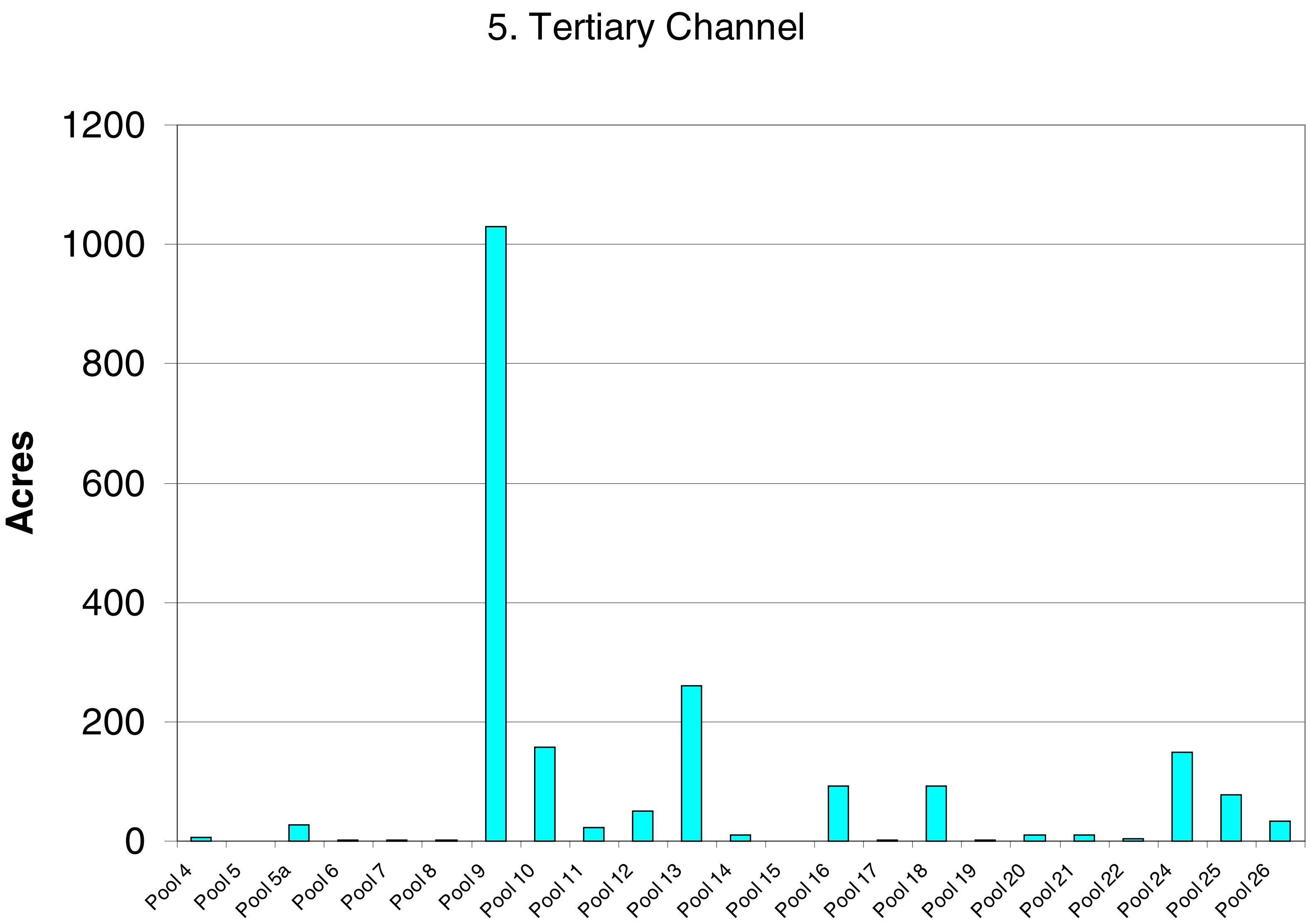

Figure 37. Tertiary channel area distribution and abundance in the UMRS.

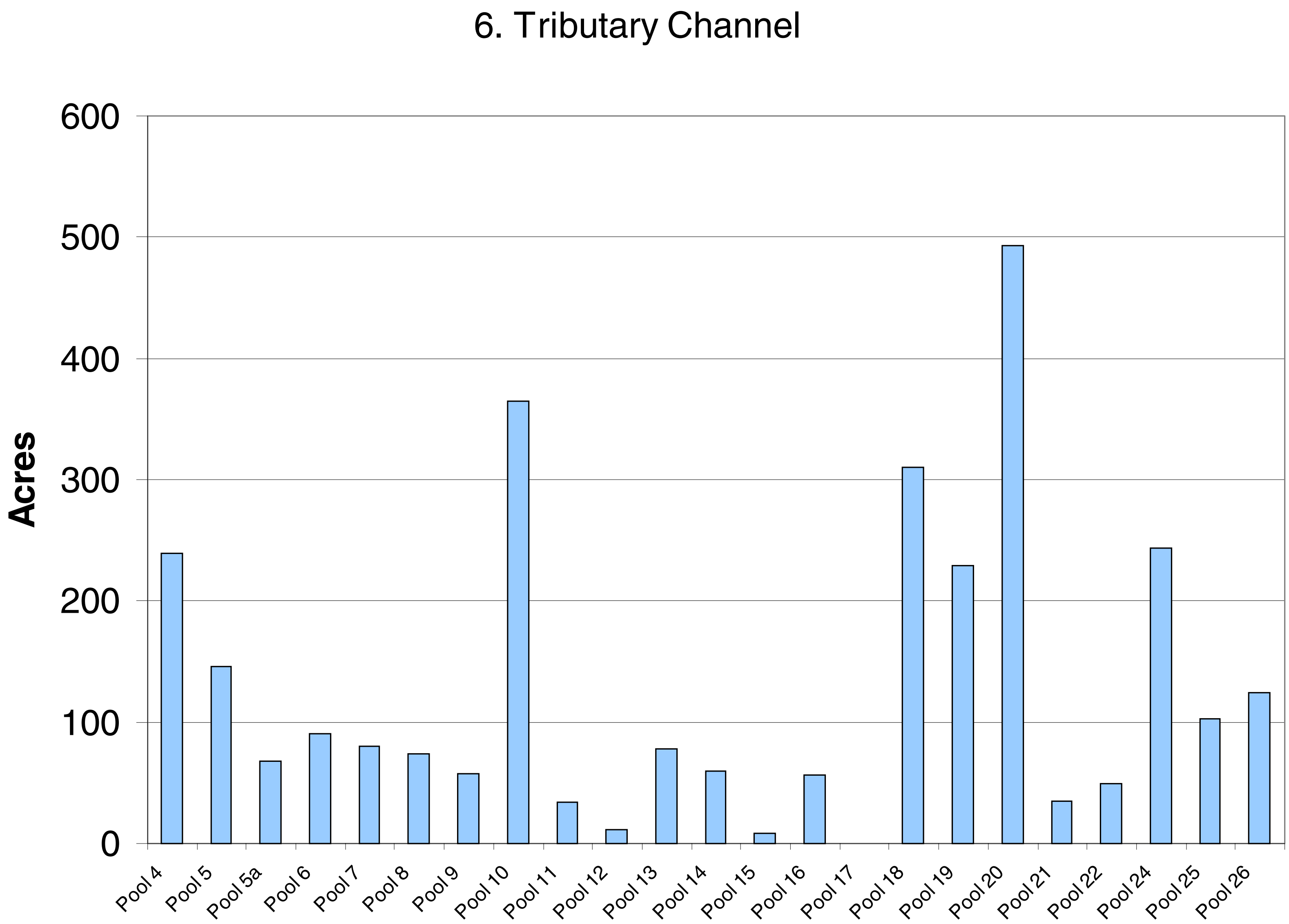

Figure 38. Tributary channel area distribution and abundance in the UMRS.

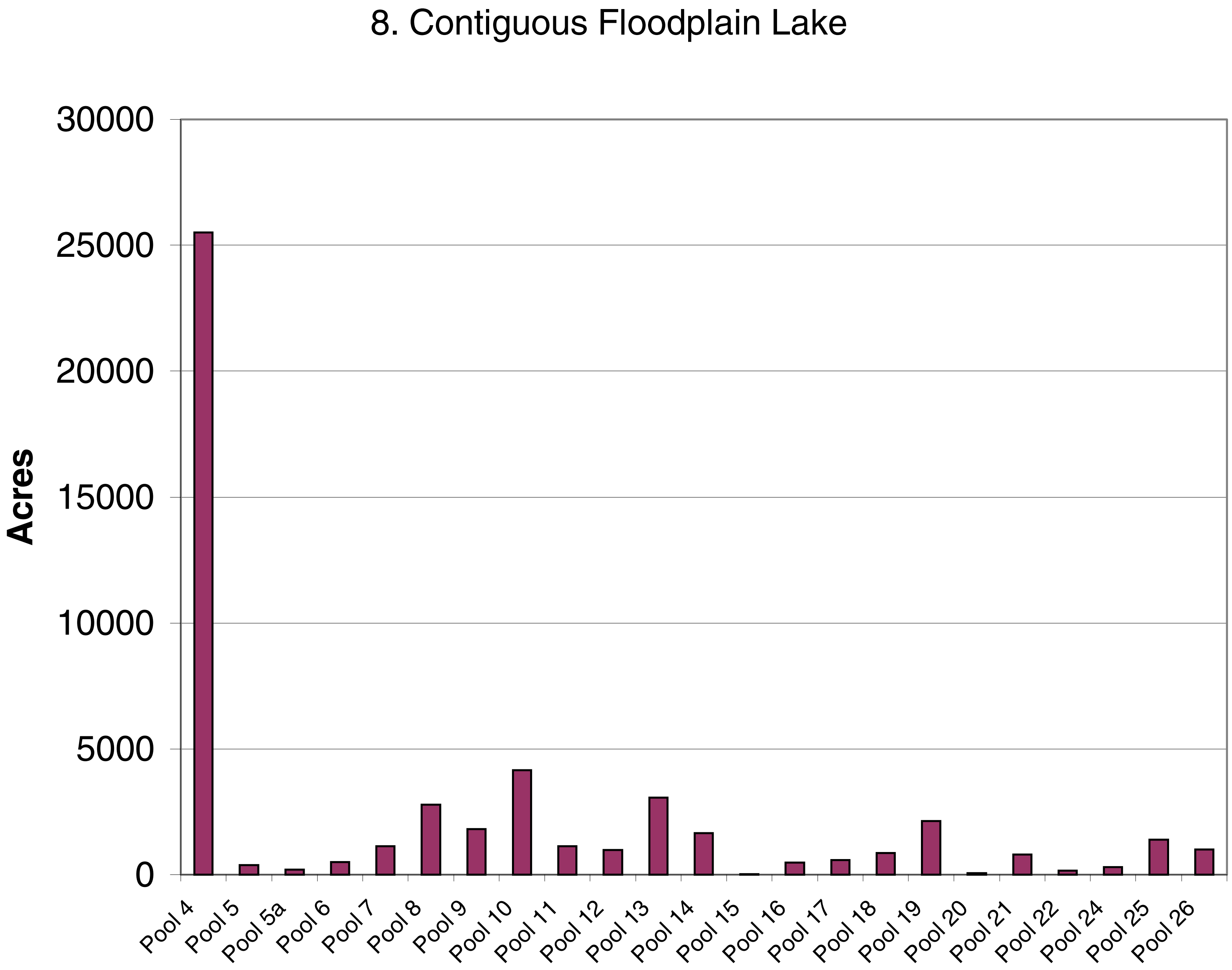

Figure 39. Contiguous floodplain lake distribution and abundance in the UMRS.

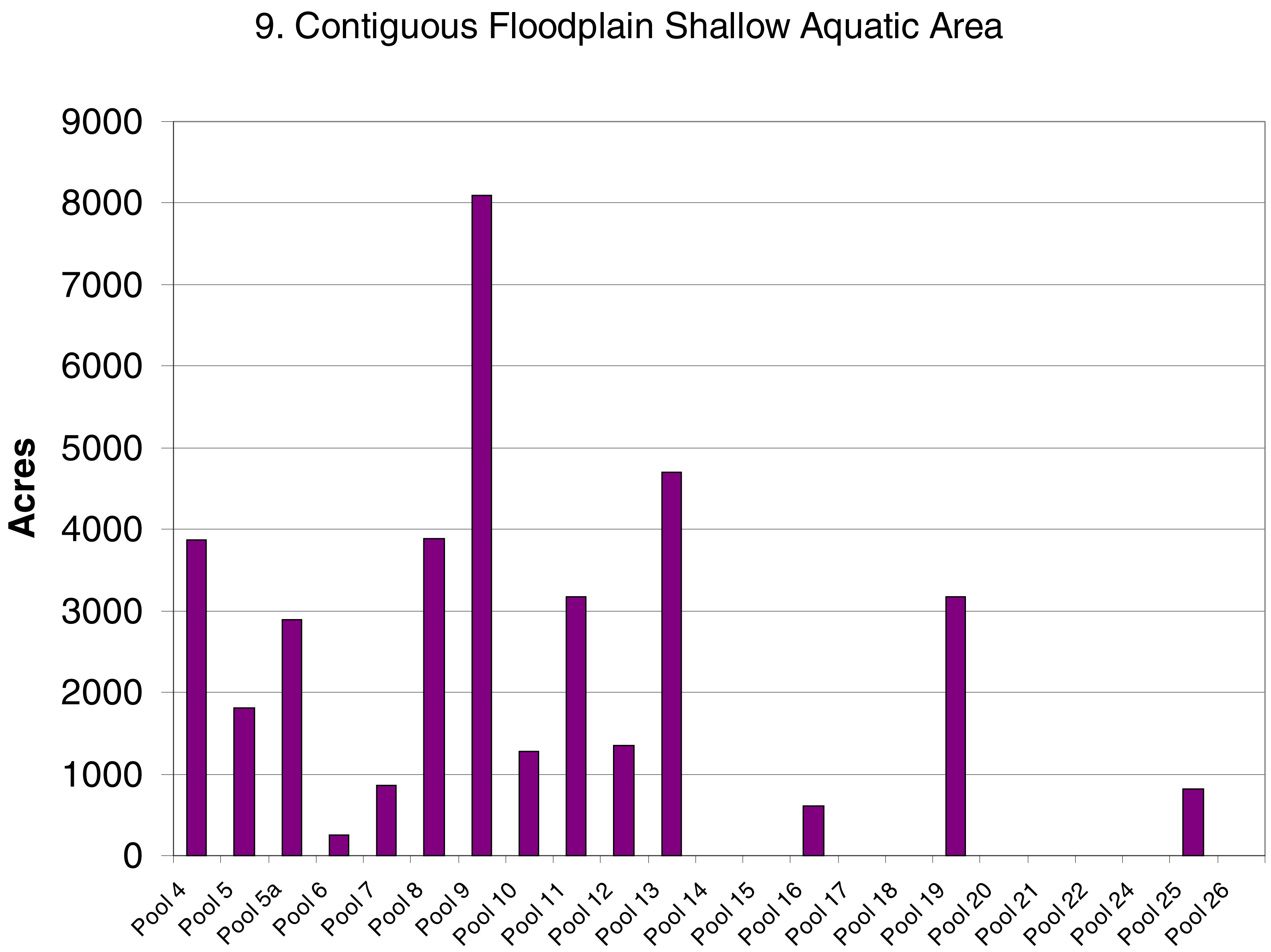

Figure 40. Contiguous shallow aquatic area distribution and abundance in the UMRS.

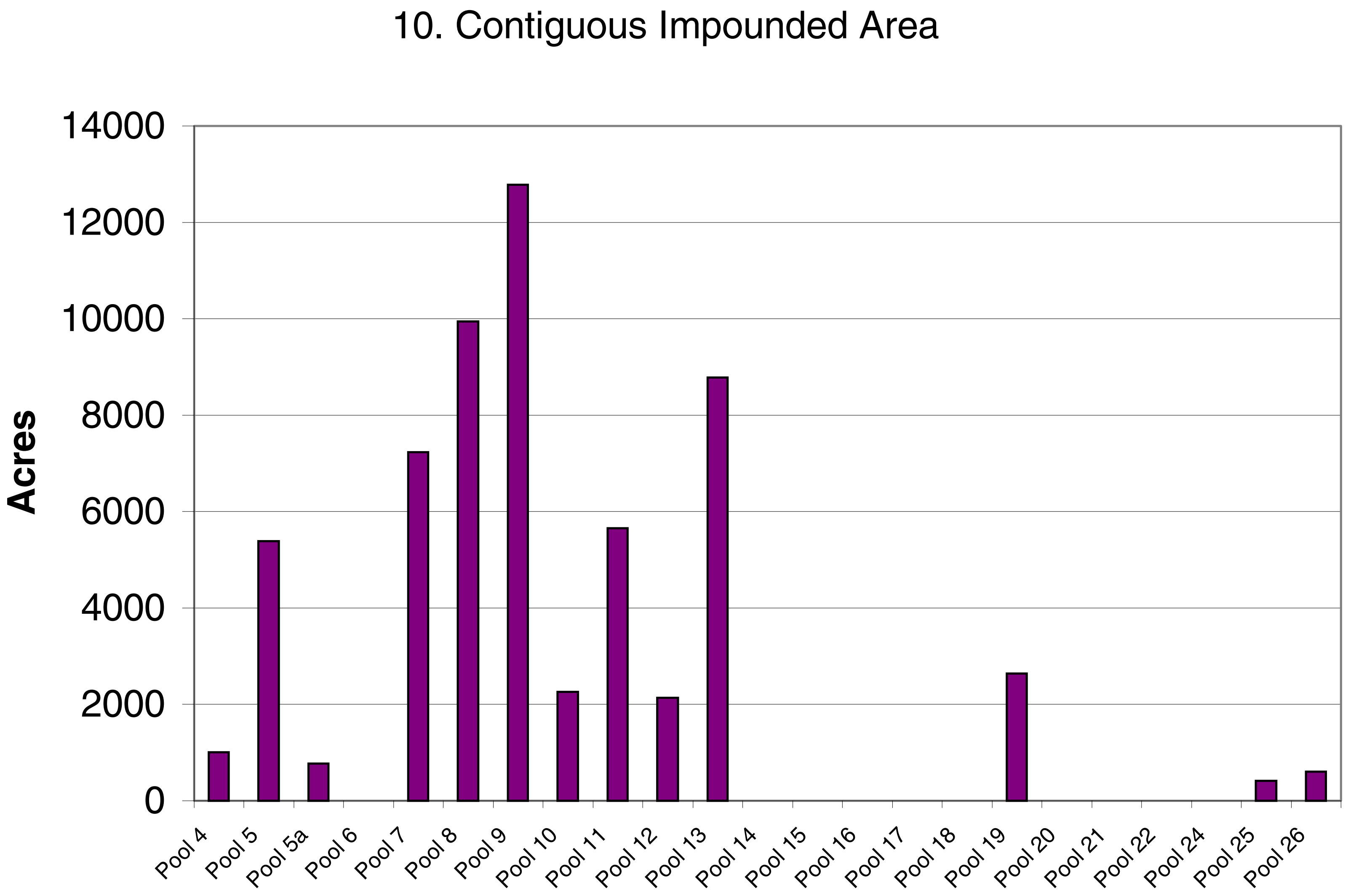

Figure 41. Contiguous impounded area distribution and abundance in the UMRS.

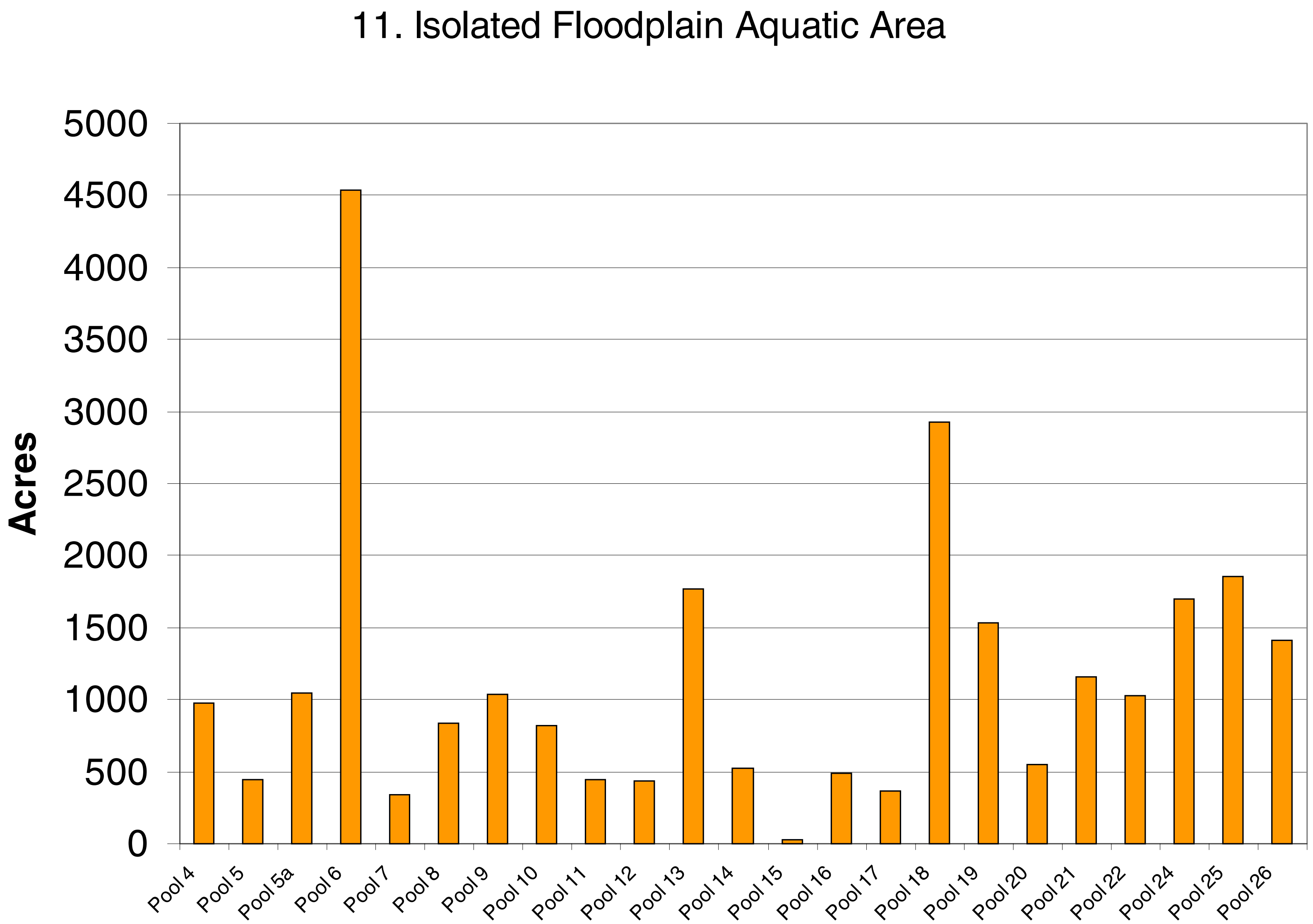

Figure 42. Isolated floodplain aquatic area distribution and abundance in the UMRS.

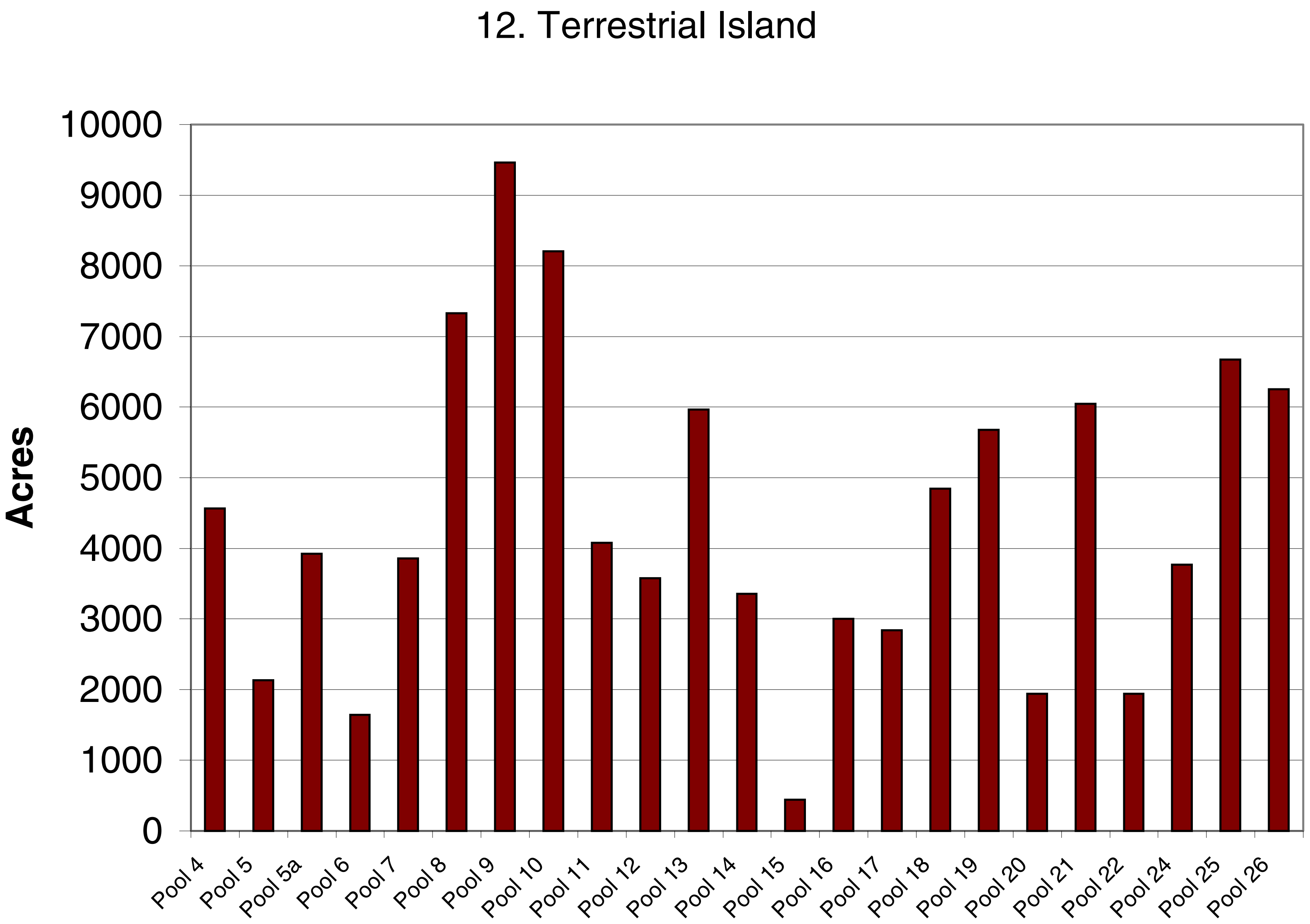

Figure 43. Island area distribution and abundance in the UMRS.

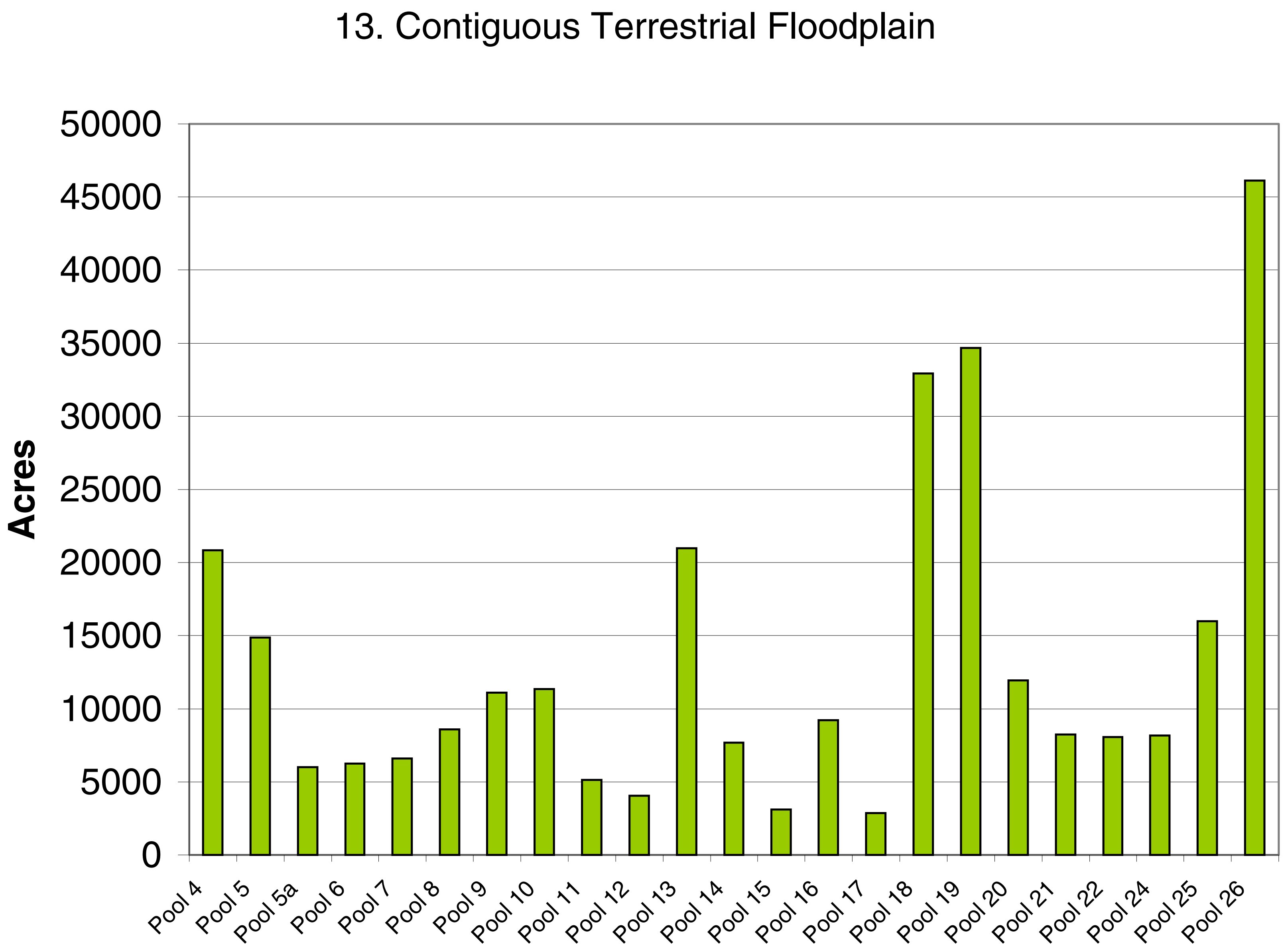

Figure 44. Contiguous floodplain area distribution and abundance in the UMRS.

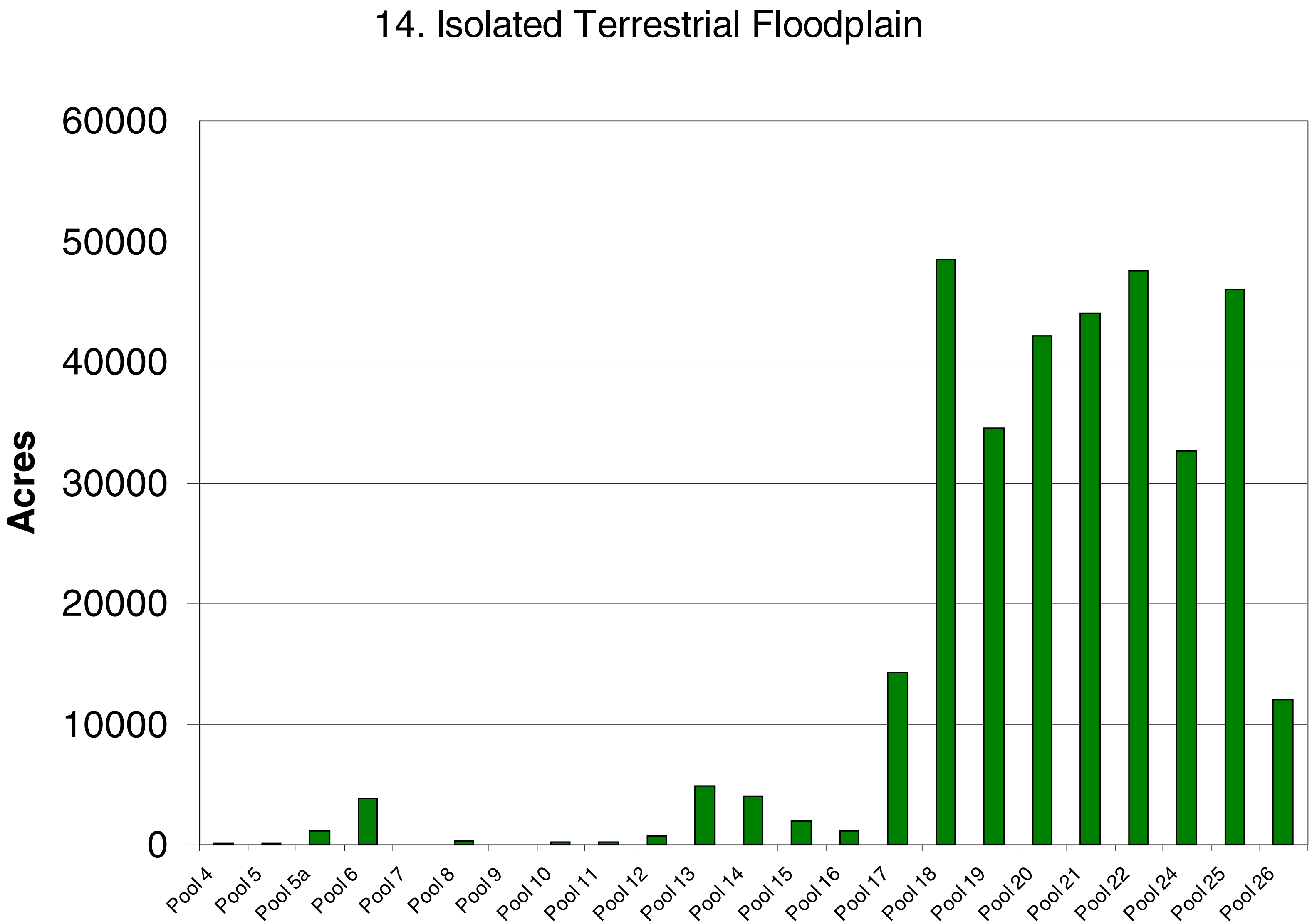

Figure 45. Isolated floodplain area distribution and abundance in the UMRS.

7.4 Habitat Richness and Diversity

Habitat richness is a term used to describe the number of HNA land cover or aquatic area classes that occur within a river reach – more classes translate to greater habitat richness. There are 18 possible land cover classes in the data derived from aerial photographs, but only 7 in the data derived from satellites. There are 16 possible aquatic area classes in the data derived from photographs, but none for the data derived from satellites. There was little variation in habitat richness among reaches. There were 12 to 16 classes in the high-resolution data and 5 to 7 classes in the satellite data (Table 21). Aquatic area richness ranged from a low of 9 in the Cape Girardeau LTRMP reach to 13 in several other reaches.

Habitat diversity is a measure of the types of habitats, their size, and their relative abundance in a defined area. The Simpson's Diversity Index used in this analysis ranges from 0.0 to 1.0, with uniform habitats scoring low and more diverse habitats approaching 1.0. Geomorphic reach 3 supported the highest land cover diversity, ranging from 0.79 to 0.88 (Table 21, Figure 46). Land cover diversity in pools 10 and 13 in geomorphic reach 4 exceeded 0.80, but pools 11 and 12 were 0.71 and 0.77, respectively. Lower diversity in pools 11 and 12 is likely because of the high proportion of open water present. Land cover diversity in geomorphic reaches 1, 5, and the Illinois River scores above 0.70 with a couple of exceptions. Pool 1 in geomorphic reach 1 has low diversity (0.51) because of the abundance of urban area. Pool 15 in geomorphic reach 5 has low diversity (0.63) because of the narrow river valley and preponderance of urban development in the reach. The Alton Pool in the lower Illinois River has low diversity (0.38) because of the preponderance of agriculture in the reach. Land cover diversity differs in pools 18 and 19, geomorphic reach 6. Pool 18 diversity is lower (0.64) than Pool 19 (0.73) because of the high proportion of floodplain agriculture in Pool 18. Land cover diversity ranges from 0.67 to 0.70 among pools in geomorphic reach 8. The floodplain in reach 8 is highly developed for agriculture. Land cover diversity ranges from 0.51 to 0.55 in pools 20 to 22, geomorphic reach 7, because the floodplain is highly agricultural. Land cover diversity in the upper part of geomorphic reach 9 (L and D 26 to Kaskaskia River) is higher than the rest of reach 9 and 10. The variety of developed areas and a large conservation area near Horseshoe Lake State Park must balance the dominance of agriculture in the upper part of the reach, whereas agriculture dominates the rest of the reach (diversity = 0.46). The low diversity in lower reach 9 and reach 10 may be an artifact of the low resolution satellite data, because the photo interpreted data for the Cape Girardeau LTRMP reach had land cover richness of 14 and diversity of 0.63.

Aquatic area diversity is also highest in geomorphic reaches 3 and 4, with all but pools 5 and 7 scoring 0.80 or above (Table 21, Figure 47). Aquatic area diversity is 0.70 in reach 2, despite the influence of Lake Pepin in the middle of the reach. Aquatic area diversity varies in geomorphic reach 5, with pools 14 and 16 scoring 0.81 and 0.79, respectively. Aquatic area diversity in Pool 15 is 0.76 and only 0.68 in Pool 17. Aquatic area diversity in geomorphic reach 8 and the portions of reaches 9, 10, and the lower Illinois River for which data are available ranges from 0.63 to 0.67. Aquatic area diversity is lowest in Geomorphic reach 7 where diversity is 0.53, 0.54, and 0.46 in pools 20, 21, and 22, respectively.

7.5 Habitat Fragmentation

Habitat fragmentation can be discussed in a very detailed sense in relation to a single or a few closely related species, or as is done here, in more general terms of changes in the amount or distribution of broadly defined habitats. The approach taken in this analysis was to rely on the pre-settlement land cover data and maps available for parts of most geomorphic reaches as a

Table 21. Land cover and aquatic area richness and Simpson's diversity.

Geomorphic Reach	River Reach	Land Cover Richness	Diversity	Aquatic Areas Richness	Diversity
Reach 1	Pool 1*	6	0.51	na	na
	Pool 2	13	0.75	na	na
	Pool 3	12	0.77	na	na
Reach 2	Pool 4	15	0.73	13	0.71
Reach 3	Pool 5	16	0.88	12	0.67
	Pool 5a	16	0.83	13	0.80
	Pool 6	15	0.86	12	0.82
	Pool 7	14	0.80	12	0.79
	Pool 8	14	0.81	13	0.82
	Pool 9	16	0.79	12	0.82
Reach 4	Pool 10	16	0.82	13	0.83
	Pool 11	16	0.71	13	0.85
	Pool 12	16	0.77	13	0.86
	Pool 13	15	0.85	13	0.82
Reach 5	Pool 14	15	0.78	11	0.81
	Pool 15	14	0.63	10	0.76
	Pool 16	15	0.78	12	0.79
	Pool 17	14	0.77	10	0.68
Reach 6	Pool 18	15	0.64	11	0.66
	Pool 19	15	0.73	13	0.76
Reach 7	Pool 20	14	0.51	11	0.53
	Pool 21	15	0.54	11	0.54
	Pool 22	15	0.55	11	0.46
Reach 8	Pool 24	15	0.70	11	0.63
	Pool 25	15	0.67	13	0.66
	Pool 26	15	0.69	12	0.64
Reach 9	L&D 26 to Kaskaskia R.*	7	0.62	na	na
	Kaskaskia R. to Grand Tower*	7	0.46	na	na
Reach 10	Grand Tower to Ohio R.***	7	0.46	9**	0.63
Reach IR1	Lockport Pool*	6	0.75	na	na
	Brandon Rd. Pool*	5	0.61	na	na
	Dresden Pool*	7	0.72	na	na
	Marseiilles Pool*	7	0.72	na	na
	Starved Rock Pool*	7	0.79	na	na
Reach IR2	Peoria Pool*	7	0.73	na	na
	La Grange Pool	13	0.77	10	0.67
	Alton Pool*	6	0.38	na	na

* = calculated from satellite data.

** = portions of geomorphic reaches 9 and 10.

*** = Cape Girardeau reach land cover richness is 14, diversity is 0.63.

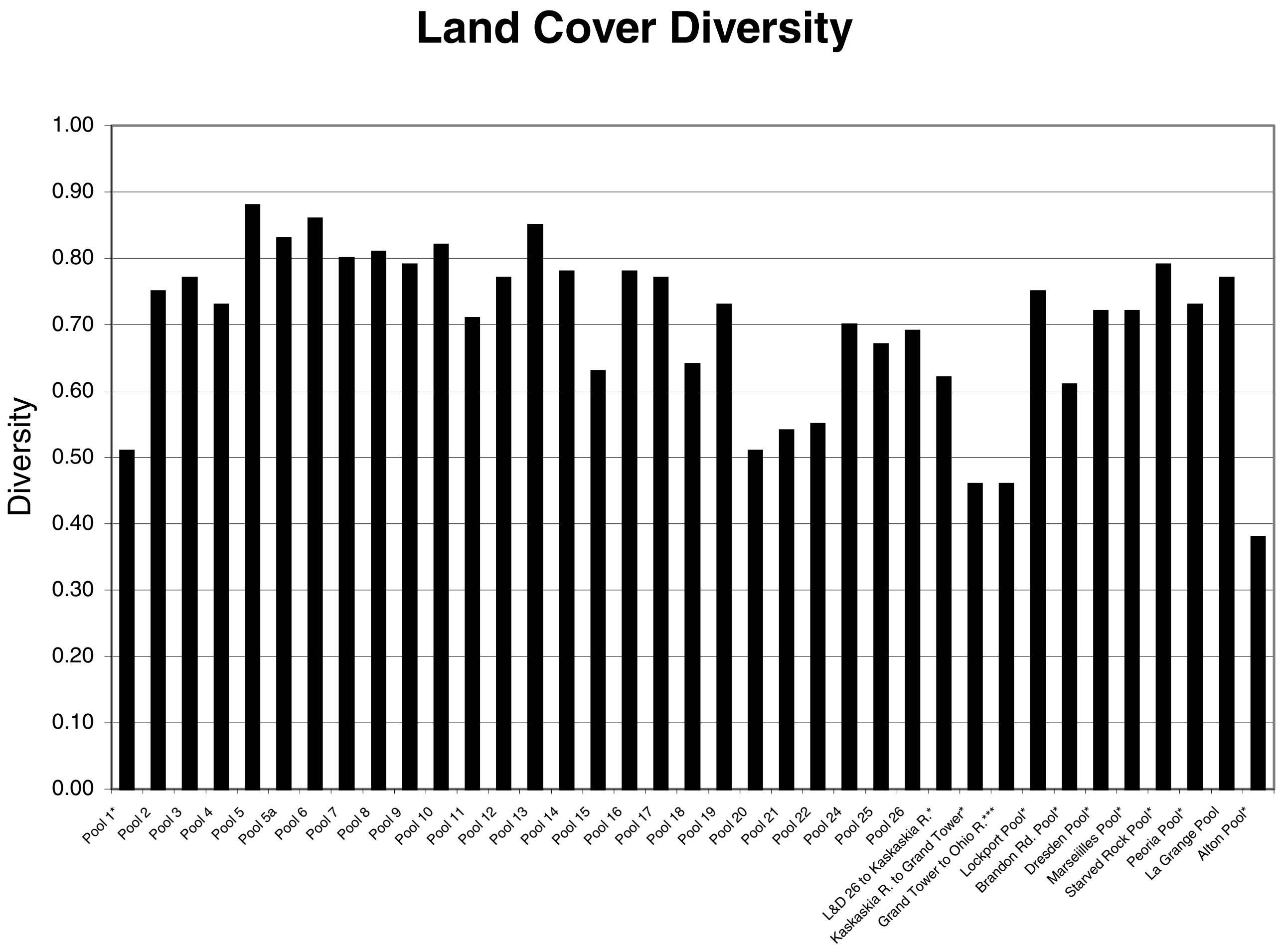

Figure 46. Land cover diversity in UMRS pools and reaches (* = satellite data).

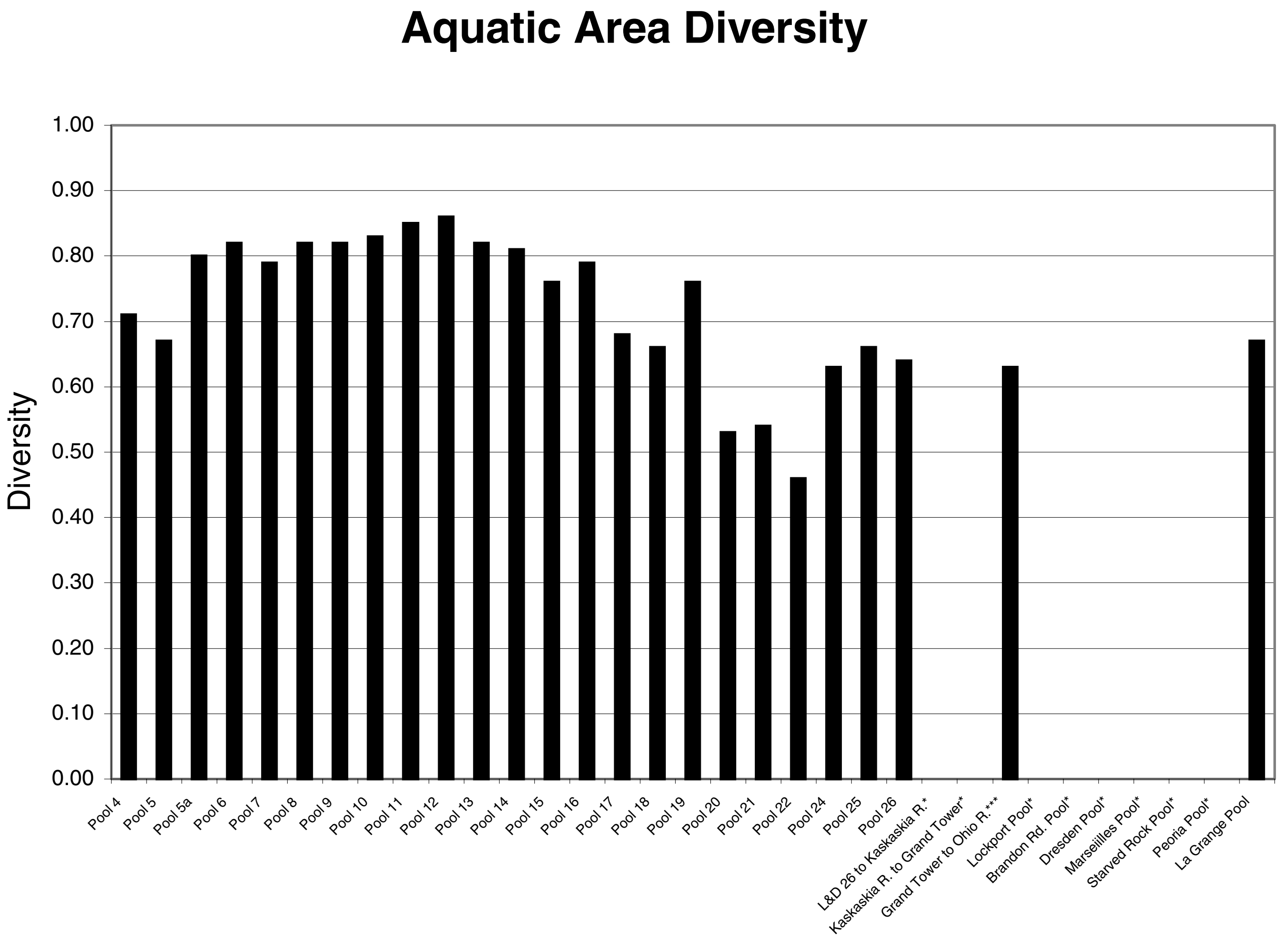

Figure 47. Aquatic area diversity in UMRS pools and reaches (* = satellite data).

general baseline for natural conditions. The change in the proportion and distribution of land cover classes in the modern era was assessed from modern land cover data and maps. The analysis provides little resolution in land cover classes (7 classes), but the changes were large and generalized enough to make strong inferences as to causes and effects. The leveed area and public ownership layers of the HNA areas database were also useful for determining the extent of and mechanisms responsible for habitat fragmentation or the lack of it.

The review of ecological change presented earlier clearly demonstrated the loss of prairie land cover (HNA class – grassland) in geomorphic reaches 5 through 9 and IR2 (see Figure 4). Prairie fragmentation and conversion to agriculture is the most extreme land cover change in many parts of the UMRS. Prairie accounted for between 35 and 56% of the floodplain in pools 13, 17, 22, 24, 25/26, and the upper part of geomorphic reach 9. The current range is from 3 to 7% of the floodplain. What had been large contiguous plains of prairie separated by wooded tributary riparian corridors are now isolated prairie patches separated by large expanses of crop fields, towns, and cities. Prairie patch connectivity has been highly reduced, and connectivity to other natural habitats has been reduced where agriculture or development abut prairie patches. The mechanism for the loss of, or extreme fragmentation, of prairies was the direct conversion to agriculture or developed areas. The amount of agriculture and developed area exceeds the amount of prairie area formerly present in pools 4, 13, 22, 24, 25/26, and La Grange indicating that other land classes (i.e., timber) were also fragmented. Longitudinal distribution of prairie has apparently not changed in the upper reaches, most likely because of the presence of large public land holdings. Geomorphic reaches 4 through 9 and the Illinois River have lost prairie to agricultural development and urban development that is protected by levees. Prairie appeared in geomorphic reach 10 in the contemporary era, probably in abandoned agricultural fields.

Forest was and remains an important component of the floodplain landscape. However, contemporary forests are distributed differently and have different species composition than in the past (see Figure 4). Changes differ among geomorphic reaches also. In Pool 4, forests have been replaced by rather small increases in agriculture, development, marsh, and water. In Pool 8, forests were replaced mostly by water impounded by the dam and also by development. The forests remaining in these two upper reaches have species composition similar to the past. The amount of forest in Pool 17 was rather consistent through time, but the remaining reaches have all lost forested area. In Pool 13, marsh and developed area replaced much of the forest. In the southern and Illinois River sites examined, agriculture was the primary mechanism for forest loss. In the southern pooled reaches, upper reach 9, and Illinois River, open forests and savannas joining dense riparian forests and prairies were eliminated. In geomorphic reach 10, the floodplain was almost completely forested, but it was largely cleared and levees were constructed to protect crops. The modern landscape has more abrupt boundaries where dense riparian forests abut levees and open crop fields. Stabilized water levels create abrupt boundaries at the forest-water interface because low river stages exposing banks, shorelines, and bars do not occur. Modern forests make up about 20% of the floodplain area, and most are in contiguous floodplain areas susceptible to flooding. Forests are also contiguous along the longitudinal gradient, except where larger cities interrupt the riparian corridor.

Marshes, or emergent aquatic plant communities, may not have been thoroughly documented in pre-settlement surveys, but changes are evident (see Figure 4). Marsh area increased slightly in pools 4, 17, 22, 24, and 25/26, and significantly in Pool 13. Marsh area dropped in Pool 8, and it remained stable or absent in La Grange Pool and Pool 22. Forested wetlands, or swamps, decreased in all river reaches investigated. Marsh fragmentation is difficult to assess because river marshes are inherently fragmented along backwater margins, wet meadows, and riverbanks. The abundance of marsh communities is linked to the abundance of backwaters, water clarity, water level fluctuations, substrate quality, and many other factors that differ along the longitudinal gradient of the rivers. Generally, contemporary marsh communities are more abundant in northern river reaches than in southern reaches where there are few backwaters, river water is turbid, and substrates are silty and flocculent. Many of the marsh habitats present in southern river reaches are in wildlife management areas that have water level management capabilities. Marshes in unmanaged areas remain contiguous, primarily with open water and forest classes, but in managed areas, fish access to marshes is prohibited except during floods. Managed areas account for about 7% of the non-agricultural floodplain along the Illinois border from the northern border south to St. Louis, and about 10% of the non-agricultural floodplain in Peoria, La Grange, and Alton Pools (Havera et al. 1995).

Changes in water area and aquatic area distribution as measured by the USACE Upper Mississippi River/Illinois Waterway Navigation Study Cumulative Effects Study (WEST 2000) differ along the length of the river. Comparing immediate pre-dam (1930s) and post dam (1943, 1973/75 or 1989) conditions, total open water area has decreased or remained stable in pools 4 and 10 to 26, the open river, and the Illinois River, but it has increased in pools 5 to 9 (geomorphic reach 3). Decreases in total water area are attributable to several geomorphic processes including loss of contiguous backwaters, filling of isolated backwaters, loss of secondary channels, filling between wing dams, and delta formation. Loss of contiguous backwaters is the most widely distributed change in aquatic areas, occurring in all but geomorphic reach 3. Many contiguous backwaters were isolated from the rivers to form isolated backwaters. Isolated backwater filling was apparent in geomorphic reaches 6 through 10 (WEST 2000) and the lower Illinois River (Bellrose et al. 1983). Loss of secondary channels was most apparent in reaches 9 and 10 where they were isolated from the river by closing structures. Filling between wing dams was apparent in southern reaches 5, 7, 8, 9, and 10. Delta formation (tributary and main stem) in backwaters and channel borders was apparent in Pools 4, 7, and 11. Loss of depth was not measured for the Cumulative Effects Study, but workshops held with natural resource manages identified many areas that were degraded by loss of depth and changes in substrate quality (see below).

7.6 Habitat Connectivity

River regulation modified aquatic habitats in many ways and the impacts differ among geomorphic reaches. The diversion of water from Lake Michigan to the Illinois River increased water levels more than 3 feet, which increased the connectivity between the floodplain aquatic areas and the main channel. Dams stabilized low flow river stages, but did not appreciably increase water levels above those of the original diversion. Isolated lakes become larger and in some cases, developed permanent connections to the main channel. Aquatic habitat connectivity was increased by the changes, but the system had evolved around the fragmentation caused by variable water levels. Sediment quality in Illinois River backwater lakes has been significantly degraded by excessive sedimentation.

River regulation caused a variety of effects among the Mississippi River reaches. Data were lacking for geomorphic reach 1. Impacts in pools 2 and 3 were likely similar to reach 3. Geomorphic reach 2 had slightly more water area in the lower pool area. Geomorphic reach 3 was the most modified of all the reaches. Dams impounded water into much of the former floodplain area and created open water impounded areas and many backwaters. Natural levees and floodplain ridges remained as islands in many areas, but many of these islands have been eroded by wave action. Dams did not create large open water impoundments in geomorphic reaches 4 through 8, but they did stabilize water levels at elevations higher than unregulated stages. Isolated backwaters were lost in geomorphic reach 4 and Pool 21; they were gained in reaches 2, 3, 5, 6, and 8, and remained stable in Pool 15 and reach 7. Contiguous backwaters increased or showed little change in all reaches.

Changes in aquatic habitats in geomorphic reaches 9 and 10 are attributable to channel training and dredging. The river channel in reaches 9 and 10 was once characterized by numerous islands and secondary channels, but early snag clearing and closing structure and wing dam construction caused island erosion and sedimentation at the margins of the channel. The channel is narrower and deeper than in the past. Isolated secondary channels have subsequently filled with sediment as have isolated and contiguous backwaters.

Dams have also modified connectivity of UMRS aquatic habitats. Tributary dams block fish migration on the main stem rivers and their tributaries. Flood control and hydroelectric dams block access to over one-half of the length of tributary streams and rivers (Figure 48; Dan Wilcox, U.S. Army Corps of Engineers, unpublished data). Fish use tributaries for spawning and for refuge from harsh flow or water quality conditions on the river. Fish from tributaries are thought to be the hosts for mussel populations recovering on the upper Illinois River (Scott Whitney, U.S. Army Corps of Engineers, Rock Island, Illinois, personal communication).

Upper Mississippi River System navigation dams are used to maintain low flow navigation only, so high flows to pass freely through the dams with all gates open. Lock and dam 19 presents a permanent barrier to migration because it is also a hydroelectric dam. Other dams are open from 1 to 30% of the time (Figure 49). The Illinois River has different types of gates, that allow the river to run freely more often than the Mississippi. Main stem navigation dams alter hydraulic conditions in impounded reaches and inhibit fish movement throughout the river system. The dams increased connectivity of permanent aquatic areas throughout the river by raising low flow river stages, though the effects are most pronounced in geomorphic reach 3. At the same time, dams decrease connectivity with the floodplain by not allowing floodplain terrestrial communities to develop in permanently inundated areas and by maintaining conditions that reduce the area subject to seasonal flooding. Fish movement in the river is related to spawning, overwintering, and feeding requirements Where fish migrations are blocked, fish may be trapped in river reaches that do not provide required habitats.

Levees prevent flooding in about 50% of the total UMRS floodplain (Table 22). The distribution of levees is highly skewed, with very few levees north of reach 5, about 50% of the floodplain levied in reaches 5 through 8 and the lower Illinois River, and about 70% of the floodplain levied in reaches 9 and 10. Levees block fish migrations during floods and limit nutrient and sediment exchange between the river and the floodplain. They also trap sediment-laden floodwater within the narrowed confines of the contiguous floodplain, which increases sedimentation rates in both aquatic and contiguous terrestrial areas. The frequency of isolated floodplain lake connectivity with the river is reduced.

7.7 Public Land Distribution

The amount and distribution of land in public ownership was an important factor affecting habitat development in the 20th Century. Many Federal, state, and county agencies own public lands, and all are subject to different degrees of management activity. Some areas are managed as public parks, others as hunting and fishing areas, and others as refuges protected from hunting. Ownership is difficult to determine because many areas have Federal easements but are managed by state agencies. Total acreage in public ownership has been estimated, but ownership and management activity have not been detailed. The U.S. Fish and Wildlife Service manages most floodplain areas in geomorphic reaches 2 through 4 for fish and wildlife (Table 22). The land was initially purchased for the establishment of the Upper Mississippi River Fish and Wildlife

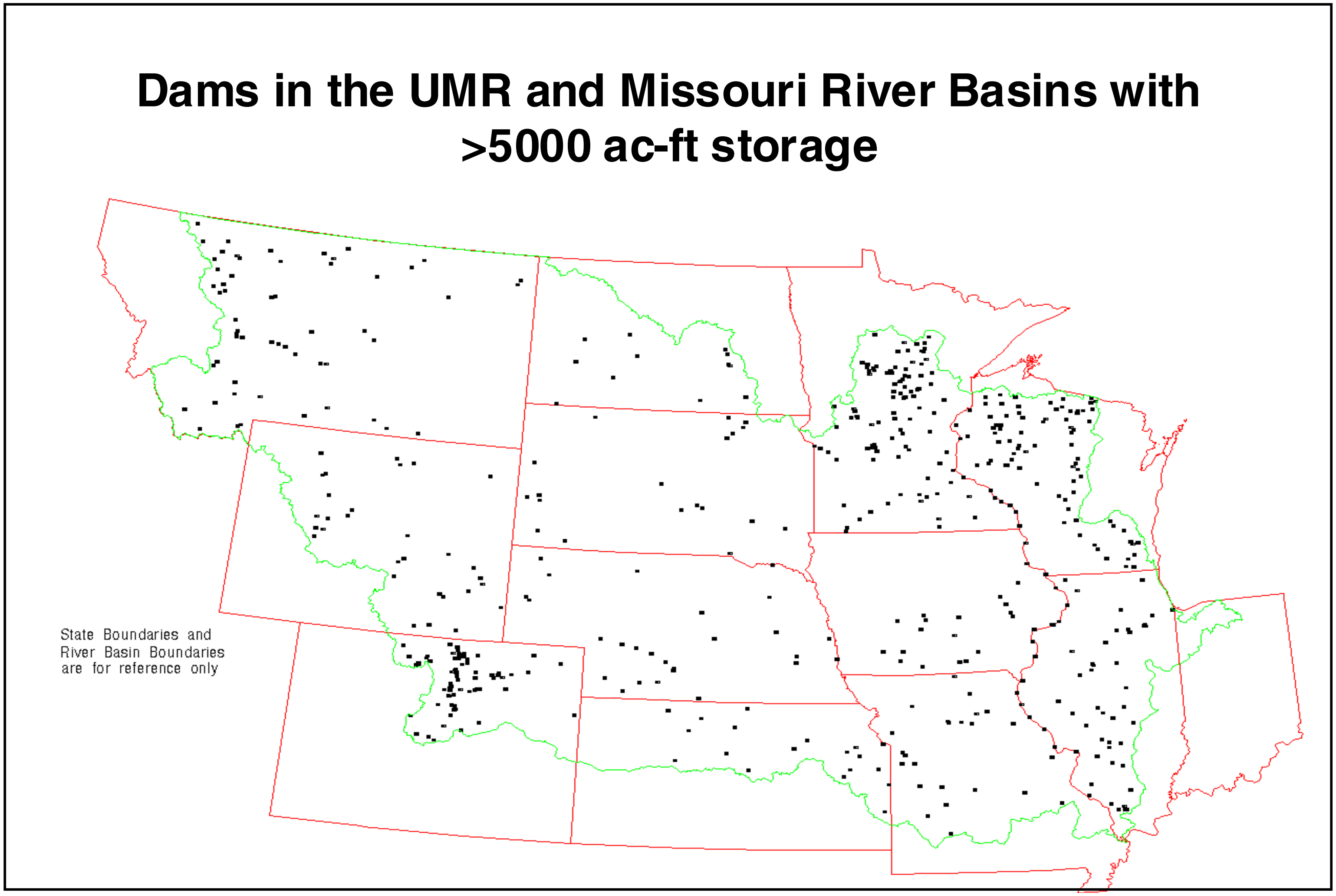

Figure 48. Distribution of Mississippi River Basin tributary dams.

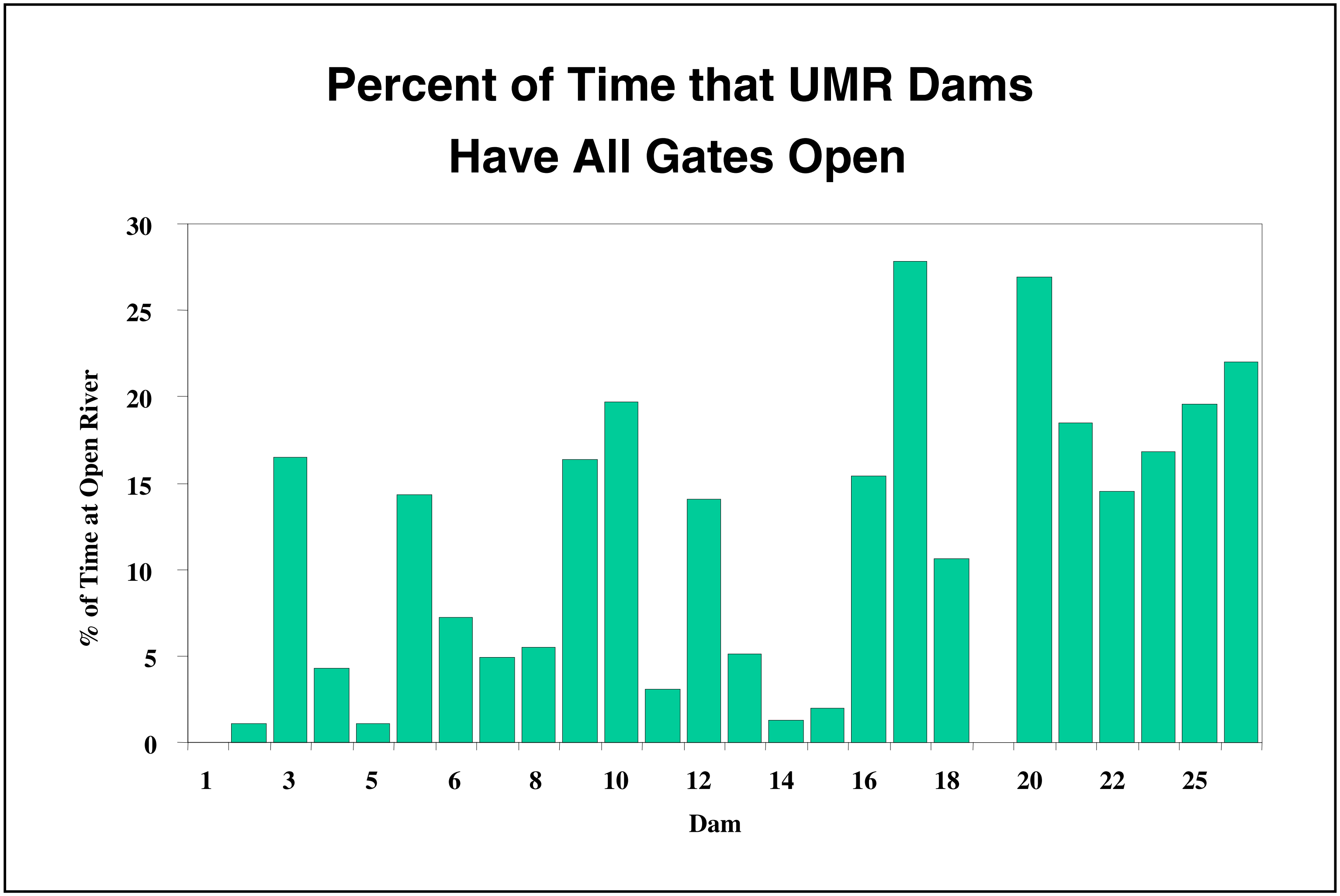

Figure 49. Frequency that UMRS dam gates are opened permitting free fish passage.

Table 22. Leveed area and public lands distribution and abundance in the UMRS.

Upper Mississippi River

River	Floodplain	Leveed Area		Public Ownership	
Reach	**Area (ha)**	**Total Area (ha)**	**% of Floodplain**	**Total Area (ha)**	**% of Floodplain**
Pool 2	8,753	410	4.7%	1,912	21.8%
Pool 3	9,548	0	0.0%	4,238	44.4%
Pool 4	28,365	76	0.3%	8,054	28.4%
Pool 5	12,118	33	0.3%	7,537	62.2%
Pool 5a	6,837	2	0.0%	5,020	73.4%
Pool 6	10,126	2,416	23.9%	4,700	46.4%
Pool 7	16,819	0	0.0%	8,030	47.7%
Pool 8	19,073	567	3.0%	11,851	62.1%
Pool 9	21,120	1	0.0%	18,601	88.1%
Pool 10	16,139	111	0.7%	9,617	59.6%
Pool 11	12,939	90	0.7%	10,278	79.4%
Pool 12	8,899	439	4.9%	5,942	66.8%
Pool 13	34,529	3,404	9.9%	21,145	61.2%
Pool 14	26,656	8,924	33.5%	4,919	18.5%
Pool 15	4,173	837	20.1%	421	10.1%
Pool 16	13,727	1,656	12.1%	4,258	31.0%
Pool 17	32,613	24,261	74.4%	3,166	9.7%
Pool 18	51,062	18,800	36.8%	8,272	16.2%
Pool 19	49,924	15,043	30.1%	341	0.7%
Pool 20	28,503	19,236	67.5%	1,588	5.6%
Pool 21	24,729	16,161	65.4%	4,868	19.7%
Pool 22	35,888	27,668	77.1%	3,291	9.2%
Pool 24	35,941	26,415	73.5%	5,693	15.8%
Pool 25	36,061	20,517	56.9%	6,596	18.3%
Pool 26	56,025	13,073	23.3%	1,471	2.6%
L+D 26 to Kaskaskia R.	112,777	84,705	75.1%	692	0.6%
Kaskaskia R. to Grand Tower	52,793	35,422	67.1%	11,122	21.1%
Grand Tower to Ohio R.*	106,921	26,687	25.0%	10,331	9.7%
Total Reach	873,061	346,956	39.7%	183,952	21.1%

Illinois River

River	Total Floodplain	Leveed Area		Public Ownership	
Reach	**Area (ha)**	**Total Area (ha)**	**% of Floodplain**	**Total Area (ha)**	**% of Floodplain**
Lockport	6,248	0	0.0%	167	2.7%
Brandon	751	0	0.0%	0	0.0%
Dresdon	2,460	0	0.0%	262	10.7%
Marseilles	10,325	0	0.0%	15	0.1%
Starved Rock	5,650	0	0.0%	0	0.0%
Peoria	53,229	2,005	3.8%	5,502	10.3%
Lagrange	89,565	48,417	54.1%	16,032	17.9%
Alton	79,616	54,074	67.9%	8,544	10.7%
Total Reach	247,845	104,496	42.2%	30,522	12.3%

Refuge, but later for the establishment of the nine-foot channel project. The majority of public land in other reaches was acquired when the U.S. Army Corps of Engineers purchased flood easements for the 9-foot channel project. The Corps subsequently granted land management responsibilities to other Federal and state conservation agencies to manage for fish and wildlife. The distribution of public land is highly skewed toward the northern reaches (reaches 1 through 4), with reaches 3 and 4 having 65% of total floodplain area in public ownership. In reach 2, the area occupied by aquatic area (primarily Lake Pepin) is about 50% of the total floodplain area. If aquatic areas are considered, the proportion of reach 2 in public ownership increases to about 80% of total floodplain area. Public ownership accounts for 17% of geomorphic reach 5, 14% of the lower Illinois River, and 11% or less of the other reaches.

Natural habitats are highly connected in the lower part of reach 1 and reaches 2, 3, and 4, though river impoundments have disrupted the continuity of terrestrial floodplain communities. While greater connectivity exists in the upper UMR reaches, the scattered distribution of public lands has resulted in significant habitat fragmentation in the geomorphic reaches 5 through 10 and the lower Illinois River. The riparian forest remains fairly contiguous along the longitudinal gradient of the rivers, but other native floodplain terrestrial classes persist mostly as remnants in the refuges and conservation areas managed by conservation agencies.

7.8 Potential Species/Guild Habitat Abundance/Scarcity/Absence

The HNA GIS query tool can generate species/guild occurrence summaries at many scales. Users can query river miles, pools, or multiple pools to obtain information for their specific needs. Users can also choose among several guilds or species. The potential habitat rank can be selected to quantify the amount of high, medium, or low potential of occurrence or combinations of the three. Users also have the ability to select several species and habitat analytical parameters (see query tool users manual). Finally, the query tool can access multiple GIS data layers.

Individual queries of high, medium, and low potential of occurrence acres for all guilds and species were conducted at the geomorphic reach scale for this summary. The query tool should be used to obtain information at the pool or smaller scales. The results presented are extensive because of the large number of species and multitude of river reaches considered. Although results are presented in tables in Appendix N, selected species/guilds will be discussed here to provide an overview of the strengths and weaknesses of the tool. Discussion will focus on the habitats ranked as high potential of occurrence.

The definition of geomorphic reaches, pool reaches, or river reaches determines to a large extent the amount of habitat available. Because the reaches and pools are not of standard length or area, direct areal comparisons among reaches cannot be made. To some extent the proportion of available habitat can be used, but it becomes readily apparent that the dominant land cover type, or overall geomorphic structure, of a reach determines the proportional distribution of habitat. Several examples will be presented to illustrate how the area estimates and their proportional distribution can be used to make habitat assessments.

Aquatic areas, especially backwater classes, are proportionally more abundant in geomorphic reaches 2 through 4 because the floodplain is relatively narrow. Lake Pepin fills much of the river valley in reach 2, and impoundment by navigation dams inundated much of the former floodplain, especially in reach 3. In southern river reaches, aquatic areas are a relatively minor component of the entire floodplain area because the river valley widens considerably and terrestrial classes dominate. Examining aquatic invertebrates, the proportion of floodplain estimated as lentic invertebrate habitat is higher in reaches 2 through 4, especially when impounded areas are included as high potential habitat. South of reach 5, backwaters are rare and impounded areas are a minor component of aquatic habitat. The proportion of lentic invertebrate habitat, although lower in absolute terms, is an exceptionally small proportion of the total floodplain area. The La Grange reach has absolute backwater area similar to reach 2 through 4, but because the pool has a greater total area the proportion of the floodplain classed as lentic invertebrate habitat is lower. Considering lotic invertebrate habitat, the amount of channel habitat is highly dependent on the length of the reach. Absolute channel habitat is similar among reaches, but the inclusion of impounded area as lotic depositional invertebrate habitat increases the amount and proportion of that guild's habitat in reaches 3 and 4. In reach 5, the proportion of lotic invertebrate habitat is high because channel habitats dominate the narrow valley. In reaches 6 through 8, acreages are similar to upper reaches, but the proportion of the floodplain classed as habitat is smaller because of the abundance of non-suitable habitat. Cape Girardeau reach aquatic habitat is almost entirely channel. However, the proportion of the total floodplain area suitable to lotic invertebrates is small. The La Grange pool has less lotic invertebrate habitat in absolute and proportional terms because channel habitat is a small component of the total floodplain area.

Similar biases and skewed results occur for all habitat estimates associated with the aquatic area coverages. Calculating aquatic animal habitat as a proportion of total aquatic area rather than total floodplain area could alleviate some of the problems. Another remedy might be to develop standardized analysis reaches, but this is very difficult because of the habitat impacts of navigation dams, dominant geomorphic features, and land use practices.

Land cover classes are also disproportionately distributed throughout the river system. The largest differences occur in the amount and distribution of agriculture and the proportion of open water in the floodplain. Agriculture dominates the floodplain south of geomorphic reach 4. Open water occupies a greater proportion of the floodplain in reaches 1 through 4. Wetland classes are generally more abundant in reaches 1 through 4, wet meadows are fairly evenly distributed, and grasslands are rare throughout the river system. Woody classes generally occupy between 10 to 20% of the floodplain throughout the system. Estimates of potential bird species occurrence are strongest where habitats are clearly defined, such as with the HNA terrestrial land cover classes. Estimates of potential bird species habitat is weak where the open water class is scored as a component of the species' habitat. The results for potential water bird occurrence are overestimates because some open water areas provide higher quality habitat than others. The fine details creating important aquatic microhabitats are not available from existing land cover maps. Bird species for which agriculture has been scored as high quality habitat show higher absolute and proportional habitat abundance in southern river reaches where agriculture dominates the floodplain.

Combining the geomorphic areas database with the land cover database could provide more resolution in aquatic areas to help improve estimates of potential water bird and reptile and amphibian habitat. While still imperfect, aquatic area classes providing little habitat benefit could be eliminated to refine habitat estimates.

The HNA query tool is likely to overestimate potential species/guild occurrence because some data are only available at coarse resolution and the specific microhabitats occupied by some species cannot be identified. The land cover classification developed for the HNA provides a reasonably high-resolution interpretation of plant communities but the open water class is extremely coarse and unsuitable for habitat modeling. The geomorphic areas classes could increase the resolution of the open water class if the two databases were combined, but this too has limitations. The aquatic areas defined in the geomorphic classification simply describe major aquatic features (i.e., main channel, backwaters, etc.); they do not identify important features, such as substrate type, water quality, hydraulic features, or depth not visible from the surface of the water. Including available bathymetry data and hydraulic models could greatly enhance the suitability of the aquatic areas classification.

Because fine resolution topographic data are lacking, the extent of the flood zone cannot be accurately predicted. This inability limits the potential to estimate the abundance and distribution of seasonally available flood zone habitat.

7.9 Species/Guild Habitat Fragmentation, Connectivity, and Distribution

Species/guild habitat, connectivity, and distribution mirror the results described above for the HNA geomorphic area and land cover classes. Navigation dams that prevent free movement throughout the river fragment fish habitat. Connectivity of aquatic habitats has increased in places where water levels have been regulated by dams. Conversely, connectivity of aquatic and floodplain terrestrial areas during floods has been reduced by levees. In terrestrial floodplain areas, agriculture has replaced most of the prairies that were once a major component of the floodplain from geomorphic reach 5 through 9 and the lower Illinois River. Animals affiliated with the prairie habitats have been extirpated in some cases but, generally, populations persist in lower abundance in isolated prairie fragments or sub-optimal habitats. Wetland habitats are presently unevenly and patchily distributed. Wetland dependent species/guilds have more potential habitat in geomorphic reaches 1 through 4 than in reaches 5 through 10 and on the Illinois River. Forests persist as the most evenly distributed and unmodified major habitat type, except for changes in species dominance. Forest dependent species have nearly continuous habitat along the length of the river, except where towns and cities or crop fields crowd riverbanks.

7.10 Summary

An assessment of existing conditions on the UMRS was conducted at system, river, river reach, and pool scales. The analysis was rather extensive because 12 river reaches, 37 pools/reaches and 33 land cover or geomorphic area classes were included in the assessment. To summarize, the greatest habitat diversity occurs north of Pool 14. The upper river reaches exhibit habitat degradation because of impoundment and development, but the large refuge system helped preserve river-floodplain connectivity and limited habitat fragmentation. The other Mississippi River reaches have lower natural geomorphic diversity and have been more heavily impacted by agricultural development. Suspended sediment concentrations increase as the river traverses the corn-belt. Backwater sedimentation in lower pooled reaches is a large problem impacting aquatic and marsh habitats. Channelization and agricultural development have greatly simplified habitats in the Open River reach. More than 80% of the Open River reach is leveed, and the only unfragmented areas occur along a narrow floodplain strip between the river and levees. Geomorphic conditions along the Illinois River are variable with some areas highly developed, large main channel lakes near Peoria, and numerous backwaters in the La Grange reach. One commonality, however, is that water level regulation and sedimentation have degraded aquatic habitats. Connectivity is reduced throughout the river and habitats are fragmented by agriculture and urban development. Considering the entire UMRS, agriculture, open water, and wet floodplain forests are the most abundant land cover classes. The amount and distribution of geomorphic area classes are quite variable among river reaches.

8 Terrestrial Vegetation Successional Model

8.1 Approach

Terrestrial plant communities provide many ecological services that support large river floodplain ecosystems. They provide the major habitats that support almost 300 bird species, over 70 reptile and amphibian species, 50 mammal species, and many fish species during floods. Floodplain plant communities are also an important source of organic energy to aquatic food webs when terrestrial plant litter is inundated by flood flows. In addition to their ecological value, their aesthetic appeal contributes to the high recreational value of the UMRS.

Terrestrial floodplain plant communities are generally distributed in accordance with major geomorphic and climatic features of the river system. The dominant geomorphic features of the UMRS floodplain were formed during the retreat of the Wisconsin Age glaciers. Glacial meltwater and huge floods scoured, then deposited, and scoured again massive sediment loads to form the major river terraces and floodplains evident today. Post glacial fluvial processes and tributary channel migrations continued to sculpt the river channels and floodplains to create more subtle features of the floodplain geomorphology. Modern plant communities were established about 4,000 years ago when the climate warmed and temperate plant communities colonized the floodplain. Prairies, oak savannas, riparian forests, and floodplain wetlands were the dominant land cover types prior to major settlement in the region.

Terrestrial plants in the UMRS include diverse communities of species adapted to the wide range of conditions found in the floodplain ecosystem. Plant species are generally distributed in relation to their soil moisture and flood tolerance, availability of light, and lack of competing species. Emergent wetlands and wet meadows develop in frequently inundated areas that maintain high soil moisture and on exposed mud flats along channel and backwater shorelines. Pioneering trees colonize new terrestrial soils with willows dominating mudflats and cottonwoods developing on coarse dry soils. Pioneering species do not regenerate under their own cover and, without disturbance, die out in 30 to 50 years. Pioneering trees do, however, condition sites for future plant communities. They trap sediments and build soil with leaf fall and plant litter. Flood and shade tolerant communities, primarily mixed silver maple forests, develop under the cover of pioneering trees. In frequently flooded low elevation areas of the UMRS, mixed silver maple forests are self-sustaining climax communities. Oaks and less flood tolerant species develop on better-drained soils, on higher elevations of the floodplain, and on terraces. Evidence suggests that prior to major changes, dense floodplain forests bordering river channels and backwaters gave way to oak savannas and prairies along a gradient from the river to the bluffs in much of the river system. Fire was once an important determinant of plant community composition on higher elevations of the UMRS floodplain.

UMRS floodplains have been highly modified over the last 150 years. The area available to natural communities has been reduced more than 50% in most river reaches. Areas not directly changed may be impacted by river regulation and other types of habitat degradation. Areas supporting dry prairies in the pre-settlement era were largely converted to crops; forests were cut for lumber, heat and cooking, and steamboat fuel wood. Floodplain wetlands have been degraded by dredged material disposal, channel regulation, impoundment, and excessive sedimentation. Natural areas are currently largely restricted to public lands and narrow strips of land riverward of levees.

Natural communities of the UMRS are highly valued for their wildlife and recreational benefits, so natural resource managers are working to protect and improve the ecological integrity of the river system. Habitat Rehabilitation and Enhancement Projects funded by the Environmental Management Program for the Upper Mississippi River System are a major tool available to protect and restore the rivers. Program managers decided that an evaluation of existing and likely foreseeable habitats needed to be completed before embarking on an expanded program of river restoration. An integral component of the Habitat Needs Assessment is a prediction of future terrestrial plant communities.

The development of this rule based terrestrial successional model builds upon previous estimates of change in the UMRS. Future projections of the Illinois River (Bellrose et al. 1983, Bhowmik and DeMisse 1989) and the Mississippi River from St. Louis, Missouri to Cairo, Illinois (Simons et al. 1974) have been completed. Upper Mississippi River geomorphic change over the last 50 years was recently assessed to help project change expected over the next 50 years in the pooled reaches of the Mississippi River (WEST 2000). Previous studies provided quantitative and qualitative assessments of geomorphic changes in aquatic environments, but failed to assess and estimate changes in terrestrial habitats.

Forest successional models have been developed for the Lower Mississippi River (Climas 1988) and southern bottomland hardwoods (Hodges 1997, Mitsch and Gosselink 1986), but none have been completed for the UMRS. The approach taken in this analysis of future habitat conditions on the UMRS was to convene an expert panel of UMRS botanists and foresters to help develop a rule-based successional model for terrestrial vegetation. The expert panel (Appendix O) met in a workshop to outline basic assumptions for land use, resource management, and disturbance regimes. The pannel also assessed important controlling factors and plotted probable plant community changes from one HNA land cover class to other HNA land cover classes based on existing land cover, published reports, and successional theory. The UMRS terrestrial succession model uses HNA land cover unit area estimates from the existing conditions analysis to produce acreage estimates of future HNA land cover unit area. Future estimates were calculated using rules predicting percent change in land cover unit composition.

Land cover data included in the analysis were obtained from the Long Resource Monitoring Program GIS and U.S. Army Corps of Engineers REEGIS database. The majority of the data were interpreted at the genus or genus group level from aerial photographs obtained in 1989 or 1994 (see Table 7). Data for the remaining areas were obtained in 1989 from Landsat thematic mapper satellites (see Table 7). Land cover types were then reclassified according to the HNA land cover classification scheme described above. Additional information layered on the land cover included public lands, leveed areas, wing dams, closing structures, and rip rap. A geomorphic classification of various aquatic areas, islands, contiguous floodplain, and isolated floodplain was available also.

A prediction of geomorphic change for Mississippi River pools 4 to 26 was obtained from the USACE Cumulative Effects Study (WEST 2000). An expert team of geomorphologists, hydrologists, and ecologists measured geomorphic features on historic maps and photos to estimate change between the 1930s (pre-dam), 1940s (immediate post dam), 1970s, and 1989. The team also examined the maps to identify a set of geomorphic processes responsible for noted changes (see Future Condition chapter). The historic analysis was used to predict future geomorphic changes expected to occur by 2050. We incorporated the plan form change predictions using their estimate of percent change in total open water area to serve as our estimate of the percent gain or loss of terrestrial area (Table 23). We predicted plant community development on new land and estimated which plant communities would be lost in erosional areas.

An expert panel of Upper Mississippi River System foresters, botanists, and ecologists was convened to develop the rule based successional model. The group met in a workshop to develop a set of conditions on which to base the model. The panel first agreed on the set of plant community types to be included in the analysis. The panel refined the forest community classification by separating populus and salix communities from other forest classes, and renaming an existing forest class to mesic bottomland hardwood floodplain forest (see Table 8). The panel also agreed on a set of assumptions that would limit the range of future change under consideration. The assumptions include:

1. land presently in agricultural use will remain in agricultural use,
2. developed land will remain developed,
3. existing plans for floodplain vegetation management will be implemented,
4. the climate and hydrologic regime will not change,
5. the present set of floodplain vegetation natural disturbances (wind, fire, flood, ice, diseases, etc.) will continue.

The final condition was a decision regarding the dominant control factors that could be considered using available data (Table 26).

The data to quantify various control factors differs in quality and quantity. The location in the river system is used as a surrogate of climate and overall geomorphology and hydrology of the defined geomorphic reaches (see Figures 1 and 2). The location in the river system factor can be scaled to the river, geomorphic reach, navigation pool/river reach, location in a pool with respect to the downstream dam (i.e., upper, middle, and lower pool), and geomorphic area (island, backwater, etc) using available GIS coverages.

The hydrologic regime and floodplain elevation are coupled to control the frequency and duration of flooding and the relative depth to the water table, all three being important factors influencing plant community development. Hydrologic records on the UMRS are extensive. Available topographic data are coarse resolution. Although the mismatch of high-resolution hydrologic data and low-resolution topographic data prevents areal estimates of the extent of flooding, some generalities can be derived. Low discharge water levels in lower pool reaches are maintained artificially high and stable by the navigation dams. The water table was elevated and the shallow root zone was saturated. Flooding is reduced because low elevation floodplains are permanently inundated and flows exceeding regulated pool stage are uncommon. Impoundment effects generally extend to half of the length of the pools – the whole pool where pooled reaches are short – but the effects taper off gradually upstream from the dam. Flood frequency and duration and the relative depth to the water table reflect more natural conditions in upper pool reaches.

Soil conditions are important determinants of plant community development. In unmodified floodplain rivers, soil particles often decrease in size – from coarse sand to fine clay and silt – as distance from active channels increases. Former channels, natural levees, and lakes provide soil diversity across the floodplain. During floods, heavy sand is deposited on the river side of natural levees and on bars and shoals. Fine sediments are transported into floodplain areas where it settles out in low current velocity areas. River regulation has disrupted sediment transport, and fewer sand bars and shoals are present. High erosion rates in the uplands, river regulation, and levees are responsible for high sedimentation rates in contiguous floodplain areas, backwater lakes, and secondary channels. Soils are not mapped at a scale relevant to ecological investigations.

The floodplain geomorphic class (i.e., island, contiguous floodplain, and leveed floodplain) correlates with the frequency of flooding, the degree of development, and a range of other disturbances. Ideally, a more ecologically relevant floodplain geomorphology classification system could be developed if topographic and soil data were more widely available. Topographic data could be used to define ridges, swales, flats, and depressions subject to different rates of

Table 23. Cumulative Effects Study predicted change in Total Open Water Area (WEST 2000) (* = change extrapolated from similar pools or extrapolated from published reports cited in text).

River Reach	Change in Total Open Water (percent)
Pool 1*	-4
Pool 2*	-4
Pool 3*	-4
Pool 4	-4
Pool 5	+11
Pool 5a	+8
Pool 6	+9
Pool 7	-1
Pool 8	+3
Pool 9	+9
Pool 10	-3
Pool 11	-11
Pool 12	+1
Pool 13	-1
Pool 14	-4
Pool 15	0
Pool 16	+1
Pool 17	-2
Pool 18	-7
Pool 19	-7
Pool 20	-1
Pool 21	-9
Pool 22	-2
Pool 24	-2
Pool 25	-2
Pool 26	-7
L+D 26 to Kaskaskia R.*	-2
Kaskaskia R. to Grand Tower*	-2
Grand Tower to Ohio R.*	-2
Lockport*	0
Brandon*	0
Dresdon*	0
Marseilles*	0
Starved Rock*	0
Peoria*	-30
Lagrange*	-30
Alton*	-30

Table 24. Control factors to be used in the floodplain vegetation successional model.

Control Factor	Examples
1) Location in river system	River (Mississippi, Illinois)
	Geomorphic reach (1 through 10)
	Navigation pool
	Location within pool (upper, middle, lower)
2) Hydrologic regime / floodplain elevation	Depth to groundwater
	Frequency of Flooding (High, Mod., Low)
	Duration of Flooding (High, Mod., Low)
3) Soil Conditions	Soil Type
	Geomorphic Features
4) HNA floodplain class	Island
	Contiguous floodplain
	Isolated floodplain (leveed)
5) Planned management	Planting - Mast-producing trees
	Planting - Prairie vegetation
	Clear cut
	Salvage logging
	Selective logging
	Other management measures that may modify HNA vegetation cover types

inundation and different soil forming processes. Soil data could be used to define the permeability of soils associated with major geomorphic features to help predict the potential species composition of an area. The current level of resolution is most useful in separating developed areas from areas influenced by the rivers. The model assumes that leveed areas are developed as agriculture, urban, or residential areas, and that natural communities have been largely replaced. Islands and floodplains are subject to many similar disturbances, but the rates or degree of specific disturbances (e.g., ice shear, tree wind-throw, etc) may differ.

Many areas of the UMRS are publicly owned and managed. Management techniques range from passively protecting an area from development to active planting, construction, and water level management activities. A range of selective harvest, clear-cut, planting, burning, mowing, and other techniques are available to land managers. Generally, public land holdings include many habitat types, each subject to slightly different management practices. Management practices in most river reaches have not been adequately documented, reviewed, and organized to allow their inclusion in future conditions analysis. Where they occur, recent Habitat Rehabilitation and Enhancement Projects provide a wealth of information for local areas. Management plans are to be compiled and reviewed by the HNA Public Involvement Committee.

We considered the various control factors and the ability to quantify them using the available data. The location in the river system was considered to the level of geomorphic reach and navigation pool. We decided the geomorphic reaches provided an adequate surrogate for climate and large-scale geomorphology, and the pools provide a common reference to location on the rivers. The location within navigation pools provides a surrogate for important hydrologic measures, but we felt we lacked information clearly documenting plant community differences within pool reaches. A general belief that less flood tolerant species occur more commonly in upper pool areas will have to be incorporated in qualitative analysis and future project planning efforts. Because we lack topographic data we were not able to quantify the flood regime.

Managers familiar with specific project areas will have to qualitatively assess to what degree certain areas are subject to flooding and incorporate that knowledge into site management and project planning. Soil conditions were not factored into the analysis because of the lack of soil data. The generalization that floodplains are mostly fine alluvium is accepted for the model. Local mangers may be able to qualitatively assess soil differences in local areas. Since we made the broad assumption that levees areas will remain in development, we decided the distinction between island and floodplain succession was too fine for our methods to detect differences. Planned management objectives were not compiled at the time of this analysis, so we assumed that plant communities represented on the 1989 GIS would evolve similarly, regardless of management.

After determining assumptions and rule modifiers, the expert panel developed general successional rules for the HNA land cover classes (Table 25). A smaller team then examined the general successional pathways with respect to the geomorphic reaches and applied a predicted percent change from one land cover type into other land cover classes (Appendix P). Percent change estimates were adjusted for the amount of geomorphic change predicted and other presumed differences among river reaches. For example, the Illinois River was predicted to achieve a high proportion of climax communities because of high sedimentation rates, but the Open River was predicted to maintain a relatively high proportion of pioneer tree species because of a high frequency of flood disturbance. The entire expert panel reviewed the percent change estimates to refine regional predictions.

Query tool output quantifying the area of the HNA land cover classes was used as the basis for future change predictions. The summed areas of each of the HNA land cover classes on the 1989 and 1994 GIS navigation pool/river reach coverages were used as the input data for the predicted succession spreadsheet calculations. A prediction of percent change to other classes was applied to each input land cover class and the predicted land cover area estimates were summed, by class, to provide an estimate for change in whole pools or reaches. Pool or reach scale estimates can be summed to provide geomorphic reach and systemic estimates.

8.2 Results

The results of the terrestrial succession analysis are presented at the systemic scale in Table 26, the reach scale in Table 27, and at the pool scale in Appendix Q. Projected trends for land cover classes and the calculations responsible for them will be summarized. Acreage changes vary among reaches and pools because projections are based on the amount of a land cover class in the first time period. Also, the proportional change estimate may differ among reaches. In some cases the percent change is very large, but this is mostly a circumstance of there being a large increase of a community that was rare in the existing condition. For example, in geomorphic reach 1 mesic bottomland hardwood forests are projected to increase from 6 to 754 acres, an 11,500% increase. This is an artifact of the predicted change in wet floodplain forest where 5% of the almost 15,000 acres was predicted to convert to mesic bottomland hardwood forest. The resolution of the data in the initial time step also affects the results of the future condition projection. In reaches and pools where satellite data were used, land classes not mapped in the initial time step can appear in the projected future. This occurs where one of the land cover classes mapped in the first time step are projected to succeed to unmapped classes. This occurs where a portion of the open water class is projected to convert to emergent perennial, salix community, or populus community.

Table 25. Upper Mississippi River System generalized terrestrial land cover class successional rules.

Aquatic Classes & Sand-mud
If not land – Aquatic Classes stay the same
If land at target year
    0-20: Wet Floodplain Forest
    0-50: Grass
        Scrub-shrub - Illinois or Lower Third of pools
    20-50: Wet Meadow
    20-50: Salix/Populus Communities

Wet Meadow (reed canary grass, rice cutgrass):
    Minor movement to Aquatic Classes
    Some movement to Scrub-shrub
    Some movement to Populus Communty
    Some movement to Wet Floodplain Forest
    Dominant movement to Salix Community

Grassland
    With management stays Grassland
    W/O management moves to Salix Community, Populus Community, Wet Floodplain Forest

Shrub/Scrub
    Stays Shrub/Scrub (deposition dependent)
    Moves to Salix Community
    Moves to Aquatic Classes

Salix Community
    Moves to Aquatic Classes
    Small amount stays Salix Community (swales)
    Moves to Wet Meadow (age dependent)
    Moves to Scrub-shrub
    Moves to Populus Community (age dependent)
    Moves to Wet Floodplain Forest (age dependent)

Populus Community
    Moves to Aquatic Classes in lower third of pools
    Moves to Scrub-shrub on Illinois River
    Moves to Wet Meadow
    Moves to Populus Community (age dependent)
    Moves to Wet Floodplain Forest
    Moves to Mesic Bottomland Hardwood Forest in upper third of pools with deposition on islands

Table 25. Continued.

Wet Floodplain Forest

Stays Wet Floodplain Forest with no cottonwood component
Moves to Sailix/Populus Communities in small areas after major disturbance, more predominant on Open River
Moves to Mesic Bottomland Hardwood
Moves to Wet Meadow
Moves to Scrub-shrub in lower and middle third of pools

Mesic Bottomland Hardwood Forest

Stays Mesic Bottomland Hardwood Forest
Moves to Wet Floodplain Forest (site dependent)

An overview of projected changes reveals many changes that differ from common perceptions of ecological change in the UMRS. Each land cover class will be briefly discussed to explain the reasons. Change in open water classes for pools 4 to 26 were obtained from the Upper Mississippi River/Illinois Waterway Cumulative Effects Study (WEST 2000). Changes for geomorphic reach 1 (Pools 1 to 3) were assumed to be similar to Pool 4. No projections for change were available for the Open River reach, so a conservative projection of 2% loss was used. The change estimated for the Illinois River is based on projections made by Bellrose et al. (1983) and Bhowmik and DeMisse (1989). Open water is projected to convert to various percentages of emergent aquatic plants, wet meadow, salix community, populus community, wet floodplain forest, or sand-mud. Sometimes the increase in these classes appears to be extreme. The dramatic changes occur primarily where there are large amounts of open water in the existing condition. For example, it seems unusual to predict that populus communities in reach 2 will increase by 156 acres when only 5 acres occurred in the initial time period. The projection arises from small percentages of open water, sand-mud, wet meadow, and scrub-shrub communities area projected to evolve to populus communities. Open water is projected to be lost in all but reach 3 where it is projected to increase by 10% and reach 5 and the upper Illinois River where no change is projected to occur.

Emergent aquatic plant classes were projected to change as outlined in Appendix P. Emergent aquatic plants could evolve from varying percentages of open water and sand-mud; they could succeed to varying percentages of wet meadow, scrub-shrub, salix communities, populus communities, or wet floodplain forest. Some percentage of the class was also projected to remain stable. Reaches 1, 2, 9, and IR2 show increases in the emergent aquatic plant class that were projected to evolve from mostly open water classes. There was little change for reaches 6, 7, 8, 10, and IR1 because projected gains were balanced by projected losses or no change was projected at all (IR1). Emergent aquatic classes were projected to be lost in reach 3 where there was also a gain in open water and in reach 5 where no loss of open water was projected to balance succession of exiting communities.

Wet meadow classes were projected to change as outlined in Appendix P. Wet meadows could evolve from varying percentages of open water, sand-mud, emergent aquatic communities, scrub-shrub, or wet floodplain forest. They were projected to succeed to varying percentages of wet meadow, scrub-shrub, salix community, populus community, or wet floodplain forest. Comparatively large increases in wet meadow were projected for reaches1 through 4 where Reed canary grass is out competing other communities. Losses are projected for reaches 5 through 8 because less aggressive species occur farther south and there is rapid succession to later stages because of high sedimentation rates. The class was not detected in the initial time step in the Open River and upper Illinois River reaches and none was projected to emerge from existing classes. The large increase in the lower Illinois River was because of wet meadow development in open water area.

Grassland classes were not projected to change (Appendix P) because the class occurs primarily in managed areas. Grasses on levees account for much of the grassland area and much of the other grassland areas are in public or agricultural areas where they are maintained as grassland or pasture. No other land cover classes were projected to evolve to grassland.

Scrub-shrub classes were projected to change as outlined in Appendix P. The scrub-shrub class was projected to evolve from emergent aquatic and wet meadow classes. It was projected to succeed to wet meadow, salix communities, populus communities, and wet floodplain forest. Scrub-shrub classes were projected to decline in all river reaches where they were mapped, but it did not occur where satellite data were used for the analysis.

Salix communities were projected to change as outlined in Appendix P. Salix communities could evolve from open water, sand-mud, emergent aquatic, and wet meadow classes. They could succeed to populus communities and wet floodplain forests. Salix communities were projected to be lost in reach 2 and 3 where large proportions of loss to wet floodplain forests were not balanced by gains from other classes. Salix communities were projected to increase in reach 1 and 4 through 8. The class was not mapped in satellite derived GIS coverages; so the increase in reaches 9, 10, and IR2 arise from loss of open water classes.

Populus communities were projected to change as outlined in Appendix P. Populus communities could evolve from open water, sand-mud, emergent aquatic, wet meadow, scrub-shrub, and salix community classes. They could succeed to floodplain forests. Populus was projected to increase throughout the river system, but greater proportional increases occurred in northern reaches where the class was rare in the initial time step. Greater absolute acreages occur further south in the system, so proportional change appears less extreme.

The populus community is most abundant in the Open River reach (Yin 1999), but the satellite data did not map populus, so the estimates for existing and future conditions greatly underestimate the abundance of populus communities. The large increase in the Illinois River occurring from loss of aquatic area is probably a gross overestimate, Nelson and Sparks (1998) document a decline in populus in the lower Illinois River.

Wet floodplain forests were projected to change as outlined in Appendix P. Wet floodplain forests are the climax successional stage in wetter, low-lying areas of the floodplain, thus they are projected to evolve in a portion of all the non-agriculture or developed classes. In northern reaches they can be invaded and replaced by the wet meadow class and mast tree (mesic bottomland hardwood forest) planting may replace some wet floodplain forest. Losses of wet floodplain forest, sometimes large, are projected for reaches 1 through 4. Gains, also sometimes large, are projected for reaches 5 through 8 and the lower Illinois River. Predictions for the Open River reach show losses of wet floodplain forest, but the lack of resolution in the satellite data yields a comparatively weaker analysis.

Mesic bottomland hardwood forests were projected to change as outlined in Appendix P. They are a climax community in higher elevation and dryer floodplain elevations. Mesic bottomland hardwood forests are much less abundant in southern river reaches than they were in the past. Bottomland hardwoods are projected to increase throughout the system except in reach 6 where they are projected to decline. The projected increase is the result of projected changes in wet floodplain forests, which appears to overestimate the probable change.

The amount of agriculture and developed classes was held constant by the assumptions laid out in the method section.

Sand-mud was projected to change as outlined in Appendix P. Sand-mud could evolve from open water only, but it could succeed to aquatic, emergent aquatic, wet meadow, salix community, populus community, and wet floodplain classes. Sand-mud was projected to increase in reaches 4, 6, 7, 8, and IR2, it was projected to decrease in reaches 1, 3, 9, and 10, and there was little or no change predicted for reaches 2, 5, and IR1.

8.3 Summary

A rule based terrestrial vegetation successional model was developed to help predict future land cover conditions. UMRS botanists and foresters participated in a workshop to develop a rule-based successional model considering disturbance regimes, land use, and navigation system operation. They also mapped probable successional pathways among HNA land cover classes. Acreage change was calculated using predicted percent change from one HNA land cover class to others at systemic, geomorphic reach, and pool scales. An interesting result of the analysis was a projected increase in early successional and bottomland hardwood forests that have actually been lost over time. This is because of the use of natural successional pathways and an expectation that hardwoods would be planted in the future. The use of natural successional pathways may not be appropriate on the highly developed UMRS. Thus, the increase in early successional species may be erroneous. The increase in hardwood forests is likely because hardwood restoration is an important natural resource management objective. Reed canary grass will likely continue to expand its distribution, causing an increase in wet meadow area in upper pooled reaches. Successional model rules included the assumption that agricultural land would remain as such, but land acquisition and restoration activities could greatly affect future land cover.

Table 26. Systemic summary of predicted HNA terrestrial land cover class successional change.

HNA Class	Total Existing Acres	Predicted Change (acres)	Predicted Change (percent)
1. Open Water	452,587	-33,095	-7.3
7. Seasonally Flooded Emergent	3,750	4,281	114.2
8. Wet Meadow	38,449	10,389	27.0
9. Grassland	54,454	0	0.0
10. Scrub-shrub	34,393	-14,142	-41.1
11. Salix Community	6,357	14,418	226.8
12. Populus Community	3,294	6,277	190.6
13. Wet Floodplain Forest	378,282	-6,376	-1.7
14. Mesic Bottomland Hardwood Forest	17,989	14,402	80.1
15. Agriculture	1,166,691	0	0.0
16. Developed	147,277	0	0.0
17. Sand-mud	6,308	4,640	73.6
18. No Photo Coverage	207,808	0	0.0

Table 27. Predicted 2050 UMRS terrestrial vegetation abundance.

Reach 1

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	15,443	14,825	-618	-4
7. Seasonally Flooded Emergent	21	316	295	1,399
8. Wet Meadow	3,278	6,102	2,824	86
9. Grassland	0	0	0	0
10. Scrub-shrub	1,737	1,043	-694	-40
11. Salix Community	14	222	208	1,497
12. Populus Community	0	163	163	NA
13. Wet Floodplain Forest	14,973	12,220	-2,753	-18
14. Mesic Bottomland Hardwood Forest	6	754	748	11,688
15. Agriculture	1,900	1,900	0	0
16. Developed	8,405	8,405	0	0
17. Sand-mud	720	579	-141	-20
18. No Photo Coverage	0	0	0	0

Reach 2

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	29,275	28,104	-1,171	-4
7. Seasonally Flooded Emergent Perennial	48	491	442	916
8. Wet Meadow	1,791	3,997	2,206	123
9. Grassland	519	519	0	0
10. Scrub-shrub	791	477	-314	-40
11. Salix Community	436	356	-81	-18
12. Populus Community	5	161	156	3,189
13. Wet Floodplain Forest	11,486	9,768	-1,718	-15
14. Mesic Bottomland Hardwood Forest	1,122	1,584	462	41
15. Agriculture	3,526	3,526	0	0
16. Developed	3,082	3,082	0	0
17. Sand-mud	225	242	17	8
18. No Photo Coverage	0	0	0	0

Table 27. Continued.

Reach 3

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	56,018	61,749	5,731	10
7. Seasonally Flooded Emergent Perennial	1,105	124	-981	-89
8. Wet Meadow	9,230	12,785	3,554	39
9. Grassland	2,283	2,283	0	0
10. Scrub-shrub	3,260	2,011	-1,249	-38
11. Salix Community	2,773	850	-1,924	-69
12. Populus Community	229	604	375	163
13. Wet Floodplain Forest	32,669	26,150	-6,519	-20
14. Mesic Bottomland Hardwood Forest	4,059	5,286	1,228	30
15. Agriculture	9,711	9,711	0	0
16. Developed	12,000	12,000	0	0
17. Sand-mud	431	215	-215	-50
18. No Photo Coverage	389	389	0	0

Reach 4

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	48,902	45,479	-3,423	-7
7. Seasonally Flooded Emergent Perennial	1,721	1,788	67	4
8. Wet Meadow	7,386	13,659	6,273	85
9. Grassland	404	404	0	0
10. Scrub-shrub	2,376	1,512	-864	-36
11. Salix Community	869	1,447	578	66
12. Populus Community	183	586	403	220
13. Wet Floodplain Forest	31,320	26,520	-4,801	-15
14. Mesic Bottomland Hardwood Forest	2,331	3,664	1,333	57
15. Agriculture	7,635	7,635	0	0
16. Developed	12,446	12,446	0	0
17. Sand-mud	219	653	434	199
18. No Photo Coverage	606	606	0	0

Table 27. Continued.

Reach 5

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	27,784	27,784	0	0
7. Seasonally Flooded Emergent Perennial	397	119	-278	-70
8. Wet Meadow	2,515	1,608	-907	-36
9. Grassland	309	309	0	0
10. Scrub-shrub	2,722	1,984	-738	-27
11. Salix Community	673	854	181	27
12. Populus Community	106	392	286	270
13. Wet Floodplain Forest	18,857	19,738	882	5
14. Mesic Bottomland Hardwood Forest	1,475	2,049	574	39
15. Agriculture	13,848	13,848	0	0
16. Developed	13,006	13,006	0	0
17. Sand-mud	55	55	0	0
18. No Photo Coverage	47,747	47,747	0	0

Reach 6

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	36,894	34,311	-2,583	-7
7. Seasonally Flooded Emergent Perennial	220	243	23	11
8. Wet Meadow	5,175	2,302	-2,873	-56
9. Grassland	325	325	0	0
10. Scrub-shrub	6,916	3,997	-2,918	-42
11. Salix Community	610	3,266	2,656	435
12. Populus Community	317	1,034	717	227
13. Wet Floodplain Forest	26,666	32,373	5,708	21
14. Mesic Bottomland Hardwood Forest	7,269	6,058	-1,211	-17
15. Agriculture	102,627	102,627	0	0
16. Developed	10,253	10,253	0	0
17. Sand-mud	293	773	480	164
18. No Photo Coverage	47,586	47,586	0	0

Table 27. Continued.

Reach 7

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	24,784	23,792	-991	-4
7. Seasonally Flooded Emergent Perennial	62	96	34	56
8. Wet Meadow	2,711	1,177	-1,534	-57
9. Grassland	41	41	0	0
10. Scrub-shrub	8,790	4,672	-4,118	-47
11. Salix Community	273	2,643	2,371	869
12. Populus Community	713	1,107	394	55
13. Wet Floodplain Forest	25,574	28,141	2,568	10
14. Mesic Bottomland Hardwood Forest	317	1,453	1,136	359
15. Agriculture	129,305	129,305	0	0
16. Developed	3,515	3,515	0	0
17. Sand-mud	430	571	140	33
18. No Photo Coverage	29,115	29,115	0	0

Reach 8

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	42,034	40,353	-1,681	-4
7. Seasonally Flooded Emergent Perennial	177	163	-13	-8
8. Wet Meadow	6,363	2,700	-3,663	-58
9. Grassland	184	184	0	0
10. Scrub-shrub	7,802	4,555	-3,247	-42
11. Salix Community	709	3,360	2,651	374
12. Populus Community	1,741	1,892	151	9
13. Wet Floodplain Forest	43,193	47,236	4,044	9
14. Mesic Bottomland Hardwood Forest	1,410	2,865	1,454	103
15. Agriculture	109,802	109,802	0	0
16. Developed	5,065	5,065	0	0
17. Sand-mud	461	766	305	66
18. No Photo Coverage	78,341	78,341	0	0

Table 27. Continued.

Reach 9

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	53,132	52,069	-1,063	-2
7. Seasonally Flooded Emergent Perennial	0	143	143	0
8. Wet Meadow	0	0	0	NA
9. Grassland	20,685	20,685	0	0
10. Scrub-shrub	0	0	0	0
11. Salix Community	0	818	818	NA
12. Populus Community	0	552	552	NA
13. Wet Floodplain Forest	62,845	59,969	-2,877	-5
14. Mesic Bottomland Hardwood Forest	0	3,142	3,142	NA
15. Agriculture	309,866	309,866	0	0
16. Developed	49,697	49,697	0	0
17. Sand-mud	2,862	2,147	-716	-25
18. No Photo Coverage	515	515	0	0

Reach 10

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	13,793	13,517	-276	-2
7. Seasonally Flooded Emergent Perennial	0	23	23	0
8. Wet Meadow	0	0	0	NA
9. Grassland	1,992	1,992	0	0
10. Scrub-shrub	0	0	0	0
11. Salix Community	0	184	184	NA
12. Populus Community	0	115	115	NA
13. Wet Floodplain Forest	19,374	18,474	-900	-5
14. Mesic Bottomland Hardwood Forest	0	969	969	NA
15. Agriculture	129,335	129,335	0	0
16. Developed	3,068	3,068	0	0
17. Sand-mud	458	343	-114	-25
18. No Photo Coverage	3,501	3,501	0	0

Table 27. Continued.

Reach IR1

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	14,461	14,461	0	0
7. Seasonally Flooded Emergent Perennial	0	0	0	0
8. Wet Meadow	0	0	0	0
9. Grassland	7,612	7,612	0	0
10. Scrub-shrub	0	0	0	0
11. Salix Community	0	0	0	0
12. Populus Community	0	0	0	0
13. Wet Floodplain Forest	12,920	12,274	-646	-5
14. Mesic Bottomland Hardwood Forest	0	646	646	NA
15. Agriculture	14,835	14,835	0	0
16. Developed	12,380	12,380	0	0
17. Sand-mud	46	46	0	0
18. No Photo Coverage	5	5	0	0

Reach IR2

Class	Sum acres 1989	Sum acres 2050	Areal Change (acres)	Percent change
1. Open Water	90,068	63,048	-27,020	-30
7. Seasonally Flooded Emergent Perennial	0	4,525	4,525	NA
8. Wet Meadow	0	4,509	4,509	NA
9. Grassland	20,101	20,101	0	0
10. Scrub-shrub	0	0	0	0
11. Salix Community	0	6,777	6,777	NA
12. Populus Community	0	2,252	2,252	NA
13. Wet Floodplain Forest	78,407	79,044	637	1
14. Mesic Bottomland Hardwood Forest	0	3,920	3,920	NA
15. Agriculture	334,301	334,301	0	0
16. Developed	14,359	14,359	0	0
17. Sand-mud	108	4,557	4,450	4,139
18. No Photo Coverage	3	3	0	0

9 Future Geomorphic and Land Cover Conditions

This section presents forecasts for the future (i.e., 2050) geomorphic and land cover conditions of the Upper Mississippi River System. The forecast incorporates information from the U.S. Army Corps of Engineers Upper Mississippi River/Illinois Waterway Navigation Feasibility Study, Cumulative Effects Study (WEST 2000), the terrestrial vegetation successional model presented in the previous section, and qualitative assessments from natural resource managers familiar with specific river reaches. Forecasts are presented for system, geomorphic reach and pool scales.

It must be noted that representatives of the Wisconsin and Minnesota Departments of Natural Resources do not concur with the findings of the Cumulative Effects Study. DNR managers believe the data used for the pool 1 through 11 plan form analysis were inadequate for several reasons. First, the data were only available for two post dam time steps (1973/75 and 1989), and managers believe changes in the 1940 to 1973/75 time period would alter conclusions of the study. Second, managers believe that differences in discharge and pool operating conditions between time periods were too extreme for valid comparisons. They provided examples of the types of differences that could be evident among photos taken during different discharge and pool operating conditions, with water level differences exceeding 2 feet at some gauges. Third, Minnesota and Wisconsin managers did not believe the plan form data provided sufficient resolution to define ecologically relevant habitat units. They thought the definition of main channel was too broad, and also thought there were classification errors among secondary channel and contiguous backwater classes. They want a plan form assessment that matches the HNA geomorphic area classes. Resource managers from Wisconsin and Minnesota did not agree with the use of Cumulative Effects Study historic and future plan form acreage estimates in the HNA Future Geomorphic Conditions or the Desired future Condition evaluations.

9.1 Qualitative Assessment of Geomorphic Change

Two methods were used to provide a qualitative assessment of geomorphic change. Both methods incorporated an analysis of historic change to predict future conditions. Both methods also resulted in maps with areas suspected to change annotated on land-water maps. The first assessment was completed as part of the Cumulative Effects Study (WEST 2000) where the consultant team reviewed historic maps and photos to identify areas of extensive change. Using this method, only large plan form changes were detectable. The second method incorporated the knowledge and experience of natural resource managers, many with 20 or more years of experience, working in specific regions of the river (Appendix R). The method allowed a more detailed analysis because the managers could provide insight into changes occurring below the water's surface. For example, backwaters that may not have displayed discernable plan form change may have lost significant depth that reduced their value as habitat.

A variety of geomorphic processes responsible for change were identified to classify geomorphic changes. The Cumulative Effects Study identified nine geomorphic processes:
delta formation,
filling between wing dams,
island dissection,
island formation,
loss of contiguous backwaters,
loss of isolated backwaters,
loss of secondary channels,
tributary delta formation,
and wind-wave erosion of islands.

The workshops with natural resource managers identified six additional geomorphic processes:

channel formation,
island migration,
loss of contiguous impounded area,
loss of bathymetric diversity,
loss of contiguous/isolated backwaters,
loss of tertiary channels,
and shoreline erosion.

The Cumulative Effects Study presents detailed descriptions and examples of the nine geomorphic processes, all will be briefly described and their distribution throughout the river will be discussed. The Cumulative Effects Study identified 58 areas in pools 4 through 26 influenced by one or more of the nine geomorphic processes. The workshops with the resource managers identified an additional 347 areas in the same reach, and an additional 125 areas in pools 2,3, the Open river, and the Illinois River. A total of 531 areas expected to change were identified (Table 28). Notes from the workshop (Appendix S) identify the source of the prediction and comments relevant to the prediction. Maps were also prepared to identify the locations where geomorphic processes were occurring (Appendix T).

Channel formation occurs where islands are dissected and new channels flow through what had previously been island land area. This is an uncommon geomorphic process detected in only pools 10 and 12.

Table 28. Occurrences of geomorphic processes effecting UMRS habitats reported by natural resource manager.

Geomorphic Process	Number of Occurrences
Channel Formation	3
Delta Formation	3
Filling between Wing Dams	34
Island Dissection	15
Island Formation	20
Island Migration	4
Loss of Contiguous Impounded	9
Loss of Bathymetric Diversity	12
Loss of Contiguous Backwaters	153
Loss of Isolated Backwaters	49
Loss of Cont/Iso Backwaters	32
Loss of Secondary Channels	116
Loss of Tertiary Channels	5
Shoreline Erosion	8
Tributary Delta Formation	43
Wind-Wave Erosion of Islands	25

Delta formation refers to the creation of landmasses from main channel sediment deposition. The process was detected in only three locations in pools 4 and 7. The delta formation in Upper Lake Pepin has been occurring since the glaciers retreated. At one point, Lake Pepin extended all the way up to the Twin Cities. The delta formation in lower pool four is the result of impoundment as sediment transported by the main channel is deposited laterally into the impounded area created by the dam. The delta formation in lower Pool 7 has formed from similar circumstances.

Filling between wing dams refers to the process where sediments are trapped between wing dams extending into the main channel. The process is a design feature of wing dams, which were constructed to trap sediment to constrict flow in the desired main channel configuration. The process has been very significant in the Open River reach where the channel was first widened by erosion associated with deforestation, and then greatly constricted by filling between wing dams that are now overlain by crop fields in many locations. There many be filling between submerged wing dams in the upper pools, but the process has not been qualified or quantified. Filling between wing dams was detected in 33 locations, all but one in Pool 6, located south of geomorphic reach 3 and most south of geomorphic reach 6. Pools 11, 20, 22, and the Open River reach had the greatest occurrence of filling between wing dams.

Island dissection refers to the process where erosion cuts through an island mass to create two separate islands. The process occurs mostly in geomorphic reaches 2 and 3, but also in one location in Pool 18. There were 15 areas experiencing island dissection in 15 locations in pools 4, 5a, 6, 7, 8, 10, 11 and 18. Pools 7 and 8 each had three locations of island dissection and Pool 10 had 4 locations.

Island formation refers to the process of sediment accumulation above the normal river stage. In natural channels, log jams, mass sediment movement, and over bank sedimentation can cause island formation. In the modified river, training structures and dredging can also promote island formation. Island formation was detected throughout much of the UMRS. Pools 5, 6, 8, 10, 15, 18, 19, 20, and 26 each had one location experiencing island formation. Pools 11, 12, 21, and 22 each had two locations of island formation. Pool 13 had 3 locations of island formation and Pool 24 had island formation in four locations.

Island migration refers to the movement of islands in the downstream direction. The process was noted in three locations in geomorphic reach four (pool 10, 11, and 13) which receives large sediment loads from several tributaries. Island formation was also noted in a single location below the Illinois River confluence in Pool 26.

Loss of bathymetric diversity refers mostly to the filling of floodplain depressions, channels, and overflow channels that were inundated with the development of the navigation system. Upon impoundment, these areas provided depth diversity and variation that increased the diversity of habitats available to aquatic plants and animals. Over time, sediment has concentrated in these areas through a process termed sediment focusing, in which sediment tends to accumulate in the deepest areas of a water body. The process was detected at nine locations in geomorphic reaches 2 through 4, 2 locations in Pool 19, and one location in Peoria pool.

Loss of backwaters is a widespread geomorphic process that can be divided into three classes: loss of contiguous-isolated backwaters, loss of contiguous backwaters, and loss of isolated backwaters. Loss of contiguous-isolated backwaters occurs in areas where both types of backwaters occur in close proximity and the two cannot be separated. The process was detected at 21 locations distributed among all geomorphic reaches except the upper Illinois River and the Open River reach.

Loss of contiguous backwaters refers to the loss of area or depth in contiguous backwaters because of filling with sediment. The process is the most widespread geomorphic process detected in this analysis, occurring at more than 150 locations distributed among all river reaches except Pool 1, Pool 15, Pool 20, and Lockport Pool. The process appears to be most prevalent in geomorphic reaches 4 through 8 and in the lower Illinois River.

Loss of contiguous impounded area is generally the same process occurring with the loss of backwaters. Sediment accumulates in the low flow impounded environment, causing either loss of depth or area. The process was identified in geomorphic reaches 3 through 7 and in Starved Rock Pool.

Loss of isolated backwaters, again, is the same process as other backwater filling. Loss of isolated backwaters was detected at 48 locations from geomorphic reach 3 through 8 and the lower Illinois River. The process was, by far, most prevalent in geomorphic reach 8 and the lower Illinois River.

Secondary channel loss refers to the filling of secondary channels or the blockage of inlets or outlets. In natural rivers, secondary channel loss is usually associated with the blockage of the channel with woody debris or mass sediment movement. In the modified system, secondary channel loss is associated with channel training structures and modified hydraulic conditions. Secondary channel loss was detected at 115 locations making it the second most prevalent type of geomorphic change. Secondary channel loss was predicted for all but geomorphic reach 1, but the process was most prevalent in geomorphic reach 8, 9, 10, and the lower Illinois River.

Loss of tertiary channels is a process similar to secondary loss. The process was detected for one location each in pools 10, 13, and 25, and two locations in Pool 16.

Shoreline erosion refers to active bank cutting or wasting by either river flow or boat propeller wash. Shoreline erosion was detected at one location each in pools 10, 11, 13, and Alton. Shoreline erosion was detected at two locations in Pool 4 and La Grange Pool. The Navigation Studies completed a systemic survey of shoreline erosion and detected many other locations with significant shoreline erosion (Bhowmik et al. 1999).

Tributary delta formation occurs where larger tributaries drop sediment at the confluence of the main stem rivers that cannot be transported away by the river. Some tributary delta formation is associated with impoundment of the river that raised and stabilized water level elevations in the main stem rivers and the low end of the tributaries. Tributary delta formation was detected in all geomorphic reaches except reach 1 and the Open River. The process was especially prevalent in Pool 19 and Peoria Pool.

Wind-wave erosion of islands occurs where former floodplain ridges remained exposed above the surface of the stabilized river elevation. Historic island erosion affected large portions of some pools in geomorphic reaches 3 and 4, but the process is still occurring in many locations. Wind-wave erosion of islands was predicted for 42 locations in geomorphic reaches 2, 3, and 4, and at one location in Pool 14. Wind-wave erosion of islands is predicted to impact large areas in pools 8 and 9.

9.2 Future Geomorphic Conditions

The Cumulative Effects Study (WEST 2000) was completed by a team of nationally recognized experts in geology, fluvial geomorphology, and hydraulics assisted by local ecologists and engineers familiar with the literature and history of the UMRS. The complete study (WEST 2000), published in two volumes with extensive appendices, presents complete methodology, analysis, and results. The Cumulative Effects Study consultant team reviewed pertinent literature, hydrological characteristics, geomorphic characteristics, human influences, and sediment budgets to assist with future predictions. The primary tools used to assess historic plan form change were historic maps and photographs. Future predictions were based on changes noted over time and the geomorphic processes responsible for the change. The summary of the chapter concerning future conditions predictions is inserted here to avoid misinterpretation of their results.

The following is excerpted from the Cumulative Effects Study (WEST 2000). Figures and tables referenced in brackets are reproduced sequentially in this report, others are referenced as they appear in the Cumulative Effects Study:

> **Summary for Upper Mississippi River [Pooled Reaches]**
> Table [not shown here] summarizes the concentrated areas of observed and predicted geomorphic processes in each pool. The involved areas of change are plotted on the maps presented in Appendix F. Reach 3 (Pools 5-9) has been and is predicted to continue to be dominated by island erosion. Reaches 4 through 10 (Pools 10 – Open River) have all experienced loss of contiguous backwater, especially reaches 6 through 10 (Pools 18 – Open River) where loss of isolated backwater has also been occurring. Generally, both of these processes are expected to continue for these reaches. Filling between wing dams has been historically observed in Reaches 6-10 (Pools 18 – Open River) but is not expected to continue except in limited cases. In most instances, the areas between wing dams have already filled and little additional filling can occur. The total number of concentrated areas of historic geomorphic change is 47 whereas the predicted number of concentrated areas of change is 39, which is a slight decrease. This represents a slight decrease in the expected geomorphic changes and is mostly related to predicted reduction in the filling of sediment between wing dams.
>
> In Figure [50] a bar chart is presented summarizing the percent change expected for each aquatic class from present (1989) to 2050. Reach 3 (Pools 5-9) is the only reach where water area is expected to increase, including both isolated and contiguous backwater. This is because of the predicted continued erosion of islands in the reach. In all other reaches, total water area is expected to decrease, including both isolated and contiguous backwater areas.
>
> In Table [not shown here] the absolute changes predicted for each aquatic class in each pool are presented. In Table [29] the absolute and percent of change predicted in each aquatic class are summarized for each geomorphic reach defined along the UMR. A summary of the total absolute and percent change predicted for all the pools along the UMR is presented in Table [30]. As seen from Table [30], total water area is predicted to decrease by 1.4% by the year 2050, with the major part of that decrease in the upper portion of the pools. Backwater areas are predicted to decrease by a slightly greater percentage. Again, the major decrease is expected in the upper portions of the pools. The area of the main channel is expected to decrease by less than 1%, while secondary channels are expected to decrease by about 2.6%. The area of islands is expected to decrease overall by 2.0% largely because of the island erosion predicted to occur in Reach 3. For many other reaches, the area of islands actually increases. Overall, the total perimeter of islands is predicted to decrease by 3.7%.
>
> When evaluating the results presented in Table [29 and 30] it is important to note the variability in the percentage change associated with each aquatic class, lower and upper portion of individual pools, and total pool. Erroneous conclusions can be drawn from the summary data if appropriate consideration is not given to the resolution of the data and the associated statistics. Furthermore, the absolute value of an aquatic class area should be considered in evaluating the significance of the calculated relative percentage change. A slight change in a small absolute value will result in a deceptively large relative

change. For example, in Pool 16 the area of isolated backwater is predicted to decrease by 89% and the main channel area to increase by 8%. Although the predicted percent loss for the isolated backwater is much larger than the predicted increase in main channel area, the predicted area increase for the main channel is almost four times larger than the predicted decrease in isolated backwater area.

Geomorphic Reaches 9 and 10

Geomorphic Reaches 9 and 10 are referred to as the Open River section of the UMR. No locks and dams are located along these reaches. Reach 9 encompasses the section of the river from below Lock & Dam 26 to Thebes Gap (River Miles 202 to 45). Reach 10 extends from the rock gorge at Thebes Gap to the confluence with the Ohio River, near Cairo, Illinois (River Miles 45 to 0).

The upper portion of Reach 9 is highly influenced by the alluvial fan of the Missouri River. Sediment supplies from the Missouri River have been reduced from historic levels by the construction of upstream main stem reservoirs (WEST 2000). However, the magnitude of the suspended sediment supply from the Missouri River is still much larger than the suspended sediment supply of the UMR upstream of their confluence.

Compared to upstream reaches of the UMR, the aquatic areas of the Open River reaches have relatively little complexity. The reaches are primarily limited to two aquatic classes, main channel, and secondary channels. As seen in Appendix F, the contiguous and isolated backwater areas along the reaches are quite small. In fact, most of the contiguous backwater area is associated with secondary channels that have been purposely blocked. A large number of wing dams are located along the reaches. It is also noted that the river is closely confined within levees, railroad embankments and bluff lines along both banks.

A previous study of the Open River (Simons et al. 1974) concluded that the position of the river is basically unchanged in the last 200 years and, in the absence of earthquakes or great floods, should remain so. Except for major secondary channels, natural side channels in the reach are being filled with sediment. Ultimately, most natural and man-induced side channels are expected to fill with sediment and become indistinguishable from the floodplain. In addition, small secondary channels can be expected to fill faster than large secondary channels.

One of the products from the Simons et al. (1974) study were maps of river bank lines for the years 1880 and 1968. The maps of historic bank lines are useful for the general identification of changes associated with main channel and secondary channel aquatic areas. Other aquatic areas cannot be distinguished from the maps. The number of secondary channels determined from the data for the years 1880 and 1968, are 35 and 27, respectively. A total of 25 secondary channels were identified from the 1989 WES Hydraulic Classification GIS coverage. It is noted that 10 of the 25 secondary channels were blocked by engineering structures as seen in the 1989 GIS coverage. The observed blockages could not be discerned from the 1968 data. Including the 10 blocked channels, the data imply a rate of decrease of number of secondary channels for both time periods to be about one secondary channel per decade. Therefore, these results indicate that the rate of decrease in the number of secondary channels today is similar to what it has been over the last 100 years.

An evaluation was also conducted to identify general changes in main channel location for the post-lock & dam era along the Open River reaches. This was accomplished by overlaying 1980s era land/water boundary information (USGS 1999) on the 1968 bank line data. The developed overlay is presented in Appendix G. The overlay indicates almost no change in the main channel location over the time period represented. A detailed discussion is provided in Section 5.5.4.

Craig (Personal communications with M. Craig, 1998) investigated changes in individual secondary channels. Plan form changes identified over the period of 1950 to 1994 for five out of six secondary channels investigated show a substantial decrease in aquatic area (see Figure 5-41). In most cases, the decrease in secondary channel area is more than 50% over the roughly 45-year period. Only one of the secondary channels investigated appeared to be relatively stable.

In general, the conditions of the Open River reaches in the Year 2050 are expected to be similar to existing conditions, with the exception that a significant percentage of secondary channels and related backwater areas will be filled with sediment. By extrapolation of the estimated rate of loss for secondary channels, approximately 6 of the remaining 25 secondary channels along the reach will be lost. However, this result is highly dependent on future river management decisions.

According to Craig's data (Personal communications with M. Craig, 1998), the rate of decrease in the area of the remaining secondary channels is slowing (See Figure 5-40). The area of the remaining secondary channels is expected to decrease by at least 40% by the year 2050. Again, river management decisions will highly influence this result. As previously concluded by Simons et al. (1974), the decreases will affect smaller chute (secondary) channels first and large chute channels last.

Illinois Waterway

The glacial history of the UMR valley strongly influences the existing and future geomorphic conditions of the IWW. Until the Mississippi River was diverted by runoff from glacial ice about 20,000 years ago the course of the river extended southeastward across northern Illinois and then into the present course of the Illinois River at the head of Reach 2. The anomalous deep, wide valley and relatively flat gradient for Reach 2 of the IWW is accounted for in large part by its being the course of the ancient Mississippi River. Since deglaciation of the region, sediments eroded from steep tributaries have built large alluvial fans and deltas into Reach 2 of the IWW river valley causing the formation of natural constrictions, lakes, and backwaters. The much steeper longitudinal gradient of upstream Reach 1 of the IWW was developed on local areas of bedrock, but mainly on glacial deposits of the most recent glaciation of the region. Reach 1 has a very steep gradient which accounts for the close spacing of locks and dams there.

As defined by its geologic history, the IWW is characteristically low gradient, aggradational, and has large backwater areas from its mouth to Starved Rock Lock & Dam (RM 231.0). The sedimentation occurring within this reach threatens to convert the backwater areas into marshes (Bhowmik, 1994). Upstream of the Starved Rock Lock & Dam, the IWW is significantly steeper and backwater areas are much less significant.

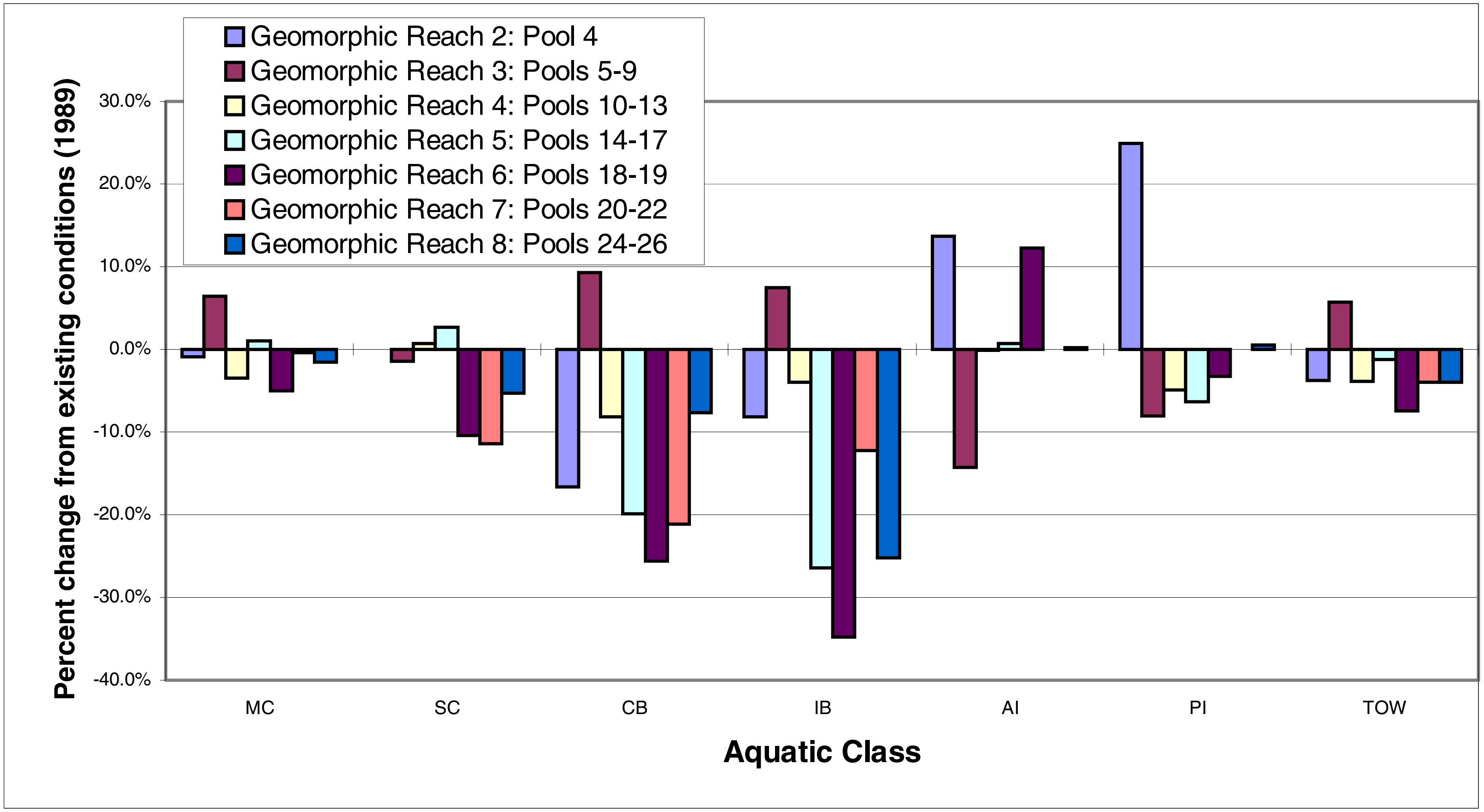

Figure 50. Predicted percent change within each geomorphic reach from present conditions (1989) to the year 2050.

Table 29. Summary of predicted geomorphic changes within UMR by Geomorphic Reach.

Geom. R. 2: Pool 4		**MC**	**SC**	**CB**	**IB**	**AI**	**PI**	**TOW**
Predictions for 2050		acre	acre	acre	acre	acre	ft	acre
Lower Pool	1989	2,230	659	4,054	189	3,718	768,400	7,132
	2050	2,230	659	3,446	180	4,462	998,920	6,515
	% Change	0.0%	0.0%	-15.0%	-4.8%	20.0%	30.0%	-8.7%
Upper Pool	1989	23,600	1,323	2,066	384	1,726	158,200	27,373
	2050	23,364	1,323	1,653	346	1,726	158,200	26,686
	% Change	-1.0%	0.0%	-20.0%	-9.9%	0.0%	0.0%	-2.5%
Total Pool	1989	25,830	1,982	6,120	573	5,444	926,600	34,505
	2050	25,594	1,982	5,099	526	6,188	1,157,120	33,201
	% Change	-0.9%	0.0%	-16.7%	-8.2%	13.7%	24.9%	-3.8%

Geom. R. 3: Pools 5-9		**MC**	**SC**	**CB**	**IB**	**AI**	**PI**	**TOW**
Predictions for 2050		acre	acre	acre	acre	acre	ft	acre
Lower Pool	1989	22,543	14,720	7,047	3,131	4,800	1,510,400	47,441
	2050	23,993	14,193	7,224	3,431	3,954	1,196,789	48,841
	% Change	6.4%	-3.6%	2.5%	9.6%	-17.6%	-20.8%	3.0%
Upper Pool	1989	8,418	4,491	20,997	3,347	25,934	5,344,271	37,253
	2050	8,962	4,738	23,798	3,528	22,383	5,108,139	41,026
	% Change	6.5%	5.5%	13.3%	5.4%	-13.7%	-4.4%	10.1%
Total Pool	1989	30,961	19,211	28,044	6,478	30,734	6,854,671	84,694
	2050	32,955	18,931	31,022	6,959	26,337	6,304,928	89,867
	% Change	6.4%	-1.5%	10.6%	7.4%	-14.3%	-8.0%	6.1%

Geom. R. 4: Pools 10-13		**MC**	**SC**	**CB**	**IB**	**AI**	**PI**	**TOW**
Predictions for 2050		acre	acre	acre	acre	acre	ft	acre
Lower Pool	1989	25,778	6,344	9,593	803	7,357	1,792,000	42,518
	2050	24,221	6,474	10,259	741	7,512	1,729,817	41,695
	% Change	-6.0%	2.0%	6.9%	-7.7%	2.1%	-3.5%	-1.9%
Upper Pool	1989	11,766	5,104	7,309	1,564	15,983	2,453,600	25,743
	2050	12,034	5,060	5,264	1,533	15,792	2,309,555	23,891
	% Change	2.3%	-0.9%	-28.0%	-2.0%	-1.2%	-5.9%	-7.2%
Total Pool	1989	37,544	11,448	16,902	2,367	23,340	4,245,600	68,260
	2050	36,255	11,534	15,523	2,274	23,304	4,039,372	65,586
	% Change	-3.4%	0.8%	-8.2%	-3.9%	-0.2%	-4.9%	-3.9%

Table continued from previous page.

Geom. R. 5: Pools 14-17		**MC**	**SC**	**CB**	**IB**	**AI**	**PI**	**TOW**
Predictions for 2050		acre	acre	acre	acre	acre	ft	acre
Lower Pool	1989	8,566	3,593	1,336	131	4,658	685,200	13,626
	2050	8,758	3,790	1,192	36	4,658	725,270	13,776
	% Change	2.2%	5.5%	-10.8%	-72.5%	0.0%	5.8%	1.1%
Upper Pool	1989	10,750	3,900	1,702	623	6,364	775,300	16,975
	2050	10,750	3,900	1,235	519	6,441	642,445	16,404
	% Change	0.0%	0.0%	-27.4%	-16.7%	1.2%	-17.1%	-3.4%
Total Pool	1989	19,316	7,493	3,038	754	11,022	1,460,500	30,601
	2050	19,508	7,690	2,427	555	11,099	1,367,715	30,180
	% Change	1.0%	2.6%	-20.1%	-26.4%	0.7%	-6.4%	-1.4%

Geom. R. 6: Pools 18-19		**MC**	**SC**	**CB**	**IB**	**AI**	**PI**	**TOW**
Predictions for 2050		acre	acre	acre	acre	acre	ft	acre
Lower Pool	1989	18,082	24	1,051	112	268	84,550	19,269
	2050	17,967	24	1,051	112	389	91,917	19,154
	% Change	-0.6%	0.0%	0.0%	0.0%	45.1%	8.7%	-0.6%
Upper Pool	1989	12,257	5,159	1,510	270	10,974	1,217,350	19,196
	2050	10,846	4,620	854	137	12,229	1,167,863	16,457
	% Change	-11.5%	-10.4%	-43.4%	-49.3%	11.4%	-4.1%	-14.3%
Total Pool	1989	30,339	5,183	2,561	382	11,242	1,301,900	38,465
	2050	28,813	4,644	1,905	249	12,618	1,259,780	35,611
	% Change	-5.0%	-10.4%	-25.6%	-34.8%	12.2%	-3.2%	-7.4%

Geom. R. 7: Pools 20-22		**MC**	**SC**	**CB**	**IB**	**AI**	**PI**	**TOW**
Predictions for 2050		acre	acre	acre	acre	acre	ft	acre
Lower Pool	1989	6,502	1,408	803	63	1,559	221,200	8,776
	2050	6,502	1,408	764	53	1,559	221,200	8,727
	% Change	0.0%	0.0%	-4.9%	-15.9%	0.0%	0.0%	-0.6%
Upper Pool	1989	9,625	2,683	520	240	8,466	592,200	13,068
	2050	9,551	2,214	279	213	8,466	592,200	12,257
	% Change	-0.8%	-17.5%	-46.3%	-11.3%	0.0%	0.0%	-6.2%
Total Pool	1989	16,127	4,091	1,323	303	10,025	813,400	21,844
	2050	16,053	3,622	1,043	266	10,025	813,400	20,984
	% Change	-0.5%	-11.5%	-21.2%	-12.2%	0.0%	0.0%	-3.9%

Table continued from previous page.

Geom. R. 8: Pools 24-26 Predictions for 2050		**MC** acre	**SC** acre	**CB** acre	**IB** acre	**AI** acre	**PI** ft	**TOW** acre
Lower Pool	1989	11,159	2,882	3,082	441	3,257	688,910	17,564
	2050	11,068	2,842	2,824	291	3,246	695,467	17,025
	% Change	-0.8%	-1.4%	-8.4%	-34.0%	-0.3%	1.0%	-3.1%
Upper Pool	1989	14,621	7,231	1,165	1,261	13,995	1,119,000	24,278
	2050	14,328	6,736	1,100	982	14,046	1,120,951	23,146
	% Change	-2.0%	-6.8%	-5.6%	-22.1%	0.4%	0.2%	-4.7%
Total Pool	1989	25,780	10,113	4,247	1,702	17,252	1,807,910	41,842
	2050	25,396	9,578	3,924	1,273	17,292	1,816,418	40,171
	% Change	-1.5%	-5.3%	-7.6%	-25.2%	0.2%	0.5%	-4.0%

MC = Main Channel; SC = Secondary Channel; CB = Contiguous Backwater;
IB = Isolated backwater; AI = Area of Islands; PI = Perimeter of Islands;
TOW = Total Open Water Area.

Table 30. Summary of predicted geomorphic changes within UMR.

Pools 4 – 26		**MC**	**SC**	**CB**	**IB**	**AI**	**PI**	**TOW**
Predictions for 2050		acre	acre	acre	acre	acre	ft	acre
Lower Pool	1989	94,860	29,630	26,966	4,870	25,617	5,750,660	156,326
River Miles	2050	94,739	29,390	26,760	4,844	25,780	5,659,380	155,733
796.9 – 202.9	% Change	-0.1%	-0.8%	-0.8%	-0.5%	0.6%	-1.6%	-0.4%
Upper Pool	1989	91,037	29,891	35,269	7,689	83,442	11,659,921	163,886
River Miles	2050	89,835	28,591	34,183	7,258	81,083	11,099,353	159,867
796.9 – 202.9	% Change	-1.3%	-4.3%	-3.1%	-5.6%	-2.8%	-4.8%	-2.5%
Total Pool	1989	185,897	59,521	62,235	12,559	109,059	17,410,581	320,211
River Miles	2050	184,574	57,981	60,943	12,102	106,863	16,758,733	315,600
796.9 – 202.9	% Change	-0.7%	-2.6%	-2.1%	-3.6%	-2.0%	-3.7%	-1.4%

MC = Main Channel; SC = Secondary Channel; CB = Contiguous Backwater;
IB = Isolated backwater; AI = Area of Islands; PI = Perimeter of Islands;
TOW = Total Open Water Area.

Comparisons were made of historic land/water boundaries along IWW. As seen in Appendix G, the land/water boundaries between the mouth and Brandon Lock & Dam (RM 286.0) in the 1980s (USGS 1999) were overlain on river mapping from the 1930s (Personal communications with C. Beckert, 1998). Generally, it was observed from the overlay comparison that the main channel of the IWW has not changed significantly since the 1930s, even in the downstream reaches of the IWW. This result is not surprising considering that the main channel is maintained for navigation. However, significant variability was noted in backwater areas along the channel. No detailed area measurements of the noted change in backwater areas were made as the resolution of the 1980s data set was insufficient since it was developed from 1:100,000 scale maps.

Numerous studies have been previously conducted to investigate the trend of sedimentation along the IWW and its backwater areas (Lee and Stall 1976, Bellrose et al. 1983, Demissie and Bhowmik 1989, Demissie et al. 1992). Lee and Stall (1976) concluded that backwater lake volume was being lost at an annual rate ranging from 0.6 to 1.1% over the period of 1903 to 1975. Bellrose et al. (1983) estimated that the number of years required for selected lakes to lose half their average depth under various sedimentation rates ranged from 24 to 127 years.

Demissie and Bhowmik (1989) conducted an investigation of the sedimentation characteristics of Peoria Lake, which is the largest and deepest lake on the IWW. Their comparison of limited historic cross sections for the lake demonstrated sediment accumulation depths of up to 14 feet in various locations of the lake and the navigation channel was relatively stable over the period of record. As of 1985, the lake was estimated to have lost up to 2/3 of its 1903 volume. The study concluded that if sedimentation continued at current rates, within 10 or 15 years the river and lake will reach dynamic equilibrium and net accumulation of sediment in the lake will be zero. Most of the area outside of the channel is predicted to become either a mud flat or marshy wetland area, depending on the ability of vegetation to grow in the lake sediment.

Currently, numerous studies are underway to address the sedimentation problem in Peoria Lake, including investigation of methods to remove existing sediment and decrease resuspension of sediment (Personal communications with C. Beckert, 1998).

Demissie et al. (1992) prepared an overall assessment of erosion and sedimentation in the IWW basin. It included a sediment budget for the IWW developed by comparing sediment input from tributaries to the main stem gages at Valley City. The sediment budget showed that on average 8.2 million tons of sediment are deposited in the IWW valley each year. Major areas impacted by the sediment deposition are backwater lakes. An average capacity loss for the lakes of 72% was calculated. Sedimentation in the navigation channel was not considered to be as high as that of the backwater lakes. The higher flow velocities and tow traffic in the channel are said to keep the sediment moving in the channel. The study concluded that without management of sediment, all bottomland lakes along the IWW would eventually fill with sediment.

Overall, the future geomorphic conditions of the IWW are well defined. The geologic history of the IWW created conditions where sedimentation is and will continue to be the predominant geomorphic process. More sediment supplies from tributary areas are deposited within the IWW river valley than are transported through it. However, the rate at which sediments are supplied to the IWW and sedimentation occurs is undoubtedly influenced by human activities, such as land-use, water regulation, and dredging.

Most of the investigators of the IWW agree that significant sedimentation is occurring under current conditions and most backwater areas will be filled with fine sediment within the foreseeable future. According to Demissie and Bhowmik (1989), equilibrium between the sediment supply and transport out of Peoria Lake, the largest and deepest pool along the IWW, will be reached within the next few years. The navigation channel has not changed significantly in plan form over the period of record. Higher flow velocities and maintenance dredging along the channel effectively prevent significant change along its length.

In summary, according to previous studies, by the year 2050 the IWW is predicted to lose a significant portion of its off-main channel backwater areas under current conditions of sediment supply. The affected contiguous and isolated backwater areas are expected to convert to mud flats or marshy wetlands. The location and area of the main channel is expected to remain relatively the same with the exception that it will become more defined within the various pools along the IWW.

9.3 Future Land Cover Conditions

The previous chapter presented the results of the terrestrial vegetation successional model, so it will be only briefly reviewed here. The projections from the successional model provide some rather unusual results, in that, early successional tree species, wetlands, sand-mud, and mesic bottomland hardwood forests are projected to increase, whereas, recent studies indicate their decline since the development of the navigation system. This occurs because natural successional pathways were used as the basis for the projections, when in fact, the forces that drive successional change have been disrupted by a variety of human influences.

The cumulative effects study was the source for the predicted change in open water classes. Loss of open water area was projected for all but geomorphic reach 3. The predicted succession from open water included portions of the new land area being colonized by emergent aquatic, wet meadow, salix community, populus community, and sand-mud land cover classes. Modified ecological processes operating in the navigation system and the degraded habitats in some river reaches will likely prevent the development of these early successional communities.

Another unexpected result of the successional model is the prediction that the amount of mesic bottomland hardwood communities will increase. The increase is derived from the prediction that a small portion of existing wet floodplain forests will convert to bottomland hardwoods. This also is in sharp contrast with change detected since the European colonization of the UMRS. Recent studies detail the widespread loss of bottomland hardwood species in river reaches south of Rock Island and on the lower Illinois River. The one factor that could influence the development of the land cover class is the widespread planting of bottomland hardwoods by natural resource management agencies.

Wet floodplain forests are one of the most prominent land cover classes in the UMRS. The terrestrial successional model predicts a small systemic decrease in their abundance, whereas, recent studies indicate they have expanded their distribution and replaced other communities. Losses and gains differ among river reaches with decreases predicted in upper river reaches where forests are being replaced by wet meadows. Gains are projected for southern pooled reaches and the lower Illinois River where portions of open water and other land cover classes are projected to convert to wet floodplain forests. Given the ability of this community to replace itself under its own canopy, wet floodplain forests are likely to continue to expand wherever they are not displaced by aggressive wet meadow species.

The terrestrial successional model predicts that areas classified as sand-mud will increase in the future. This is the result of a small percentage of open water becoming land, but not being colonized by vegetation. Again, this is opposite of recent observations that the sand-mud class is less common in the developed river than it was in the undeveloped river. It is also suspected that any new land formed will be rapidly colonized by terrestrial vegetation.

9.4 Summary

In the words of Yogi Berra, “Making predictions is difficult, especially when it’s about the future.” Considering this wisdom, the results of this future condition estimate must be carefully interpreted and considered. Acreage change predictions (geomorphic and land cover) should not be considered to be precise estimates of change, but should rather be considered indicators of the types and general amounts of changes likely to occur in the future. In fact, areal change estimates were structured so that locations of change would not be identified. Qualitative analyses were used to identify locations of change.

The results of the qualitative analysis clearly indicate that resource managers are concerned about backwater and secondary channel loss. Over 65% of their comments referred to backwater or secondary channel loss. Some geomorphic changes are a systemic concern, whereas others are restricted to specific regions of the river based on unique geomorphic characteristics. In general, resource managers were concerned with loss of aquatic area, habitat quality, and diversity.

The quantitative assessment of geomorphic change also revealed that backwaters and secondary channel loss were the most prominent changes in most river reaches. While absolute acreages of backwater classes differ among reaches and absolute acreage loss may be small in some reaches, the proportional loss of backwaters exceeded 10% in more than half the reaches examined. Several reaches are projected to loose 20 to over 30% of backwaters. Island loss and a resultant increase in aquatic classes was the largest change identified in geomorphic reach 3. This implies a loss of habitat diversity and degradation of aquatic areas as they fill with island soils. System-wide summaries that predict small amount of system-wide change mask the importance of change at the local scale. It is also important to reiterate that the analysis examined only plan form change; loss of depth and other factors affecting habitat quality were not assessed.

The projections from the successional model provide some rather unusual results. In particular, early successional tree species, wetlands, sand-mud, and mesic bottomland hardwood forests are projected to increase, whereas, recent studies indicate their decline since the development of the navigation system. This occurs because natural successional pathways were used as the basis for the projections, when in fact, the forces that drive successional change have been disrupted by a variety of human influences.

Natural resource managers working to protect and restore UMRS habitats should use these estimates to assist large-scale habitat rehabilitation program planning, but they should develop more detailed analyses at the site-specific scale.

10 Natural Resource Managers' Desired Future Condition

10.1 Introduction

A primary element of the Environmental Management Program (EMP) Habitat Needs Assessment (HNA) is to identify the desired future mix of habitats throughout the Upper Mississippi River System. The difference between the desired future conditions and the present habitat conditions is the habitat need. The desired future conditions identified in this first Habitat Needs Assessment can be considered a first approximation of goals for habitat protection and restoration for the UMRS.

Characterization of UMRS river habitats requires identifying plan form, or geomorphic, area types (aquatic and floodplain areas) that delineate broad areas of similar habitat, and a number of additional attributes such as water depth, current velocity, dissolved oxygen concentration, vegetation cover, etc. All these characteristics together define the multidimensional niche space (Hutchinson 1967) occupied by different species and life stages. In this first EMP Habitat Needs Assessment, availability of spatial data constrained identifying desired future conditions to plan form area types and the "quality" of these areas in terms of their ability to support desirable species.

The challenging and thought provoking effort of identifying desired future habitat conditions was accomplished through a series of workshops with river scientists and natural resource managers. A series of workshops were held to consider the Cumulative Effects Study forecast of future conditions and ongoing geomorphic processes, to add qualitative information to better characterize ongoing geomorphic processes and future conditions, and ultimately to identify desired future conditions. Information developed in prior HNA tasks to assess historic and predicted UMRS plan form habitat changes was distributed to natural resource managers in advance of the series of workshops. They were also provided summaries of post-impoundment and forecasted year 2050 plan form change statistic and then asked to quantitatively identify desired future habitat conditions, as defined by plan form area types. Data on existing (derived from 1989 areal photography) HNA land cover and geomorphic area conditions were provided, along with results from the terrestrial vegetation successional model developed for the HNA. Managers were also asked to identify the desired land cover composition for floodplain areas.

Qualitative assessments provided information necessary to reveal which habitats are threatened or degraded and consequently, are in need of preservation or restoration. It is important to emphasize that the acreage estimates of plan form areas do not account for the total acreage of either acceptable or degraded lower quality habitat. Maps developed by the resource managers in an earlier workshop series displayed the results of a prior qualitative assessment of habitat change that could not be detected in the plan form analysis. Managers were also asked a number of questions to assess the existing quality of river habitats.

The results of the workshops were inconsistent among river reaches because of differences in the quality or amount of information about existing and forecasted future conditions provided prior to the workshops. Also, the willingness of individual managers (or agencies) to participate in the quantification of desired habitat conditions as characterized by plan form features differed among reaches. Most of the detailed plan form, land cover, and geomorphic area data were lacking for the Illinois River and Open River reaches. We were, however, able to establish general habitat abundance and quality goals for those reaches. In the pools 11 to 26 reach we obtained estimates of the proportion of present, expected, and desired plan form areas described as "acceptable quality" aquatic habitat. In the northern river reaches (pool 4 to 8) we obtained estimates of the proportion of present, expected, and desired HNA geomorphic areas described as "acceptable quality" aquatic habitat. We also received an estimate of desired HNA geomorphic area acreage for the pool 9 to 19 reach, but the proportion of habitat rated as "acceptable quality" was not obtained. Managers at all the workshops were hesitant to express quantitative goals without better historic and predicted change estimates, and without a more detailed planning process.

An additional workshop was held with invited avian ecologists to identify desired future habitat conditions for migratory birds, including neotropical migrating songbirds, fish-eating raptors, colonial-nesting water birds, and waterfowl.

The workshops resulted in a set of first approximations describing desired future habitat conditions, and revealed how this goal-setting exercise may be refined in the future.

10.2 Methods

The expression of desired future habitat conditions is important to natural resource planners seeking to prevent habitat degradation or restore degraded habitats because it sets a target for what is physically, biologically, and socially achievable. The National Research Council (1992) examined the issues of river restoration and devised a method, including social and ecological desires, to assess the state and potential for river resources (Figure51). The process starts by examining the recorded trend in habitat change since human manipulation of an ecosystem and projecting an ideal state (A). Planners then determine a breakpoint (B) of unacceptable quality at which restoration is initiated. They establish an upper limit (U) of habitat restoration that might be achieved as determined by: 1) human and economic resources applied to the problem, 2) state of our knowledge, and 3) present condition of the ecosystem. The lower limit (L) of habitat quality is the level expressed as ecologically or socially acceptable. The range between U and L represents the target range of what is acceptable and achievable. The HNA natural resource manager's desired future habitat condition represents a first approximation of the lower limit.

10.2.1 Background Materials

Results of qualitative assessments of habitat change completed by resource managers during fall 1999 workshops were also distributed. Items included maps with anticipated types and locations of habitat change, tabular summaries of predicted geomorphic change at the pool, reach, and systemic scale (Table 31 and 32), and comments recorded during the workshops.

Two methods were used to provide a qualitative assessment of geomorphic change. Both methods incorporated an analysis of historic change to predict future conditions. Both methods also resulted in maps with areas suspected to change annotated on land-water maps. The first assessment was completed as part of the Cumulative Effects Study (WEST 2000) in which a consultant team reviewed historic maps and photos to identify areas of extensive plan form change. Using this method, only large plan form changes were detectable. The second method incorporated the knowledge and experience of natural resource managers, many with 20 or more years of experience, working in specific regions of the river. The method allowed a more detailed analysis because the managers could provide insight into changes occurring below the water's surface. For example, backwaters that may not have displayed discernable plan form change may have lost significant depth that reduced their habitat value.

The Cumulative Effects Study identified nine geomorphic processes responsible for large-scale plan form changes:

1. delta formation,
2. filling between wing dams,
3. island dissection,
4. island formation,
5. loss of contiguous backwaters,
6. loss of isolated backwater,
7. loss of secondary channels,
8. tributary delta formation,
9. wind-wave erosion of islands.

The workshops with natural resource managers identified seven additional geomorphic processes that could not be detected in the plan form analysis:

1. channel formation,
2. island migration,
3. loss of contiguous impounded area,
4. loss of bathymetric diversity,
5. loss of contiguous/isolated backwaters,
6. loss of tertiary channels,
7. shoreline erosion.

The Cumulative Effects Study identified 58 areas in pools 4 through 26 influenced by one or more of the nine geomorphic processes. The workshops with the resource managers identified an additional 347 areas in the same reach, and an additional 125 areas in pools 2, 3, the Open river, and the Illinois Waterway. A total of 531 areas expected to change were identified (Tables 31-33). Notes from the workshop identify the source of the prediction and comments relevant to the prediction. Maps were also prepared to identify locations where geomorphic processes were occurring.

Quantitative assessments of geomorphic area types developed by the USACE – Cumulative Effects Study (WEST 2000) were adapted for the desired future condition assessment. Plan form area statistics for 1930, 1940 (some pools), 1973/75, 1989, and 2050 projections were distributed (Appendix U). Statistics were available for the broad area classes: main channel, secondary channel, contiguous backwater, isolated backwater, island area, and island perimeter (Table 34) for pools 4 through 26. Resource managers were asked to fill in blank rows for geomorphic area type acreage desired in 2050. Habitat need was to be calculated as the difference between the desired and existing geomorphic area acreage. Projections for 2050 condition would have allowed extrapolations of future habitat need if no action is taken between now and 2050.

Data from the pre-settlement period was presented (see Table 7; see Figure 4; Appendix V) to describe the natural potential vegetation among the various river reaches. The legends are presented in the HNA 18 land cover classes, but were only recorded for the general classes in Table 7. There are pre-settlement examples from 9 of the 12 geomorphic reaches. Data from reaches 1, 9, and the upper Illinois Waterway are lacking.

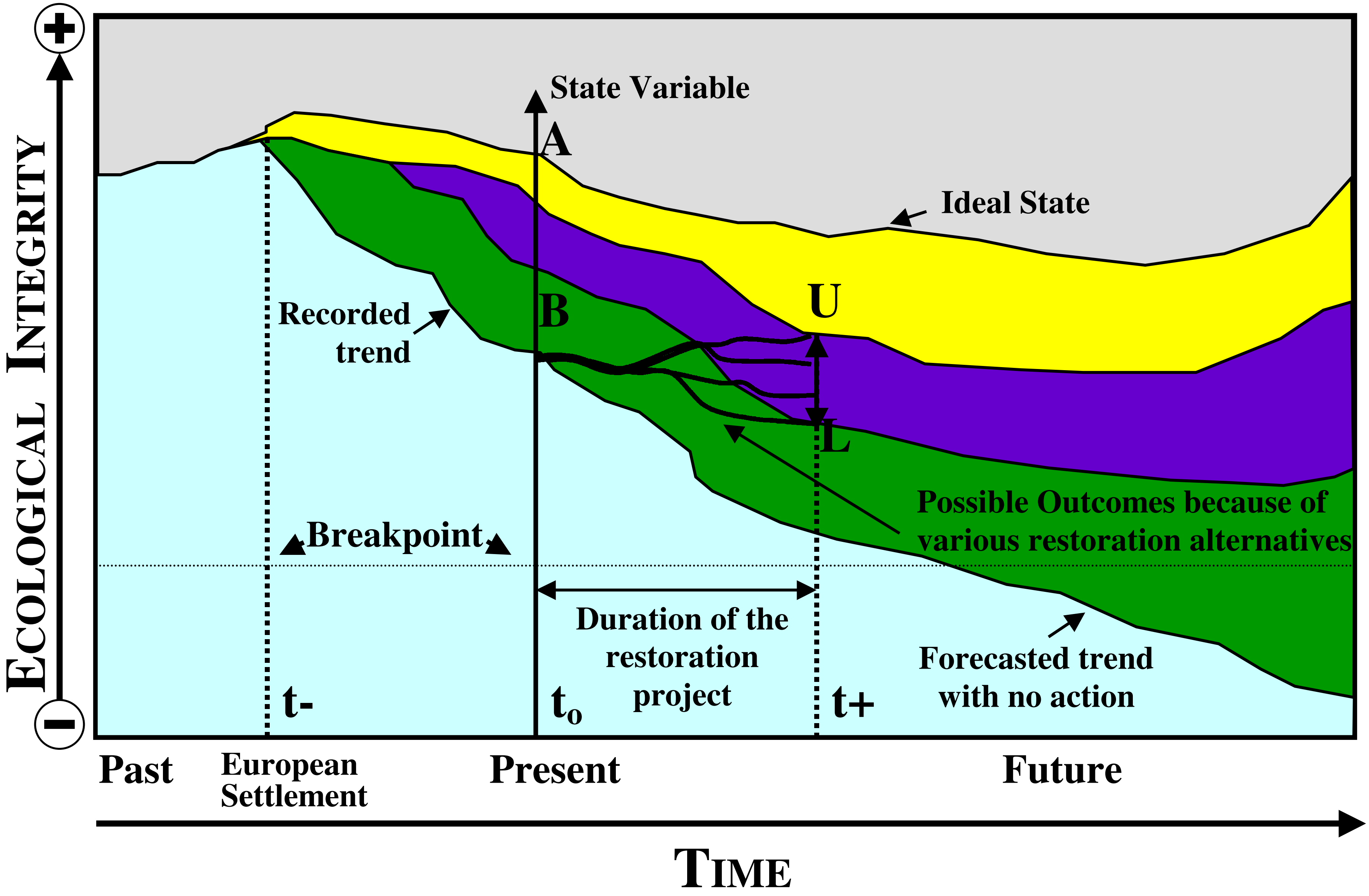

Figure 51. National Research Council (1992) suggested restoration planning framework (see text for details).

Table 31. Number of occurrences of geomorphic processes effecting UMRS habitats.

Geomorphic Process	Upper Mississippi River Reach													
	1	**2**	**3**	**4**	**5**	**5a**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Channel Formation	0	0	0	0	0	0	0	0	0	0	2	0	1	0
Delta Formation	0	0	0	2	0	0	0	1	0	0	0	0	0	0
Filling between Wing Dams	0	0	0	0	0	0	1	0	0	0	0	3	0	1
Island Dissection	0	0	0	1	0	1	1	3	3	0	4	1	0	0
Island Formation	0	0	0	0	1	0	1	0	1	0	0	1	2	2
Island Migration	0	0	0	0	0	0	0	0	0	0	1	1	0	1
Loss of Contiguous Impounded	0	0	0	0	1	0	0	1	0	0	0	1	0	2
Loss of Bathymetric Diversity	0	0	0	2	1	1	0	1	1	0	0	2	1	0
Loss of Contiguous Backwaters	0	1	1	5	5	4	3	6	2	5	12	5	9	9
Loss of Isolated Backwaters	0	0	0	0	0	0	1	0	0	2	1	0	2	1
Loss of Cont/Iso Backwaters	0	0	1	0	1	3	1	0	4	0	1	4	1	2
Loss of Secondary Channels	0	0	0	3	1	1	0	3	0	0	5	4	1	3
Loss of Tertiary Channels	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Shoreline Erosion	0	0	0	2	0	0	0	0	0	0	1	1	0	1
Tributary Delta Formation	0	0	0	4	1	0	1	1	3	0	0	2	1	1
Wind-Wave Erosion of Islands	0	0	0	1	3	1	0	3	5	2	3	1	1	4
TOTALS	**0**	**1**	**2**	**20**	**14**	**11**	**9**	**19**	**19**	**9**	**31**	**26**	**19**	**28**

Table 31. Number of occurrences of geomorphic processes effecting UMRS habitats (continued).

Upper Mississippi River Reach																
Geomorphic Process	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**24**	**25**	**26**	**OR1**	**OR2**	**OR3**	**Total**
Channel Formation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Delta Formation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Filling between Wing Dams	2	0	0	1	1	1	3	0	6	0	2	0	5	3	5	**34**
Island Dissection	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	**15**
Island Formation	0	1	0	0	1	2	1	2	2	3	0	0	0	0	0	**20**
Island Migration	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**4**
Loss of Contiguous Impounded	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	**8**
Loss of Bathymetric Diversity	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	**11**
Loss of Contiguous Backwaters	8	0	3	2	4	5	0	5	6	7	8	6	1	1	1	**124**
Loss of Isolated Backwaters	0	0	2	1	1	0	3	0	3	3	7	10	0	0	0	**37**
Loss of Cont/Iso Backwaters	1	1	1	1	1	3	1	0	1	1	1	0	0	0	0	**30**
Loss of Secondary Channels	2	2	2	3	5	2	3	1	5	7	9	7	9	2	13	**93**
Loss of Tertiary Channels	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	**5**
Shoreline Erosion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**5**
Tributary Delta Formation	0	0	2	0	1	7	0	1	2	3	1	0	0	0	0	**31**
Wind-Wave Erosion of Islands	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**25**
TOTALS	**15**	**4**	**13**	**8**	**15**	**22**	**12**	**9**	**25**	**24**	**29**	**24**	**15**	**6**	**19**	**448**

Table 31. Number of occurrences of geomorphic processes effecting UMRS habitats (continued).

Illinois Waterway Reach								**UMRS TOTAL**
Geomorphic Process	**ALT**	**LGR**	**PEO**	**STR**	**MAR**	**DRS**	**Total**	
Channel Formation	0	0	0	0	0	0	**0**	**3**
Delta Formation	0	0	0	0	0	0	**0**	**3**
Filling between Wing Dams	0	0	0	0	0	0	**0**	**29**
Island Dissection	0	0	0	0	0	0	**0**	**15**
Island Formation	0	0	0	0	0	0	**0**	**20**
Island Migration	0	0	0	0	0	0	**0**	**4**
Loss of Contiguous Impounded	0	0	0	1	0	0	**1**	**9**
Loss of Bathymetric Diversity	0	0	1	0	0	0	**1**	**12**
Loss of Contiguous Backwaters	2	9	11	2	4	1	**29**	**152**
Loss of Isolated Backwaters	3	8	1	0	0	0	**12**	**49**
Loss of Cont/Iso Backwaters	2	0	0	0	0	0	**2**	**32**
Loss of Secondary Channels	10	9	2	1	0	1	**23**	**103**
Loss of Tertiary Channels	0	0	0	0	0	0	**0**	**5**
Shoreline Erosion	1	2	0	0	0	0	**3**	**8**
Tributary Delta Formation	1	1	8	1	1	0	**12**	**43**
Wind-Wave Erosion of Islands	0	0	0	0	0	0	**0**	**25**
TOTALS	**19**	**29**	**23**	**5**	**5**	**2**	**83**	**512**

Table 32. Number of occurrences of geomorphic processes effecting UMRS habitats summarized by geomorphic reach.

Summary by Geomorphic Reaches

Geomorphic Process	Upper Mississippi River											IWW			UMRS TOTALS
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**	**1**	**2**	**Total**	
Channel Formation	0	0	0	3	0	0	0	0	0	0	**3**	0	0	**0**	3
Delta Formation	0	2	1	0	0	0	0	0	0	0	**3**	0	0	**0**	3
Filling between Wing Dams	0	0	1	4	3	2	9	2	5	8	**34**	0	0	**0**	34
Island Dissection	0	1	8	5	0	1	0	0	0	0	**15**	0	0	**0**	15
Island Formation	0	0	3	5	1	3	5	3	0	0	**20**	0	0	**0**	20
Island Migration	0	0	0	3	0	0	0	1	0	0	**4**	0	0	**0**	4
Loss of Contiguous Impounded	0	0	2	3	2	0	1	0	0	0	**8**	1	0	**1**	9
Loss of Bathymetric Diversity	0	2	4	3	0	2	0	0	0	0	**11**	0	1	**1**	12
Loss of Contiguous Backwaters	2	5	25	35	13	9	11	21	1	2	**124**	7	22	**29**	153
Loss of Isolated Backwaters	0	0	3	4	3	1	6	20	0	0	**37**	0	12	**12**	49
Loss of Cont/Iso Backwaters	1	0	10	8	3	4	2	2	0	0	**30**	0	2	**2**	32
Loss of Secondary Channels	0	3	5	13	9	7	9	23	9	15	**93**	2	21	**23**	116
Loss of Tertiary Channels	0	0	0	2	2	0	0	1	0	0	**5**	0	0	**0**	5
Shoreline Erosion	0	2	0	3	0	0	0	0	0	0	**5**	0	3	**3**	8
Tributary Delta Formation	0	4	6	4	2	8	3	4	0	0	**31**	2	10	**12**	43
Wind-Wave Erosion of Islands	0	1	14	9	1	0	0	0	0	0	**25**	0	0	**0**	25
TOTALS	**3**	**20**	**82**	**104**	**39**	**37**	**46**	**77**	**15**	**25**	**448**	**12**	**71**	**83**	**531**

Table 33. Number of occurrences of geomorphic processes effecting UMRS habitats summarized by major river reaches (continued).

Geomorphic Process	1-13	14-26	OR	IR	Total
Channel Formation	3	0	0	0	3
Delta Formation	3	0	0	0	3
Filling between Wing Dams	5	16	13	0	34
Island Dissection	14	1	0	0	15
Island Formation	8	12	0	0	20
Island Migration	3	1	0	0	4
Loss of Contiguous Impounded	5	3	0	1	9
Loss of Bathymetric Diversity	9	2	0	1	12
Loss of Contiguous Backwaters	67	54	3	29	153
Loss of Isolated Backwaters	7	30	0	12	49
Loss of Cont/Iso Backwaters	19	11	0	2	32
Loss of Secondary Channels	21	48	24	23	116
Loss of Tertiary Channels	2	3	0	0	5
Shoreline Erosion	5	0	0	3	8
Tributary Delta Formation	14	17	0	12	43
Wind-Wave Erosion of Islands	24	1	0	0	25
TOTALS	**209**	**199**	**40**	**83**	**531**

Table 34. Definitions of plan form features assessed in the Cumulative Effects Study.

(a) Main channel – the main channel of the river conveys the majority of the discharge. Boundaries of the main channel are the apparent shorelines (i.e., land/water boundaries visible from aerial photographs of the river for average river flow conditions), straight lines across the mouths of secondary, tertiary, and tributary channels, and the outer boundary of inundated open-water areas upstream of locks. In most reaches, the main channel encompasses the navigation channel.

(b) Secondary channels – Secondary channels were defined as waterways that are directly connected to the main channel and have a minimum width of 150 ft. A secondary channel will have definitive entrance and exit and may contain submerged closure structures under average flow conditions.

(c) Contiguous backwaters - Contiguous backwaters are off-main channel areas that include impounded areas, backwater lakes, and tertiary channels of less than 150 feet minimum width under average flow conditions. The contiguous backwaters have inlets or outlets to the main channel.

(d) Isolated backwaters - Isolated backwaters are located adjacent to the main channel, but lack an inlet and outlet to the main channel.

(e) Islands – Islands were defined as discrete vegetated land areas isolated by open water.

Forest successional models had been developed for the Lower Mississippi River (Climas 1988) and southern bottomland hardwoods (Hodges 1997, Mitsch and Gosselink 1986), but none had been completed for the UMRS. The approach taken in the HNA analysis of future habitat conditions on the UMRS was to convene an expert panel of UMRS botanists and foresters to help develop a rule-based successional model for terrestrial vegetation. The expert panel met in a workshop to outline basic assumptions for land use, resource management, and disturbance regimes. We also assessed important controlling factors and plotted probable plant community changes from one HNA land cover class to other HNA land cover classes based on existing land cover, published reports, and successional theory. The UMRS terrestrial succession model uses HNA land cover unit area estimates from the existing conditions analysis to produce acreage estimates of future HNA land cover unit area. Gain of terrestrial area was obtained from the Cumulative Effects Study (i.e., loss or gain in Total Open Water), or conservatively estimated. Future land cover unit area estimates were calculated using rules predicting percent change in land cover unit composition. A summary for the geomorphic reaches of the UMRS (HNA Tech. Report Appendix Q) was provided for resource manager review and consideration.

An HNA Land Cover Inventory (Appendix W) was developed to help quantify resource manager's desired future land cover condition. The HNA Habitat Inventory presents contemporary (1989) and 2050 predicted land cover class acreage estimates. Geomorphic areas are not predicted because plan form change estimates were derived using different methodology. The change in Total Open Water area from the plan form analysis was used to predict change in the Open Water land cover class. A set of blank columns in the HNA Habitat Inventory provided space for resource managers to express their 2050 desired acreage or percent of the floodplain area

10.3 Workshop Approach

The approach used to express desired acreages (i.e., quantitative assessment) at each workshop was slightly different because of differences in data availability and quality, and the willingness of individual resource managers (agencies) to participate in the effort. Differences among the workshops are described below. Several aspects of the process were similar among the workshops, however. An introductory overview of the need to establish a desired future habitat condition was provided. We also presented the natural potential vegetation from the pre-settlement period and existing conditions, and explained how they were derived. We then asked for responses to the qualitative questions. Including all meetings, 44 participants signed attendance sheets (Appendix X).

10.3.1 Qualitative Assessment

Participants were asked to respond to five questions before attending the workshop (Table 35). The questions addressed: (1) the quality of the approach and information used in the description of historic, present, and predicted habitat; (2) desired habitat quality; (3) areas, processes, species, or habitat characteristics critical to maintaining habitat integrity; (4) threatened habitats; and (5) stressors or disturbances limiting restoration potential. Managers had the opportunity to review and respond to the questions prior to the workshops, but none did. Instead, we devoted a portion of each morning to presenting each question and giving the participants 5 minutes to respond. Responses were categorized and summarized in total, and separately for each workshop location.

10.3.2 Quantitative Assessment

Spreadsheets with the Cumulative Effects Study geomorphic areas, the HNA land cover areas, and HNA geomorphic areas past, present, or predicted acreages were distributed prior to the workshops (Appendices U and W). The spreadsheets contained columns for resource managers to express their desired future acreage preferences. None of the workshop participants completed the exercise as requested, so we adapted the approach at the workshops. The process was slightly different at each workshop as described below.

Rock Island

The first workshop was held May 9, 2000 in Rock Island, Illinois to assess desired future conditions for Mississippi river pools 11 to 22. A full set of materials was provided at the Rock Island meeting. None of the workshop participants had entered desired habitat acreages or proportional areas on the spreadsheets provided prior to the workshop. Resource managers at Rock Island were concerned that the plan form change estimates overestimated the amount of habitat because of the fact that many aquatic areas are degraded and do not support ecologically or socially desirable species. By group consensus, the resource managers established a "percent acceptable habitat" parameter that expressed their understanding of the proportional area supporting quality habitats. Percent acceptable area was expressed for the present, predicted 2050, and desired 2050. The percentages expressed were computed with the acreage estimates to obtain desired acreages. Habitat need was calculated as the difference between both the desired acceptable acreage and the existing acceptable acreage, and the desired acceptable acreage and the predicted acceptable acreage. HNA land cover and geomorphic area desired habitat condition were not scored, but desired habitat quality was expressed in discussions and responses to questions.

Havana

The second workshop was held May 10, 2000 in Havana, Illinois to assess desired future conditions for the Illinois Waterway. Materials provided in advance of the Illinois Waterway reach workshop lacked plan form change estimates. Land cover data for most of the reach was derived from low-resolution satellite coverages, but Peoria and La Grange pools had high-resolution photo interpreted land cover data. HNA geomorphic areas were only available for La Grange Pool. We modified the first question to ask resource managers, "What is good about the HNA process?" rather than the future prediction because of the lack of plan form change predictions. Likewise, the second question was modified to ask, "What is bad about the HNA process?" We did not estimate functional habitat area because of the lack of plan form and geomorphic area. Instead, we had discussions regarding the fact that almost every non-channel habitat is degraded and the main channel is highly disturbed by barge traffic. We also discussed other habitat restoration planning initiatives and on-going habitat management. Results are presented as a short summation of discussions.

St. Louis

The third workshop was held May 11, 2000 in St. Louis, Missouri to assess desired future conditions for Mississippi River pools 24 to 26 and the Open River reach. The read-ahead materials for the pooled reaches (pools 24 – 26) were complete, but the Open River reach lacked plan form change estimates. Land cover data for pooled reaches was from aerial photography; most of the Open River reach data were derived from low-resolution satellite coverages. The Cape Girardeau reach (RM 0 to 80) had high resolution photo interpreted data. HNA geomorphic areas were only available for the pooled reaches and the Cape Girardeau reach. We modified the first question to ask Open River resource managers, "What is good about the HNA process?" rather than the future prediction because of the lack of plan form change predictions. Likewise, the second question was modified to ask, "What is bad about the HNA process?" We did estimate functional habitat for pools 24 to 26, but did not estimate functional habitat area because of the lack of plan form and geomorphic area in the Open River reach. Instead, we had discussions regarding the fact that almost every secondary channel area is degraded, and the main channel is highly disturbed by channel training and barge traffic. We also discussed an assessment of side channel habitats conducted by Open River reach resource managers. A tabular summary of desired land cover types and acreages prepared by one participant was reviewed and accepted by the others. Land acquisition in leveed areas was also discussed.

La Crosse

The final workshop was held May 16, 2000 in La Crosse, Wisconsin to assess desired future condition for Mississippi River pools 1 to 10. The read-ahead materials were complete, except for pools 1 to 3 plan form assessment. Most pools lacked data for the early post dam time step (1940) of the plan form change analysis. None of the workshop participants had entered desired habitat acreages or proportional areas on the spreadsheets provided. Resource managers in La Crosse were adamant that the plan form change estimates were incorrect because of flawed methodology and refused to score plan form area spreadsheets. They also believed the plan form assessment overestimated the amount of habitat because of the fact that many aquatic areas are degraded and do not support ecologically or socially desirable species. In addition, several managers documented that some misclassification errors occurred. By group consensus, the resource managers decided to express a desired future geomorphic condition based on the 1989 HNA geomorphic areas acreage estimates. The Minnesota representative declined to participate, leaving the State of Minnesota unrepresented in the expressed quantitative desired future habitat condition. They reluctantly accepted the "percent acceptable habitat" parameter that expressed their understanding of the proportional area supporting quality habitats. Percent acceptable habitat area was expressed for the present, predicted 2050, and desired 2050. The percentages expressed were computed with the acreage estimates to obtain desired acreages. Habitat need was calculated as the difference between both the desired functional acreage and the existing functional acreage, and the desired functional acreage and the predicted functional acreage. HNA land cover was not scored, but desired habitat quality was expressed in discussions and responses to questions. The resource managers in La Crosse expressed their belief that a different approach – the pool plans – recently initiated would provide better estimates of desired future habitat conditions.

10.4 Habitat Needs

Habitat needs were derived slightly differently following each workshop because of the differences in data availability and quality, and the willingness of individual resource managers (agencies) to participate in the effort described above. The difference between the best quantitative estimate of desired acres of each geomorphic area or land cover type and the existing condition was the habitat need. In pools 4 to 19, habitat need estimates are based on HNA geomorphic area classes. In pools 11 to 19, habitat need estimates are also calculated for the Cumulative Effects Study geomorphic area classes. In pools 20 to 26, habitat need estimates are calculated for the Cumulative Effects Study geomorphic area classes. In the Open River, quantitative estimates for 7 land cover classes were used to calculate habitat need. In the Illinois River, the quantitative habitat need was expressed as a need to rehabilitate at least 25% of backwater areas. Where the predicted geomorphic area or land cover information was available, the information was used to calculate habitat need in 2050 if no action is taken.

Table 35. Questions for resource managers to identify desired future habitat conditions.

(1) **Q: What is good, and what is bad, about the predicted future conditions?**

A: Good: (List)
Bad: (List)

(2) **Q: How would you qualitatively describe your desired future habitat conditions?**

i.e. Geometry of water bodies
Appearance
Connectivity of water bodies
Spatial/Physical structure of habitats
Hydrologic regime
Water Quality
Species specific goals
Ecological Stressors
Other disturbance regimes

A: Provide a list and description of qualitative variables as they apply to the various habitat types.

(3) **Q: Identify areas, processes, species, or habitat characteristics, which you feel are critical to the sustainable ecological integrity of the UMRS?**

i.e.: Large, unfragmented habitat areas
High biodiversity
Critical habitat
Keystone species
Flood Pulse
Migratory species rest areas (i.e. string-of-beads theory)

A: Provide a list, description, or map identifying these critical elements

(4) **Q: What are the most highly threatened habitat types in your reach of the UMRS?**

A: Provide a list, description, or map identifying these habitat types.

(5) **Q: What are the primary stressors or disturbances that would threaten habitat restoration?**

A: Provide a list and description of qualitative variables as they apply to the various habitat types.

10.5 Results

10.5.1 Qualitative Questions

Question 1a. What is good about the predicted future condition (or HNA process)?

The greatest response to question 1 was that the HNA process aids planning and consensus building (Table 36; Appendix Y) by establishing a common set of acreage estimates. This response was most prominent in Rock Island and Havana. In La Crosse, eight resource managers responded that the process was adequate to detect specific geomorphic change or resource problems. Four La Crosse area managers responded that the approach and data were inadequate and should not be used. In Rock Island, nine resource managers responded that the process was adequate to detect specific geomorphic change or resource problems. Six managers among the Rock Island, St. Louis, and Havana meetings responded that the approach was acceptable. Four respondents liked the systemic aspect of the HNA.

Question 1b. What is bad about the predicted future condition (or HNA process)?

Question 2 received the greatest single response among all questions; 47 people inferred that the approach used inadequate data, was the wrong approach, or was poorly timed or hurried (Table 37; Appendix Y). The proportion of managers at each meeting providing this response was nearly 100%. There were 17 total responses indicating projected geomorphic area or land cover changes were bad for the ecosystem.

Question 2. How would you qualitatively describe your desired future habitat condition?

The desire to restore aquatic area quality was the highest ranked response with 32 managers expressing the need to reduce sedimentation, improve sediment quality, or otherwise improve mostly backwater and side channel habitat (Table 38; Appendix Y). This was the highest ranked response among all meetings except Havana where it ranked second by one response. The desire to improve terrestrial habitat and plant community diversity was noted by 23 managers (mostly in Rock Island and La Crosse). In both cases, managers expressed the desire to restore forest diversity, wetland communities, and aquatic plants. Managers responded that restoration of a more natural hydrograph and improved habitat connectivity were fundamental to support desirable future habitat conditions. Responses were evenly distributed among the workshop locations. Seven other responses received five or fewer responses.

Question 3. Identify elements that you feel are critical to the sustainable ecological integrity.

The natural river hydrograph was the highest ranked element critical to maintaining ecological integrity. Overall, 22 managers provided the response and it was the highest ranked response at all workshops except St. Louis (Table 39; Appendix Y). Four other responses were received between 13 and 17 times. In descending order, managers thought improved geomorphic area quality, improved terrestrial habitat and plant community diversity, improved water quality, and increased habitat connectivity were critical elements. Six other responses received five or fewer responses. Levee removal, cropland restoration, and combating or preventing exotic species were among the lower ranked responses.

Question 4. What are the most highly threatened habitat types in your area?

Deep backwaters acceptable for fish overwintering were the highest ranked threatened habitat type. Twenty-three managers commented about backwaters, and the response was the highest ranked at all meetings except La Crosse (Table 40; Appendix Y). Marsh habitat was the second highest ranked threatened habitat among all respondents. It was tied for highest rank in La Crosse, second highest ranked in Rock Island and Havana, and third highest ranked in St. Louis. The second highest ranked threatened habitat in St. Louis was secondary channels, which were rarely mentioned in other workshops. Bottomland hardwood forests were the third ranked threatened habitat among all respondents. Concern for hardwoods was expressed at all workshop locations; it was tied for first rank in La Crosse. The remaining responses were distributed over 15 other categories.

Question 5. What are the primary stressors or disturbances that would threaten habitat restoration?

Impoundment, river regulation, sedimentation, and non-point pollution resulting from watershed development were the highest ranked stressors or disturbances threatening habitats and habitat restoration with 30 and 29 responses, respectively (Table 41; Appendix Y). The two responses were the highest ranked at all workshops, except St. Louis where they were ranked second and third. Floodplain development and levees were the third highest ranked stressors or disturbances overall and in all locations except St. Louis. Floodplain development was the highest ranked stressor or disturbance in St. Louis. Exotic species and general human influence were the highest recorded stressors among 13 other stressors or disturbances mentioned.

10.5.2 Desired Habitat Quality

Resource managers expressed their desire for improved habitat quality in many ways. In the quantitative assessment below they expressed their assessment of habitat quality by defining the proportional area that they believed supported acceptable habitat characteristics and species. The desired mix of land cover was also difficult to assess quantitatively, but was alluded to in the discussion of habitat quality.

Regarding aquatic habitats, resource managers thought that impoundment and upland sedimentation were responsible for loss of aquatic area, water depth, and sediment quality in secondary channel, backwater, and impounded habitats. They also believed that stabilized water levels kept deposited sediments saturated and in a loose flocculent state. In southern river reaches especially, flocculent sediments disturbed by waves are easily resuspended thereby reducing water clarity. In many locations, industrial contaminants degrade sediment quality also. River managers want to improve sediment quality and reduce excessive sediment delivery from upland areas.

Sediment quality issues are key determinants of ecologically important submersed aquatic plant communities. These plant communities can be quite dynamic. In some locations submersed plants are limited by water and sediment quality during most years, but plants may appear when conditions are most favorable. In locations where plants are typically abundant, there may be years when plant communities decline. Submersed aquatic plant abundance increased when the rivers were impounded, but over the post dam period aquatic plants have been lost from many areas where they once occurred in abundance. Exposure to wind and boat generated waves, in addition to sediment quality, appears to be an important determinant of the long-term persistence of plant beds. Changes in dam operating procedures in the St. Paul District may have influenced the persistence of submersed aquatic plant beds in contiguous impounded and floodplain shallow aquatic areas. River managers want submersed aquatic plant communities restored.

Table 36. Response to desired future condition qualitative question number 1a.

1a. What is good about the <u>predicted</u> future conditions?

Letter Code	General Response	Pooled Responses	La Crosse	Rock Island	St Louis	Havana
A	Specific geomorphic change	12	3	8		1
B	Systemic approach	4	3			1
C	Approach demonstrates change or problems (especially qualitative methods)	9	5	1	1	2
D	Aids planning and consensus building	21	3	10	1	7
E	Bad data/approach/timing	4	4			
F	Approach acceptable (especially qualitative methods)	6		3	1	2

Table 37. Response to desired future condition qualitative question number 1b.

1b. What is bad about the <u>predicted</u> future conditions?

Letter Code	General Response	Pooled Responses	La Crosse	Rock Island	St Louis	Havana
A	Specific geomorphic change	10	1	5	1	3
B	Systemic approach					
C	Approach demonstrates change or problems (especially qualitative methods)	2	1	1		
D	Aids planning and consensus building	3		2		1
E	Bad data/approach/timing	47	16	18	6	7
F	Approach acceptable (especially qualitative methods)	1				1
G						
H	Specific land cover change	7	1	5		1
I	Exotic species	1				1

Table 38. Response to desired future condition qualitative question number 2.

2. How would you qualitatively describe your desired future habitat conditions?

Letter Code	General Response	Pooled Responses	La Crosse	Rock Island	St Louis	Havana
D	Aids planning and consensus building	2	1			1
J	Restore hydrology	11	3	5	2	1
K	Improve water quality	4	2	1	1	
L	Combat exotic species	1	1			
M	Improve geomorphic area habitat quality	32	7	19	3	3
N	Increase amount of geomorphic area type	5	1	2	2	
O	Wait for pool plans	3	3			
P	Improve habitat and plant community diversity	23	6	15	2	
Q	Improve connectivity	9	2	3	4	
R	Compatible navigation regulations	1		1		
S	Better management tools	1				1

Table 39. Response to desired future condition qualitative question number 3.

3. Identify elements which you feel are critical to the sustainable ecological intergity.

Letter Code	General Response	Pooled Responses	La Crosse	Rock Island	St Louis	Havana
D	Aids planning and consensus building	2				2
I	Combat exotic species	4	1	1		2
J	Restore hydrology	22	7	11	1	3
K	Improve water quality	14	1	7	4	2
M	Improve geomorphic area habitat quality	17	4	3	9	1
P	Improve habitat and plant community diversity	16	5	5	4	2
Q	Improve connectivity	13	5	2	4	2
T	Restore crop land/remove levees	5	1		3	1
U	Limit navigation	1		1		
V	Restore rare species	2			1	1
W	Reduce human impacts	1				

Table 40. Response to desired future condition qualitative question number 4.

4. What are the most highly threatened habitat types in your specified area?

Number Code	General Response	Pooled Responses	La Crosse	Rock Island	St Louis	Havana
1	Closed areas	1	1			
2	Low river stage	1	1			
3	Islands	6	4	1	1	
4	Marsh habitat (including submersed plants)	17	6	5	2	4
5	Wet meadow	5	1	3	1	
6	Bottomland hardwoods and floodplain forests	14	6	4	2	2
7	Prairie	4	2	2		
8	Deep backwaters (especially for overwintering)	23	3	10	6	4
9	Diverse habitats	7	4			3
10	Unfragmented habitats	3	1		2	
11	Mussel habitat	2	2			
12	Natural banks	1	1			
13	Bad approach, see pool plans	2	2			
14	Natural hydrology and connectivity	2	1	1		
15	Early successional forests	5	3	2		
16	Savanas	1		1		
17	Sandbars and mudflats	3		1	2	
18	Secondary channels	7		1	5	1
19	Water Qaulity	1				1

Table 41. Response to desired future condition qualitative question number 5.

5. What are the primary <u>stressors</u> or <u>disturbances</u> that would threaten habitat restoration ? (pooled response)

Number Code	General Response	Pooled Responses	La Crosse	Rock Island	St Louis	Havana
1	Impoundment and river regulation	30	10	12	3	5
2	Exotic species	8	5	2		1
3	Floodplain development and levees	20	4	7	7	2
4	Sedimentation and non-point pollution (watershed development)	29	8	14	2	5
5	Humans (especially engineers)	6	3	1	1	1
6	Island loss	1	1			
7	See pool plans	1	1			
8	Boats	3	2			1
9	Water quality	3	1		1	1
10	Flooding	1		1		
11	Lack of funding	2			1	1
12	Grain markets	1			1	
13	Crop damage caused by deer	1			1	
14	Animal population declines	1				1
15	Conflicts among users	1				1

Emergent aquatic plant communities (or marsh habitats) are impacted by sediment quality factors, and also by water level regulation. Deep-water marshes that developed in the early post-dam expanded backwaters have degraded over time because of declining sediment quality, wave erosion, and lack of water level drawdown. The distribution of emergent aquatic plants that develop in shallow marginal aquatic areas or on mud flats (i.e., moist soil plants) is much reduced because many areas are no longer exposed during low flow periods. Waves, and barge-induced drawdowns on the Illinois Waterway, can limit emergent plant propagation in marginal channel areas. River managers want marsh habitats restored and enhanced, especially in southern river reaches. Emergent plant communities have shown a remarkable ability to recover when backwater areas on the Illinois Waterway are dewatered with pumps.

Floodplain grassland and wet meadow abundance and distribution has been reduced throughout the river. In northern river reaches these habitats have been replaced by water and development. In southern reaches, where prairies were expansive at one time, crops have replaced grasslands and wet meadows. Resource managers would like to restore these habitats to the extent possible, in the context of acquiring lands from willing sellers or through partnerships with private landowners.

Floodplain forest abundance, distribution, species diversity, and age structure have been greatly modified by human activities. Logging and inundation are responsible for the direct loss of forest area. High-grade logging, fire suppression, and physical habitat modification (i.e., altered hydrology) are responsible for changes in forest composition. The artificially high groundwater table prevents deep root development, making floodplain trees unusually susceptible to wind throw. Resource managers would like to recover a greater proportion of early successional species and mast producing tree species. They are also concerned that an aggressive wet meadow grass (European ecotype of reed canary grass) is replacing floodplain forest in northern river reaches.

Resource managers did not express a desire to acquire vast tracts of floodplain levee districts, although, they thought opportunities for land acquisition from willing sellers should be a high priority in lower river reaches. Resource managers would also like to partner with floodplain landowners to manage remnant wetlands and marginal croplands within leveed areas.

Resource managers implied that many of the problems responsible for habitat degradation could be reduced, delayed, or eliminated with the restoration of more natural stage/discharge relationships. They also thought upland sediment retention would help improve river habitats in the long term.

10.5.3 Quantitative Desired Future - HNA Geomorphic Areas

Pools 1 - 3

There was no prediction for change from the Cumulative Effects Study available for pools 1 to 3. Also, resource managers from Minnesota declined to participate in the quantitative aspect of the workshops. Therefore, there is no quantitative predicted or desired future condition available for pools 1 to 3. The Minnesota Valley National Wildlife Refuge has a plan for restoration of lands along the lower 32 miles of the Minnesota River.

Pool 4

Resource mangers rated 10 of 13 geomorphic area types as currently having greater than 50% of their area providing acceptable habitat for desirable species. Main channel, main channel border, and excavated channel areas were rated as having less than 50% of their area providing acceptable habitat. Resource managers predicted that all geomorphic areas would degrade to the point that only tailwater areas would provide more than 50% acceptable habitat. The managers expressed the desire that most geomorphic area classes be restored so that more than 70% of their area supports desirable species. Managers thought only 60% of the channel border area could be restored. They weren't very concerned about excavated channel habitat. They only desire 10% of the contiguous impounded area, suggesting they want it converted to other area classes. Managers want to increase island, isolated floodplain lake, tributary channel, and secondary channel area. They want a large increase in tertiary channel area. The calculated habitat need is summarized in Table 42 and Appendix Z.

Pool 5

Resource managers rated 7 of 11 geomorphic area types as currently having 50 to 80% of their area providing acceptable habitat for desirable species (Appendix Z). Main channel, main channel border, excavated channel, and contiguous impounded areas were rated as having less than 50% of their area providing acceptable habitat. Resource managers predicted that all geomorphic areas would degrade to the point that only tailwater areas would provide more than 50% acceptable habitat. The managers expressed the desire that most geomorphic area classes be restored so that more than 70% of their area supports desirable species. Managers thought only 60% of the channel border area could be restored. They weren't very concerned about excavated channel habitat. They only desire 50% of the contiguous impounded area, suggesting they want it converted to other area classes. Managers want to increase island, isolated floodplain lake, contiguous shallow aquatic, and secondary channel area. The calculated habitat need is summarized in Table 42 and Appendix Z.

Pool 5a

Resource managers rated 7 of 12 geomorphic area types as currently having 50 to 70% of their area providing acceptable habitat for desirable species (Appendix Z).
Main channel, main channel border, tertiary channel, excavated channel, and contiguous impounded areas were rated as having less than 50% of their area providing acceptable habitat. Resource managers predicted that all geomorphic areas would degrade to the point that only tailwater areas would provide more than 50% acceptable habitat. The managers expressed the desire that most geomorphic area classes be restored so that more than 70% of their area supports desirable species. Managers thought only 60% of the channel border area could be restored. They weren't very concerned about excavated channel habitat. They only desire 50% of the contiguous impounded area, suggesting they want it converted to other area classes. Managers want to increase island, isolated floodplain lake, contiguous shallow aquatic, tertiary channel, and secondary channel area. The calculated habitat need is summarized in Table 42 and Appendix Z.

Pool 6

Resource managers rated 7 of 11 geomorphic area types as currently having 50 to 70% of their area providing acceptable habitat for desirable species (Appendix Z).
Main channel, main channel border, tertiary channel, excavated channel, and contiguous impounded areas were rated as having less than 50% of their area providing acceptable habitat. Resource managers predicted that all geomorphic areas would degrade to the point that only tailwater areas would provide more than 50% acceptable habitat. The managers expressed the desire that most geomorphic area classes be restored so that more than 70% of their area supports desirable species. Managers thought only 60% of the channel border area could be restored. They weren't very concerned about excavated channel habitat. They only desire 50% of the contiguous impounded area, suggesting they want it converted to other area classes. Managers want to increase island, isolated floodplain lake, contiguous shallow aquatic, tertiary channel, and secondary channel area. The calculated habitat need is summarized in Table 42 and Appendix Z.

Pool 7

Resource managers rated 7 of 13 geomorphic area types as currently having 50 to 85% of their area providing acceptable habitat for desirable species (Appendix Z).

Main channel, main channel border, tertiary channel, contiguous impounded, island, and contiguous floodplain areas were rated as having less than 50% of their area providing acceptable habitat. Resource managers predicted that all geomorphic areas would degrade to the point that only tailwater, tributary channels, and shallow aquatic areas would provide more than 50% acceptable habitat. The managers expressed the desire that most geomorphic area classes be restored so that more than 70% of their area supports desirable species. Managers thought only 60% of the channel border area could be restored. They desire that 55% of island and contiguous floodplain areas provide high quality habitat. Managers want to increase isolated floodplain lake, contiguous shallow aquatic, contiguous floodplain lake, tertiary channel, and secondary channel area. The calculated habitat need is summarized in Table 42 and Appendix Z.

Pool 8

Resource managers rated 7 of 13 geomorphic area types as currently having 50 to 85% of their area providing acceptable habitat for desirable species (Appendix Z).

Main channel, main channel border, tertiary channel, contiguous impounded, island, and contiguous floodplain areas were rated as having less than 50% of their area providing acceptable habitat. Resource managers predicted that all geomorphic areas would degrade to the point that only tailwater, tributary channels, and shallow aquatic areas would provide more than 50% acceptable habitat. The managers expressed the desire that most geomorphic area classes be restored so that more than 70% of their area supports desirable species. Managers thought only 60% of the channel border area could be restored. They desire that 55% of island and contiguous floodplain areas provide high quality habitat. Managers want to increase isolated floodplain lake, contiguous shallow aquatic, contiguous floodplain lake, tertiary channel, and secondary channel area. The calculated habitat need is summarized in Table 42 and Appendix Z.

Pool 9

Percent acceptable habitat was not provided for pools 9 to 19. Instead, total desired future habitat acres were provided and present habitat need was calculated as the difference between desired future habitat and 1989 total acreage. Mike Griffin (Iowa DNR, Belleview, Iowa) provided the estimates for desired future habitat condition.

In Pool 9, Mr. Griffin was satisfied with the present extent of main navigation channel, main channel border, tailwater, and secondary channel habitat (Table 42). He wanted increased tributary channel habitat, and excavated channels in the form of deep channels in backwaters. Increases in both contiguous and isolated backwaters were recommended. Large reductions in contiguous floodplain shallow aquatic area and contiguous impounded area were balanced by an equally large increase in island area, suggesting island construction to modify open impounded areas. No changes in floodplain terrestrial areas were recommended, but all floodplain areas should be mapped in GIS.

Pool 10

In Pool 10, Mr. Griffin was satisfied with the present extent of main navigation channel, main channel border, tailwater, and secondary channel habitat (Table 42). He wanted tertiary channel area doubled, and more excavated channels in the form of deep channels in backwaters. Moderate increases in contiguous backwaters, shallow aquatic area, and isolated backwaters were recommended. Reductions in contiguous impounded area were balanced by increases in island area, suggesting island construction to modify open impounded areas. No changes in floodplain terrestrial areas were recommended, but all floodplain areas should be mapped in GIS.

Pool 11

In Pool 11, Mr. Griffin was satisfied with the present extent of main navigation channel, main channel border, tailwater, and secondary channel habitat (Table 42). He wanted tertiary channel area doubled, and more excavated channels in the form of deep channels in backwaters. Moderate increases in contiguous backwaters, shallow aquatic area, and isolated backwaters were recommended. Reductions in contiguous impounded area were somewhat balanced by increases in island area, suggesting island construction to modify open impounded areas. No changes in floodplain terrestrial areas were recommended.

Pool 12

In Pool 12, Mr. Griffin was satisfied with the present extent of main navigation channel, main channel border, tailwater, secondary channel, tertiary channel, and tributary channel habitat (Table 42). He wants to double the acreage of excavated channels in the form of deep channels in backwaters. Reductions in contiguous impounded area and increases in island area and contiguous backwater area, suggest island construction to modify open impounded areas. Only slight changes in isolated backwater and floodplain terrestrial areas were recommended.

Pool 13

In Pool 13, Mr. Griffin was satisfied with the present extent of main navigation channel, main channel border, tailwater, secondary channel, tertiary channel, and tributary channel habitat (Table 42). He wants to more than double the acreage of excavated channels in the form of deep channels in backwaters. Significant increases in contiguous backwaters, shallow aquatic area, and island area, combined with reductions in contiguous impounded area suggest island construction to modify open impounded areas. Only slight changes in isolated backwater and no changes in floodplain terrestrial areas were recommended.

Pool 14

In Pool 14, Mr. Griffin recommended few changes (Table 42). Slight increases in contiguous backwater area were recommended. Increased shallow aquatic area is achieved with increased island area to create the braided channel characteristic of the habitat class. A slight loss of contiguous floodplain is recommended. All floodplain areas should be mapped in GIS

Pool 15

No changes were recommended for Pool 15 (Table 42).

Pool 16

In Pool 16, Mr. Griffin recommended few changes (Table 42). An increase in isolated terrestrial floodplain and isolated backwater imply construction of wildlife management units. Loss of contiguous floodplain is balanced by the increase in isolated floodplain and shallow aquatic area. All floodplain areas should be mapped in GIS.

Pool 17

In Pool 17, Mr. Griffin recommended few changes (Table 42). Loss of contiguous floodplain area was balanced by the increase in isolated floodplain and shallow aquatic area. All floodplain areas should be mapped in GIS.

Table 42. Upper Mississippi River (pools 4 – 26) HNA geomorphic area need (acres).

Present Habitat Need

Reach	1. Main Navigation Channel	2. Main Channel Border	3. Tailwater	4. Secondary Channel	5. Tertiary Channel	6. Tributary Channel	7. Excavated Channel	8. Contiguous Floodplain Lake	9. Contiguous Floodplain Shallow Aquatic Area	10. Contiguous Impounded Area	11. Isolated Floodplain Aquatic Area	Total Aquatic	12. Terrestrial Island	13. Contiguous Terrestrial Floodplain	14. Isolated Terrestrial Floodplain	15. No Photo Coverage	Total Terrestrial
Pool 4	1,080	388	7	800	111	24	200	1,275	581	-403	587	4,650	2,511	3,128	0	0	5,639
Pool 5	333	464	14	789	0	26	0	19	1,268	1,346	265	4,523	1,173	2,233	0	0	3,406
Pool 5a	215	219	19	422	42	12	0	10	2,024	193	628	3,783	2,160	902	0	0	3,062
Pool 6	302	481	10	2,753	3	16	0	25	182	0	2,724	6,496	903	940	0	0	1,842
Pool 7	226	525	12	1,522	2	12	2	618	517	3,254	202	6,894	386	659	0	0	1,044
Pool 8	620	522	13	1,448	3	11	0	1,528	2,333	4,475	499	11,451	733	859	0	0	1,592
Pool 9	0	0	0	74	71	92	100	193	4,209	-4,978	562	323	638	0	0	0	638
Pool 10	1	0	0	-413	177	136	0	0	1,725	-1,426	0	199	195	0	0	0	195
Pool 11	0	0	0	446	46	36	0	275	2,010	-1,487	59	1,386	516	0	0	0	516
Pool 12	0	0	0	11	-8	19	0	408	-447	-336	-35	-389	427	-64	0	0	363
Pool 13	0	0	0	0	40	112	0	931	500	-2,786	236	-966	336	0	0	0	336
Pool 14	1	0	0	0	39	1	0	149	200	0	0	389	647	-678	3	0	-27
Pool 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pool 16	0	0	0	0	25	0	5	16	91	0	113	249	0	-232	141	0	-92
Pool 17	0	0	0	8	29	0	0	106	200	0	0	342	-37	-271	0	0	-308
Pool 18	0	0	0	0	27	90	0	127	500	0	1,076	1,819	153	-323	-1,476	0	-1,646
Pool 19	0	0	0	1	28	0	0	856	831	-642	463	1,537	0	0	-1,558	0	-1,558
Pool 20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 22	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Total	2,774	2,598	74	7,859	635	587	307	6,538	16,724	-2,789	7,379	42,685	10,740	7,153	-2,890	0	15,003

Table 42. Upper Mississippi River (pools 4 – 26) HNA geomorphic area need (acres; Continued).

Future (2050) Habitat Need

Reach	1. Main Navigation Channel	2. Main Channel Border	3. Tailwater	4. Secondary Channel	5. Tertiary Channel	6. Tributary Channel	7. Excavated Channel	8. Contiguous Floodplain Lake	9. Contiguous Floodplain Shallow Aquatic Area	10. Contiguous Impounded Area	11. Isolated Floodplain Aquatic Area	Total Aquatic	12. Terrestrial Island	13. Contiguous Terrestrial Floodplain	14. Isolated Terrestrial Floodplain	15. No Photo Coverage	Total Terrestrial
Pool 4	1,350	498	9	914	114	24	200	12,751	1,743	-403	685	17,885	3,196	6,255	0	0	9,452
Pool 5	416	596	16	858	0	26	0	192	1,811	1,615	309	6,134	1,493	4,467	0	0	5,960
Pool 5a	268	281	23	458	46	12	0	100	2,892	231	732	5,045	2,749	1,804	0	0	4,553
Pool 6	377	619	12	2,993	3	16	0	252	259	0	3,178	7,709	1,149	1,880	0	0	3,029
Pool 7	282	675	15	1,655	2	55	5	843	474	1,446	236	5,688	772	1,317	0	0	2,089
Pool 8	774	671	15	1,573	3	51	0	2,084	2,139	1,989	583	9,882	1,466	1,719	0	0	3,185
Pool 9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 13	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 14	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 18	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 19	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 22	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Pool 26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0	NA	NA	NA	NA	0
Total	3,468	3,341	90	8,451	463	184	205	16,222	9,318	4,878	5,723	52,341	10,824	17,442	0	0	28,266

Pool 18

In Pool 18, Mr. Griffin was satisfied with the present extent of main navigation channel, main channel border, tailwater, secondary channel, tertiary channel, and tributary channel habitat (Table 42). He wants more acreage of excavated channels in the form of deep channels in backwaters. Increases in contiguous backwaters and shallow aquatic area, and island area, suggest island construction to modify open water areas. Increased isolated backwater area corresponds to changes recommended in isolated floodplain terrestrial areas. All floodplain areas should be mapped in GIS.

Pool 19

In Pool 19, Mr. Griffin recommended few changes (Table 42). Increased contiguous and isolated lakes and shallow aquatic area, and reduced isolated floodplain terrestrial area suggest reconnecting isolated habitats. All floodplain areas should be mapped in GIS.

10.5.4 Quantitative Desired Future - Cumulative Effects Study Geomorphic Areas

Pools 1 – 3

The Cumulative Effects Study did not provide plan form change statistics for pools 1 through 3.

Pools 4 – 10

Resource managers at the La Crosse workshop did not express desired future habitat conditions for the geomorphic areas defined in the Cumulative Effects Study. They did not agree with the methods or results and requested that they score the HNA geomorphic area tables only.

Pool 11

Resource managers at the Rock Island workshop accepted the projected change for main channel, isolated backwater, island area, island perimeter, and total open water (Appendix AA). They thought that only 45% of secondary channel area and 10% of contiguous backwater area currently provides acceptable habitat for desirable species. They projected slight degradation over the next 50 years. Resource managers desire that 55% of secondary channel area and 40% of contiguous backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 12

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 80% of secondary channel area, 10% of contiguous backwater area, and isolated backwater area currently provides acceptable habitat for desirable species. They projected slight degradation over the next 50 years. Resource managers desire that 90% of secondary channel area and 40% of contiguous and isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 12

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 80% of secondary channel area, 10% of contiguous backwater area, and 10% of isolated backwater area currently provides acceptable habitat for desirable species. They projected slight degradation over the next 50 years. Resource managers desire that 90% of secondary channel area and 40% of contiguous and isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 13

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 80% of secondary channel area, 50% of contiguous backwater area, and 50% of isolated backwater area currently provides acceptable habitat for desirable species. They projected slight degradation over the next 50 years. Resource managers desire that 90% of secondary channel area and 50% of contiguous and isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 14

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 80% of secondary channel area, 40% of contiguous backwater area, and 25% of isolated backwater area currently provides acceptable habitat for desirable species. They projected slight degradation over the next 50 years. Resource managers desire that 90% of secondary channel area and 50% of contiguous and isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 15

Resource managers at the Rock Island workshop accepted the projected change for main channel, contiguous backwater, isolated backwater, island area, island perimeter, and total open water (Appendix AA). They thought that only 95% of secondary channel area provides acceptable habitat for desirable species. Resource managers desire that 100% of secondary channel area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 16

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 50% of secondary channel area, 50% of contiguous backwater area, and 50% of isolated backwater provides acceptable habitat for desirable species. They projected degradation over the next 50 years, especially isolated backwater loss. Resource managers desire that 80% of secondary channel area and 50% of contiguous and isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 17

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 70% of secondary channel area, 50% of contiguous backwater area, and 0% of isolated backwater area currently provides acceptable habitat for desirable species. They projected degradation over the next 50 years. Resource managers desire that 70% of secondary channel area and 50% of contiguous backwater area provide acceptable habitat for desirable species. They wanted a 210% increase in the amount of isolated backwater area capable of supporting desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 18

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 40% of secondary channel area, 50% of contiguous backwater area, and 10% of isolated backwater area currently provides acceptable habitat for desirable species. They projected extensive degradation over the next 50 years. Resource managers desire that 60% of secondary channel area provide acceptable habitat for desirable species. They wanted a 210% increase in the amount of contiguous backwater and a 200% increase in isolated backwater area capable of supporting desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 19

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 80% of secondary channel area, 40% of contiguous backwater area, and 40% of isolated backwater area currently provides acceptable habitat for desirable species. They projected extensive degradation over the next 50 years. Resource managers desire that 80% of secondary channel area 40% of contiguous backwater, and 70% of isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 20

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 70% of secondary channel area, 5% of contiguous backwater area, and 5% of isolated backwater area currently provides acceptable habitat for desirable species. They projected extensive degradation over the next 50 years. Resource managers desire that 70% of secondary channel area provide acceptable habitat for desirable species. They wanted a 300% increase in the amount of contiguous backwater and a 300% increase in isolated backwater area capable of supporting desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 21

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 80% of secondary channel area, 20% of contiguous backwater area, and 20% of isolated backwater area currently provides acceptable habitat for desirable species. They projected extensive degradation over the next 50 years. Resource managers desire that 80% of secondary channel area 50% of contiguous backwater, and 120% of isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 22

Resource managers at the Rock Island workshop accepted the projected change for main channel, island area, island perimeter, and total open water (Appendix AA). They thought that only 80% of secondary channel area, 10% of contiguous backwater area, and 5% of isolated backwater area currently provides acceptable habitat for desirable species. They projected extensive degradation over the next 50 years. Resource managers desire that 150% of secondary channel area, 100% of contiguous backwater, and 100% of isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 24

Resource managers at the St. Louis workshop accepted the projected change for main channel, island perimeter, and total open water (Appendix AA). They thought that only 50% of secondary channel area, 10% of contiguous backwater area, and 70% of isolated backwater area currently provides acceptable habitat for desirable species. They projected degradation over the next 50 years. Resource managers desire that 120% of secondary channel area, 200% of contiguous backwater, 300% of isolated backwater area, and 120% of island area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 25

Resource managers at the St. Louis workshop accepted the projected change for main channel, island perimeter, island area, and total open water (Appendix AA). They thought that only 50% of secondary channel area, 50% of contiguous backwater area, and 70% of isolated backwater area currently provides acceptable habitat for desirable species. They projected degradation over the next 50 years. Resource managers desire that 100% of secondary channel area, 125% of contiguous backwater, and 450% of isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Pool 26

Resource managers at the St. Louis workshop accepted the projected change for main channel, island perimeter, island area, and total open water (Appendix AA). They thought that only 50% of secondary channel area, 5% of contiguous backwater area, and 5% of isolated backwater provides acceptable habitat for desirable species. They projected degradation over the next 50 years. Resource managers desire that 120% of secondary channel area, 300% of contiguous backwater, and 150% of isolated backwater area provide acceptable habitat for desirable species. The calculated habitat need is summarized in Table 43 and Appendix AA.

Table 43. Upper Mississippi River (pools 4 – 26) Cumulative Effects Study geomorphic area need (acres) (continued).

Present Habitat Need

Reach	MC	SC	CB	IB	AI	PI	TOW
Pool 4*	NA	NA	NA	NA	NA	NA	NA
Pool 5*	NA	NA	NA	NA	NA	NA	NA
Pool 5a*	NA	NA	NA	NA	NA	NA	NA
Pool 6*	NA	NA	NA	NA	NA	NA	NA
Pool 7*	NA	NA	NA	NA	NA	NA	NA
Pool 8*	NA	NA	NA	NA	NA	NA	NA
Pool 9*	NA	NA	NA	NA	NA	NA	NA
Pool 10*	NA	NA	NA	NA	NA	NA	NA
Pool 11	-1,973	204	1,317	-53	60	-27,835	-444
Pool 12	0	243	702	197	0	0	1,142
Pool 13	0	220	0	0	367	0	587
Pool 14	0	140	137	64	0	-137,055	341
Pool 15	0	20	0	0	0	0	20
Pool 16	192	1,142	0	0	0	40,070	1,334
Pool 17	0	0	0	124	77	4,200	201
Pool 18	-361	387	1,707	317	287	28,070	2,337
Pool 19	-1,165	0	0	65	1,089	-70,190	-12
Pool 20	0	0	292	115	0	0	407
Pool 21	-74	0	265	182	0	0	373
Pool 22	0	725	306	78	0	0	1,108
Pool 24	-105	2,175	1,260	975	1,157	803	5,461
Pool 25	-174	1,709	1,608	1,744	140	7,705	5,027
Pool 26	-105	2,512	4,248	1,188	0	0	7,843
Total	-3,765	9,475	11,842	4,996	3,177	-154,232	25,725

Table 43. Upper Mississippi River (pools 4 – 26) Cumulative Effects Study geomorphic area need (acres; continued).

Future Habitat Need

Reach	**MC**	**SC**	**CB**	**IB**	**AI**	**PI**	**TOW**
Pool 4*	NA	NA	NA	NA	NA	NA	NA
Pool 5*	NA	NA	NA	NA	NA	NA	NA
Pool 5a*	NA	NA	NA	NA	NA	NA	NA
Pool 6*	NA	NA	NA	NA	NA	NA	NA
Pool 7*	NA	NA	NA	NA	NA	NA	NA
Pool 8*	NA	NA	NA	NA	NA	NA	NA
Pool 9*	NA	NA	NA	NA	NA	NA	NA
Pool 10*	NA	NA	NA	NA	NA	NA	NA
Pool 11	0	408	1,536	0	0	0	1,944
Pool 12	0	486	819	230	0	0	1,535
Pool 13	0	440	240	52	0	0	732
Pool 14	0	279	275	89	0	0	643
Pool 15	0	20	0	0	0	0	20
Pool 16	0	1,903	195	204	0	0	2,301
Pool 17	0	379	291	124	0	0	794
Pool 18	0	967	2,219	334	0	0	3,520
Pool 19	0	1,949	568	151	0	0	2,668
Pool 20	0	841	297	117	0	0	1,255
Pool 21	0	1,158	398	209	0	0	1,765
Pool 22	0	1,035	333	81	0	0	1,449
Pool 24	0	2,486	1,313	1,060	1,157	0	6,015
Pool 25	0	2,050	2,466	1,951	0	0	6,467
Pool 26	0	3,589	4,291	1,220	0	0	9,101
Total	0	17,989	15,241	5,822	1,157	0	40,208

Open River

Plan form change statistics were not available from the Cumulative Effects Study and detailed land cover was also unavailable for most of the reach. We did, however, obtain some useful comments and a quantitative assessment of six land cover classes available from satellite imagery. Resource managers expressed a desire for 25,000 more acres of non-main channel aquatic habitat along the 200-mile river reach. Of the 25,000 acres, at least 7,000 acres should be high quality isolated backwaters. Managers want to see secondary channel or contiguous backwater habitat spaced every 5 to 7 miles along the river reach. Because of the current lack of public land, managers want to acquire 20 or more parcels of land (approximately 10 miles apart) greater than 600 acres. They have a preference for parcels greater than 3,000 acres. Managers believe all islands should be in public ownership. In addition to new habitats, managers have evaluated existing secondary channel habitats and have recommendations for their preservation and restoration. There may be restoration opportunities in the lower Kaskaskia River also.

The manager's quantitative assessment of land cover is summarized in Table 44. Joyce Collins (U.S. Fish and Wildlife Service, Marion, Illinois) prepared a land cover change summary for 1950, 1975, 1989, and 1994 to help quantify predicted land cover change, express a desired condition, and calculate habitat need. The summary documents a loss of 25,000 acres of open water and projects a predicted loss of 21,000 more acres. The desired condition is to return to the 1950 value of about 90,000 acres. The present habitat need is about half of the predicted need if no action is taken. The emergents and grasses class has remained relatively stable and is projected to increase, but managers would like to increase the value greater than predicted. The present habitat need is greater than the future, but this is the result of grasses colonizing aquatic areas expected to fill by 2050. The woody terrestrial class increased from 60,000 to almost 90,000 acres between 1950 and 1989, but dropped to 75,000 acres after extreme flooding in 1993. Resource managers would like to double the abundance of forests. The habitat need is the largest acreage increase, at about 80,000 acres. Managers desire about 110,000 acres, or a 25%, decrease in agriculture and no change in the urban-developed class. Sand-mud does not map well on the satellite imagery, so a 1994 hydrographic survey that estimated 20,412 acres of non-vegetated sand bars above the low water reference plane and an estimated change of 0.2 acres/river mile/year losses was used to generate sand-mud acreage estimates. Managers would like to double the existing amount of sand bar habitat. An important consideration in the Open River reach is establishing both lateral and longitudinal connectivity by providing a diversity of habitats along the entire 200-mile reach.

Table 44. Past, present, and predicted Open River reach land cover, with resource manager's desired land cover, and calculated habitat need (provided by Joyce Collins, U.S. Fish and Wildlife Service, Marion, Illinois).

							Habitat Need	
Land Cover Class	1950	1975	1989	1994	Predicted 2050	Desired 2050	Desired - Present	Desired - Predicted
Open Water*	89,886	72,066	66,926	64,746	43,746	89,886	22,960	46,140
Emergents/Grasses & Forbs	24,805	25,585	25,265	29,945	38,685	50,530	25,265	11,845
Woody Terrestrial	60,299	73,119	82,219	74,839	88,319	164,438	82,219	76,119
Agriculture	437,102	439,262	439,202	438,842	437,982	329,402	-109,800	-108,580
Urban/Developed	52,325	52,485	52,765	52,753	53,985	52,765	0	-1,220
Sand-mud**	22,172	21,172	20,612	20,412	18,172	40,824	20,212	22,652
Total	686,589	683,689	686,989	681,537	680,889	727,845	40,856	46,956

* = 50% of Open Water should be secondary channels or backwaters.

** = San/Mud area estimates based on COE 1994 hydrographic survey (see Text).

Illinois Waterway

Plan form change statistics were not available from the Cumulative Effects Study and detailed land cover was also unavailable for most of the reach. There is, however, a wealth of information available from previous studies (Starrett 1972, Bellrose et al. 1983, Bhowmik and DeMisse 1989, and DeMisse et al. 1992). There is a long history of development and pollution of the Illinois Waterway. Lake Michigan water and sewage diverted from the Chicago region increased water levels along the length of the river and delivered massive amount of organic pollution that destroyed aquatic life for hundreds of miles downstream. Navigation dams further regulated river stages to prevent low summer water levels. In some instances, dam operations create wide, unnatural stage fluctuations in the river. Non-point pollution is a serious problem in the highly agricultural Illinois Waterway Basin. Studies of Illinois Waterway backwater sedimentation suggest that most lakes will fill over the next 100 years at the current rate of sediment delivery. Sediment quality is degraded by contaminants, nutrients, and the lack of drying over the last 100 years. Sediments are flocculent and easily resuspended by waves. Bathymetric diversity has been lost, and most lakes are shallow (< 3 feet deep) platter shaped basins. More than 60% of the lower one-half (160 miles) of the Illinois Waterway are leveed. The upper Illinois Waterway is highly urbanized, with many miles of canals dug in the early 1900s. Exotic species threaten many native species through their direct (zebra mussels) and indirect effects (carp, various zooplankton species, etc.). All classes of natural vegetation have declined in abundance and quality.

Given the multiple disturbances affecting the Illinois Waterway, it was easy for resource managers to express a desire to improve habitat quality. Although sewage and chemical pollution has been largely controlled, there are latent pollutants in sediments that can be mobilized if disturbed. There is also significant non-point pollution from urban and agricultural areas. Managers want to continue and strengthen pollution control; they also want to determine if herbicides introduced from the watershed are limiting aquatic plant populations. Illinois Waterway managers thought that water level regulation through diversions and dams was one of the primary factors limiting habitat quality. They would like to drain and dry backwaters periodically to maintain sediment quality. They also want unnatural water level fluctuations reduced to the extent possible. Managers also want to reduce the amount of sediment delivered to the river from the watershed. Backwater diversity is an important component of aquatic habitat. Resource managers expressed a desire that 25% of Illinois Waterway backwater lakes have an average depth of six feet and considerable bathymetric variability. Managers want to restore floodplain lands through purchase from willing sellers or cooperative agreement. Increased river-floodplain connectivity is an important goal. The control of exotic species was important to Illinois Waterway managers because they receive many of the species introduced to Lake Michigan from freshwater European ports. Managers also want to increase aquatic and terrestrial vegetation diversity, abundance, and distribution.

10.6 Discussion

The HNA Project Management Plan states the following as project goals and objectives: “The UMRS does not yet have an overall set of objectives for desired future habitat conditions. Therefore, the need exists to conduct an assessment of habitat needs, and to set objectives for the desired future condition of UMRS habitats.” Key words in the statement, “overall set of objectives,” prevent the conclusion that project goals and objectives were fully achieved. Differences in data availability, quality, and quantity among river reaches prevented a uniform systemic approach. Also, resource managers clearly expressed their concern that the information provided and the approach used were inappropriate assessments of past change and expressions of desired habitat. While some particulars of the data and approach have been, and will continue to be, criticized, information collected can help both systemic and site specific planning efforts.

Information derived at the workshops should serve as an additional piece in the overall planning puzzle guiding Upper Mississippi River and Basin preservation and restoration.

It appears that the workshop approach worked well for qualitatively assessing change occurring in specific locations in prior HNA tasks. When it came to expressing desired habitat conditions at a pool scale, however, the workshop approach did not allow the time to consider the intricacies necessary to precisely identify and balance change in specific geomorphic areas. Although no resource managers were particularly pleased with the assignment of the proportional area of geomorphic areas capable of supporting desirable species, they did for the most part, complete the exercise where data were available. Managers found it very difficult to express quantitative desires for land cover and provided mostly qualitative desires for improved land cover diversity.

The HNA does not exist in a planning vacuum as resource managers pointed out at the workshops. The HNA was developed to support other EMP planning efforts and to incorporate information from other planning efforts. Managers at the La Crosse workshop introduced the concept of "Pool Plans" being developed by the St. Paul District Fish and Wildlife Work Group and the Rock Island District Fish and Wildlife Interagency Committee to assist HREP planning. Through detailed analysis of pooled reaches, resource managers are developing conceptual maps of their desired future condition and extensive documentation of desired habitat quality and unique features. The schedule for the completion of pool plans for the entire UMRS has not been determined.

At the St. Louis workshop, resource managers provided a draft plan describing the existing condition and desired conditions of secondary channels in the Open River. Resource managers have a clear understanding of current conditions and have conceptual goals for restoration, but resource management in the Open River reach has been hindered by navigation, flood protection, and a lack of public land. A Pool Plan approach is being developed for the St. Louis District to refine restoration objectives. It is anticipated that opportunities presented by the second phase EMP will open new restoration opportunities in the Open River reach.

There is considerable concern for the Illinois River in the state of Illinois. In 1994, the Lieutenant Governor's Office established the Illinois River Coordinating Council "to streamline and coordinate programs to enhance the Illinois River watershed" (Lt. Governor Corinne Wood; http://www.state.il.us/ltgov/river.htm). With participation from leaders in business, agriculture, and conservation, 150 Illinoisans participated in strategy meetings that resulted in 34 recommendations to help create "a naturally diverse and productive Illinois River Valley that is sustained by natural ecological processes and managed to provide for compatible social and economic activities." The plan should help coordinate state programs and leverage Federal support for restoration. A Pool Plan approach will be developed for the Illinois River to refine EMP restoration objectives.

There are also management plans developed for migratory waterfowl, migratory birds, freshwater mussels, several fishes, endangered species, state conservation areas, and National Wildlife Refuges. Previous HREP planning documents provide substantial documentation of goals and objectives for river resources.

At the basin scale, recently introduced legislation – the Upper Mississippi River Basin Conservation Act – seeks to reduce polluted runoff to the UMRS. The bill increases spending on voluntary conservation programs, creates a basin-wide water quality monitoring network, and encourages river managers to target major sources of sediment and nutrients. Concern over river resources and Gulf of Mexico hypoxia have driven many new basin studies in recent years.

There is no shortage of problems that require coordinated planning to solve. We will also likely continue to identify new problems and refine our understanding of previously identified problems as new data are collected. The EMP will continue to collect data and develop restoration objectives at many scales. The HNA will be periodically updated and revised to reflect important milestones in data collection, restoration planning, or establishing desired conditions. As clearly expressed by resource managers, this iteration of assessing their desired future condition should be considered a first approximation that needs to be refined in the future.

10.7 Summary

A natural resource manager's desired future condition was needed to help establish habitat needs for the entire UMRS. The desired future condition can be compared to the existing condition and the predicted future condition to establish present and future habitat needs. A variety of materials were provided to managers in advance of a series of workshops. The goal was to have resource managers provide desired acreage or proportional areas of suitable habitat for HNA land cover and geomorphic area classes. Resource managers working on pools 4 through 26 were also asked to express desired conditions using the Upper Mississippi River/Illinois Waterway Cumulative Effects Study plan form change analysis. A series of questions were asked to help assess habitat quality issues. The quantitative assessment was not completed prior to the workshops, and resource managers expressed discomfort with assigning firm numbers for desired future conditions. Instead, resource managers were asked to express their professional opinion regarding the proportion (i.e., percent) of geomorphic area classes in "acceptable" condition for the present, predicted future and desired future. These percentages were then transformed into an approximation of "acceptable" acres needed for each geomorphic area type. Responses to questions revealed that resource managers did not believe there were adequate data yet available for an in-depth, uniform, systemic quantitative needs assessment. They also indicated that in addition to the loss of aquatic area, they were concerned about general habitat degradation that is not detected in plan form assessments or snapshots in time. Many resource managers remarked that the HNA process was a good tool to aid restoration planning. Resource managers want improved habitat quality, habitat diversity, and hydrologic variability. They believe the same factors are critical to the sustainability of the river ecosystem. Deep backwaters, floodplain prairies, hardwood forests, and marsh habitats were rated the most threatened habitats. River regulation, sedimentation, and floodplain development were rated as the primary stressors affecting river habitats. Resource managers from Wisconsin and Minnesota declined to use the Cumulative Effects Study plan form areas to express quantitative desired future conditions, rather they scored the HNA geomorphic areas classes. We did not achieve a systemic desired future condition assessment using uniform units for habitat characterization, but we did achieve a first approximation of natural resource manager's desired future condition. The information will provide the first system-wide set of objectives for use in planning habitat protection and restoration on the UMRS.

11 Habitat Needs

The Habitat Needs Assessment was developed to provide Environmental Management Program managers a system-wide accounting of existing, predicted and desired habitat conditions. The HNA is the latest effort undertaken to document broad habitat protection and restoration objectives to help assist selection and planning of future EMP habitat projects. To assist habitat project planning, the HNA has provided a detailed accounting of land cover and geomorphic area distribution and abundance. The HNA has also identified the types, relative amounts, rates, and locations of specific geomorphic changes throughout the UMRS. Natural resource managers helped assess habitat quality, critical habitats, threatened habitats, and stressors impeding the development of high quality habitats. Focus groups, representing various river interest groups, were used to obtain their comments on desired future conditions.

The information gathered is vast, and does not provide a simple clear-cut number documenting habitat needs. It does, however, provide a first approximation for desired future habitat conditions from which habitat protection and restoration planning can proceed. The HNA presents some clear differences among river reaches, as well as, some systemic habitat needs or resource problems. The land cover analysis clearly documents the abundance of potential habitat in some river reaches, versus a scarcity of potential habitat in others. The differences are largely related to the amount and distribution of public land available. Analysis of geomorphic changes identifies which are of systemic nature (e.g., loss of backwaters), and which are more localized in nature and extent (e.g., island dissection). This can help direct habitat project planners toward the type or number of projects that would be appropriate for their river reach. The assessment of habitat quality proved to be rather uniform in that most resource managers thought habitats were currently degraded and expected to get worse. The factors responsible for degradation (e.g., sedimentation, impoundment, channelization, levees, etc.) were also seen as the most important stressors necessitating ecological restoration. Quantitative assessments do not provide precise estimates of change or need, but they do provide an initial assessment of the geomorphic area type managers believe should be emphasized or where the quality of habitat needs to be improved for a given pool/reach/system to reach the broad restoration objectives identified in the HNA.

Habitat project planning is a complex process of problem identification, site selection, detailed site assessment, goal and objective prioritization, engineering design, and construction. The HNA will not replace nor override the detailed planning necessary to implement the second phase of EMP HREPs. The HNA will provide the first approximation of a system-wide set of objectives for use in planning habitat protection and restoration on the UMRS. More detailed and spatially explicit planning for habitat protection and restoration will be conducted at the navigation pool and river reach scale. It may also help focus HREP planners on the geomorphic processes, and thus rehabilitation measures, likely to work in their river reach. The Habitat Needs Assessment will also provide a mechanism to help evaluate the systemic contribution of individual HREPs.

11.1 Summary – Qualitative analysis

Responses to questions revealed that resource managers did not believe there was adequate data for an in-depth, system-wide quantitative needs assessment using a uniform set of attributes to characterize river habitats. They also indicated that in addition to the loss of aquatic area, they were concerned about habitat degradation that is not detected in plan form assessments or snapshots in time. Most resource managers did think the HNA process will be a good tool to aid in planning for habitat protection and restoration. All resource managers want improved habitat quality, habitat diversity, and a hydrologic regime that is closer to the unregulated condition. They believe the same factors are critical to the sustainable ecological integrity of the river ecosystem. Deep backwaters, floodplain prairies, hardwood forests, and marsh habitats were rated the most threatened habitats. River regulation, sedimentation, and floodplain development were rated as the primary stressors affecting river habitats.

11.2 Summary – Geomorphic Change

The qualitative assessment of geomorphic change incorporated the knowledge and experience of natural resource managers, many with 20 or more years of experience. The method allowed a more detailed analysis than plan form assessments because the managers could provide insight into changes occurring below the water's surface. For example, backwaters that may not have displayed discernable change in water surface area may have lost significant depth that reduced their value as habitat.

A variety of geomorphic processes responsible for change were identified to classify geomorphic changes. The Cumulative Effects Study identified nine geomorphic processes:
delta formation,
filling between wing dams,
island dissection,
island formation,
loss of contiguous backwaters,
loss of isolated backwaters,
loss of secondary channels,
tributary delta formation,
and wind-wave erosion of islands.

The workshops with natural resource managers identified six additional geomorphic processes:
channel formation,
island migration,
loss of contiguous impounded area,
loss of bathymetric diversity,
loss of contiguous/isolated backwaters,
loss of tertiary channels,
and shoreline erosion.

The Cumulative Effects Study identified 58 areas in pools 4 through 26 influenced by one or more of the nine geomorphic processes. The workshops with the resource managers identified an additional 347 areas in the same reach, and an additional 125 areas in pools 2,3, the Open river, and the Illinois River. A total of 531 areas expected to change were identified. Maps were prepared to identify the locations where geomorphic processes were occurring. The analysis of geomorphic changes identifies which are of systemic nature (e.g., loss of backwaters), and which are more localized in nature and extent (e.g., island dissection).

11.3 Summary – Quantitative analysis

The quantitative assessment was not completed uniformly because adequate data were not available for all river reaches. Resource managers also expressed discomfort with assigning firm numbers for desired future conditions. Resource managers decided to estimate the proportion of each geomorphic area type capable of supporting desirable species (i.e., percent acceptable) for either the Cumulative Effects Study plan form areas or the HNA geomorphic areas. Acreages were calculated using their proportional area Figure s. Desired land cover conditions were not quantitatively expressed, but improved diversity and quality was expressed qualitatively. Analysis of HNA geomorphic area need in pools 4 to 19 indicate that 3,000 acres each of main channel and main channel border habitat, and more than 7,500 acres of secondary channel habitat require restoration. Almost 25,000 acres of the various backwater classes require restoration.

Resource managers evaluating the Cumulative Effects Study plan form area estimates for the pool 11 to 26 reach accepted the predicted change in main channel area. They would like to restore about 10,000 acres of secondary channel area, 12,000 acres of contiguous backwater, 5,000 acres of isolated backwater, and 3,000 acres of islands. These estimates of habitat restoration need would almost double by the year 2050 if no action is taken. In the Open River reach, resource managers want about 25,000 acres of new or restored backwater or secondary channel habitat. They want to acquire about one-quarter of presently agricultural land (110,000 acres) and convert it to prairie, marsh, backwaters, and forest. They would like to restore geomorphic processes that create and maintain sand bars and shoals. In the Illinois River resource managers want to restore existing backwaters so that 25%of backwater lakes have an average depth of 6 feet. They want depth diversity and connectivity increased throughout the river. They would also like to restore hydrologic variability important to restoring and maintaining backwater habitats.

11.4 Discussion

One thing that was evident among all the analyses is that UMRS habitats are degraded throughout the river. The qualitative and quantitative analyses compliment each other quite well, in that general habitat trends are common among all analyses. HNA results also compliment the response of resource managers when asked what the most critical resource problems were 15 years ago, prior to the first EMP authorization. State and Federal resource managers have completed many successful HREPs without the HNA, but in the future resource managers can adapt HNA results and tools to their particular river reaches to refine local restoration planning and management activities. EMP managers can use the information to determine the role of individual projects in achieving systemic goals.

12 Information Needs

Conduct of this first Habitat Needs Assessment for the UMRS revealed clear needs for information that is basic to characterizing river habitats. A lack of important data is illustrated by the rule-based approach to predicting the successional change of UMRS plant communities. A more detailed successional model for UMRS floodplain vegetation is needed. Such a model should incorporate site characteristics (geomorphic unit type, hydrologic regime), and information on plant community response to disturbances (flood, wind, fire). Better information on existing floodplain plant communities is also needed. A list of information needs is presented below to help improve the Habitat Needs Assessment for the UMRS.

1. **High Resolution Topographic Data.**
   Current floodplain elevation maps are available at 1:24,000 scale in digital format, but their vertical resolution rarely exceeds ten feet between contours. Some areas have been surveyed as fine as two-foot resolution, but they are typically small, widely dispersed areas. Recent innovations in remote sensing technology allow high-resolution mapping using aircraft mounted lasers; the technology needs to be tested and applied on the UMRS.

2. **System-Wide Bathymetric Data**
   Bathymetric data is essential in characterizing the geometry, depth, and volume of aquatic habitats, and for developing hydraulic models to simulate current velocity and water depth at different levels of river discharge. Although bathymetric data is available for some of the system, completing bathymetric surveys for the remainder of the UMRS should be given a high priority.

3. **Numerical Hydraulic Models**
   Two-dimensional numerical hydraulic models have been developed for a number of UMRS navigation pools. The models provide good simulations of current velocity patterns and water surface elevation profiles at selected levels of river discharge. This information is essential for characterizing aquatic habitat conditions and for describing the hydrologic regime for floodplain habitats. Completing hydraulic modeling of the remaining navigation pools and river reaches of the UMRS should be given a high priority.

4. **Substrate Characterization**
   Substrate characteristics, to a large degree, determine habitat suitability for aquatic plants, benthic organisms, and substrate spawning fishes. Also, identification of areas with highly contaminated sediments may assist in identifying where restoration measures (especially dredging) would be best deferred because of potential adverse ecosystem and social impacts. Widespread sediment monitoring programs should be established to characterize sediments in HREP and other areas, and also to develop models to predict substrates based on depth and flow.

5. **Habitat Quality Metrics**
   Habitat quality metrics based on rapid assessment protocols can efficiently evaluate large areas in an unbiased fashion. The results can be used to help prioritize restoration projects where habitat quality is low, and identify areas with the greatest need for protection where habitat quality is acceptable. The metrics should include random spatial sampling of a suite of water quality and terrestrial habitat characteristics. Fish and wildlife population sampling can be included to meet monitoring and management

objectives. A “roaming team” component could be added to the LTRMP to conduct rapid assessments in non-trend pools.

6. **Floodplain Inundation Models.**
   The combination of high-resolution topography data, the hydrologic record, and output from numerical hydraulic models can provide information on the hydrologic regime (frequency and duration of inundation) to characterize floodplain habitats. Models should be developed to characterize the hydrologic regime of floodplains throughout the UMRS.

7. **Floodplain Geomorphic Classification and Survey**
   High-resolution floodplain topographic data can also be used to help define geomorphic features of the floodplain. Slight topographic variations may define former channels, natural levees, lakes, and terraces that affect plant community development. These features can be classified based on their geomorphic origins. Geomorphic floodplain units can serve well to characterize soil conditions. Geomorphic units of the floodplain and information on the hydrologic regime are essential to characterize floodplain habitat and plant communities.

6. **Surveys of Existing Floodplain Plant Communities**
   The only widespread standardized plant community database for the UMRS is the LTRMP 1989 land cover database. High-resolution data interpreted from photos is available for most of the system, and lower resolution satellite data is used to complete the systemic coverage. While very useful for assessing the distribution and abundance of broad land cover classes, the data do not permit detailed analysis of species composition and fine changes over time. Refined photo interpretation classification procedures are in development, but species level classification is beyond the capabilities of the methodology. Botanical surveys documenting species composition and dominance are needed to relate species distribution to various environmental variables. Botanical surveys over time, or in response to disturbances, would be helpful to document successional pathways. Identification of existing rare and threatened plant communities is needed in planning for habitat protection.

7. **Characterization of the Existing and Pre-Impoundment Hydrologic Regime**
   An essential attribute for characterizing river habitat is the hydrologic regime. The seasonal progression of water levels, and the frequency and duration of inundation are overwhelmingly important ecological conditions that define different river habitats. Work is presently under way as part of the EMP Long Term Resource Monitoring Program to characterize the existing and the pre-impoundment (unregulated) hydrologic regime. This effort should identify the various ways that the present hydrologic regime differs from the unregulated regime in which life in the river has evolved and to which it is adapted. This effort should allow identification of targets for future habitat improvements through river regulation to more closely approximate the unregulated hydrologic regime.

8. **Confirmation/Validation of Species-Habitat Models Using Stratified Random Sampling Data**
   Models associating species and life stages with habitat types will continue to be developed, based on information from the scientific literature, expert estimation, and from direct observation of organisms in their habitats. Where possible, these models should be confirmed through use of data on organism occurrence from stratified-random

sampling. EMP Long-Term Resource Monitoring Program data on the occurrence of fish, aquatic plants, and selected macroinvertebrates should be used to refine and confirm species-habitat models.

9. **Development of Refined Life History Information**
   While numerous studies have been conducted on wildlife taxa of the UMRS, there are still many species whose life histories we know little about. Because the UMRS is vastly different from most upland habitats, the applicability methods used in, and conclusions drawn in other studies to the UMRS needs to be investigated. For example, methods used to survey turtles in small isolated lakes may not provide the same type of information on the UMRS. Differences between the former study area and the UMRS may influence habitat use and behavioral responses of different species, size classes and sexes. Life history traits of some species on the UMRS may differ from those in other areas because of different resource levels and climatological regimes. Furthermore, because of the latitudinal extent of the UMRS, species compositions and life history traits also differ within the system.

10. **Development of Refined Species-Habitat Models**
    Models associating species and life stages with habitat types need to be refined using more complete characterization of habitats. The system of habitat characterization in use on the UMRS is hierarchical, starting with large land cover and geomorphic areas. Additional habitat attributes, such as current velocity, water depth, frequency and duration of inundation of floodplain areas, geomorphic floodplain unit type, etc. can be used to refine habitat characterizations, and "zero-in" on areas that are actually occupied by organisms of interest. Development of advanced species-habitat models is highly recommended.

11. **Analysis of Seasonal Habitat Availability**
    Many species of riverine organisms occupy different habitats when in different life stages and at different times of year. Availability of suitable habitat at any time may impose a "bottleneck" and limit the size of an animal or plant population. Further analysis of the spatial and temporal availability of habitats for highly valued and ecologically important organisms is recommended. Identification of apparent habitat 'bottlenecks' should be confirmed through targeted sampling to confirm the presence of limited habitat and the cause of apparently limited population levels. Scarce habitats identified in this way can be targets for future habitat protection and restoration efforts.

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