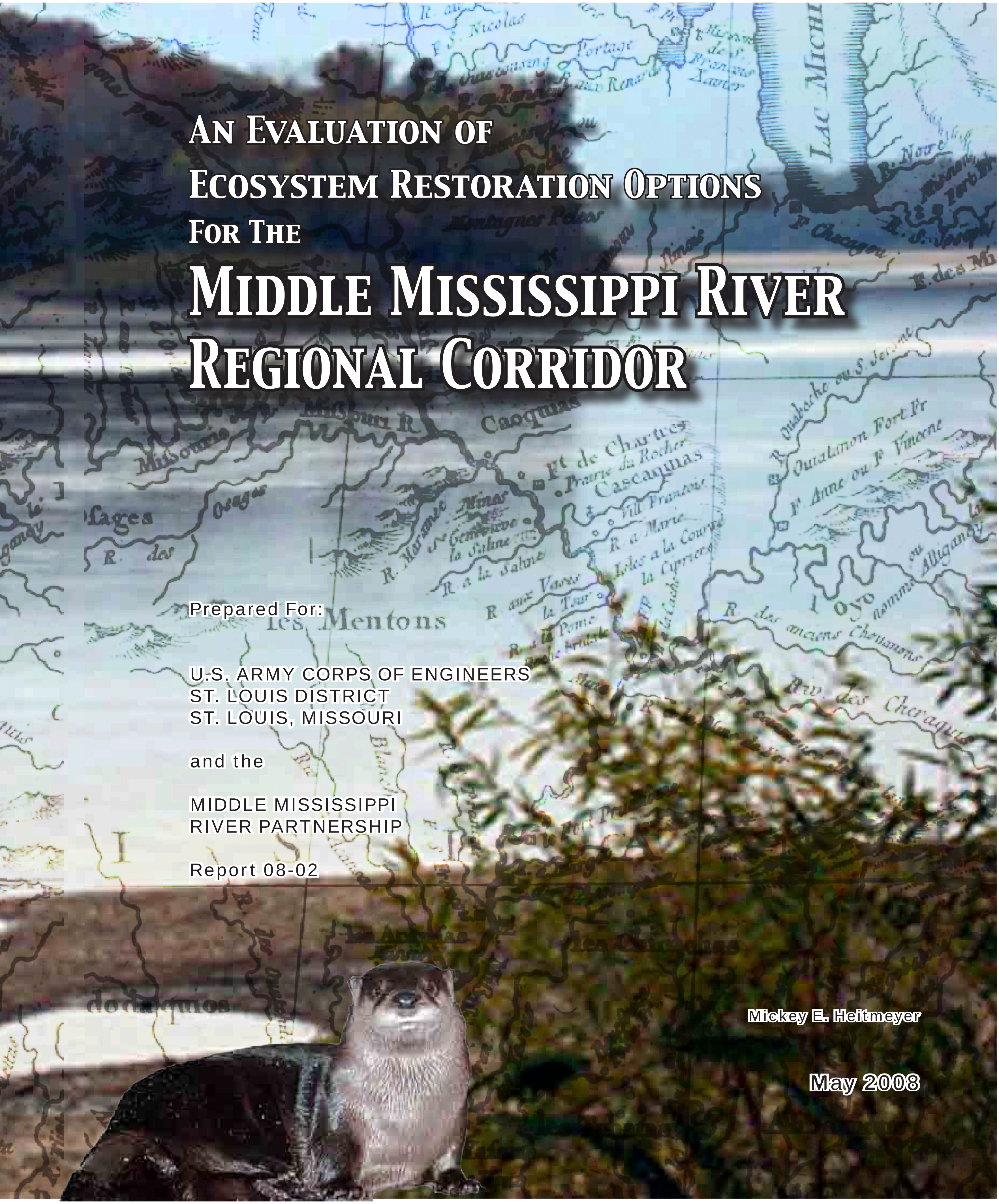

# An Evaluation of Ecosystem Restoration Options for The

# Middle Mississippi River Regional Corridor

Prepared For:

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS DISTRICT
ST. LOUIS, MISSOURI

and the

MIDDLE MISSISSIPPI
RIVER PARTNERSHIP

Report 08-02

Mickey E. Heitmeyer

May 2008

# AN EVALUATION OF ECOSYSTEM RESTORATION OPTIONS FOR THE MIDDLE MISSISSIPPI RIVER REGIONAL CORRIDOR

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ST. LOUIS DISTRICT
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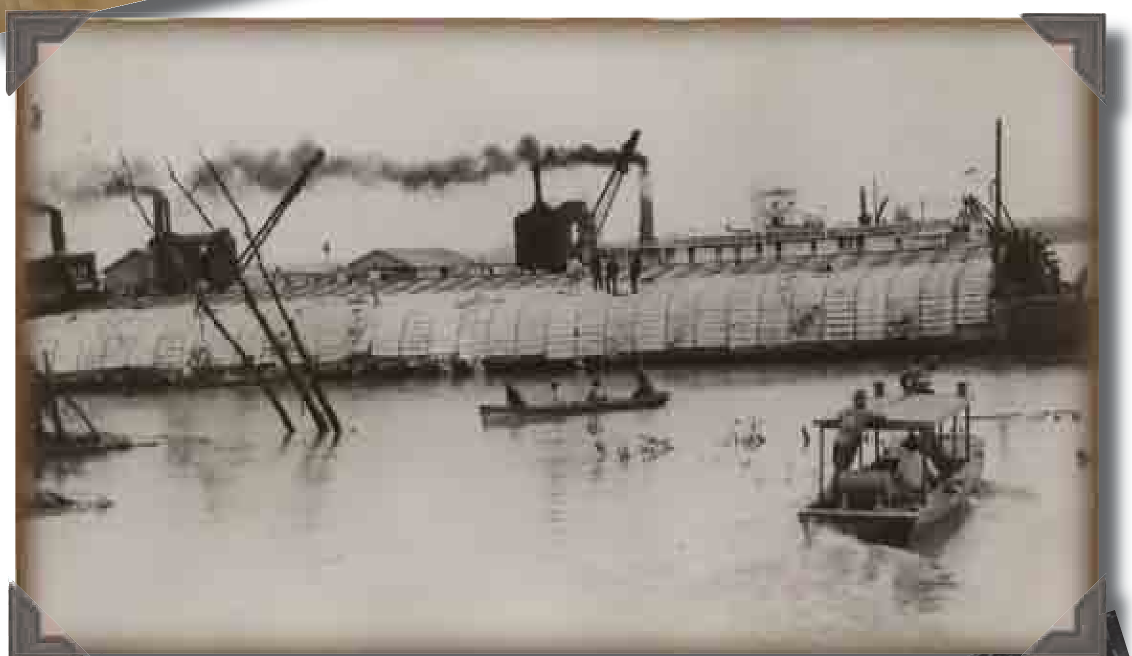


# EXECUTIVE SUMMARY

The Middle Mississippi River Regional Corridor (MMRRC) contains about 673,000 floodplain acres and 195 miles of the Mississippi River from the confluence of the Mississippi and Missouri rivers at St. Louis, Missouri south to the confluence of the Mississippi and Ohio rivers near Cairo, Illinois. The MMRRC is a major navigation transportation corridor and historically supported a continuous corridor of floodplain vegetation communities that supported diverse and abundant fish and wildlife species. Many changes have occurred to this ecosystem including clearing of large areas for agriculture and urban developments; construction of levees, roads, ditches, and rail lines; and alterations to fundamental ecological processes that created and sustained communities and their functions and values.

Many public and private groups are interested in restoring parts of the MMRRC ecosystem. Efforts to coordinate conservation efforts in the region recently have been facilitated by the Middle Mississippi River Partnership, a coalition of nearly 20 partners that includes state and federal resource agencies, non-governmental organizations, and universities. The St. Louis District of the U.S. Army Corps of Engineers and the Middle Mississippi River Partnership recently initiated a cooperative planning project to develop landscape-level restoration plans for the MMRRC using hydrogeomorphic (HGM) analyses to identify ecosystem restoration options. This report provides this HGM-based assessment with the following objectives: 1) Identify the pre-European settlement ecosystem condition and ecological processes in the MMRRC; 2) Evaluate differences between pre-European settlement and current conditions in the MMRRC with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species; and 3) Identify restoration and management approaches and ecological attributes needed to successfully restore specific habitats and conditions within the MMRRC.

The MMRRC contains three distinct ecoregions and evaluations of ecosystem condition and restoration options are categorized by these regions. The first ecoregion, the American Bottoms, extends from the confluence of the Mississippi and Missouri rivers south to where the Kaskaskia River enters the Mississippi River floodplain near Chester, Illinois. The second ecoregion extends from Kaskaskia to the narrow floodplain constriction at Thebes Gap, immediately south of Cape Girardeau, Missouri. The third ecoregion extends from Thebes Gap south to the confluence of the Mississippi and Ohio rivers.

Repeated cycles of vertical incision, aggradation, erosion of bluff materials, and lateral migration by the Mississippi River formed and reshaped the geomorphological surfaces of the MMRRC. The geology of the American Bottoms has been heavily influenced by sediments and flows of the Missouri River and 24 extinct meanders of the Mississippi and Missouri rivers are present in the northern part of the American Bottoms; most of these abandoned channels were created in the last 5,000 years. The Kaskaskia ecoregion reflects attenuation of sediments and flows from the American Bottoms, entry of sediments and flows from the Kaskaskia River, and floodplain constriction at Thebes. The Mississippi River cut through Thebes Gap about 14,000 years ago and the region below Thebes is the northern most extension of the historic Mississippi Embayment.

Eight distinct, Holocene-derived, geomorphic surfaces are present in the MMRRC and include: 1) the main Mississippi and tributary river channels, 2) abandoned river channels, 3) point bars, 4) river chutes and bars, 5) backswamp, 6) alluvial fans and colluvial aprons, 7) natural levees, and 8) tributary valley alluvium. A Pleistocene-age sand and gravel terrace, the Savanna Terrace, also is present at the north end of the American Bottoms and in a small area north of Prairie du Rocher, Illinois. The complex geomorphology of the MMRRC has created a heterogeneous mosaic of floodplain topography, soils, and elevations that in turn have created a complex and heterogeneous vegetation ecosystem.

The climate of the MMRRC is continental with a strong seasonal pattern and wide ranges of interannual temperature and precipitation extremes. These seasonal and annual patterns, especially precipitation, influence the hydrology of the MMRRC as does amount and distribution of flows in the Mississippi River related to climate and snowmelt in the watershed above St. Louis. Mississippi River flows and floodplain hydroperiods are highest during spring and early summer, decline to low levels in late summer and early fall, and usually stay low through winter. Historically, at least some overbank flooding occurred annually in much of the MMRRC floodplain. Long-term historical records indicate an approximate 11-15 year pattern of increasing discharge and floodplain flooding followed by declining flows and droughts.

Major historical vegetation communities/habitat types in the MMRRC included: 1) the main channel and islands of the Mississippi River and its tributaries, 2) river Chutes and Side Channels, 3) Bottomland lakes, 4) Riverfront Forest, 5) Floodplain Forest, 6) Bottomland Hardwood Forest (BLH), 7) Slope Forest, 8) Bottomland Prairie, 9) Mesic Terrace Prairie, and 10) Savanna.

An HGM-matrix was developed to describe the location and characteristics of each major community. Bottomland Lakes historically were present throughout MMRRC floodplains and occupied abandoned river channels. Many Bottomland Lakes in the American Bottoms were surrounded by prairie-type communities, but more southern Bottomland Lakes contained forest and shrub/scrub edges and the natural levees along these lakes were forested. Water regimes in Bottomland Lakes were mostly permanent, with seasonal drawdowns of lake edges and occasional complete drying in older, sediment-filled, channels during dry periods of long-term hydrological cycles.

Riverfront Forest was present on chute and bar geomorphic surfaces, some point bar areas near the current Mississippi River channel, and along edges of some Bottomland Lakes. These communities were flooded annually for some duration during spring and summer and supported early succession trees such as willow, silver maple, cottonwood, and sycamore with occasional swamp white oak, pin oak, and pecan on higher elevation ridges.

Floodplain Forest historically covered large expanses of the MMRRC floodplain on point bar surfaces and along tributary streams. This forest community was a transition from the early succession Riverfront Forest on new coarse-sediment surfaces along river channels to BLH communities that occurred in clay-type soils in backswamps and southern floodplain depressions. Floodplain Forest typically developed on mixed silt loam soils on older point bar ridge-and-swale topography and were within the 1-2 year flood frequency zone. Floodplain forest was dominated by elm, ash, sweetgum, sugarberry, and box elder; higher elevation ridges and natural levees contained scattered pecan, pin and swamp chestnut oak, honey locust, and hickory.

BLH, also sometimes called "lowland depressional forest" was present in low elevation depressions, backswamps, and old braided river terraces in the MMRRC mostly south of Kaskaskia. These communities were dominated by oak; had thick clay-type soils; and were seasonally flooded from local or upland runoff, slow backwater or sheetflow overbank flows of MMRRC tributaries, and backwaters of larger Mississippi River floods. BLH communities range from Cypress-Tupelo stands in low elevations that were flooded for extended periods each year to High BLH stands dominated by red oak, hickory, and elm at high elevations that were flooded only a few weeks annually during most years.

Slope Forest occupied alluvial fans and higher terraces along the edges of MMRRC floodplains. These forests contained a unique mix of tree species representing both upland and bottomland communities that occurred in adjacent higher elevation uplands or bluffs and lower elevation floodplains. These communities often contained hickory, sugarberry, swamp white and swamp chestnut oak, white and bur oak, black walnut, ash, mulberry, box elder, paw paw, hawthorn, persimmon, and slippery elm. Slope Forest was not flooded except during extreme Mississippi River flood events.

Prairies occupied extensive areas of the MMRRC north of Kaskaskia. Most of these prairies were Bottomland Prairie communities, but smaller areas of Mesic Prairie were present on higher elevation terraces and ridges. Generally, Bottomland Prairie occupied older point bar surfaces where elevations were at 2-5 year flood frequencies. Soils under Bottomland Prairies ranged from silt-clays in swales to silt or sandy loams on ridges. The distribution of Bottomland Prairie was determined by the dynamic line of where floodwaters regularly ranged toward higher floodplain elevations vs. the line where fires that originated from uplands and higher elevations moved into the wetter lowlands. At the higher elevations of the MMRRC floodplain, Bottomland Prairie changed to zones of Mesic Prairie and eventually into Savanna and Slope Forest on alluvial fans and upland/bluff margins.

The distribution and area of the Presettlement communities in the MMRRC ecoregions were mapped using HGM matrix criteria and confirmed by a combination of historic maps, botanical accounts, General Land Office surveys, and reference sites of remnant native vegetation. The diversity of Presettlement communities was highest in the American Bottoms and lowest in the southern Thebes ecoregion. Moving from north to south in the MMRRC, prairie was abundant (29% of total mapped area excluding the Mississippi and tributary river channels, bars, and side channels/chutes) in the American Bottoms, but was present only on what is now Kaskaskia Island (1.8% of the Kaskaskia ecoregion), and did not occur in the Thebes ecoregion. Floodplain Forest increased from 19% in the American Bottoms to 53% in Kaskaskia and then declined to 10% at Thebes. In contrast, BLH was absent of the American Bottoms, but increased to 8% at Kaskaskia and 63% at Thebes. Riverfront Forest occupied 25% in the American Bottoms, but only 20% and 16% at Kaskaskia and Thebes, respectively. Bottomland Lakes occupied 6-8% of all ecoregions.

Many ecosystem changes have occurred in the MMRRC since the Presettlement period; the most notable changes have been widespread conversion of native habitats to agriculture and urban areas; structural modifications to the Mississippi

River channel and changed river geomorphology; reduced overbank flooding into MMRRC floodplains in areas behind mainstem levees; modified drainage from roads, levees, and ditches; altered topography from human activities; and decreased abundance and diversity of certain invertebrate, fish, and wildlife populations. A large amount of the MMRRC had been converted to agriculture and urbanization by 1890. Total MMRRC area of prairies, Savanna, and Slope Forest were over 90% destroyed compared to the Presettlement period. Floodplain Forest declined 70%, BLH declined 65%, Riverfront Forest declined 40% over this time, and Bottomland Lake area declined nearly 66% by 2006.

Despite the many alterations to the MMRRC ecosystem, opportunities exist to restore at least some parts of the region. The HGM process used in this report allows conservation interests to: 1) identify what communities "belong" in specific locations, 2) determine what ecological processes are needed to restore and sustain specific habitats, 3) determine the extent and types of alterations to historic communities, 4) determine constraints to restoration and management of specific sites, and 5) determine the best opportunity to restore specific habitats and locations.

Based on information from this study, conservation actions in the MMRRC should seek to:

1. Protect and sustain existing floodplain areas that have plant communities similar to Presettlement conditions.

2. Restore plant and animal communities in appropriate topographic and geomorphic landscape position related to HGM characteristics.

3. Restore at least some sustainable patches of habitats that have been highly destroyed or degraded such as prairie, Bottomland Lake, and Floodplain Forest.

4. Restore habitats and areas that can serve as a "core" of critical, sometimes limiting, resources that can complement and encourage restoration and management on adjacent and regional private lands.

This report does not attempt to prioritize specific sites that can be restored. The key to restoring biodiversity, functions, values, and sustainable communities in the MMRRC is to restore a mosaic of habitats in natural distribution patterns and to restore some semblance of natural hydrology and floodplain water flows in this ecosystem. The report identifies landscape and ecological characteristics that are needed to successfully restore specific habitats. The HGM matrices produced in this report help decide what restoration options are most useful and appropriate if: 1) sites are sought to restore specific habitat types including those types that are greatly reduced in area and distribution (e.g., prairies), represent a key "gap" in coverage or connectivity (e.g., Floodplain Forest), provide key resources for animal species of concern (e.g., giant canebrakes within BLH), or are needed for mitigation; or 2) a site becomes available or offered to a group and decisions must be made on what habitats can/should be restored on the site given budget, management, and development constraints. The report identifies specific HGM characteristics of all major communities in the MMRRC related to these restoration contexts.

A productive strategy for ecosystem restoration within the MMRRC will be to proactively seek sites that offer potential for restoration of habitat complexes. It is recommended that the following items be incorporated into a comprehensive ecosystem restoration and conservation strategy for the MMRRC:

1. Restore at least some functional areas of the most destroyed habitat types, especially Bottomland and Mesic Prairie, Savanna, Bottomland Lake, and Floodplain Forest.

2. Expand remnant BLH patches and restore natural hydrological regimes that match natural dynamics of respective Low to High BLH communities.

3. Expand and diversify Riverfront Forest communities to create functional corridors along the Mississippi River and include some hard mast tree species on the highest ridges and natural levee elevations.

4. Reconnect select Side Channels and Chutes along the Mississippi River.

5. Create buffers of habitat complexes around floodplain wetlands, especially Bottomland Lakes, point bar swales, and backswamp depressions.

6. Identify possibilities for restoring hydraulic connectivity between MMRRC rivers and their floodplains, especially backwater flows into sloughs, swales, abandoned channels, and backswamp depressions.

Information in this report provides most, but not all, of the answers to help conservation planners make restoration decisions in the MMRRC. At a broad landscape scale, the report identifies historic types and distribution of communities, what communities now exist, and the suitability of contemporary areas to restore each community type. This regional information then can be used by conservation partners to understand which communities have been most lost and where they may wish to work to restore basic parts of the MMRRC ecosystem. At the site-specific scale, this report also provides much of the information needed to determine what communities potentially could be restored at a site. The report offers a procedure to determine optimal restoration options for sites and provides an example of this "How-To" process for one MMRRC area, Wilkinson Island.

Ultimately, restoring components of the historic MMRRC ecosystem will require many physical and biological strategies. Much information developed in this report will help inform strategies, but some uncertainties remain about specific techniques, hydrological variables, community responses, and larger-scale interactions of habitats and sites. Future restoration and management of ecosystems in the MMRRC can be done in an adaptive management framework where predictions about specific management or restoration actions can be made and then select biotic and abiotic parameters are monitored and evaluated to determine system responses and to suggest changes in management or strategies that are needed to achieve desired results. The most important features that will need monitoring include: 1) hydrological regimes including routes and interactions of surface and subsurface water flows; 2) sediment and nutrient loads and contamination rates; 3) occurrence and effect of soil and vegetation disturbances; 4) composition, distribution, survival, and regeneration of plant species expected in restored communities; and 5) occurrence, abundance, and distribution of key invertebrate and vertebrate animals.

# INTRODUCTION

The Middle Mississippi River Regional Corridor (MMRRC) contains about 673,000 floodplain acres and 195 miles of the Mississippi River from the confluence of the Missouri and Mississippi rivers at St. Louis, Missouri south to the confluence of the Ohio and Mississippi rivers (Fig. 1). The MMRRC is a major navigation transportation corridor, located centrally within the larger Mississippi River drainage system, and it is heavily used for shipping agricultural commodities, industrial products, and commercial goods. The Mississippi River in the MMRRC is often referred to as the "Open" or "Unimpounded" river because no locks and dams are present on it in this region. Several major ports and larger cities including the St. Louis metroplex; Cape Girardeau and St. Genevieve, Missouri; and Chester and Cairo, Illinois are located in the MMRRC.

The MMRRC begins near the confluences of three of the largest rivers in North America, the Mississippi, Missouri, and Illinois rivers. The large watersheds of each of these rivers and their temporal and spatial dynamics have greatly influenced the physical nature and ecological attributes of the MMRRC. The MMRRC contains some of the most diverse and productive ecosystems in North America. The productivity and fertility of the MMRRC was attractive to some of the first native people to populate North America and many early villages were present in the region (Temple 1965, 1966). For example, the native settlement at Cahokia was one of the largest Mississippian era communities in North America and was a hub of society, commerce, and cultural exchange at that time (Pauketat 2004). Early European explorers and settlers moving westward in the United States in the 1700s and early 1800s also were attracted to the region and they established forts, communities, and ports throughout the MMRRC (Gums 1988). Most early settlers were of French and German descent and the region retains a strong cultural heritage and influence of these people.

The MMRRC contains three distinct ecoregions (Fig. 2). The northern part, often referred to as the "American Bottoms" ranges from the confluence of the Missouri and Mississippi rivers at St. Louis south to where the Kaskaskia River joins the Mississippi River near Chester, Illinois. The term

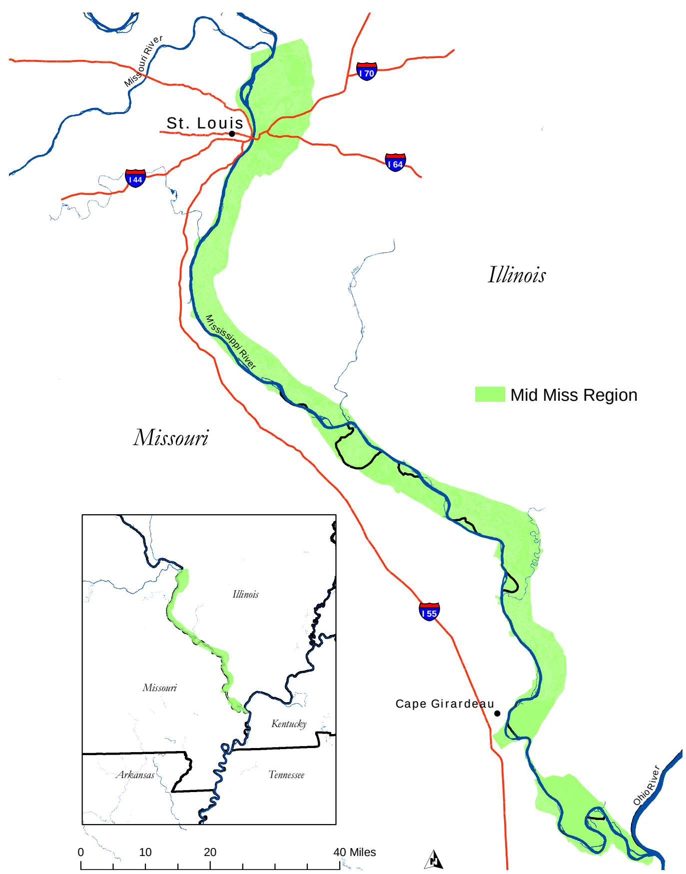



Fig. 1. General location map of the Middle Mississippi River Regional Corridor.

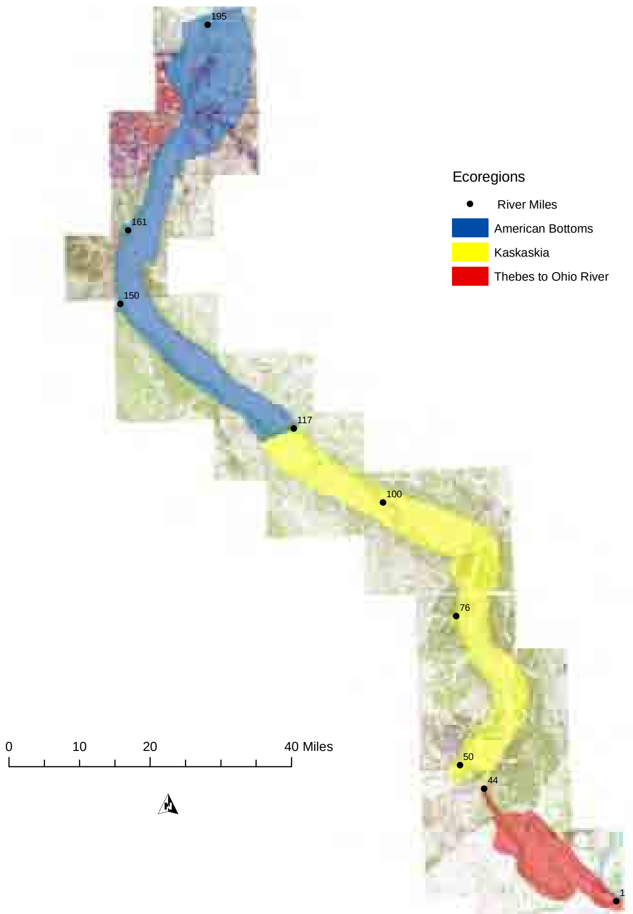



Fig. 2. Ecoregions within the Middle Mississippi River Regional Corridor.

"American Bottoms" was used to describe the area east of the Mississippi River in the MMRRC that became part of the United States following the American Revolutionary War in the late 1700s. The west side of the Mississippi was owned first by Spain and then France, and subsequently was transferred to the Unites States in 1803 as part of the "Louisiana Purchase." Vegetation communities in the American Bottoms represent a southern extension of the northern "Prairie Peninsula" physiographic region (Transeau 1935) and landforms have been influenced greatly by the junction of the Missouri and Mississippi rivers (Fenneman 1909, Schwegman 1973a). The second MMRRC ecoregion ranges from Kaskaskia to the narrow river floodplain "gap" located at Thebes, Illinois just south of Cape Girardeau. This "Kaskaskia" ecoregion is influenced and changed by the entry of water and sediments from the Kaskaskia River into the Mississippi River floodplain. The third ecoregion of the MMRRC, referred to as the "Thebes" ecoregion, extends from Thebes to the confluence of the Ohio and Mississippi rivers and represents the northern most part of the Mississippi Alluvial Valley (MAV) that extends from the Gulf of Mexico to Thebes.

Some early explorers described the MMRRC, especially the northern American Bottoms area across from St. Louis, as a "land of immeasurable beauty and vast prairies", "a pristine natural paradise", a "sea of verdure" and "the most diverse and productive land ever encountered" (e.g., Schoolcraft 1825 and many other explorer accounts summarized in White 2000). Others, such as Charles Dickens (1987:220-222) were not so kind in words, and called the area "a thoroughly distasteful and unwholesome place", and on every side of his path he described it as "vast tracts of undrained swampy land with stagnant, slimy, rotten, filthy water." Still other writers called the region "inhospitable", "dark and dreary", a "swamp morass full of voracious insects", and an "unbroken slough" (Beck 1823, Peck 1837, 1839, Oliver 1843, Reynolds 1854, 1855). The descriptions from the early explorers attest to the diversity of ecological communities in the MMRRC that ranged from prairie-dominated floodplains in the north to lowland bottomland hardwood forests and "swamps" in the south.

Beginning with native peoples, ecosystems and landforms in the MMRRC have been modified both in form and function. Human developments for communities, transportation, agriculture, access to building and fuel materials, drainage, and flood protection have forever changed the region. The Mississippi River in the MMRRC now is confined by major levees as are some larger tributaries (such as the Kaskaskia and Big Muddy rivers), and the floodplain is laced with smaller levees, drainage ditches, roads, and urban developments especially in the American Bottoms east of St. Louis (Fig. 3). Despite these changes, the MMRRC retains many areas of pre-European settlement landforms and vegetation/aquatic communities.

Many public and private groups are interested in restoring parts of the MMRRC ecosystem (e.g., Schwegman 1973b, S. 507 Water Resources Development Act of 1999, Theiling et al. 2000, American Land Conservancy 2005). Efforts to coordinate conservation efforts in the region recently have been facilitated by the formation of the Middle Mississippi River Partnership. This partnership group is a coalition of nearly 20 partners that include state and federal resource agencies, non-governmental conservation organizations, and universities. The collection of partners share a common goal of restoring and enhancing natural resources within the MMRRC through direct management of public lands and promoting conservation efforts on private lands. Each partner offers different, but complementary, capabilities and objectives to assist with ecosystem restoration projects and policies. The success of restoration efforts in the MMRRC depends on obtaining information about: 1) what presettlement communities were present and how they were distributed in the region; 2) what ecosystem types have been most destroyed and where key "gaps" exist in habitat complexes; 3) what ecosystem changes are most permanent, and in contrast, which changes can be reversed; 4) what ecological processes controlled and sustained communities; and 5) where the most economically and ecologically efficient sites for restoration are located.

Recently, hydrogeomorphic (HGM) analyses have been used to identify ecosystem restoration options of large river floodplain systems such as the MMRRC (e.g., Heitmeyer et al. 2002, Heitmeyer and Fredrickson 2005, Heitmeyer and Westphall 2007). The HGM approach: 1) uses information on geomorphology, soils, topography, and hydrology to develop appropriate and realistic habitat and landscape-scale objectives; 2) seeks to emulate natural water regime and vegetation patterns where possible; 3) understands, complements, and at least partly mitigates negative impacts to floodplain ecosystems; 4) incorporates "state-of-the-art" scientific knowledge of floodplain processes and requirements of key fish and wildlife species; and 5) recognizes the desire to provide for multiple uses including recreational, agricultural, navigation, and educational opportunities for the public.

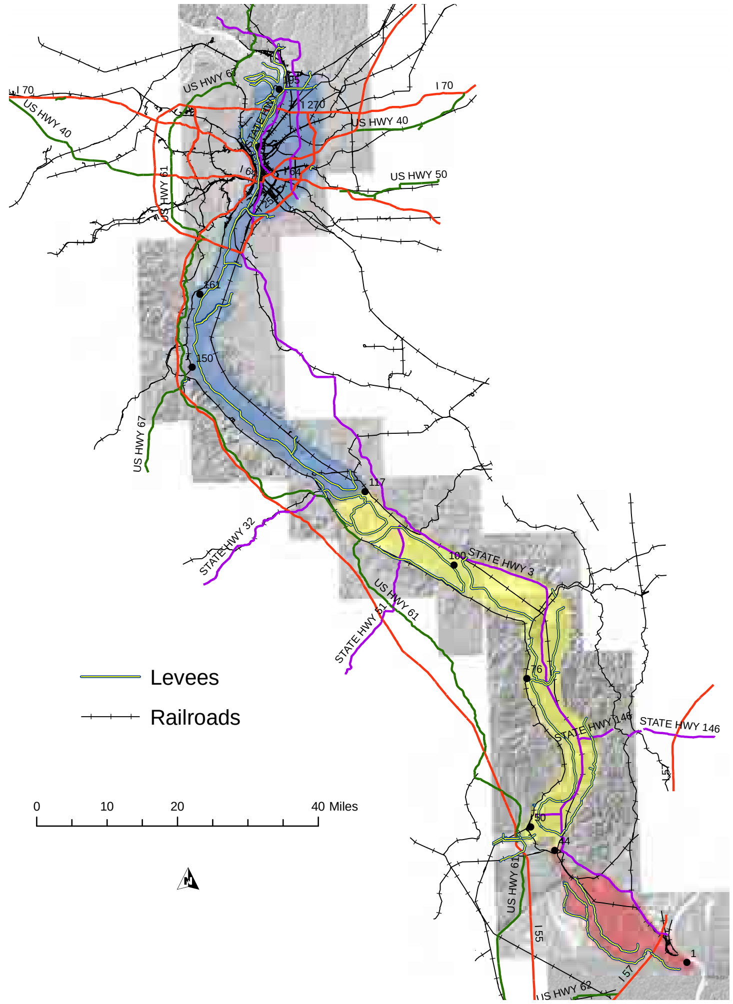



Fig. 3. Major roads, railroads, and levees within the Middle Mississippi River Regional Corridor.

This report uses the HGM process to evaluate ecosystem restoration options for the MMRRC. Objectives of this report are to:

1. Identify the pre-European settlement ecosystem condition and ecological processes in the MMRRC.
2. Evaluate differences between pre-European settlement and current conditions in the MMRRC with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.
3. Identify restoration and management approaches and ecological attributes needed to successfully restore specific habitats and conditions within the MMRRC.

This HGM-based assessment supports the Middle Mississippi River Regional Corridor Project of the St. Louis District of the U.S. Army Corps of Engineers (USACE) . This project is a cooperative planning project with the Middle Mississippi River Partnership and it seeks to develop a landscape-scale restoration plan for the MMRRC. This report identifies ecosystem restoration options to: 1) sustain long-term system function, values, and processes; 2) provide a "core" area of floodplain resources and communities that can be a foundation for restoration and management on adjacent and regional lands; 3) emulate natural hydrological and community distribution and dynamics; and 4) restore critical habitats and resources for key fish and wildlife species.

# THE HISTORIC MIDDLE MISSISSIPPI RIVER ECOSYSTEM

## GEOLOGY, SOILS, AND TOPOGRAPHY

The MMRRC is the central part of the incised channel of the Mississippi River, which has been the primary drainage system for Interior North America since the Late Mesozoic period (the last 150 million years) (Mann and Thomas 1968). Paleozoic sediments underlay and surround the alluvial surfaces of the MMRRC floodplain and range from Ordovician through Mississippian age (McCracken 1961, Willman 1967, Willman and Frye 1970). The Paleozoic river bluffs contain sandstones, shale, and limestones, while the floodplain contains Pleistocene glacial outwash and Holocene fluvial deposits. The southern portion of the MMRRC transitions into the Mississippi Embayment, now typically referred to as the MAV. The average elevation of the down-cut Holocene Mississippi River valley varies from about 300 feet above mean sea level (amsl) at St. Louis to about 220 feet amsl at Cape Girardeau (Fenneman 1909, Soileau 2002). Current floodplain elevations range from slightly over 400 feet amsl at St. Louis to about 300 feet amsl at Cairo, Illinois. Consequently, alluvial fill is up to 100 feet deep in much of the MMRRC floodplain along the axis of the valley and becomes progressively shallower along bluff walls.

Upland bluffs, 100 to 200 foot high, border the MMRRC floodplain and represent the Ozark Plateau to the west in Missouri and the Central Lowland to the east in Illinois (Schwegman 1973a, Nelson 2005). A small part of the bluffs south of Stolle, Illinois lie in the eastern most extreme of the Salem Plateau of the Ozark Plateau. Much of the Central Lowland in Illinois is considered the Springfield Till Plain that is covered by loess deposited during the Pleistocene epoch. The Salem Plateau consists of low hills and broad drainage divides that developed on thick Mississippian limestone, which is overlain by several feet of sandy, gravelly glacial till probably Kansan in age and by 10-26 feet of silt and silty clay. The Illinois uplands were sculpted by advances and retreats of glaciers and the depth of unconsolidated materials over bedrock is up to 150 feet. The Salem Plateau south of Stolle is karst topography and contains numerous sinkholes (Lineback 1979). The east-central part of the MMRRC boundary is often referred to as the "Sinkhole Plain" (Illinois Department of Natural Resources 1998).

Repeated cycles of vertical incision, aggradation, erosion of bluff materials, and lateral migration by the Mississippi River formed and reshaped the geomorphological surfaces of the MMRRC (Simons et al 1974, Saucier 1974, 1994, Hajic 1990, 2000, Woerner et al. 2003, Brauer et al. 2005). The oldest deposits in the MMRRC floodplain are from Pleistocene glacial outwash that contain sand and gravel and grade upward into silty sands. A wedge of coarse-grained deposits associated with the meandering Mississippi River overlies these outwash deposits. The Mississippi River apparently changed from a more braided system to a meandering system about 6,000 years before the present (BP). To the south, the Mississippi River cut through the Thebes Gap about 14,000 BP following massive glacial meltwater flows at the end of the Wisconsin glacial period. After the Mississippi River cut through Thebes Gap it occupied the former channel of the Cache River in southern Illinois and then joined the Ohio River at Cairo. Prior to this period the Mississippi River flowed southwest from Cape Girardeau through the Advance Lowland and down what is now the St. Francis River channel corridor and joined the Ohio River near the present town of Helena, Arkansas (Saucier 1994, Heitmeyer et al. 2006). Consequently, the MMRRC region below Thebes represents a relatively recent channel of the Mississippi River and has sedimental characteristics of both the MAV and recent Mississippi River outwash deposits.

Table 1. Approximate age (years before the present) that abandoned channels were cut-off from the Mississippi River in the Northern American Bottoms (from Munson 1974).

| Meander Segment | Cut-off |
|---|---|
| Cahokia Slough | Pre-275 |
| Chouteau-Gaberet | Pre-275 |
| Horseshoe Lake | Pre-900 |
| Goose Lake | Pre-1100 |
| St. Thomas | Pre-1600 |
| Grand Marais | Pre-1600 |
| Oldenberg | Pre-1600 |
| Nameoki | Pre-1600 |
| Edelhardt Lake | Pre-2200 |
| Stallings | Pre-2200 |
| Pontoon Beach | Pre-2200 |
| McDonough Lake | Pre-2800 |
| Spring Lake-Jones Park | Pre-2800 |
| Fish Lake | Pre-2800 |
| Rock Road | Pre-2800 |
| Prairie Lake | Pre-2800 |
| Bullfrog Station | Pre-2800 |
| Crooked Lake | Pre-2800 |
| Grassy Lake | Pre-5000 |

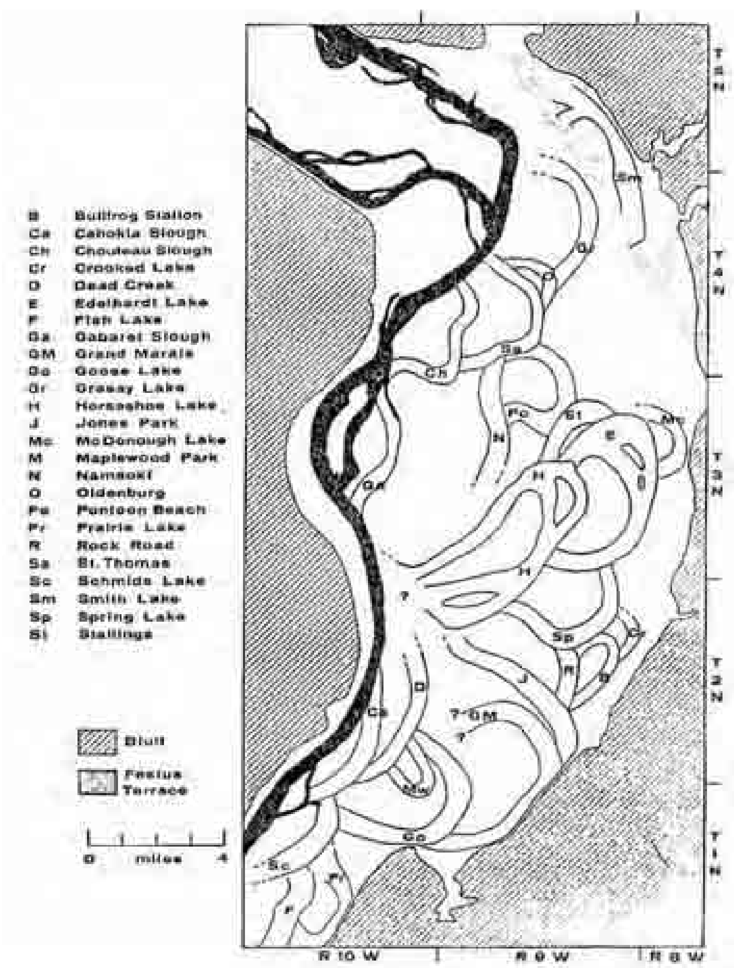



Fig. 4. Paleochannels and meander loops within the American Bottoms (from Munson 1974).

The current floodplain of the MMRRC has been sculpted by scouring and deposition in the Holocene period caused by a frequently meandering river system. For example, 24 extinct meanders of the Mississippi and Missouri rivers are present in the northern part of the American Bottoms (Fig. 4); most were created within the last 5,000 years (Table 1). Coarse-grained substratum deposits are overlain by a relatively thin, often discontinuous, veneer of fine-grained deposits throughout the MMRRC. The depth of veneers depends on the geomorphic surface and age of deposition and subsequent flood/scour events (Fig. 5).

Eight distinct Holocene-derived geomorphic surfaces are present in the MMRRC and include: 1) the main Mississippi River and its tributary channels, 2) abandoned river channels (often called paleochannels), 3) point bars, 4) river chutes and bars, 5) backswamp, 6) alluvial fans and colluvial aprons, 7) natural levees, and 8) tributary valley alluvium that is often mapped as undifferentiated alluvium (Fig. 6). A Pleistocene-age sand and gravel terrace also is present at the north end of the American Bottoms and a smaller terrace area is present north of Prairie du Rocher, Illinois (Fig. 6, Munson 1966, Hajic 1993). These Pleistocene terraces rise 25-35 feet above the floodplain and contain rolling sand dunes in some areas. These terraces were named the "Wood River Terrace" by Bergstrom and Walker (1956), but now are recognized as the southern-most part of the "Savanna Terrace" that is preserved in many northern parts of the Mississippi Valley (Hajic 1993). The Savanna Terrace is an extensive late Wisconsin valley surface that extends northward into Mississippi Valley tributary floodplains in Wisconsin and Minnesota. The channels of Cahokia Creek, Indian Creek, and Wood River dissect the Savanna Terrace in the northern part of the American Bottoms. The ancient "Smith Lake" meander of the Mississippi River lies on the north side of the terrace between Roxana, Illinois and the bluff and another, more recent meander "Grassy Lake", bounds the south edge of the terrace at South Roxana.

Abandoned channels are partly or entirely filled segments of ancient river channels. Abandoned channels are numerous in the MMRRC (Fig. 6) and represent frequent migrations of the Mississippi River and fluvial influences of the Missouri, Ohio, Kaskaskia,

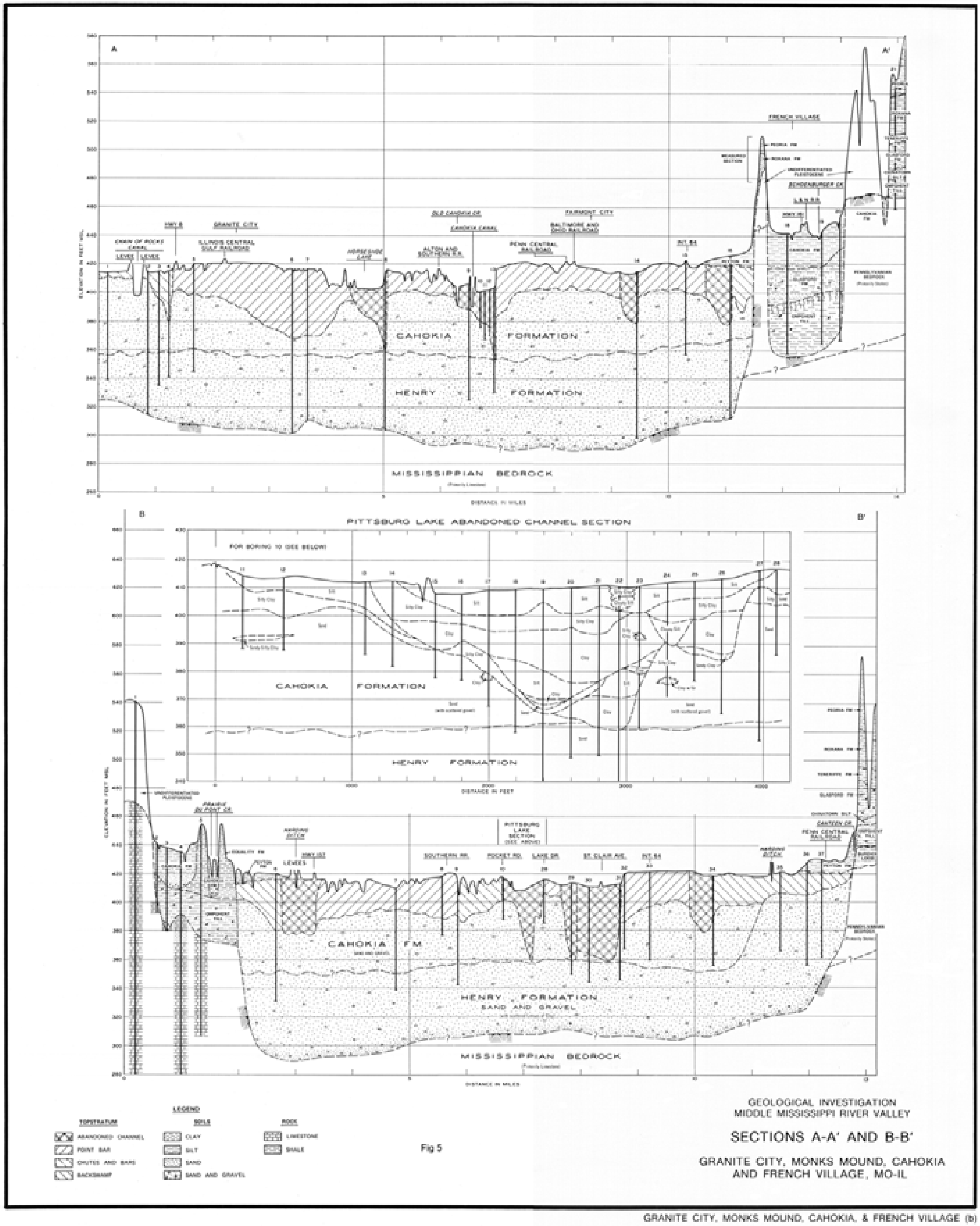



Fig. 5. Cross-section of the geological surface and subsurface stratigraphy of the Mississippi River floodplain from Granite City, Missouri to Cahokia, Illinois (from Woerner et al. 2003).

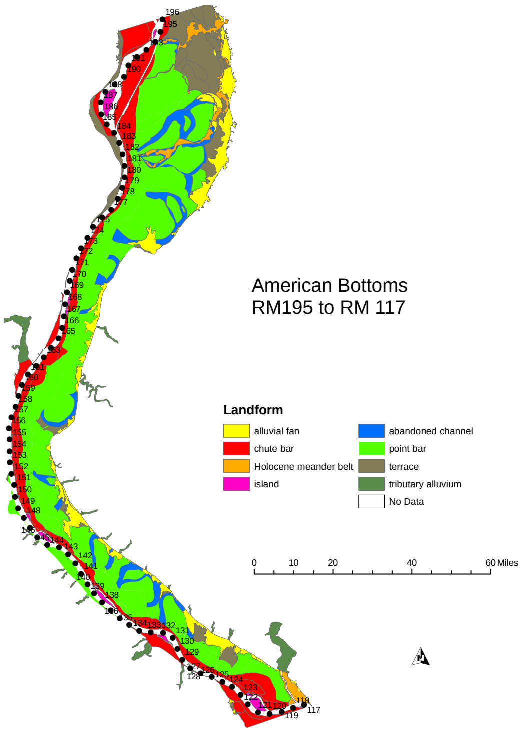



Fig. 6a. Geomorphology maps of the Middle Mississippi River Regional Corridor (modified from Saucier 1994, Hajic 2000, and Woerner et al. 2003).

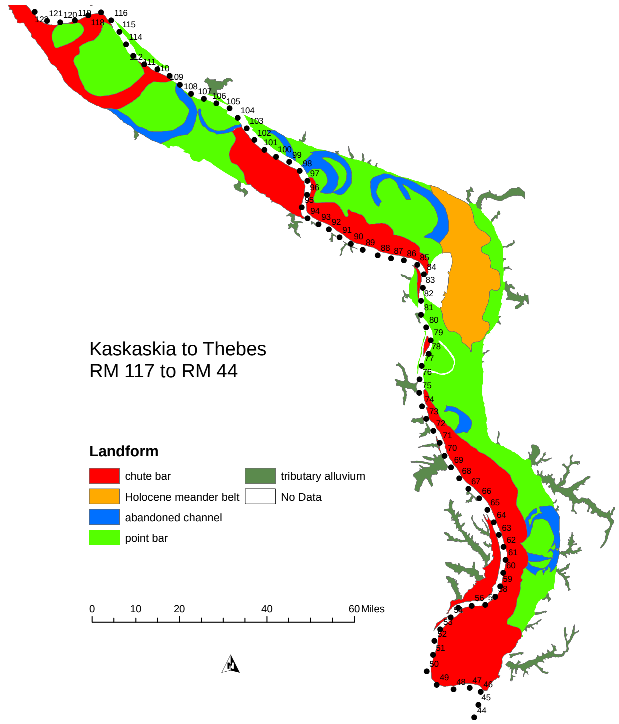



Fig. 6b. Geomorphology maps of the Middle Mississippi River Regional Corridor (modified from Saucier 1994, Hajic 2000, and Woerner et al. 2003).

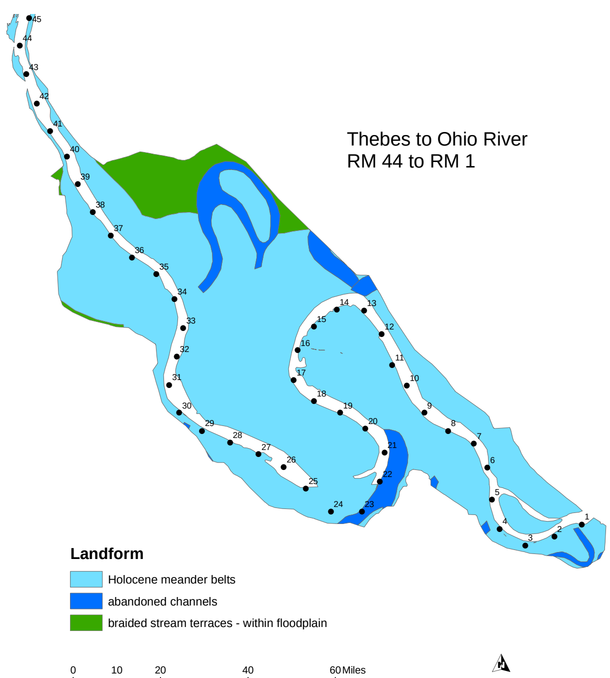



Fig. 6c. Geomorphology maps of the Middle Mississippi River Regional Corridor (modified from Saucier 1994, Hajic 2000, and Woerner et al. 2003).

and Big Muddy rivers where they join the Mississippi River. More recent abandoned channels usually are deeper and have open water habitat in the central parts of the channel. Abandoned channels become "Bottomland Lakes" or "oxbows" after they separate from the main river channel. The upper portion of abandoned channel "arms" usually are filled with a short wedge of sand or silty sand, while the remainder of the abandoned channel depression is filled with fine-grained clay and silty clay (Fig. 7). Over time Bottomland Lakes gradually fill with sediments and eventually become obscured by subsequent meander belt deposits. Abandoned channels that rapidly fill after separation from the main river channel usually are mapped as chute and bar geomorphic surfaces (Woerner et al. 2003). Other older abandoned channels often are partly, or completely, buried by newer sediments including backswamps and braided stream terraces, especially south of Kaskaskia. Most abandoned channels in the MMRRC are < 5,000 years old (Table 1), range from 3 to 17 miles in length, are up to several thousand feet wide, and are 20-30 feet deep. More abandoned channels occur in the American Bottoms than in other MMRRC regions.

Point bar surfaces in the MMRRC are lateral accretion deposits formed during horizontal migration of river and stream channels. As channels migrate they laterally build a bar of silt and sand on the inside (point bar "ridge") bank and create a "cut" or "swale" on the outside bank. The formation of a series of lateral bars creates a corrugated surface of silty sand ridges and alternating clay or silty clay filled depressions or swales (Fig. 7). Point bar deposits are the predominant depositional environment in the MMRRC (Fig. 6). Point bar surfaces typically are much older ( > 2,000 years), and contain thicker alluvial soils (5-25 feet) than chute and bar surfaces.

Chute and bar geomorphic surfaces form in similar manner to point bar deposits, except that their surfaces are frequently inundated by high velocity floodwaters that cause considerable scouring and redistribution of sediments. Consequently, chutes and bars typically are arrayed in parallel bands near the active channel of the Mississippi River and represent relatively new geomorphic and soil environments (Fig. 6). Chutes and bars have less developed top stratum than point bars and often contain a very thin, often temporary, veneer of recently deposited natural levee material. Chutes and bars are the second most common geomorphic surface in the MMRRC (Fig. 6). Soils on chutes and bars range from sand and gravel at the base near the river to highly irregular top strata of silty sand ridges and moderately deep silty clay and clay-filled river chutes (Fig. 7). Sediments in chutes are laterally variable and may contain as much as 20-30 feet of silt and clay. Side channels are flow channels that remain connected, and that river water flows through, for at least some portions of the year. Over time, as side channels become plugged with sediments, and/or as the main river channel migrates away from the side channel, they become isolated chutes.

Backswamp deposits contain fine-grained sediments deposited in broad low elevation basins usually on the edges of floodplains. Backswamp deposits occur between natural levee ridges of former channels of the Mississippi River or between natural levee ridges along tributaries and floodplain valley walls. Backswamps often cover older geomorphic surfaces (such as abandoned channels that occurred along floodplain bluffs) and are relatively flat with complicated, labyrinth-like, internal drainage systems where channels alternatively serve as tributaries or distributaries of the Mississippi River during various flood events. Backswamp deposits in the MMRRC are confined to a small area along the eastern valley wall in the northern American Bottoms and a large contiguous basin east of Fountain Bluff (Fig. 6). Soils in backswamps are almost entirely clay and silty clay 15-30 feet thick; occasional thin lenses or lamina of silt and sand may be present (Fig. 7). Some backswamps have considerable organic material in surface layers in the form of disseminated plant particles, peat, and woody residue.

Fan-shaped deposits of sediments form at the base of upland bluffs in the MMRRC where tributary streams enter the Mississippi River floodplain (Leigh 1985, Hajic 1993). These "alluvial fans" or "colluvial aprons" radiate outward onto the floodplain and have variable shape and size depending on volume and velocity of material that has eroded from the bluffs and tributaries. Alluvial fans and colluvial aprons are present throughout the MMRRC, mostly on the eastern side of the floodplain and on the east side of Fountain Bluff (Fig. 6). Soils on alluvial fans are mostly redeposited loessial silts with lenses of sand and silty clay (Fig. 7). These alluvial fan soils generally are relatively "loose" and well drained compared to clay or silt-veneered floodplain surfaces.

Natural levees are low wedged-shaped ridges that border one or both sides of river channels, either recent or ancient. Soils on natural levees usually are sandy silts, silts, and sometimes silty clay (Fig. 7). Natural levees are highest and contain more coarse-grain sediments near the active channels of current MMRRC rivers and decrease in height and sediment size away from the main channel. Natural levees in the MMRRC were formed primarily on the concave or cut banks of the major abandoned channels, but also are found on some older point bar and chute and bar surfaces (Fig. 6). Natural levee deposits on chute and bar surfaces usually are not well developed, however, because of the highly dynamic nature of sediment and scouring rates. Natural levees along older abandoned channels may range from 5 to 15 feet thick, while those associated with chutes and bars usually are less than 5 feet thick.

The stream valleys of larger MMRRC tributaries are partly filled with alluvium derived from local watershed formations and are termed "tributary valley alluvium." The alluvium in these tributary valleys grades upward from sand with gravel to silty clays and often is underlain by various glacial fill formations (Fig. 7). Tributary valley alluvium is scattered throughout the MMRRC on floodplain edges (Fig. 6).

The complex geomorphology of the MMRRC has created a heterogeneous mosaic of floodplain topography and elevations (e.g., Fig. 5). Areas that have abandoned channel remnants often have highly undulating topography that includes up to 20 feet

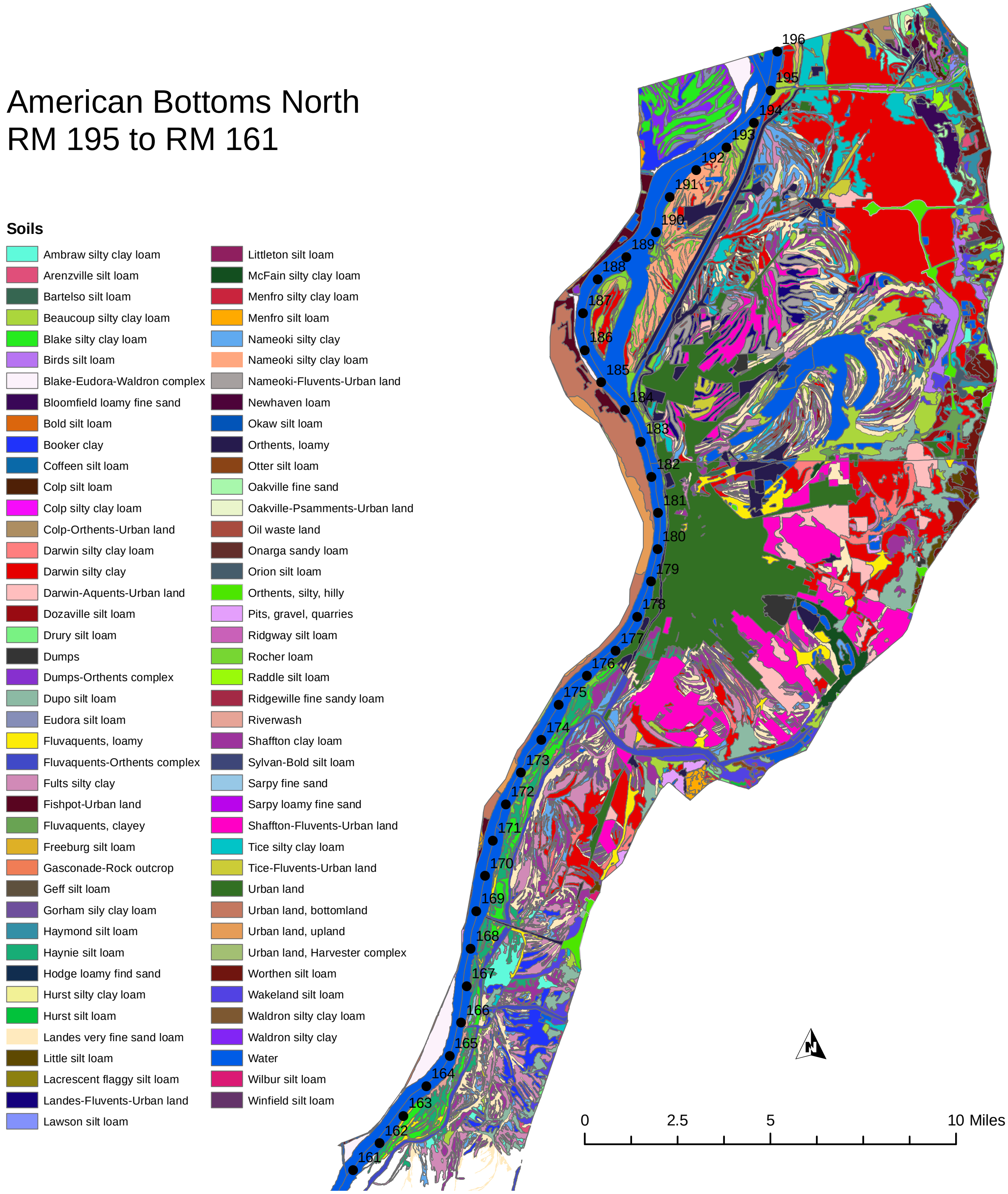



Fig. 7a. Soil maps of the Middle Mississippi River Regional Corridor (from U.S. Department of Agriculture, Natural Resources Conservation Service www.websoilsurvey.nrcs.usda.gov).

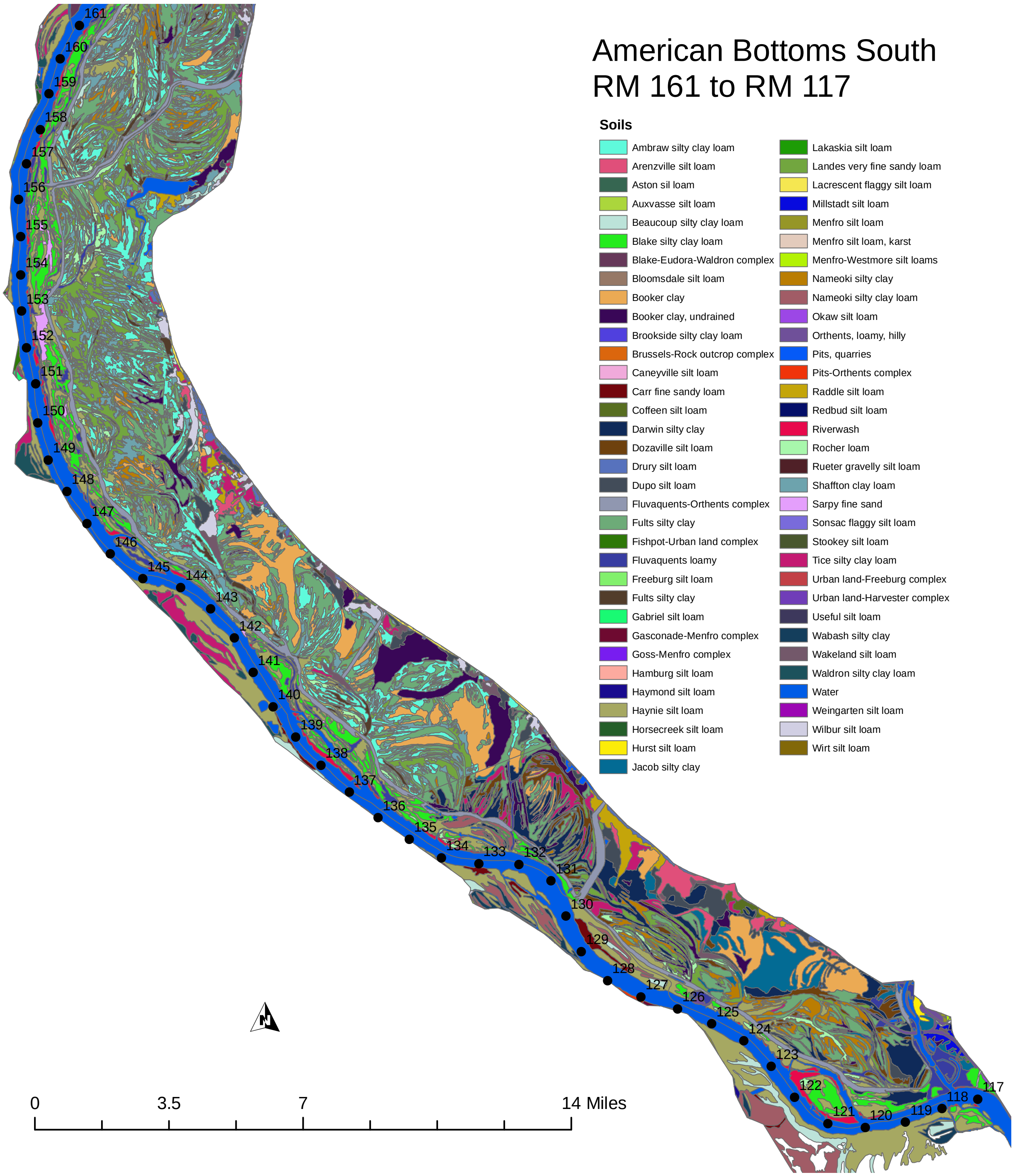



Fig. 7b. Soil maps of the Middle Mississippi River Regional Corridor (from U.S. Department of Agriculture, Natural Resources Conservation Service www.websoilsurvey.nrcs.usda.gov).

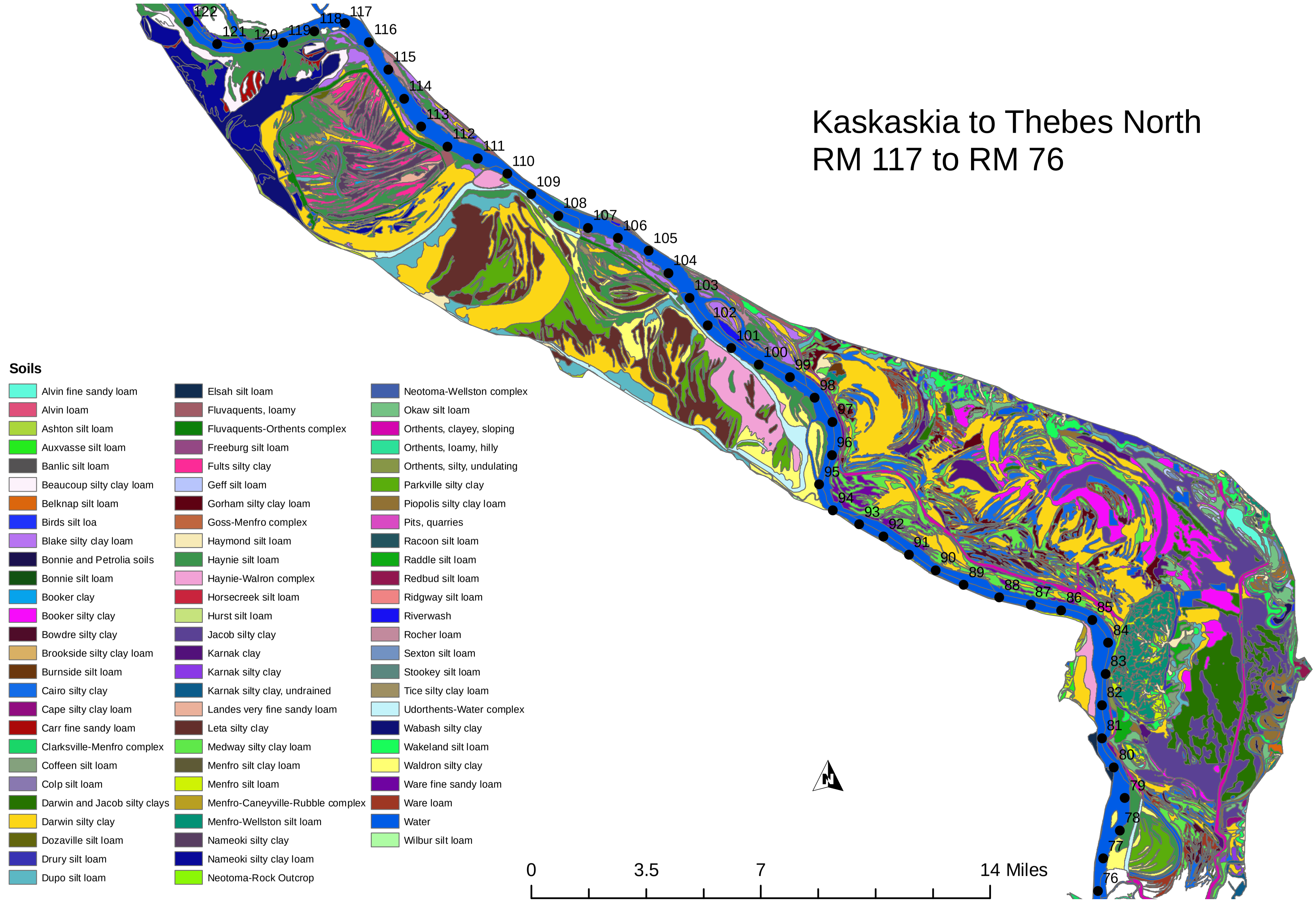



Fig. 7c. Soil maps of the Middle Mississippi River Regional Corridor (from U.S. Department of Agriculture, Natural Resources Conservation Service www.websoilsurvey.nrcs.usda.gov).

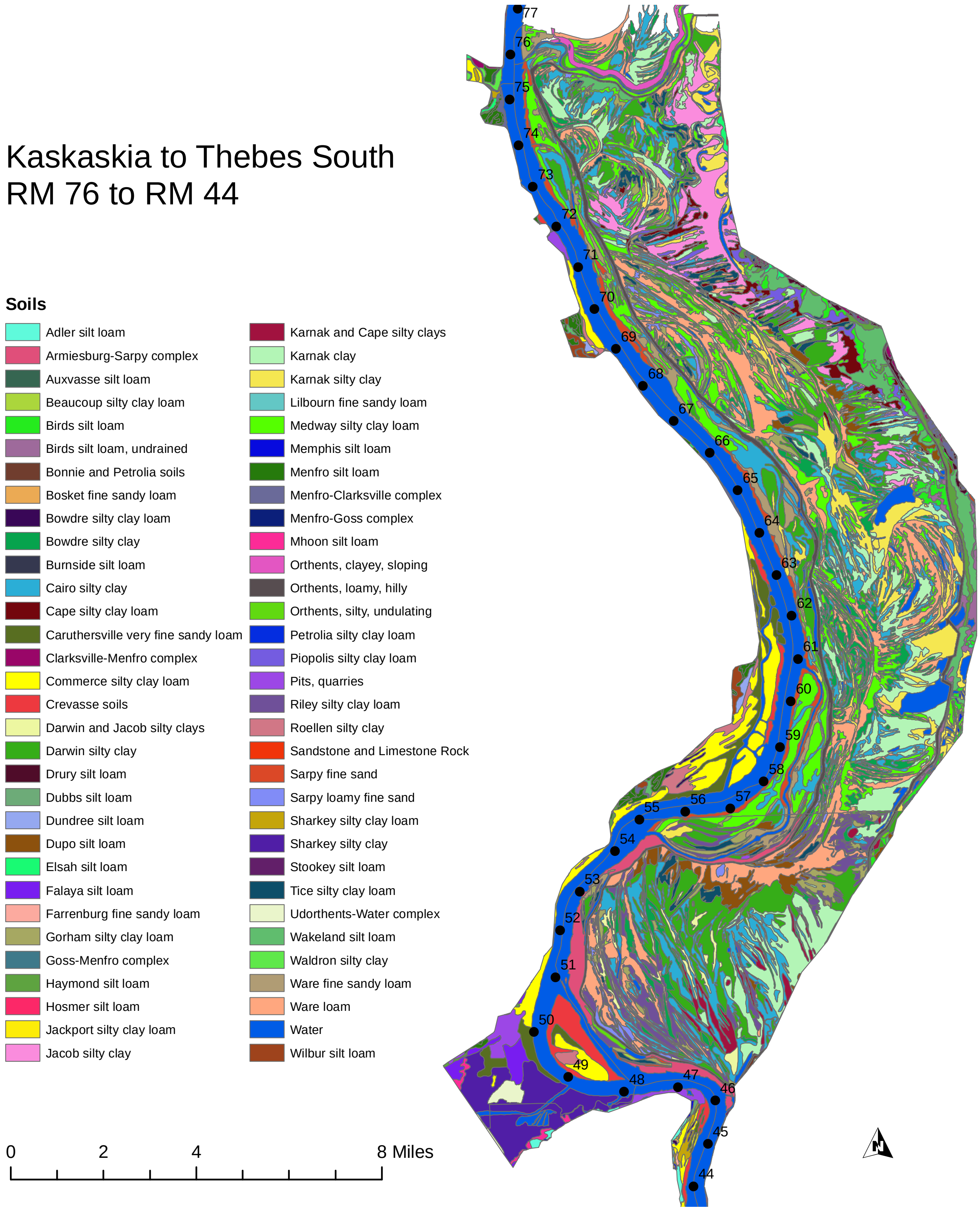



Fig. 7d. Soil maps of the Middle Mississippi River Regional Corridor (from U.S. Department of Agriculture, Natural Resources Conservation Service www.websoilsurvey.nrcs.usda.gov).

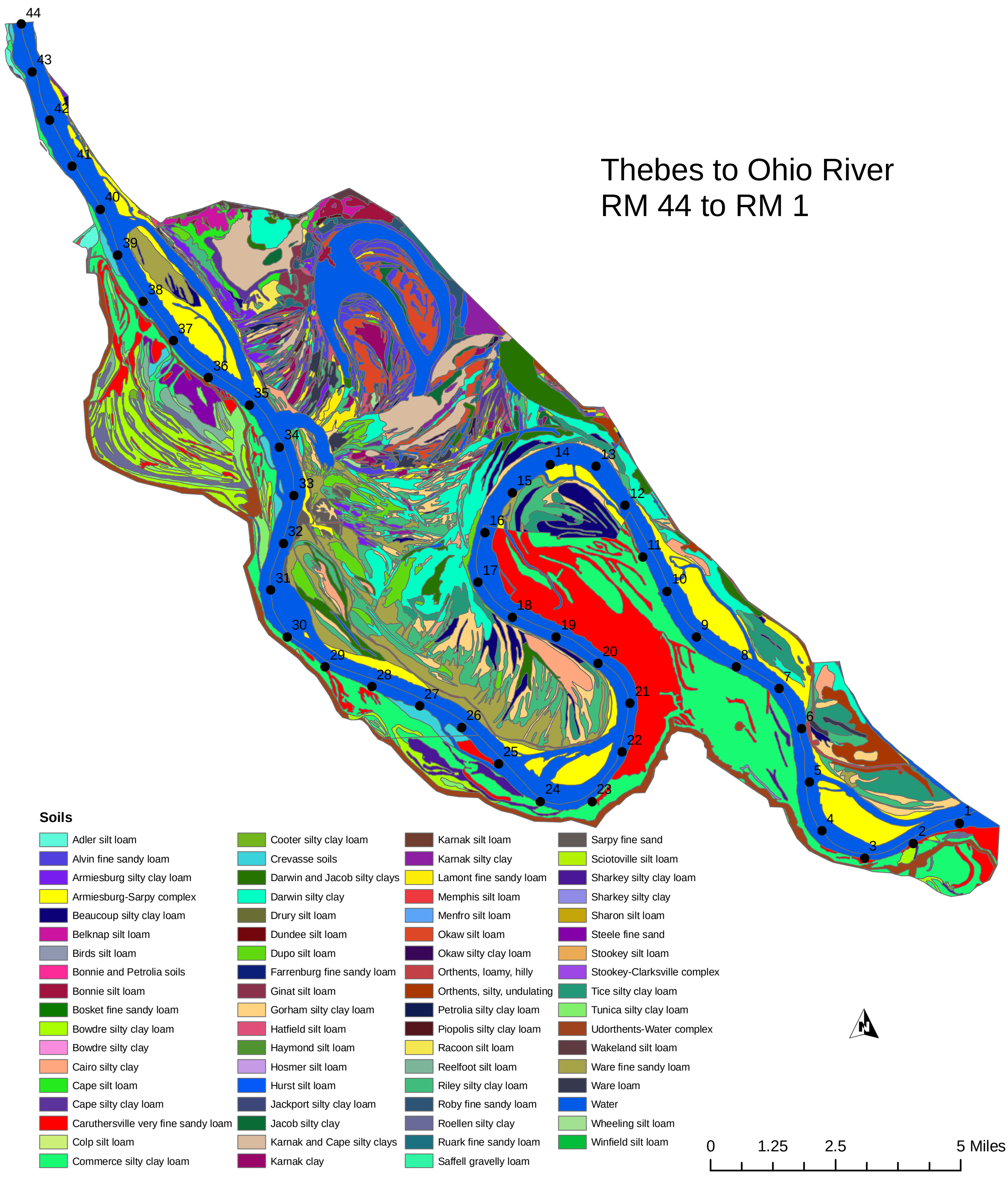



Fig. 7e. Soil maps of the Middle Mississippi River Regional Corridor (from U.S. Department of Agriculture, Natural Resources Conservation Service www.websoilsurvey.nrcs.usda.gov).

Table 2. Temperature Summary for Anna, Illinois. (Averages are from 1961-1990 and extremes are from 1901-1996. Temperatures are in ºF).

| Month | Avg high | Avg low | Record high (year) | Record low (year) | # of days with high ≥90°F | # of days with low ≤32°F | # of days with low ≤0°F |
|---|---|---|---|---|---|---|---|
| January | 40.8 | 22.5 | 76 (1909) | -20 (1918) | 0.0 | 23.0 | 1.1 |
| February | 45.9 | 26.3 | 78 (1917) | -13 (1905) | 0.0 | 19.0 | 0.4 |
| March | 57.2 | 36.3 | 91 (1910) | 0 (1960) | 0.0 | 12.0 | 0.0 |
| April | 68.4 | 46.4 | 92 (1915) | 21 (1996) | 0.1 | 2.1 | 0.0 |
| May | 77.5 | 54.9 | 98 (1911) | 31 (1903) | 1.2 | 0.0 | 0.0 |
| June | 85.9 | 63.3 | 105 (1936) | 42 (1903) | 9.0 | 0.0 | 0.0 |
| July | 89.1 | 67.2 | 112 (1901) | 46 (1947) | 17.0 | 0.0 | 0.0 |
| August | 87.5 | 65.3 | 110 (1930) | 45 (1918) | 13.0 | 0.0 | 0.0 |
| September | 80.7 | 58.6 | 107 (1925) | 32 (1995) | 5.5 | 0.0 | 0.0 |
| October | 70.4 | 46.8 | 95 (1910) | 20 (1981) | 0.3 | 1.5 | 0.0 |
| November | 57.2 | 37.8 | 83 (1902) | -5 (1991) | 0.0 | 11.0 | 0.0 |
| December | 44.7 | 27.4 | 76 (1982) | -14 (1989) | 0.0 | 20.0 | 0.5 |

deep channel depressions, 5-10 foot natural levees along parts of the channel, and 5-10 foot "scrolling" point bar ridges and swales on the inside bends of abandoned channels. Alluvial fans often rise 20-30 feet above adjacent floodplain surfaces. Older point bar deposits have more gently rolling ridge and swale complexes, but local elevations can change as much as 20+ feet from the tops of older ridges (that also may include older natural levee veneers) to the bottoms of swales. Chutes and bars often have highly dissected and variable topography depending on age and type of deposit or scour; some side channels that remain connected to the Mississippi River channel can have depths of 20-30 feet in some places.

## CLIMATE AND HYDROLOGY

The climate of the MMRRC is continental with marked seasonal changes and wide ranges of temperature and precipitation extremes (e.g., Wendland and Angel 1997). Seasonal climate varies somewhat from north to south in the MMRRC, but summer maximum Fahrenheit (F) temperatures consistently are in the 80s or 90s with lows in the 60s and 70s, while daily high temperatures in winter generally are in the 40s with lows in the 20s. One of the longer records of climate within the MMRRC is from Anna, Illinois and dates to 1901. At Anna, the mean January maximum and minimum temperatures are 41 F and 23 F, respectively. The mean July maximum and minimum temperatures at Anna are 89 F and 67 F, respectively (Table 2). Since 1961, the average date of first occurrence of 32 F is October 27 and the average last occurrence of 32 F in spring is April 10.

Precipitation in the MMRRC is greatest during spring and early summer and lowest in early fall and midwinter (Table 3). Average annual precipitation ranges from about 37 inches at St. Louis to 48 inches at Anna. Thunderstorms are common from spring through fall and often produce high winds, hail, and occasional tornadoes. Long-term trends in precipitation at Anna indicate relatively regular 15-20 year patterns of greater annual precipitation in the

Table 3. Precipitation Summary for Anna, Illinois. (Averages are from 1961-1990 and extremes are from 1901-1996. Precipitation is in inches.)

| Month | Avg. preclp. | Record high (year) | Record low (year) | Largest one-day amount (year) | Snow-fall | # of days w/ preclp. |
|---|---|---|---|---|---|---|
| January | 3.03 | 16.55 (1950) | 0.35 (1943) | 4.22 (1950) | 5.5 | 8 |
| February | 3.40 | 8.59 (1989) | 0.28 (1947) | 4.04 (1945) | 4.8 | 7 |
| March | 5.17 | 13.69 (1945) | 0.10 (1910) | 5.40 (1964) | 2.4 | 10 |
| April | 4.61 | 12.07 (1911) | 0.73 (1915) | 3.63 (1948) | 0.2 | 9 |
| May | 5.26 | 13.80 (1957) | 0.30 (1925) | 4.75 (1973) | 0 | 9 |
| June | 3.76 | 18.21 (1928) | 0.25 (1933) | 4.86 (1983) | 0 | 8 |
| July | 3.86 | 13.57 (1958) | 0.18 (1974) | 6.15 (1909) | 0 | 7 |
| August | 3.88 | 12.77 (1985) | 0.34 (1936) | 4.45 (1959) | 0 | 6 |
| September | 3.29 | 11.65 (1965) | 0.00 (1928) | 4.45 (1993) | 0 | 6 |
| October | 3.07 | 11.43 (1910) | 0.00 (1908) | 5.10 (1910) | 0 | 6 |
| November | 4.16 | 9.28 (1934) | 0.26 (1910) | 5.05 (1934) | 0.5 | 8 |
| December | 4.34 | 13.01 (1982) | 0.18 (1925) | 5.15 (1918) | 2.7 | 9 |

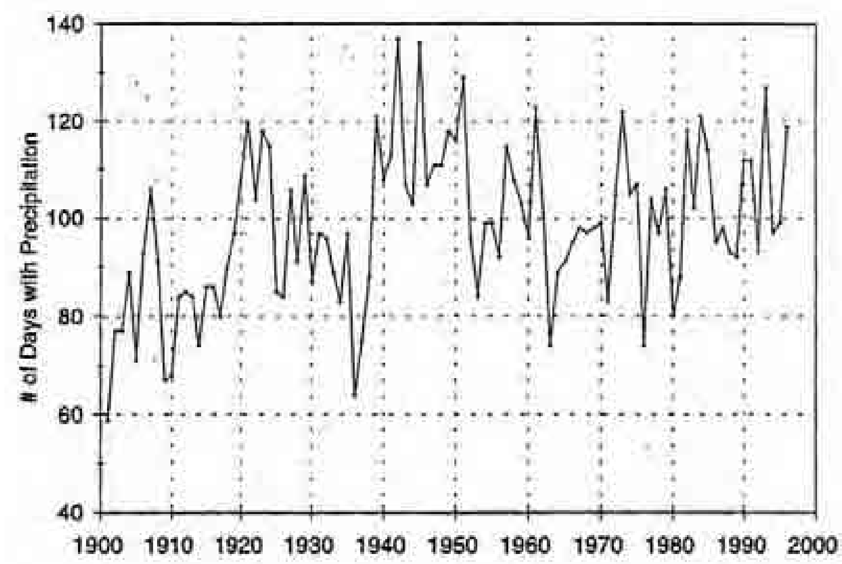



Fig. 8. Annual number of days with measurable precipitation at Anna, Illinois, 1901-1996 (from Wendland and Angel 1997).

1920s, 1940s, late 1950s to early 1960s, the 1980s, and 2000s that alternated with lower precipitation amounts in the 1930s, early 1950s, 1970s, and 1990s (Fig. 8). The recurring regular patterns of alternating peak and low precipitation in the MMRRC suggests at least some long-term regular dynamic of local water inputs to the MMRRC ecosystem. Long-term historic records at gauges along the Upper Mississippi River, including the MMRRC, indicate an approximate 11-15 year cycle of increasing discharge followed by declining flow and droughts (Knox 1984, 1999, Franklin et al. 2003). At least some snowfall is common in the MMRRC from December through March; heavy snowfalls rarely exceed 12 inches. At Anna, snowfall > 6 inches occurs on average about once every three years, while similar snowfall at St. Louis occurs about once every two years.

The amount and distribution of flows in the Mississippi River are highly influenced by climatic and snowmelt conditions in its watershed above St. Louis (including both the Missouri and Upper Mississippi systems), local and regional tributary flows, and backwater influences of the Ohio River at the south end of the MMRRC (e.g., Knapp et al. 1998). Consequently, flows in the Mississippi River in the MMRRC are strongly seasonal (Fig. 9) but with variation among years that follow the above 11-15 year pattern of precipitation and river discharge in the watershed (Fig. 10). Mississippi River flows are highest during spring and early summer (March through June), decline to low levels in late summer and early fall (September to October), and usually stay low throughout winter. At least some overbank flooding occurs in much of the MMRRC annually; most flooding occurs in April and May. The monthly distribution of top flood events on the Mississippi also reflects this seasonal pattern (Table 4), but indicates that a large flood occasionally can occur in most months (Fig. 9). For example, the very large flood on the Mississippi River in 1993 peaked in August.

Typically, the winter freeze and spring snowmelt in northern states coupled with increases in spring precipitation are major factors causing increased seasonal flows in the Mississippi River in the MMRRC. Variation in Mississippi River flows and overbank flooding are influenced by large-scale rain events throughout the Upper Mississippi River watershed and by regional droughts. These large scale influences cause changes in flows in the Mississippi River in the MMRRC to be relatively gradual. In contrast to the Mississippi River, flows in major tributaries such as the Kaskaskia, Meramec, and Big Muddy rivers are mostly influenced by local climatic events and seasonal pulses of rain or drought; seasonal

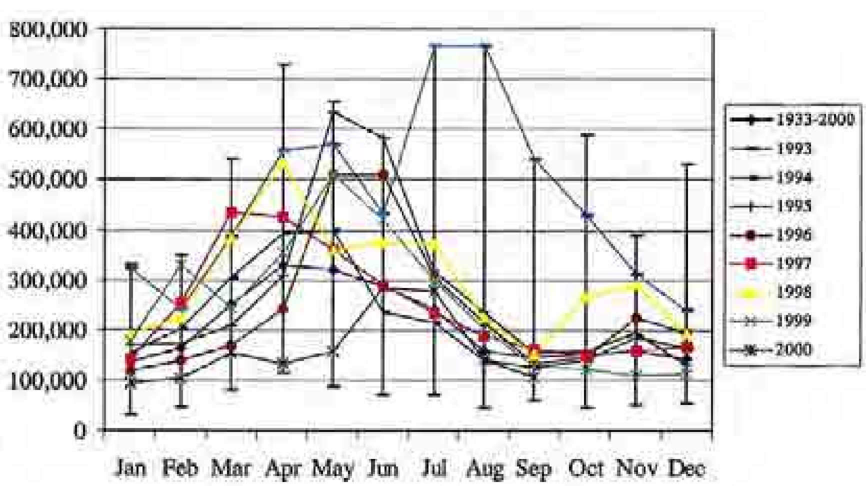



Fig. 9. Mean (and range) monthly discharge (cubic feet/second) of the Mississippi River at Thebes, Illinois 1933-2000 compared to mean monthly discharge 1993 to 2000 (from www.usgs.gov river gauge data prepared by Papon 2002).

flows in these rivers rise and fall more quickly than in the Mississippi River. When correspondence in either increased or decreased precipitation and runoff occur throughout the watershed of the MMRRC, the region can either be highly flooded (e.g., 1993, 1995) or near drought condition (e.g., 1940, 1955-56, 1976-77). Certain data suggest the long-term average flow for both the Mississippi and Illinois rivers near the confluence region have been noticeably higher since 1970 (Fig. 10,11).

The Mississippi River in the MMRRC reached flood stage almost every year (often multiple times/year) prior to major levee, wing dike, and other flood control developments (i.e., pre-1945) (e.g., Bowman 1907, Allen 1945, USACE 1947). In the St. Louis area, extremely large floods (> 34 feet) occurred in 1828, 1844, 1851, 1855, 1858, 1883, 1892, 1903, 1908, 1909, 1929, and each year 1942-1945 (USACE 1947). Similar floods (> 34 feet) at Cape Girardeau were slightly less common than at St. Louis and occurred in 1844, 1858, 1903, 1908, 1909, 1912, 1915-1917, 1922, 1927, 1929, 1933, 1935, and 1942-1945. Flooding at St. Louis is influenced more from upstream and Missouri River contributions whereas flooding at Cape Girardeau is influenced both from upstream flows and also those in the Ohio River. When the Ohio River is in flood stage water discharge from the Mississippi River slows and essentially is backed upstream. Analyses of long-term flooding data suggest that large flood events, that covered most of the MMRRC floodplains, occurred about every 11-15 years with intervening periods of low, non-flood, conditions (Franklin et al. 2003). This dynamic "cycle" of long term flood and drought events was a major factor influencing ecological relationships and distribution of plant communities in the MMRRC.

The MMRRC contains sand-and-gravel aquifers throughout the region (Bergstrom and Walker 1956, Smith and Smith 1984). These aquifers typically are 20-50 feet below the surface and are annually recharged from the Mississippi River and surrounding upland discharges. Deeper bedrock aquifers (Lower Cahokia and Henry aquifer formations, Fig. 5) are present in rock units below the MMRRC, and are of variable depth and quantity; most are at least 150 feet below the floodplain surface. The elevation of the piezometric surface is temporally and spatially variable along the MMRRC. For example, the piezometric surface may occur at depths of 10 to 50 feet in the American Bottoms, but usually is less than 20 feet south of Thebes (Luckey 1985). When Mississippi River stages are high, water

Table 4. Monthly distribution of the 25 largest flood events on the Mississippi River at St. Louis (calculated from U.S. Army Corps of Engineers 1947, Knapp et al. 1998, and U.S. Army Corps of Engineers, St. Louis District unpublished river gauge data 1945-2007).

| Month | Number of Large Flood Events |
|---|---|
| January | 1 |
| February | 0 |
| March | 4 |
| April | 6 |
| May | 4 |
| June | 3 |
| July | 2 |
| August | 1 |
| September | 1 |
| October | 2 |
| November | 0 |
| December | 1 |

flows through coarse subsurface sediments and can discharge surface water into floodplain depressions, abandoned channels, and swales. This subsurface

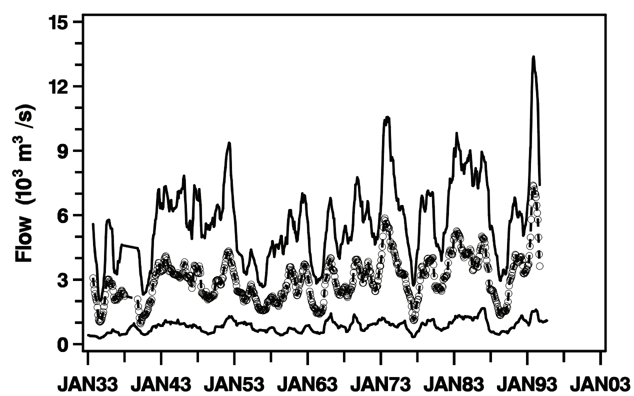



Fig. 10. Daily discharge of the Mississippi River at Winona, Minnesota (lower line), Alton, Illinois (middle line), and Thebes, Illinois (top line) (from Theiling et al. 2000).

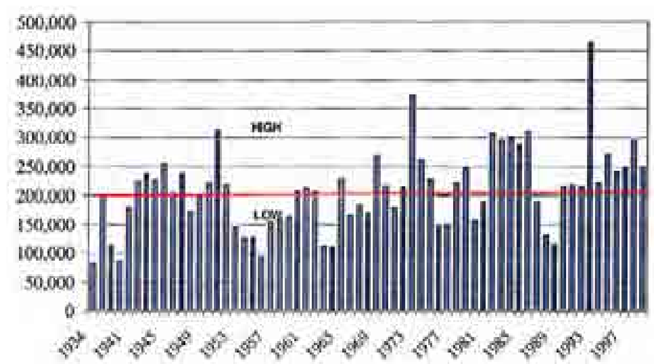



Fig. 11. Mean annual discharge (cubic feet/second) and mean long-term discharge (209,105 cfs) of the Mississippi River at Thebes, Illinois 1934-2000. Yearly means above or below the long-term means indicate a "high" or "low" flow year, respectively (from www.usgs.gov, river gauge data prepared by Papon 2002).

water flow is most common in bar and chute and point bar geomorphic stratigraphy where sand and gravel subsoil layers are present. Water levels in many floodplain wetlands in the MMRRC have seasonal fluctuations that roughly parallel Mississippi River stages (Smith and Smith 1984).

## PRESETTLEMENT HABITATS

The heterogeneity of geomorphic surfaces, soils, and topography in the MMRRC created diverse and highly interspersed vegetation communities distributed across elevation and hydrological gradients (Fig. 12). Major natural communities/ habitat types that historically were present in the MMRRC included: 1) the main channel and islands of the Mississippi River and major tributaries, 2) river "Chutes" and "Side Channels", 3) Bottomland Lakes, 4) Riverfront Forest, 5) Floodplain Forest, 6) Bottomland Hardwood Forest (BLH), 7) Slope Forest, 8) Bottomland Prairie, 9) Mesic "Terrace" Prairie, and 10) Savanna. A complete list of fauna and flora in these MMRRC habitats is provided in Terpening (1974).

The main channels of the Mississippi River and its major tributaries (e.g., Kaskaskia, Meramec, Big Muddy) contained open water with little or no plant communities other than phytoplankton and algae (Theiling 1996). During low river levels in late summer and early fall, some river Chutes and Side Channels became disconnected from main channel flows and held stagnant water that supported sparse herbaceous "moist-soil" plants that germinated on exposed mud flats. During high river flows Chutes and Side Channels were connected with the main channel and scouring action of river flows prevented establishment of rooted plants in these habitats. The extent and duration of river connectivity was the primary ecological process that controlled nutrient inputs and exports, primary and secondary productivity, and animal use of Chutes and Side Channels. A wide variety of fish were present in the Mississippi River and tributary rivers and their Side Channels (e.g., Pflieger 1975), and these habitats also were used by many amphibians, a few aquatic mammals, and some water and shorebirds (Smith 1996).

Few large permanent "islands" historically occurred within the Mississippi River or tributary channels in the MMRRC, but "bars" were common on the edges of channels, especially on the downward side of major bends (Mississippi River Commission 1881, USACE 2004a, Brauer et al. 2005). Most "islands" in the MMRRC actually were extensions of floodplain chute and bar geomorphic surfaces and usually were separated from the floodplain by narrow, often highly sedimented, older Side Channels. During dry periods these "islands" became extensions of terrestrial floodplain surfaces. Vegetation on islands and bars depended on size, configuration, and connectivity to banks (Turner 1936). The degree and duration of flooding and connectivity to either the river or floodplain controlled ecological attributes and animal use of islands and river bars. Most islands and bars historically were 1-4 feet below adjoining floodplain elevations and were overtopped during annual high flow periods. During floods, river bars often were extensively scoured or destroyed, and new bars were created in other locations. Vegetation on bars was mostly pioneering plants that germinated on newly deposited alluvium. Annual herbaceous plants and seedlings of cottonwood, sycamore, and willow were the most common plants. Larger islands such as Chouteau, Wilkinson, Devils, etc. contained Riverfront Forest communities with some aquatic and moist-soil plants in interior swales and sloughs.

Bottomland Lakes were present throughout MMRRC floodplains and occupied abandoned channels (Bareis 1964, Munson 1974, Woerner et al. 2003). The location, age, and size of Bottomland Lakes determined depth, slopes, and consequently composition and distribution of vegetation communities. Many Bottomland Lakes in the American Bottoms were surrounded by prairie communities and essentially were large "prairie marshes" with little or no woody vegetation on their edges. (Fig. 13). The sparse woody vegetation along prairie-type lakes was mostly scattered willow and shrubs such as buttonbush. Robust emergent vegetation such as cattail and river bulrush dominated plant composition along the edges of these lakes. Other Bottomland Lakes, especially those south of Kaskaskia, were surrounded by Floodplain Forest or BLH. These lakes usually contained a narrow band of Shrub/Scrub (S/S) vegetation along their edges (Fig. 13). S/S communities represented the transition area from more herbaceous and emergent vegetation in the aquatic part of Bottomland Lakes to higher floodplain surfaces that supported trees. S/S habitats typically were flooded a few inches to 2-3 feet deep for extended periods of each year except in extremely dry periods. S/S habitats were dominated by buttonbush, swamp privet, and willow. Often a natural levee was present along the edges of Bottomland Lakes and these areas supported Floodplain Forests. The edges of Bottomland Lakes south of Kaskaskia contained a mix of baldcypress, tupelo, and Floodplain Forest species. In contrast, the ends of Bottomland Lakes in the American Bottoms often contained Riverfront Forest species that germinated on coarse-grain materials that had “plugged” the old abandoned channel.

Most newer and deeper Bottomland Lakes had central areas of permanent “open water” that contained abundant aquatic “submergent” and “floating-leaved” vascular species such as pondweeds, coontail, water milfoil, American lotus, spatterdock, and duckweeds. The edges of these lakes typically dried for short periods during summer and contained emergent and herbaceous vegetation. Emergent vegetation included arrowhead, cattail, rushes, river bulrush, sedges, and spikerush. Herbaceous vegetation was dominated by smartweeds, millet, panic grasses, sprangletop, sedges, spikerush, beggarticks, and many other perennial and annual “moist-soil” species. The distribution of emergent and herbaceous communities in Bottomland Lakes depended on length and frequency of summer drying seasonally and among years (see previous hydrology section about long-term dynamics of flood events and intervening dry periods). In drier periods, herbaceous communities expanded to cover wide bands along the edges of Bottomland Lakes, while in wetter periods herbaceous plants were confined to narrow bands along the edges of deeper open water.

Bottomland Lakes, both “prairie-marsh” and “forest-edge” types, supported a high diversity of animal species. Historically, fish moved into these lakes for foraging and spawning when they became connected with the Mississippi or Ohio rivers during flood events. Many fish subsequently moved back into the main channel when flood water receded or after they spawned or fattened during flood events; some fish remained to populate the deeper lakes (e.g., Sparks 1995). Bottomland Lakes also supported high density and diversity of amphibian and reptile species and some species, such as turtles, moved into and out of these lakes similar to fish (e.g., Tucker 2003). Aquatic mammals regularly used Bottomland Lakes and more terrestrial mammals traveled in and out of these areas for seasonal foraging, breeding, and escape cover during dry periods. Bird diversity in these lakes was high, and extremely high densities of waterfowl, rail, shorebirds, and wading birds used these habitats for foraging, nesting, and resting sites.

Riverfront Forest (also called “River-edge Forest” in some older botanical literature) was present on chute and bar surfaces, some point bar areas near the current channel of the Mississippi River,


Fig. 12. Ecological cross-section of major habitat types in the Middle Mississippi River Regional Corridor: a) a typical prairie-dominated landscape and b) a typical forest-dominated landscape.

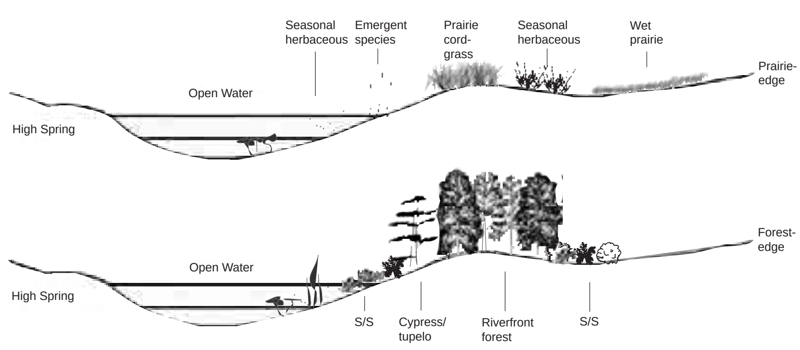



Fig. 13. Ecological cross-sections of abandoned channel Bottomland Lakes within the Middle Mississippi River Regional Corridor: a) a typical prairie-edge landscape and b) a typical forest-edge landscape showing 1) mean low summer water depth and 2) mean high spring water depth.

and along the edges of some abandoned channels (Hus 1908, Chmurny 1973, Gregg 1975, Klimas 1987, Mohlenbrock 1989, Patterson 1989, Nelson 1997). These geomorphic surfaces contained recently accreted lands and were sites where river flows actively scoured and deposited silt, sand, gravel, and some organic debris within the last decade or so. Soils under Riverfront Forest, especially on chute and bar surfaces, were young, annually overtopped by flood waters, highly drained, influenced by groundwater dynamics as the Mississippi River rose and fell, and contained thin veneers of silt. Riverfront Forest was dominated by early succession tree species and varied from water tolerant species such as willow and silver maple in low elevations and swales to intermediate water tolerant species such as elm, ash, cottonwood, sycamore, pecan, and sugarberry on ridges. Swamp white oak and pin oak occasionally were present in higher elevations in Riverfront Forest areas, but these species had high mortality during extended flood events and oak patches probably were small and scattered. Shrubs and herbaceous vegetation in Riverfront Forest were sparse near the Mississippi River but dense tangles of vines, shrubs, and herbaceous vegetation were present on higher elevations away from the river where alluvial silts were deposited. Giant cane occasionally was present on these higher elevations, but repeated river flooding and scouring limited its occurrence and persistence (e.g., Gagnon 2007). The dynamic scouring and deposition in chute and bar areas limited the tenure of many woody species except on the highest elevation ridges where species such as cottonwood and sycamore often became large mature stands (e.g., Hosner and Minckler 1963).

Riverfront Forests were used by many animal species, especially as seasonal travel corridors and foraging sites. Many bird species nested in Riverfront Forest, usually in higher elevation areas where larger, older, trees occurred (Papon 2002). Arthropod numbers apparently were high in Riverfront Forest during spring and summer and these habitats also contained large quantities of soft mast that was consumed by many bird and mammal species (e.g., Knutson et al. 1996). Few hard mast trees occurred in Riverfront Forest, but occasional "clumps" of pecan or oak provided locally abundant nuts. The very highest elevations in chute and bar areas provided at least some temporal refuge to many ground-dwelling species during flood events (Heitmeyer et al. 2005).

Floodplain Forest historically covered large expanses of the MMRRC floodplain, especially north of Thebes Gap, on point bar surfaces and along tributary streams (Hus 1908, Telford 1927, Gregg 1975, Robertson et al. 1978, Brugam and Patterson 1996, Yin 1999). This forest type represents a transition zone from early succession Riverfront Forest located on coarse-sediment chute and bar surfaces to BLH forests that occurred in clay-type soils in backswamps and southern floodplain depressions. Floodplain Forest typically developed on mixed silt loam soils where older point bar "ridge-and-swale" topography occurred. Most of these older point bar surfaces were within the 1-2 year flood frequency zone. Floodplain Forests were dominated by elm, ash, sweetgum, sugarberry, and box elder but included many other species depending on elevation and soil type. Some botanical literature calls this forest type the "sugarberry-elm-sweetgum" zone (e.g., Gregg 1975). Higher elevation ridges, and older remnant natural levees, often contained pecan, pin and swamp chestnut oak, honey locust, and scattered hickory. Low elevation swales within Floodplain Forest contained a mix of more water tolerant species that included willow, cottonwood, maple, and sycamore on coarser soil sediments to oak, ash, sweetgum, and inclusions of gum or baldcypress in southern MMRRC point bar swales that had thicker layers of silt and clay. Some authors have described Floodplain Forest as BLH (e.g., Yin et al. 1997), however, Floodplain Forests are ecologically distinct from typically defined BLH communities that are dominated by oaks (e.g., Conner and Sharitz 2005).

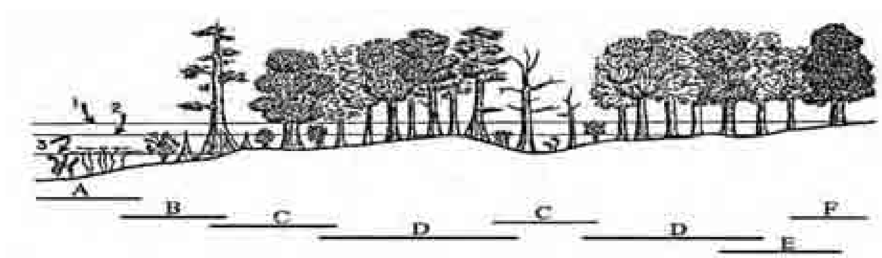
Larger, deeper, swales in Floodplain Forest often contained surface water for extended periods of the year and supported gradients of vegetation similar to forest-edge Bottomland Lakes but at a smaller spatial scale. Dense understory layers of hophornbeam, spicebush, and paw-paw and many vines such as trumpet-vine, grape, poison ivy, Virginia creeper, peppervine, and catbrier were present in many Floodplain Forests. Early explorers often commented on the relatively "impenetrable" nature of these Floodplain Forests (e.g., Collot 1826). Herbaceous cover was extensive in higher elevations of Floodplain Forests and included many herbs such as Virginia snakeroot, smooth Ruellia, honewart, elephant's foot, fleabane, and rough bedstraw. Giant cane was common in some floodplain forest locations, mostly on higher ridges.

The floral and elevation diversity of Floodplain Forest provided abundant resources to many animal species. Many mammals, including rodents, ungulates, and canids were present as were amphibians and reptiles. Bird abundance in Floodplain Forest was high and included species that bred, wintered, and migrated through the area (Knutson et al. 1996, Papon 2002). During flood events, Floodplain Forest often became refuge for species that occupied lower elevation Riverfront Forest. During larger floods fish moved into Floodplain Forest for spawning and foraging.

BLH, also sometimes called lowland-depressional forest (e.g., Leitner and Jackson 1981), was present in low elevation depressions, backswamps, and old braided river terraces in the MMRRC (Miller and Fuller 1921, Hosner and Minckler 1963, Voigt and Mohlenbrock 1964, Korte and Fredrickson 1977, Conner and Sharitz 2005). BLH communities typically occurred between Floodplain Forests and the bluff edges of the MMRRC floodplain. BLH was most common south of Kaskaskia and this habitat type dominated the MAV portion of the MMRRC south of Thebes. BLH typically had thick clay-type soils and were seasonally flooded from local or upland runoff, slow backwater or "sheetflow" overbank flows of MMRRC tributaries, and backwaters of larger Mississippi River floods.

BLH vegetation communities were distributed along elevation and flooding gradients (Bedinger 1979, Fig. 14). The lowest elevations in BLH areas contained baldcypress and tupelo that were flooded for extended periods each year and occasionally year round (e.g., Coulter 1904). At times Cypress/Tupelo habitats became flooded up to several feet deep. Other common species in Cypress/Tupelo were buttonbush, water locust, water elm, and swamp privet. Cypress/Tupelo often was present immediately adjacent to, or within, older abandoned channels south of Kaskaskia such as at Oakwood Bottoms, Horseshoe Lake, and Union County Wildlife Management Areas.

Low BLH communities were present at slightly higher elevations than Cypress/Tupelo sites and typically were shallowly flooded 1-3 months each winter and spring. Low BLH contained slightly less water tolerant trees such as overcup oak, green ash, red maple, and pecan with scattered pin oak present on higher ridges. Many understory vines occurred in Low BLH communities and included rattan vine, eardrop vine, greenbrier, and poison ivy. Ground herbaceous cover usually was sparse in Low BLH because of extended flooding, but sedges and rice cutgrass often were abundant during dry periods. Low BLH sites often occurred immediately adjacent to Cypress/Tupelo habitats and had inclusions of baldcypress, buttonbush, and swamp privet in depressions. Low BLH was present in deeper point bar swales, older abandoned channels, backswamps, and depressions behind small natural levees.




| Duration of flooding | Herbaceous plants | Woody plants |
|---|---|---|
| (A) Permanent | Water Milfoil<br>Watershield<br>American Lotus | Common Baldcypress |
| (B) Semi-permanent water | American Lotus<br>Duckweed<br>Swamp Smartweed | Common Baldcypress<br>Water Tupelo<br>Water Elm<br>Buttonbush |
| (C) 3 to 8 Months | Swamp Smartweed<br>Lizard's Tail<br>Sticktights<br>Arrowarum | Common Baldcypress<br>Overcup Oak<br>Red Maple<br>Waterlocust<br>Possomhaw Holly |
| (D) 1 to 6 Months | Lizard's Tail<br>Sticktights<br>Sedge | Overcup Oak<br>Willow Oak<br>Pine Oak<br>Cherrybark Oak<br>Sweetgum<br>Blackgum Tupelo |
| (E) 0 to 2 Months | Spotted Snapweed<br>Nettle<br>Giant Cane<br>Nightshade | Sweetgum<br>Blackgum Tupelo<br>Sugar Hackberry<br>Shagbark Hickory<br>American Elm<br>Swamp Chestnut Oak |
| (F) Once in 10 years | Spotted Snapweed<br>Nettle<br>Giant Cane<br>Wildrye<br>Pokeberry | Sweetgum<br>Sugar Hackberry<br>Shagbark Hickory<br>White Oak<br>Flowering Dogwood |

Fig. 14. Typical bottomland hardwood vegetation profile in the Middle Mississippi River Regional Corridor showing: 1) maximum flooding depth, 2) mean annual dormant season flooding depth, and 3) mean annual low water depth during the growing season (modified from Fredrickson and Batema 1982).

Intermediate BLH occurred mainly in backswamp areas that typically flooded 1-2 months annually during the dormant season and into early spring. Soil saturation in Intermediate BLH often was extended for 3-4 months, but surface flooding may not have occurred in some dry years. Dominant vegetation in Intermediate BLH included pin oak, swamp chestnut oak, sugarberry, American elm, sweetgum, and some widely scattered willow oak and swamp white oak. Small depressions in Intermediate BLH zones, such as vernal pools, include overcup oak, green ash, maple, and pecan. Common privet, honeysuckle, greenbrier, and poison ivy were common understory plants.

The highest elevations in BLH communities historically were flooded for up to a few weeks annually during most years; slightly longer duration flooding occurred during wetter periods and during major Mississippi River flood events. Some High BLH sites were dry for several years during dry periods, but soils in High BLH usually were saturated for some periods annually. Dominant plant species in High BLH included willow, pin, and cherrybark oak; shagbark and shellbark hickory; sweetgum; and American elm. Some High BLH contained scattered post oak and winged elm. Herbaceous cover was extensive in High BLH sites and understory plants included dense stands of poison ivy, climbing dogbane, crossvine, and Virginia and trumpet creeper. Giant cane patches occurred in many BLH habitats, usually on the higher ridges or older natural levee surfaces.

Animal diversity was high in BLH communities because of the deep alluvial soils, seasonal flooding regimes, diverse plant communities, high structural complexity, and rich detrital food bases (Heitmeyer et al. 2005). Foods within BLH became available in many seasonal "pulses" that provided many different types of nutrients used by many trophic levels and within many niches. Consequently, this community supported large numbers of species and individuals. The primary ecological process that sustained BLH communities and their productivity was seasonal, mostly dormant-season, flooding. Regular disturbance events also sustained this ecosystem through periodic extended flooding or drought, wind storms, and fire in at least the higher elevations.

Slope Forest occupied alluvial fans and higher terraces along the edges of MMRRC floodplains (Munson 1974, Chmurny 1973, Gregg 1975). Slope Forest contained a unique mix of trees representing both upland and bottomland communities that occurred in higher (upland) and lower (floodplain) elevations adjacent to the alluvial fan or terrace. Some authors refer to this habitat as the "shatter zone" between upland and valley floor plant associations (Gregg 1975). The diverse tree species present in Slope Forest included hickory, sugarberry, swamp white and swamp chestnut oak, white oak, bur oak, red oak, black walnut, ash, mulberry, maple, box elder, paw paw, hawthorn, persimmon, green ash, honey locust, Kentucky coffeetree, and slippery elm. Many other woody species occurred in the understory and as occasional canopy trees. Herbaceous cover often was extensive, especially on the lowest elevations and included columbine, spikenard, wild ginger, spring beauty, pepperroot, cleavers, sensitive fern, sweet jarvil, pokeberry, may apple, great Solomon's seal, and false Solomon's seal (Zawacki and Hausfater 1969).

Slope Forests were not flooded except during extreme Mississippi River flood events. Even during extreme floods, only the low elevation bottom parts of slopes would have been inundated. Most water flowed off the slopes in a wide overland sheetflow manner and only minor drainages originated from the slopes. Slopes often were bounded by slightly larger drainages that originated in bluffs and uplands. Some slope areas in the American Bottoms were bounded by prairie. In these prairie-forest transition sites, savanna was present as narrow bands at the bottom of the slopes and probably was maintained by occasional fire. Fires in these areas may have originated in either the floodplain bottoms or uplands and likely contributed to sustaining the diverse mix of woody, herbaceous, and grass species. Soils on slopes were unique mixes of erosional and alluvium sources often in the Worthen-Littleton-Drury association.

Many animals used Slope Forest and these sites also were preferred sites for Native American settlements. These sites contained rich floral communities, multiple food types, and relief from periodic flooding and bothersome insects in the lowlands. These areas also provided a natural sloping movement corridor from bottomland to uplands and bluffs.

Prairies occupied extensive parts of the MMRRC floodplain north of the Kaskaskia River. Most of these prairies were wet "Bottomland" types, but smaller areas of drier "Mesic" type prairies occurred on higher elevation terraces and ridges (Allen 1870, Hus 1908, Sampson 1921, Turner 1934, Chmurny 1973, Gregg 1975, Benchley 1976, Bareis and Porter 1984, Patterson 1989, Nelson et al. 1994, 1998, USACE 2004b). Bottomland Prairies often are described in older naturalist accounts as “slashy”, “wet meadow”, or even shallow “marsh” habitats (e.g., Oliver 1843). These Bottomland Prairies contain a variety of plant associations dominated by grasses and sedges depending on soil moisture conditions. Generally, Bottomland Prairie occupied older point bar surfaces where elevations were at 2-5-year flood frequencies. Soils under Bottomland Prairie ranged from clay-silts in swales to silt loams or even sandy loams on ridges. Bottomland Prairie “ridges” on point bars contained many grasses such as big bluestem, blue joint, and switch grass. Bottomland Prairie “swales” included many sedges and wetland-type plants such as river bulrush, floating manna grass, bur reed, sweetflag, duck potato, water parsnip, pickerel weed, water plantain, dock, smartweeds, spikerush, ditch stonecrop, common skullcap, monkey flower, and yellow water-crowfoot. They also contained abundant prairie cordgrass, marsh elder, sumpweed and asters at the transition zones between “ridge” and “swale.”

The distribution of Bottomland Prairie was determined by the dynamic “line” of where floodwater ranged toward higher elevations in floodplains vs. the “line” where fires originating from uplands and higher elevations moved into the wetter lowlands (Nelson et al. 1998, Nelson 2005, Heitmeyer and Westphall 2007). Historically, Bottomland Prairie vegetation was partly maintained by seasonal burning by native people and by herbivory from elk, bison, deer, and many rodents. This herbivory cropped and recycled prairie vegetation and also browsed invading woody shrubs and plants. Bottomland prairie supported many animal species and prairie swales that were seasonally flooded for short periods in spring and summer provided extensive foraging and breeding habitat for wetland-dependent birds and amphibians/reptiles.

At the higher elevations of the MMRRC floodplain, especially on terraces (such as the Savanna Terrace in the northeast part of the American Bottoms), Bottomland Prairie changed into zones or patches of Mesic Prairie and then eventually into Savanna and Slope Forest on alluvial fans and upland/bluff margins. Mesic Prairie was dominated by perennial upland type grasses including little bluestem, Indian grass, switchgrass, drop-stem, side-oats gramma, bunch grass, plains muhly, and panic grasses. Forbs included broomsedge, scurf-pea, sunflowers, goldenrods, and ragweeds (Turner 1934). Vegetation in Mesic Prairie often was 3-4 feet tall and during spring early travelers viewed these areas as a veritable flower garden (see descriptions in White 2000). Woody vegetation encroached on the upland edges of this prairie type and hazelnut, box elder, hickory, elm, and Slope Forest species were common. Fire likely sustained Mesic prairies and bands of Savanna also were present in some locations. Given the position of Mesic Prairie and savanna, animal species common to both forest and prairie were present. These sites also were common camp or occupation sites for native peoples because of their higher, less flood prone, location; the presence of grasslands where small cultivation areas could be easily maintained; locally available wood for fires; and natural travel corridors between uplands and floodplains.

## DISTRIBUTION AND EXTENT OF PRESETTLEMENT HABITATS

The exact distribution of vegetation communities (habitat types) in the MMRRC prior to significant European settlement in the late 1700s is not known. However, many sources of information about the geography and distribution of major vegetation communities are available for the MMRRC and they include historic cartography, botanical data and accounts, and general descriptions of landscapes from early explorers and naturalists. While the precise geography of early maps (e.g. river channel boundaries) is often flawed, these maps provide general descriptions of relative habitat types, distribution, and configuration.

Apparently, the first maps of the Mississippi River (and parts of its floodplain) in the MMRRC were made during French governance of the region by the French cartographers Franquelin (produced in1682) (Fig. 15), De L’Lsle (1703 and 1718), d’Anville (1746 and 1755), and Bellin (1755) (Wood 2001). When the British Regime succeeded French rule of the area in the mid-1700s, new maps of the MMRRC were prepared. The first known British map was drawn by Philip Pitman in 1765 and it essentially was a compendium of the earlier French maps (Thurman 1982). Although it was not highly original, the Pittman map became the accepted “standard” for geography of the MMRRC; subsequent maps expanded coverage and descriptions to lower course tributaries (e.g., the Ross map produced in 1867) and floodplains (Hutchins 1784). The Hutchins’ map relied heavily on Pitman’s map and his book “A topographic description of Virginia, Pennsylvania, Maryland, and North Carolina” published in 1778 contained

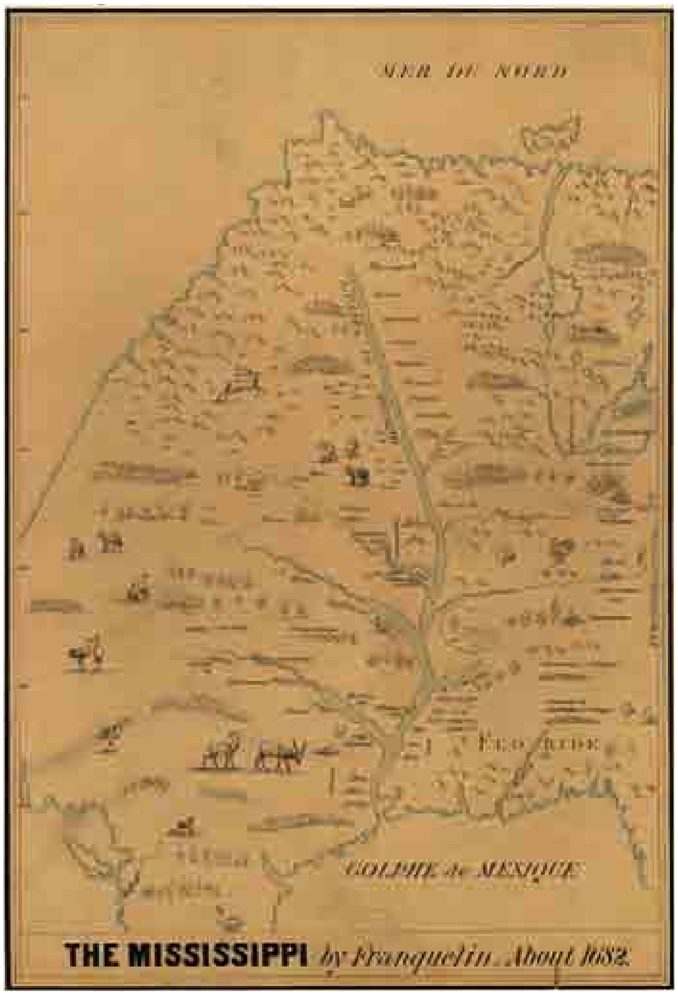



Fig. 15. Map of the Middle Mississippi River Regional Corridor produced by Franquelin in 1682.

the most accurate map of the Illinois Country at that time. The journal from Hutchins' mapping trip and that of Captain Harry Gordon at the same period offered detailed description of many important MMRRC features. Subsequent to Hutchins' map was the excellent map of General Victor Collot prepared from field surveys in the late 1790s and published in 1826 (Fig. 16). This "Collot" map provided expanded notes and coverage of vegetation and larger wetlands in the MMRRC floodplain and became the basis for additional maps and naturalist accounts of Nicolas de Finiels (Fig. 17) in the early 1800s (Ekberg and Foley 1989).

In the early 1800s, following American occupation and rule, the MMRRC was mapped by the U.S. General Land Office (GLO) to establish a geometric system of land ownership and governance (i.e., the Range-Township-Section system developed by Thomas Jefferson and codified in the Land Survey Ordinance of 1785). These GLO surveys established right-angle "section lines" in a geometric land grid system, and the surveyors also documented vegetation and "witness" trees at section corners and center points between the corners (GLO 1817, 1821). Consequently, the GLO maps and surveys established a "georeference" of locations and distribution of MMRRC features including general habitat types. GLO surveyors usually described vegetation communities in broad categories (e.g., forest, bottomland, prairie) and grouped witness trees in general taxonomic groups (e.g., black vs. white oak). Consequently, considerable interpretation often is needed to determine the exact species composition that was noted. Most likely, the "black oaks" described in GLO notes for the MMRRC were "red oak" species such as pin, willow, and cherrybark oaks and the "white oaks" probably were a collection of overcup, swamp white, post, and swamp chestnut oak. GLO notes that describe general habitat types of forest, bottomland, prairie, open water, etc. do not describe composition of forests nor do they delineate small areas of trees or herbaceous wetlands within bottomland settings (Bourdo 1956, Hutchinson 1988). GLO surveys probably mapped savannas as forest, but this is unclear because many savanna areas may have contained larger amounts of prairie or other grasses. In the MMRRC, GLO notes and maps often mix the terms "bottomland", "woodland", and "forest". Most "bottomland" appears to have been Bottomland Prairie-type communities, however, the scale of mapping, and definition of communities often is gross and inconsistent. Further, GLO notes suggest travel through, and precise documentation of, vegetation in low elevation, wet, floodplain locations (such as abandoned channels and floodplain depressions) was difficult and somewhat cursory. Notes in these areas often refer to lands simply as "water", "wet", "swampy", "marais", or "flooded."

In addition to the GLO surveys, many other cartographers, naturalists, and explorers produced maps (often small- scale maps of a local area) and provided natural history accounts and botanical records for many MMRRC areas (Hutchins 1784, Brackenridge 1814, Schoolcraft 1825, Flint 1828, Flagg 1838, Wild 1841, Oliver 1843, Featherstonhaugh 1844, Warren 1869, Allen 1870, Brink and Co. 1875). In 1879, the Mississippi River Commission (MRC, 1881) produced the first complete set of maps for the Mississippi River from New Orleans to Minneapolis. This map set included detailed descriptions of the Mississippi River channel, side channels and chutes, tributaries, floodplain habitats (general habitat types), floodplain lakes, and settlements (Fig. 18). Other maps made in 1890 and the early 1900s documented landscape changes and river geomorphology (e.g., Brauer et al. 2005).

Collectively, the above maps, historical accounts, and published literature suggest historical vegetation communities in the MMRRC were distributed along elevation, geomorphology, and hydrological gradients (e.g., Fig. 12). Similar community distribution associations also occur in other Mississippi Valley floodplain areas and help validate information from the MMRRC (e.g., Sparks 1993, Heitmeyer and Westphall 2007). Relationships between community types and geomorphology, soils, topography, and flood frequency zones were used to prepare HGM matrices that identified the potential distribution, composition, and area of Presettlement habitats for the three MMRRC ecoregions (Tables 5-7). The methods of determining these relationships involved the following steps of overlaying data layers from historical and current maps and then validating relationships using field reference sites (see Klimas et al. 2004, Klimas et al. 2005 for specific methodology):

1. General habitat type maps (e.g., forest, prairie, Bottomland Lake) determined from GLO surveys (General Land Office 1817, 1821) and historic cartography (e.g., Hutchins 1784, Collot 1826, De Finiels maps from the 1800s in Ekberg and Foley 1989, Mississippi River Commission 1881) were overlain on contemporary geomorphology (Saucier 1994, Hajic 2000, Woerner et al. 2003), soils (U.S. Department of Agriculture SSURGO soils data), flood frequency (data from USACE, St. Louis District), and topography (various elevation maps) maps.

2. The general correspondence of communities with the abiotic geomorphology, soils, topography layers was determined where possible. Confidence in this "map" correspondence was best when geo-referenced digital maps were available, such as the GLO surveys, and was weakest when older maps and cartography were used. Despite the imprecision, analyzing habitat information from the older maps provided useful information to determine the general distribution of communities. Using this first-step overlay of map information, relationships between communities and abiotic factors sometimes became clearly defined by one factor. For example, in the MMRRC all chute and bar surfaces were forested. Usually, however, it was necessary to use multiple abiotic factors to understand and predict relationships.

3. Remnant native vegetation communities were identified from aerial photographs and were visited to determine if they matched community types predicted from # 2 and to document vegetation characteristics, such as species composition. If the historic map and contemporary field data were consistent, then the field sites were considered a reference site of former community types.

4. Major community types (e.g., forest, prairie) were subdivided into ecologically distinct sub-communities using botanical information for the respective communities. For example, prairie consists of wet Bottomland and drier Mesic types (Nelson 2005). Botanical literature indicates that Bottomland Prairie typically occupied clay type soils within the 2-5 year floodplain (e.g., Turner

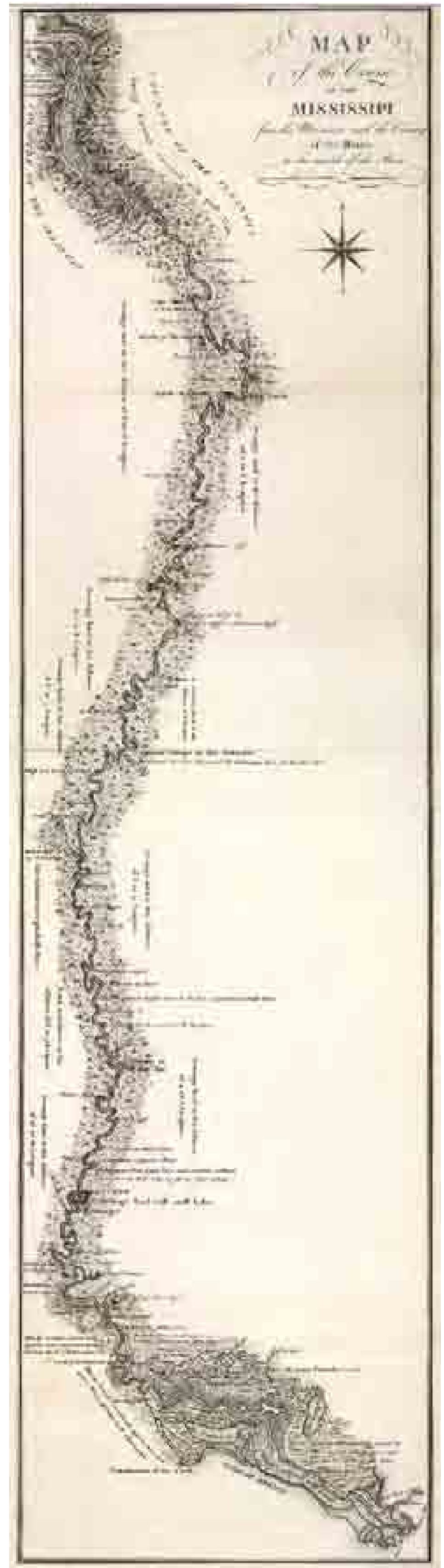



Fig. 16. Map of the Middle Mississippi River Regional Corridor produced by Victor Collot in the late 1790s


Fig. 17. Map of the Middle Mississippi River Regional Corridor produced by Nicholas De Finiels in the early 1800s.

1934, Nelson et al. 1998, Nelson 2005, Heitmeyer and Westphall 2007). In contrast, Mesic Prairie occurred on higher elevation Pleistocene terraces that had mixed silt loam soils (e.g., Chmurny 1973, Gregg 1975, Nelson 2005). Similar types of information distinguished characteristics of Riverfront, Floodplain, BLH, and Slope Forests.

Further refinement of some communities also was possible where eco-physiological relationships among species within a community were known. For example, many forest types contain a diversity of species that are distributed along topographic gradients (see e.g. Fig. 14 on species gradients within BLH). Consequently, the combination of soils, geomorphology, and topography often could separate species groups within forest types. As an example, Floodplain Forest typically occupied point bar surfaces that contained ridge and swale topography. The swales in Floodplain Forest usually had clay-type soils, whereas ridges contained loams and sandy soils. Consequently, by mapping soils on point bar surfaces, Floodplain Forest areas were sub-divided into swale-type communities that had more water tolerant species such as maple, sugarberry, and green ash vs. ridge-type communities that had mainly elm, oak, and pecan present. A similar separation (swale vs. ridge) was done for Bottomland Prairies that had swales or other depressions interspersed with higher elevation ridges. BLH was separated into "High BLH" vs other lower elevation "BLH" (that contained the combined Intermediate, Low, and Cypress/tupelo communities) using topography and geomorphology information; soils were less useful because most backswamp areas that support BLH are predominantly clay-type soils regardless of topography.

Distinction of sub-classes within habitat communities was not always possible in the MMRRC because digital data were not available for all factors. A major problem in the American Bottoms is the extensive urbanization that has flattened topography and covered soils. In these areas, the historic general community type (e.g., forest or prairie) usually was predictable or known, however further refinement usually was not possible and maps simply state the general habitat type with an "urban" modifier (see Appendices maps A-E).

5. A matrix of predicted community types in relationship to the geomorphology, soils, topography, and flood frequency variables discovered in steps 1-4 above was prepared (e.g., Tables 5-7).

6. The position of predicted communities from the HGM matrix on the composite digital geo-referenced maps of geomorphology, soils, topography, and flood frequency for each MMRRC ecoregion was mapped where possible (note the caveats stated in #4 above).

7. Aerial photographs were used to identify remnant habitats of the refined community types (i.e. distinct prairie and forest communities) and reference sites and remnant habitats were revisited to determine what vegetation was present. This field data collection was similar to step #3 in finding reference sites that represent various communities.

8. Based on field and map data developed in steps 6 and 7, the HGM matrices were refined and areas or communities were identified

where correspondence with various abiotic factors were weak. For example, in the MMRRC, soil and topography data did not predict the presence of prairie on what is now Kaskaskia Island. Older maps and accounts from this area clearly indicated Bottomland Prairie was present on this site prior to the major changes in position of the Mississippi and Kaskaskia rivers in the late 1800s (Meyer 1996). Undoubtedly, the major changes in Mississippi River flows that occurred at Kaskaskia also changed sediment scouring and deposition patterns from Presettlement periods and created new topography and geomorphic surfaces in the late 1800s. In this case it was necessary to overlay historic maps from the Kaskaskia area onto current digital maps to produce an estimate of the Presettlement community and how its distribution was related to current landscape features.

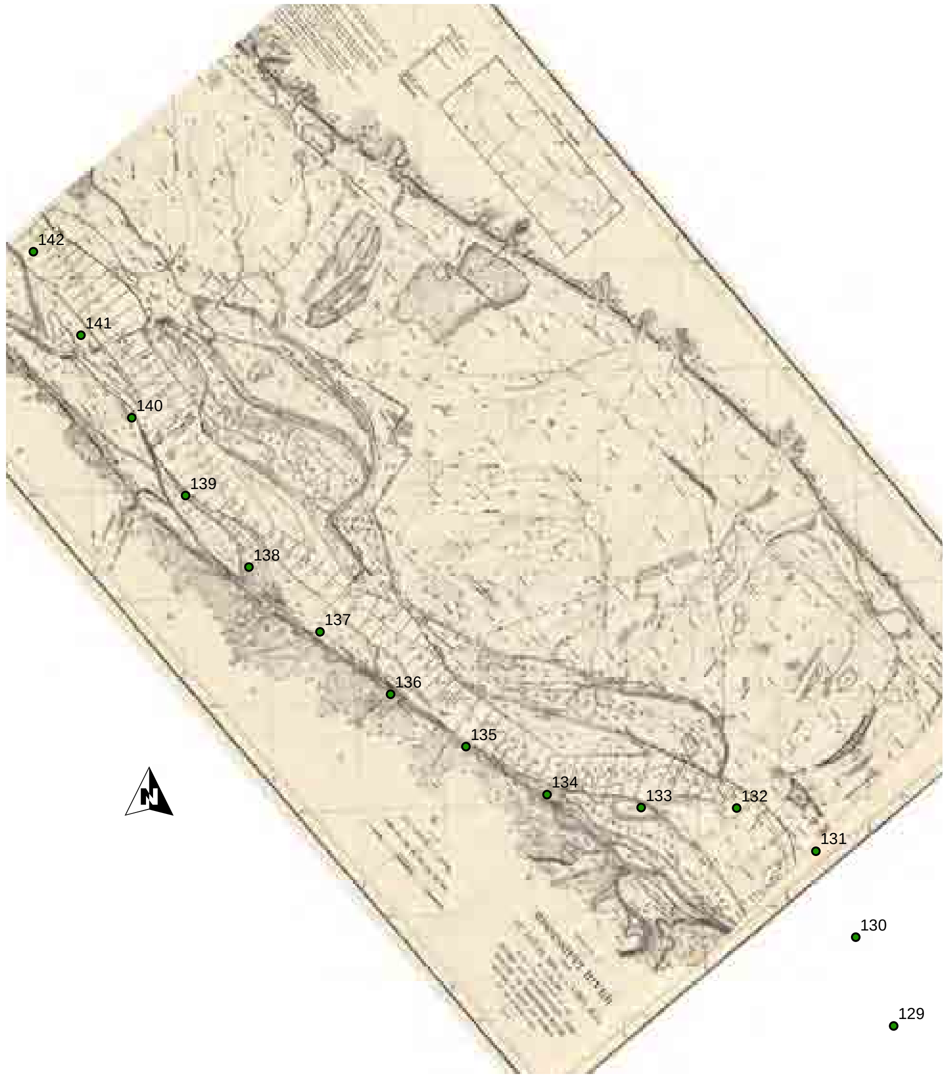



Fig. 18. An example of a Mississippi River Commission map (1881) prepared for the Middle Mississippi River Regional Corridor.

Another problem area in predicting HGM relationships from historic information was the Bois Brule region immediately south of Kaskaskia. Historic information suggests this region supported Floodplain Forest, yet current geomorphology maps (Hajic 2000) map the site as chute and bar surfaces, which in other MMRRC areas supports Riverfront Forest. Likely, this discrepancy between historic information and current community relationships at Bois Brule occurred for the same reasons that differences occurred on what is now Kaskaskia Island. The changes in position and sediment scouring and deposition at Bois Brule in the late 1800s probably caused new surfaces to be formed and community-geomorphological relationships became more complex. A similar pattern of potentially changed biotic-abiotic relationships also appears to have occurred in the floodplain region adjacent to Devils Island. Hopefully, future studies of historic geological surfaces and stratigraphy and analyses of new botanical information on historical vegetation community relationships in these "problem" areas will clarify the HGM relationships in the MMRRC.

9. The predicted potential Presettlement community distribution for the MMRRC was mapped for each MMRRC ecoregion (Appendices A-E).

As stated above, only general habitat maps could be prepared in urban areas of the American Bottoms. In these urban areas, geomorphic data was present and could predict general distribution of some communities, however, topography has been highly altered and soils are often covered by concrete, asphalt or gravel and historic surface soil layers are highly redistributed. Consequently, the potential Presettlement vegetation map for the American Bottoms can only suggest whether current urban sites historically were prairie or forest, except where chute and bar surfaces are present (i.e. these would have been Riverfront Forest communities, Table 5).

The diversity of Presettlement major community types in the MMRRC was highest in the American Bottoms and lowest in the MAV ecoregion south of Thebes (Table 8, Appendices A-E). Prairie vegetation was common and widely distributed in the American Bottoms on terraces and older point bar surfaces (Table 5, Appendices A-E ). The American Bottoms also contained highly interspersed ridge and swale complexes that were associated with the numerous river channel changes and development of point bars. The highly dynamic river flow regimes of the Illinois, Missouri, and Mississippi rivers regularly scoured and deposited sediments in this region and the many remnant abandoned channels demonstrate complex geomorphic stratigraphy. This confluence region represents the southern terminus of the "Prairie Peninsula" physiographic region of mid-North America and includes a southern extension of Bottomland Prairies that historically were present along the Mississippi, Missouri, and Illinois rivers north of St. Louis (e.g., Nelson et al. 1994, 1998). Prairie habitats were relatively contiguous (albeit interspersed with other habitats such as Floodplain Forest and Bottomland Lakes) for the Upper 35 miles (RM 161 to RM 195) of the American Bottoms, became more fragmented from RM 161 to RM 135, but then became more connected through RM 117 at Kaskaskia. Fortunately, many excellent maps have been prepared of prairie and forest vegetation in the Upper American Bottoms (e.g., Chmurny 1973, Gregg 1975, Benchley 1976, USACE 2004b) and these maps combined with GLO survey notes provide corroboration of the distribution of prairie and forest communities in the American Bottoms ecoregion.

Forest in the American Bottoms historically was distributed as relatively distinct communities. Riverfront Forest was present on chute and bar surfaces with sandy-type soils near the Mississippi River, Floodplain Forest was present on older point bar surfaces often adjacent to Bottomland Lakes, and Slope Forest were present on alluvial fans and the Savanna Terrace (Appendices A, B). No true BLH occurred in the American Bottoms, but scattered patches of oak and pecan-dominated forests were present on higher elevation point bar areas. The many abandoned channels in the American Bottoms, coupled with numerous point bar swales, created a mosaic of "wetland" types in the ecoregion and made the entire confluence area

Table 5. Hydrogeomorphic (HGM) matrix of historic distribution of major vegetation communities/habitat types in the American Bottoms ecoregion of the Middle Mississippi River Regional Corridor in relationship to geomorphic surface, soils, and flood frequency. Relationships were determined from land cover maps prepared from the Government Land Office survey notes taken in the early 1800s, historic maps prepared by Hutchins in 1784, Collot in the 1790s, de Finiels in the early 1800s, and the Mississippi River Commission in 1890; U.S. Department of Agriculture soil maps; geomorphology maps prepared by Saucier 1994, Hajic 2000, and Woerner et al. 2003; flood frequency data provided by the U.S. Army Corps of Engineers St. Louis District; and various naturalist/botanical accounts and publications from the 1800s and early 1900s.

| Habitat type | Geomorphic Surface | Soil Type | Flood Frequency |
|---|---|---|---|
| Open Water | Active river channels | Riverine | Permanent |
| | Side channels | Riverine | Permanent-seasonally dry |
| | Abandoned channels | clay, silt clay | Permanent-seasonally dry |
| Bottomland Lake | Abandoned channels | clay, silt clay with sand/loam plugs | Permanent to semi-permanent |
| Riverfront Forest | Bar-and-chute and Braided bar | sand, sandy loam and silt loam in swales | 1-2 year |
| Floodplain Forest | | | |
| Ridges | Point bar ridges | loam, sandy loam | 2-5 year |
| Swales | Point bar swales and Tributary riparian zones | silt loam, silt clay veneer | 1-2 year |
| Bottomland Hardwood Forest | Backswamp, larger point bar swales and floodplain depressions | silt loam, silty clay | 2-5 year |
| Slope Forest | Alluvial fans, colluvial aprons, terrace edges | mixed erosional | > 20 year |
| Savanna | Alluvial fans, colluvial aprons, terrace interface | silt loam | 10-20 year |
| Bottomland Prairie | | | |
| Wet | Point bar and terrace swales and depressions | clay, silt clay | 2-5 year |
| Intermediate | Point bar ridges | silt loam | > 5 year |
| Mesic Prairie | Point bar edges and | sandy loam, silt terraces | > 20 year loam |

one of the most diverse and extensive wetland areas of the middle U.S.

In contrast to the American Bottoms, habitat types from Kaskaskia to Thebes were predominantly forest communities; prairie vegetation did not occur south of what is now Kaskaskia Island (Tables 7,8). The entry of the Kaskaskia and Big Muddy rivers into the Mississippi River floodplain greatly altered velocity, seasonal discharge, flooding patterns and sediment deposition in this ecoregion. Soils in this ecoregion contained several wide expanses of coarse-grain sediments in chute and bar deposits (e.g., Wilkinson and Devils Islands), whereas point bars and backswamps contained relatively deep alluvial sediments dominated by silts and clays. Seasonal flooding in the Kaskaskia ecoregion was influenced by both local (Kaskaskia and Big Muddy watersheds) and upstream precipitation and flood events and included overbank Mississippi River flows and backwater flooding up tributaries. The large backswamp region east of Fountain Bluff along the Big Muddy River (U.S. Forest Service Oakwood Bottoms Recreation Area) (Fig. 6) is a transitional geomorphology from more braided channel and sand-based morphology, that had more frequent overbank flooding of the Mississippi River, in the northern American Bottoms to wider alluvial deposition that was created from slower backwater flooding in the southern Kaskaskia ecoregion. The narrow bluff "gap" at Thebes greatly constricted

Table 6. Hydrogeomorphic (HGM) matrix of historic distribution of major vegetation communities/habitat types in the Kaskaskia ecoregion of the Middle Mississippi River Regional Corridor in relationship to geomorphic surface, soils, and flood frequency. Relationships were determined from land cover maps prepared from the Government Land Office survey notes taken in the early 1800s, historic maps prepared by Hutchins in 1784, Collot in the 1790s, de Finels in the early 1800s, and the Mississippi River Commission in 1890; U.S. Department of Agriculture soil maps; geomorphology maps prepared by Saucier 1994, Hajic 2000, and Woerner et al. 2003; flood frequency data provided by the U.S. Army Corps of Engineers St. Louis District; and various naturalist/botanical accounts and publications from the 1800s and early 1900s.

| Habitat type | Geomorphic Surface | Soil Type | Flood Frequency |
|---|---|---|---|
| Open Water | Active river channels | Riverine | Permanent, 1 year |
| | Side channels | Riverine | Permanent-seasonally dry, 1 year |
| | Abandoned channels | clay, silt clay | Permanent-seasonally dry, 1 year |
| Bottomland Lake | Abandoned channels | clay, silt clay with sand/loam Plugs | Permanent to semi-permanent, 1-2 year |
| Riverfront Forest | Bar-and-chute and Point bar | sand, sandy loam and silt loam in swales | 1-2 year |
| Floodplain Forest[a] | | | |
| Ridges | Point bar ridges | loam, sandy loam | 2-5 year |
| Swales | Point bar swales and Tributary riparian zones | silt loam, silt clay veneer | 1-2 year |
| Bottomland Hardwood Forest | Backswamp, larger point bar swales and floodplain depressions | silt loam, silty clay | 2-5 year |
| Slope Forest | Alluvial fans, colluvial aprons, terrace edges | mixed erosional | > 20 year |
| Savanna | Alluvial fans, colluvial aprons, terrace interface | silt loam | 10-20 year |
| Bottomland Prairie[b] | | | |
| Wet | Point bar and terrace swales and depressions | clay, silt clay | 2-5 year |
| Intermediate | Point bar ridges | silt loam | > 5 year |

[a] The Bois Brule Bottom currently is mapped as a bar-and-chute surface (Woerner et al. 2003), however, it appears that much of this floodplain bottom was an older point bar surface prior to the sequence of large Mississippi River floods from 1844 to 1880 that ultimately caused the Mississippi River to shift eastward and join the Kaskaskia River at river mile 117. This river shift changed sediment and scouring patterns in the area and deposited layers of sand and sandy silt throughout the Bois Brule, which subsequently changed forest composition from a Floodplain Forest type to predominantly Riverfront Forest after 1880.

[b] The only Bottomland Prairie in this ecoregion was an area in what is now Kaskaskia Island. This prairie was identified by many early maps and accounts and HGM characteristics apparently were similar to prairie areas within the American Bottom. Several large floods from 1844 to 1880 caused the Mississippi River to shift eastward where it merged with the Kaskaskia River at ca. River Mile 117. This river course shift created the abandoned channel now named Horse Island and extensively scoured and deposited sediments throughout Kaskaskia Island. This scouring and sedimentation likely changed soil types from the Presettlement period and former prairie was replaced by Floodplain Forest and Riverfront Forest communities.

the Mississippi River at this point and occasionally "backed" Mississippi River flows up the MMRRC north of this gap during high flows (i.e. there was no wide floodplain to disperse floodwater)

The change in river dynamics and geomorphology immediately south of Kaskaskia created a more frequent "backwater" flooding system and deeper alluvial soils that supported forest vegetation, but not prairie (Tables 6-8). The combination of clay and silt soils on higher elevation floodplains coupled with a relative absence of fire apparently deterred the establishment of prairie vegetation in the region. Fire occasionally did burn into forest areas (e.g., the history of nomenclature and fire scars on buried tree remains in the Bois Brule Bottoms southwest of Chester) (Maggard 1998, USACE 2003a), but it was relatively rare and occurred only during very dry periods. Large amounts of chute and bar coarse-grain sediments occur immediately north of Thebes in the Devils Island area and suggest the floodplain constriction at Thebes Gap caused the Mississippi River to frequently move laterally across the floodplain during high discharge periods. The largest abandoned channel complex in this region is in the Union County Wildlife Management Area. Fluvial dynamics north of Thebes created conditions that supported extensive corridors of Riverfront Forest along the Mississippi River channel. Wide bands of Floodplain Forest were present on point bar surfaces and BLH was present in backswamp and abandoned channel areas. BLH areas were created and sustained primarily by seasonal dormant-season back floods and ponding from on-site precipitation. In contrast, Riverfront and Floodplain Forests that were subjected to overbank flooding of the Mississippi River from late winter to early summer.

South of Thebes, vegetation communities in the MMRRC became similar to lowland habitats in the Upper MAV. In this southern ecoregion of the MMRRC, the Ohio River significantly influences flows and back flooding upstream along the Mississippi River. During backwater flooding events, waters in the Mississippi River slow and alluvial silts and clays are deposited throughout the floodplain. This alluvial deposition of clays and silts and a predominance of backwater flooding created an environment where BLH became the dominant vegetation community behind chute and bar and natural levee deposits (Tables 7,8). The large Horseshoe Lake complex in southern Illinois was created by the merging and dispersing Ohio and Mississippi rivers and became a low elevation "sump" that supported baldcypress, water tupelo, S/S, and Low BLH vegetation (USACE 2003b). The low elevation "wet" nature of the Upper MAV prohibited development of prairie vegetation and limited fire and seasonal herbivory.

In summary, the MMRRC historically contained landforms

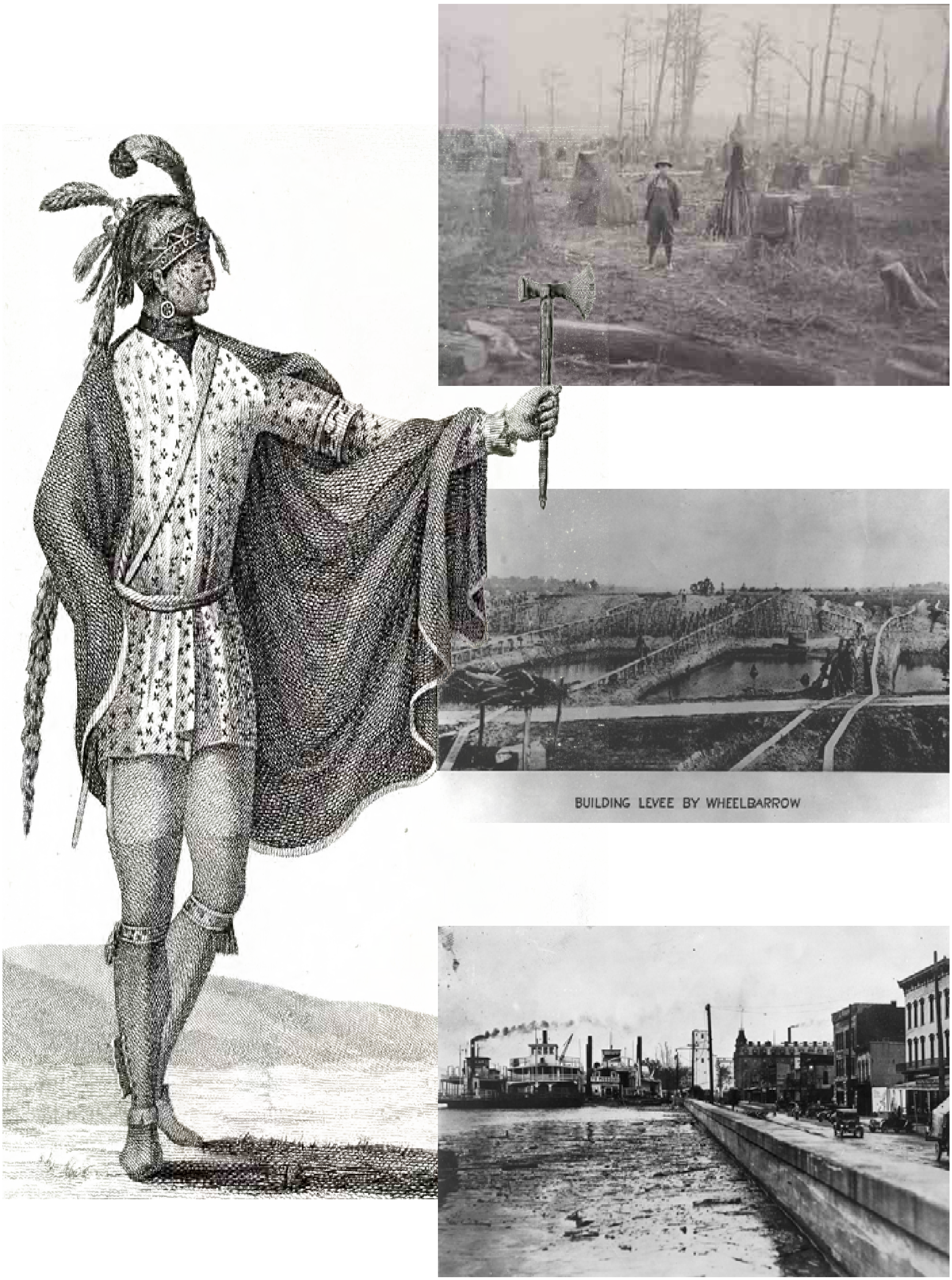
Table 7. Hydrogeomorphic (HGM) matrix of historic distribution of major vegetation communities/habitat types in the Thebes to Ohio River ecoregion of the Middle Mississippi River Regional Corridor in relationship to geomorphic surface, soils, and flood frequency. Relationships were determined from land cover maps prepared from the Government Land Office survey notes taken in the early 1800s, historic maps prepared by Hutchins in 1784, Collot in the 1790s, de Finiels in the early 1800s, and the Mississippi River Commission in 1890; U.S. Department of Agriculture soil maps; geomorphology maps prepared by Saucier 1994, Hajic 2000, and Woerner et al. 2003; flood frequency data provided by the U.S. Army Corps of Engineers St. Louis District; and various naturalist/botanical accounts and publications from the 1800s and early 1900s.

| Habitat type | Geomorphic Surface | Soil Type | Flood Frequency |
|---|---|---|---|
| Open Water | Active river channels | Riverine | Permanent, 1 year |
| | Side channels | Riverine | Permanent-seasonally dry, 1 year |
| | Abandoned channels | clay, silt clay | Permanent-seasonally dry, 1 year |
| Bottomland Lake | Abandoned channels | clay, silt clay with sand/loam plugs | Permanent to semi-permanent, 1-2 yea |
| Riverfront Forest | Bar-and-chute and Braided bar meander belt immediately next to the Mississippi River | sand, sandy loam and silt loam in swales | 1-2 year |
| Floodplain Forest | | | |
| Ridges | Point bar, meander belt ridges | loam, sandy loam | 2-5 year |
| Swales | Point bar, meander belt ridges and Tributary riparian zones | silt loam, silt clay veneer | 1-2 year |
| Bottomland Hardwood Forest | Backswamp, larger point bar swales, braided stream terraces and meander belts | silt loam, silty clay | 2-5 year |
| Slope Forest | Alluvial fans, colluvial aprons, terrace edges | mixed erosional | > 20 year |

Table 8. Area (acres) of Hydrogeomorphic (HGM) habitats in the three ecoregions of the Middle Mississippi River Regional Corridor during the Presettlement Period (based on Appendices A-E maps) and remnant patches remaining in 2006 (based on Appendices K-O maps).

| | Ecoregion | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | American Bottoms | | | Kaskaskia to Thebes | | | Thebes-Ohio River | | | Combined | | |
| Habitat type | Presettlement | 2006 | % Loss | Presettlement | 2006 | % Loss | Presettlement | 2006 | % Loss | Presettlement | 2006 | % Loss |
| BLH | | | | 15,045 | 10,630 | 29.3% | 33,540 | 9,304 | 72.3% | 48,585 | 19,934 | 59.0% |
| BLH High | | | | 2,370 | 331 | 86.0% | | | | 2,370 | 331 | 86.0% |
| Bottomland Lake | 16,959 | 7,450 | 56.1% | 16,288 | 3,504 | 78.5% | 4,986 | 3,066 | 38.5% | 38,233 | 14,020 | 63.3% |
| Bottomland Prairie Ridge | 4,777 | 357 | 92.5% | 3,936 | 67 | 98.3% | | | | 8,713 | 424 | 95.1% |
| Bottomland Prairie Swale | 34,493 | 3,948 | 88.6% | 516 | 79 | 84.7% | | | | 35,009 | 4,027 | 88.5% |
| Bottomland Prairie Urban | 16,071 | 446 | 97.2% | | | | | | | 16,071 | 446 | 97.2% |
| Terrace Mesic Prairie | 18,924 | 655 | 96.5% | | | | | | | 18,924 | 655 | 96.5% |
| Slope Savanna | 10,365 | 137 | 98.7% | | | | | | | 10,365 | 137 | 98.7% |
| Floodplain Forest Ridge | 8,618 | 755 | 91.2% | 31,818 | 8,375 | 73.7% | | | | 40,436 | 9,130 | 77.4% |
| Floodplain Forest Swale | 32,721 | 2,764 | 91.6% | 73,489 | 16,467 | 77.6% | 5,700 | 1,273 | 77.7% | 111,910 | 20,504 | 81.7% |
| Floodplain Forest Urban | 9,323 | 345 | 96.3% | | | | | | | 9,323 | 345 | 96.3% |
| Loessal Upland | | | | 3,387 | 3,387 | 0.0% | | | | 3,387 | 3,387 | 0.0% |
| Riverfront Forest | 65,125 | 24,104 | 63.0% | 46,094 | 24,632 | 46.6% | 9,080 | 8,794 | 3.1% | 120,299 | 57,530 | 52.2% |
| Slope Forest | 16,934 | 1,207 | 92.9% | 6,861 | 1,913 | 72.1% | 1,695 | 1,080 | 36.3% | 25,490 | 4,200 | 83.5% |
| TOTALS | 234,310 | 42,168 | 82.0% | 199,804 | 69,385 | 65.3% | 55,001 | 23,517 | 57.2% | 489,115 | 135,070 | 72.4% |

and communities that represented a gradual transition from a prairie-dominated "confluence" floodplain ecosystem in the north to a BLH-dominated forested ecosystem in the south. Glacial advance and retreat, the development and merging of three large interior U.S. rivers at St. Louis, and the expansion and subsequent retreat of the Mississippi Embayment in the MAV created this dynamic transitional ecosystem region and the highly diverse and productive communities it supported.


BUILDING LEVEE BY WHEELBARROW

# CHANGES TO THE MIDDLE MISSISSIPPI REGION ECOSYSTEM

## REGIONAL LANDSCAPE CHANGES

*Settlement and Early Landscape Changes.* – At least some humans apparently occupied parts of the MMRRC as early as 10,000 BP (Hudson 1976). Since initial human occupation by the Paleo-Indians, many succeeding cultures were present in the MMRRC until the early 1800s. Archaic period people built some of the first public monuments in the New World around 5,000 BP including mounds in the Thebes ecoregion. The subsequent Woodland period in the MMRRC was characterized by intensification of horticulture and use of pottery to cook seed and native grasses (Pauketat 2004). At this point, semi-sedentary "base" camps were disappearing and larger collective groups of people were establishing "communities" that were centers of occupation and culture. The Mesoamerican cultigen, maize, was first grown by native people in mid-North America during the Middle Woodland period. During the Late Woodland period (ca. 1100 to 1600 BP) native populations expanded greatly, some tribes undertook apparently long "migrations", bows and arrows were developed, and food production intensified. At this time settlement sizes and locations shifted often, and major "ceremonial centers" developed in central Arkansas and the American Bottoms of the MMRRC. Maize production apparently was extensive in some areas.

The terminal Woodland period (ca. 900-1100 BP) was a time of notable change from the older Woodland way of life and native people developed several large villages throughout the MMRRC. One larger village was located at Cahokia in the American Bottoms. Other villages were distributed at regular intervals south to Cairo; most occurred along the higher elevation edges of Bottomland Lakes. Production of maize intensified during this period, pottery was colored and protected by films of red clays, and chipped-stone hoe blades were developed. The village of Cahokia enlarged greatly beginning in the Early Mississippian period (ca. 800-900 BP). At this time many native populations abandoned or vacated more scattered MMRRC locations, and more centralized societies became established (Milner 1998, Pauketat 2004). Mound building reached its peak during this time and Cahokia contained multiple mound centers, each being a seat of a locally important chief (Milner 1998). Other mounds were built for burial and other purposes. These elaborate structures signified the complex social culture and governing system of these Mississippian era people. At the height of its development, Cahokia covered 5 ½ square miles and contained nearly 40,000 people. It was the largest, most densely populated site in aboriginal North America.

The location of Cahokia at the confluence area in the American Bottoms contained a diversity of prairie, forest, and wetlands that provided ample food resources for the huge Native American population (Milner 1998). The area also was a natural travel corridor along the Missouri, Illinois, and Mississippi rivers and became a center of transport and trading in central North America. The higher elevation of Cahokia (older point bar deposits) coupled with its proximity to the Mississippi River (and other abandoned channel connections) protected it from most excessive floods and the prairie landscape and rich alluvial soils also were suitable for growing maize. Undoubtedly, native people used fire to maintain parts of the surrounding prairie landscape and create agricultural plots. Nearby forests and savannas provided wood for fuel, and abundant fish and wildlife were used for food (e.g., Kelly 1979, Kelly et al. 1979, Fowler 1989, Lopinot et al. 1991, Witty and Kelly 1993). Local overexploitation of forest and wood immediately adjacent to the Cahokia settlement site appears to have occurred and was a factor influencing the tenure and sustainability of the settlement, especially when hostilities began to emerge among rival chiefs and factions. During the peak of Cahokia's regional dominance, more southerly located villages such as the Ware and Linn-Helig sites became mostly depopulated and many people moved north either to Cahokia or northern Jackson County, Illinois (where many mounds also were built). The land in the middle part of the MMRRC was comprised of extensive point bar surfaces that contained long, narrow, sandy ridges separated by shallow swales and was less capable of supporting large villages or sustaining large numbers of people (Milner 1993). The mid and southern MMRRC also was heavily forested and contained extensive swamps (such as at Oakwood Bottoms and in Union County) and its physical structure was less conducive to maize production.

The decline of the Cahokia-dominated regional chiefdom culture occurred over several decades as competing factions of chiefs eroded continuity in governance. The central part of Cahokia became enclosed by an earthen wall as conflicts among chiefs and regional factions occurred. This wall restricted movements of village peoples and restricted their access to floodplain resources, including wood, fish, and wildlife. Eventually, the hostilities eroded the once powerful sociopolitical system and populations gradually redistributed from Cahokia about 500-700 BP mostly to surrounding uplands where prairies and savannas enabled simple agriculture production. Further, by about 700 BP culturally dissimilar people (e.g., Oneota groups) began allying with valley inhabitants and centralized cultures eroded further. By the Late Mississippian period, people in the MMRRC were widely distributed, which caused local autonomy to increase and chiefly authority to decrease. These societal changes greatly altered how people may have been used resources in MMRRC habitats and by about 400 BP, occupation in the American Bottom was "archaeologically invisible" (Milner 1998). At this time a broader "shuffling" of native people also was occurring in eastern North America following European occupation and their movement west. By the 1600s, much of the Ohio-Mississippi confluence area in the lower MMRRC was depopulated.

Beginning in the sixteenth century, European countries and their empires began sending explorers to America to stake claims to these new lands. The first European to claim discovery of the Mississippi River was the Spanish explorer Hernando De Soto, who in 1541 found the Mississippi River near present day Memphis, Tennessee. De Soto apparently did not travel into the MMRRC, but lands west of the Mississippi River were claimed for Spain. In1673 the French missionary Jaques Marquette led the first European exploration of the Upper Mississippi River including the MMRRC. Marquette's journey essentially laid claim of the MMRRC (at least the area east of the Mississippi River) to the French. The historic French village of Cahokia was established in 1699 as a mission among the remnant Tamaroa and Cahokia Indians and it became the first permanent Euro-American settlement on the Mississippi River. Other early eighteenth-century villages and forts established in the MMRRC included Kaskaskia (1703), Fort de Chartes (1719), Prairie du Rocher (1721), and St. Phillippe (ca. 1723) on the Illinois side of the Mississippi River. On the Missouri side, early French settlements were formed at St. Genevieve (1750) and St. Louis (1764). Through most of the eighteenth century, these "frontier" settlements were the westernmost parts of the French regime, with governmental headquarters in Quebec, Canada.

All early European settlements were on or near the Mississippi River and usually were located near larger interspersed prairie-woodland ecosystems (excepting St. Genevieve, which was located on a forested river bluff). Individual settlements maintained self-sufficiency during the 1700s with small garden plots, establishment and use of village "commons" (usually referred to as "common fields") for livestock pastures and agriculture, harvest of local timber, fur trapping, and river commerce. Expansion of agriculture in the late 1700s and early 1800s gradually started clearing MMRRC prairies, savannas, and Floodplain Forests in the American Bottoms (Branom 1941, Gums 1988). Major crops produced by French colonials included wheat, corn, tobacco, flax, cotton, and hemp (Ekberg 1985). Agriculture production was especially prevalent in the American Bottoms "prairie" regions and 300,000 lbs of flour were reported to have been shipped from the American Bottoms to New Orleans in 1738 and 1739. Salt production and lead mining in Missouri near St. Genevieve also provided economic bases for the region. Timber harvest, especially along the Mississippi River provided fuel for steamboats and eventually, more extensive harvest of floodplain and BLH forests occurred throughout the MMRRC (e.g., Perrin 1883, Yin and Nelson 1996, Norris 1997).

French domination of the MMRRC ended with the British Victory in the Seven Years War in 1763. British rule over the MMRRC was relatively short and

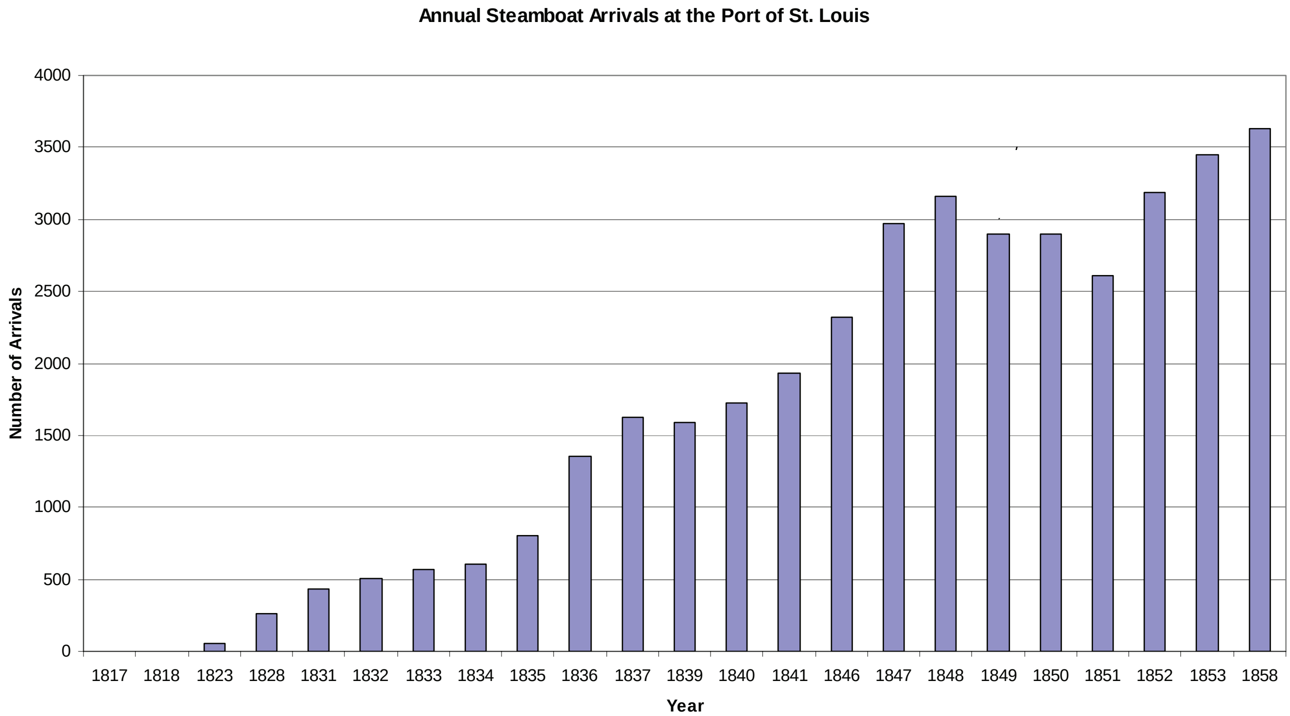



Fig. 19. Annual steamboat arrivals at St. Louis, 1817-1858 (from Brauer et al. 2005).

ended with the American Revolutionary War a decade later, at which time Americans began moving to the region in larger numbers. Throughout the nineteenth century, the MMRRC remained a small semirural-dominated society with a mixture of French and European descendants and "new" American pioneers. Following the Louisiana Purchase of lands west of the Mississippi River from France (who had received these lands from Spain in 1801) in 1803, the United States began commissioning regular surveys and explorations of the Mississippi and Missouri rivers, most notably the Lewis and Clark expedition.

St. Louis quickly developed into the primary trading post in the Mississippi River Valley following the advent of steamboats in the early 1800s. Mississippi River traffic and commerce increased rapidly; annual steamboat arrivals at St. Louis grew from 3 to 3,600 between 1817 and 1858 (Fig. 19). The population of St. Louis grew from 3,000 in the early 1800s to 160,000 by 1860. Collectively, the expanding human population and commerce in the MMRRC caused extensive clearing of MMRRC lands, especially prairie, for agriculture by 1890 (Appendices F-J). In the East St. Louis area, urban expansion also began converting Bottomland and Mesic Prairie and forest to cities. Based on the potential Presettlement vegetation maps (Appendices A-E), > 90% of prairie had been lost by 1890 and > 50% of Floodplain and BLH Forest in the MMR were destroyed by that time (Appendices F-J). In contrast, less Riverfront Forest was cleared by 1890 and most larger Bottomland Lakes were largely unchanged, except for developments and settlements on their edges.

*Hydrological and Later Landscape Changes.* – The first attempt to control flows and channel movements of the Mississippi River in the MMRRC involved construction of river training structures near St. Louis in 1838 (Brauer et al. 2005). Robert E. Lee designed a series of dikes to move the Mississippi River channel back towards the Missouri side of the river and to protect the integrity of the St. Louis harbor. No further dikes were built in the region until 1872. In 1879, the Mississippi River Commission (MRC) was established with the purpose "to improve and give safety and ease to navigation" and "to prevent destructive floods on the Mississippi River." All work of the MRC was conducted by the U. S. Department of the Army and a master plan was developed in 1881 to stabilize the main channel downstream from St. Louis by reclaiming eroded land, building up new banks, and reducing the width of the river to about 2,500 feet (Ernst 1881). Major structures involved with these efforts were wooden pile dikes and willow-weave mattresses. Dike construction accelerated from 1880-1900 (Fig. 20). Later in

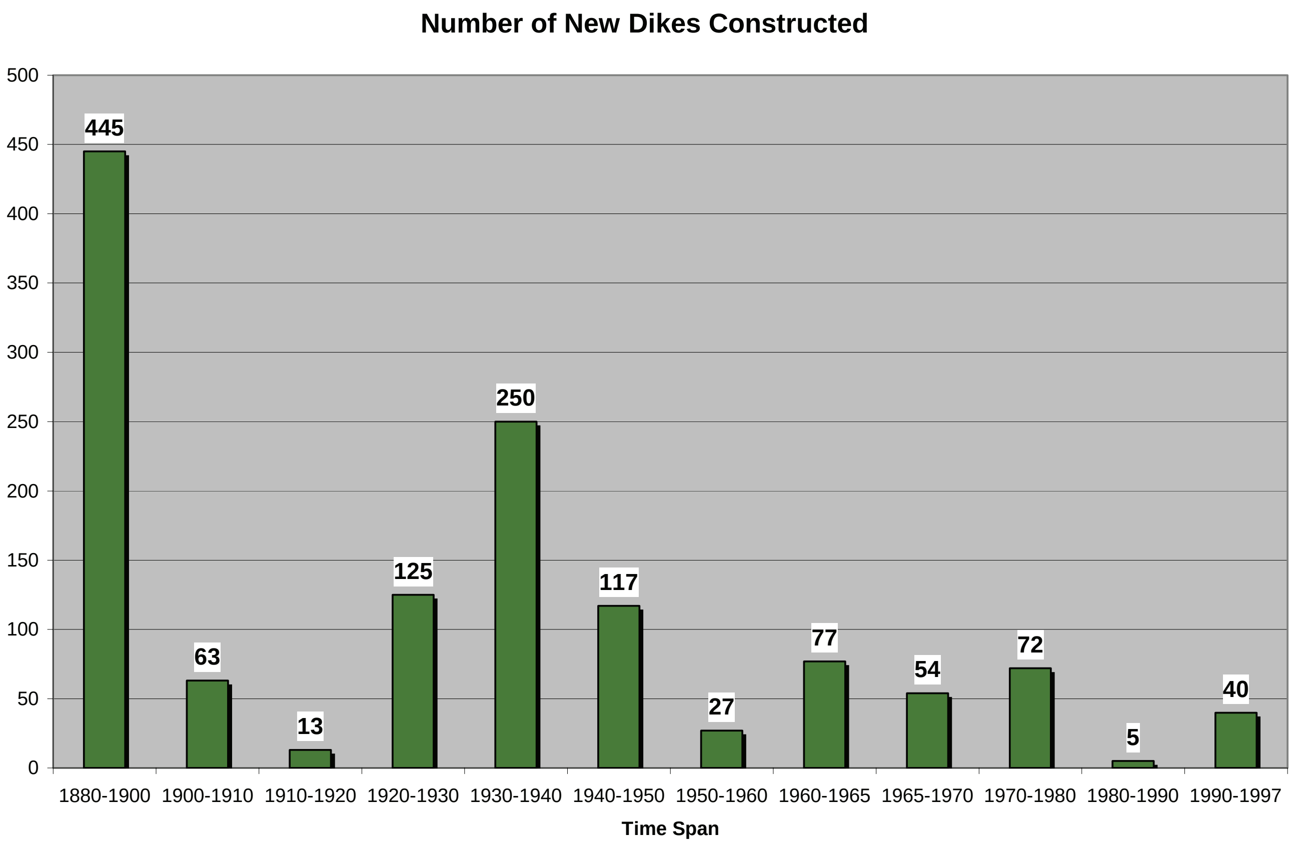



Fig. 20. Number of dikes constructed along the Mississippi River in the Middle Mississippi River Regional Corridor from 1880 to 1997 (from Brauer et al. 2005).

the 1930s, stone riprap was placed along eroding bank shores, and in the 1960s, wooden pile dikes were replaced with stone "wing dikes or dams." Recently, new river channel training structures including bendway weirs and chevrons have been used to mitigate channel movements (Davinroy 1990).

Recent analyses of the Mississippi River channel geomorphology in the MMRRC have documented the many physical changes in the region from 1817 to the present (Brauer et al. 2005). Average width of the river declined from 5,026 feet in 1817 to 2,974 feet in 2003 (Fig. 21). The mean river width increased in 1881 when the Mississippi River shifted to occupy the Kaskaskia River channel at RM 118 (Burnham 1914, Meyer 1996). This change created a large side channel (now a leveed abandoned channel) and island between the new and old locations of the confluence of the Mississippi and Kaskaskia rivers (Fig. 22). Following construction of wing dikes in the 1900s, the width of the Mississippi River began to shorten substantially. While channel width has declined over time, the length of the Mississippi River has not changed much since 1817 (Fig. 23). Sinuosity of the river has not changed much from Thebes to St. Louis, but has steadily increased from Thebes to the Ohio River because of increased meandering (Fig. 24).

The number and size of islands present in the Mississippi River channel within the MMRRC initially increased from 1817 to 1881 and the river became a more "braided" system (Fig. 25). In the 1900s, wing dikes and other river training structures started to close many side channels (Fig. 26) and the number of islands, and braided nature of the river decreased. These river changes were caused by a combination of developments including the aforementioned wing and pile dikes, dredging to maintain a nine-foot low water channel for navigation, construction of large mainstem levees along the Mississippi River and the Big Muddy and Kaskaskia rivers, and construction of locks and dams on the Mississippi River above St. Louis and on the Illinois River beginning in 1938. Levees along the Mississippi River at St. Louis originally were built in the early 1900s to protect the city to 11-12 feet above flood stage. These levees and others in the MMRRC were greatly enlarged and heightened between 1936 and 1945 and by 1960 protection for St. Louis was about 21 feet above flood

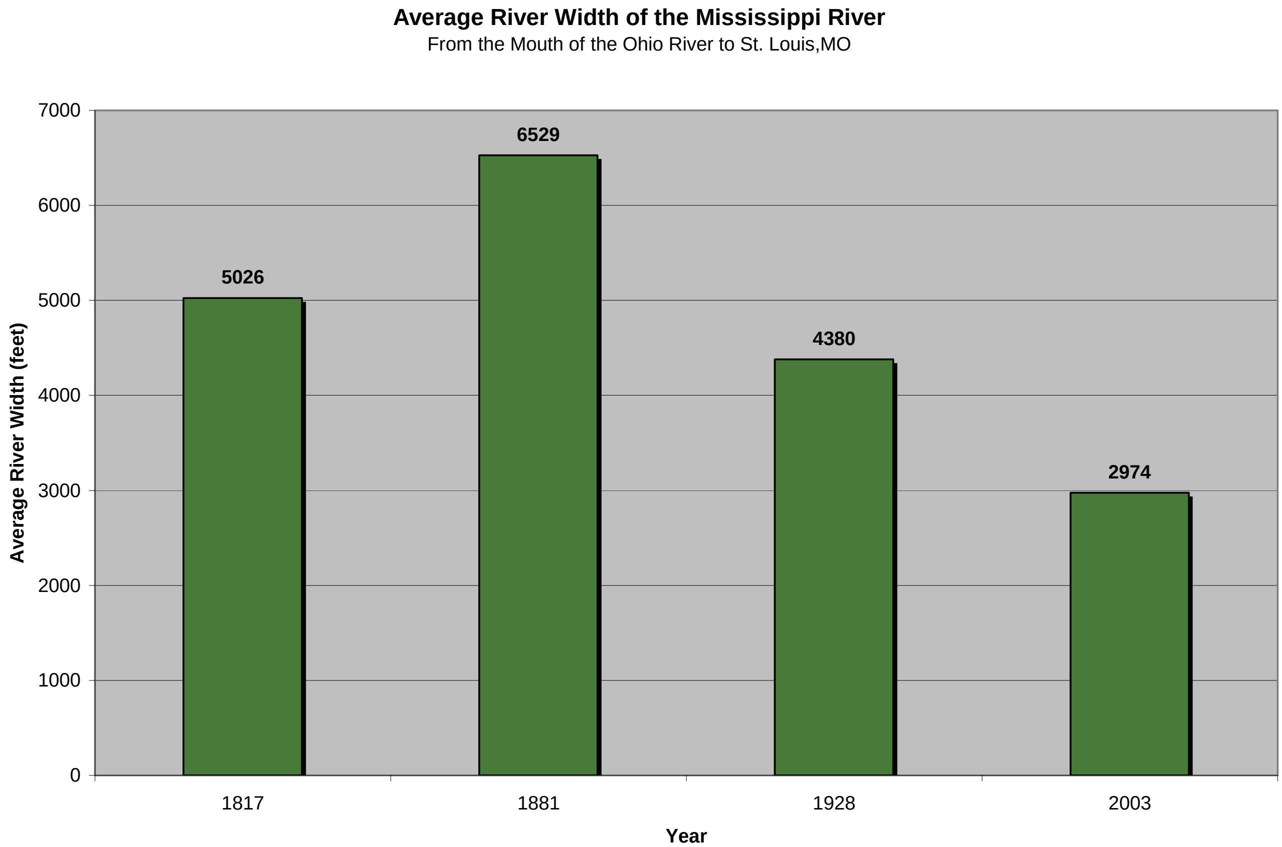



Fig. 21. Average width (feet) of the Mississippi River in the Middle Mississippi River Regional Corridor from 1817 to 2003 (from Brauer et al. 2005).

stage (Dobney 1978, Dyhouse 1993). Over 75% of the MMRRC floodplain area is now behind mainstem levees (Theiling et al. 2000).

Prior to major river developments and construction of upstream locks and dams, the Mississippi River in the MMRRC gradually rose from early winter through spring, declined during summer, and reached low flows in fall (Theiling 1996, Sparks et al. 1998, Franklin et al. 2003). Long-term historic records suggest approximately 11-15 year cycles of increasing discharge followed by extreme droughts (Fig. 10). The presence of mainstem levees along the Mississippi River have obviously changed the connectivity of river flows with MMRRC floodplains. Additionally, the construction of large reservoirs on the Missouri River have increased storage capacity of spring runoff in headwater areas and have attenuated some Missouri River-influenced flood peaks in the MMRRC. Other trends in Mississippi River discharge

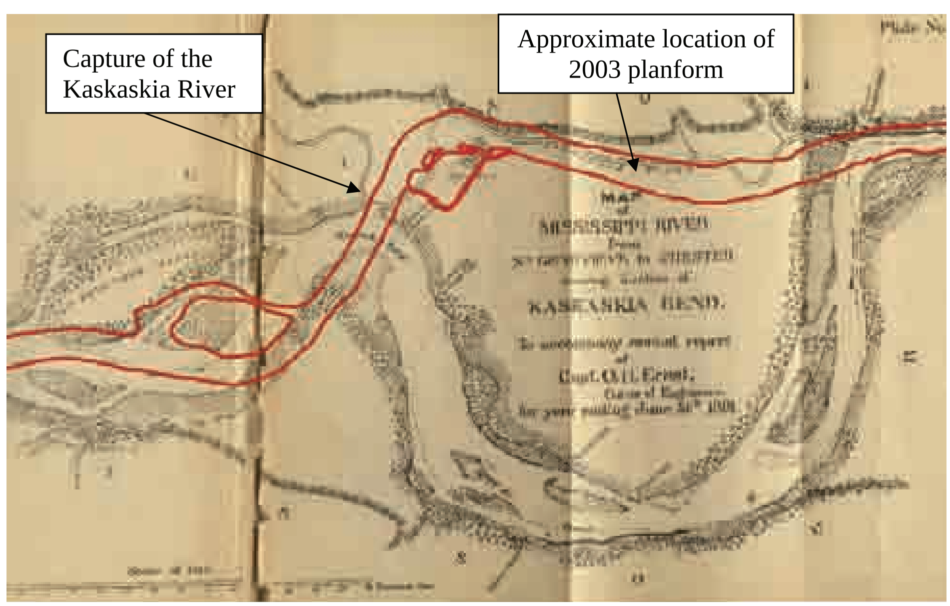



Fig. 22. Map of the Mississippi River at the Kaskaskia Bend following the capture of the Kaskaskia River (from Brauer et al. 2005).

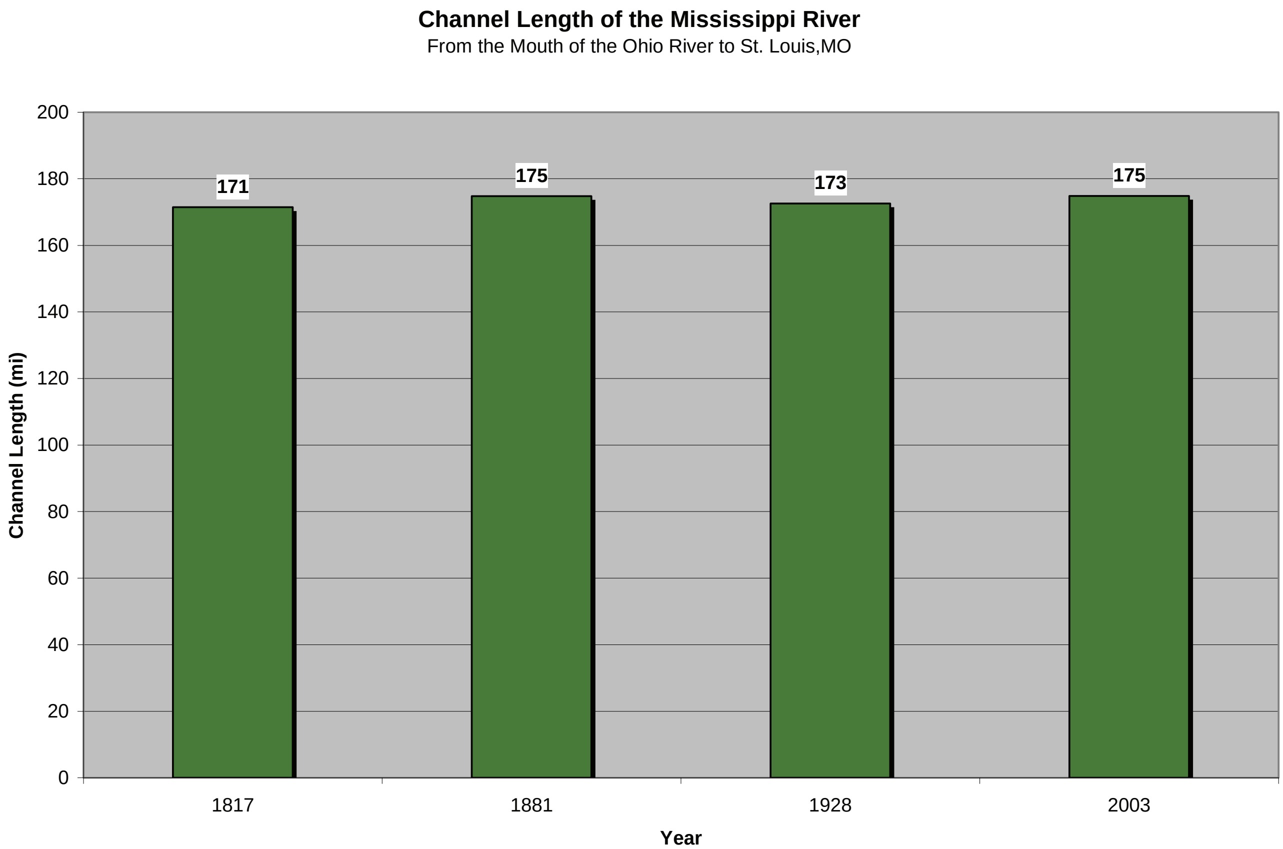



Fig. 23. Channel length (miles) of the Mississippi River in the Middle Mississippi River Regional Corridor from the mouth of the Ohio River to St. Louis, Missouri 1817-2003 (from Brauer et al. 2005).

and overbank flooding are difficult to determine because of limited historic information, variation in methods used to determine discharge, changes in river elevation and channel configuration over time, and vegetation/structural changes along the river and in the floodplain (e.g., Stevens 1979).

Analyses of remnant floodplain habitats (excluding the Mississippi River channel, islands, chutes and side channels, and tributary alluvium) in the MMRRC were conducted by digitizing the location and area of all remnant patches, including areas such as USDA Wetland Reserve Program (WRP) tracts, and determining what the Presettlement community was for each patch (Appendices K-O). In some cases the remnant habitat is not yet restored (e.g., new WRP tracts) or has been partly changed from historic communities (e.g., former prairie tracts that now include substantial trees), however, the tract was assigned the historic community designation to determine habitat patch area loss over time. Analyses of geomorphic and changes in river, side channel, island, and chutes area in the MMRRC are provided in West Consultants, Inc. (2000) and Brauer et al. (2005).

By 2006, land use and distribution and coverage of MMRRC floodplain ecosystem types had changed substantially from the late 1700s and early 1800s. Generally, the MMRRC floodplain had become mostly deforested and prairies had been converted to agriculture production, or urban development. (Table 8, Fig. 27, Appendices K-O, Korte and Fredrickson 1977, Nelson et al. 1994, Theiling et al. 2000). Generally, habitat loss from the Presettlement period to 2006 has been greatest (82%) in the American Bottoms and least (57.2%) in the Thebes ecoregion (Table 8). For all areas combined, total loss of Presettlement habitats has been 72.4%. Net loss of habitats has been greatest for Savanna, Bottomland Prairie, Mesic Prairie, Slope Forest, High BLH, and Floodplain Forest and least for lower elevation BLH, Bottomland Lake, and Riverfront Forest communities (Table 8).

Remnant forest patches in the MMRRC now are mostly: 1) Riverfront Forest habitats located next to the main channel and within mainstem levees, 2) larger BLH tracts at Oakwood Bottoms, in and near Union County WMA, and around Horseshoe Lake WMA in southern Illinois, and 3) scattered small fragments of Floodplain and Slope Forest (Appendices K-O). Prior to the large flood of 1993, mature trees in Riverfront Forests in the MMRRC were mostly silver maple, cottonwood, and willow and regenerating saplings were dominated by silver maple (Yin 1999). The flood of 1993 killed many trees and most saplings. Regeneration since that time has continued to be dominated by silver maple and willow, although some areas do have substantial cottonwood, sycamore, ash, elm, and pecan. Bottomland Lakes have declined in area throughout the MMRRC as they have been filled or drained, mostly for agriculture production. Vegetation in remnant Bottomland Lakes now contains more woody species in northern areas, and many have received large sediment inputs that have caused increased turbidity and decreased submergent vegetation. Likewise, most point bar swales, excepting a few larger ones, have been drained and now are farmed. Only a few remnant patches of historic prairie remain in the American Bottoms and most areas are badly degraded and occupied by woody vegetation or introduced grass/forb species.

*Sedimentation and Water Quality Changes.* – Suspended sediments and sedimentation rates have increased over time throughout the Mississippi River system, including the MMRRC, as watersheds and floodplains have been cleared for agriculture, drainage and levee districts were formed, and rivers and drainages were channelized (Theiling et al. 2000). In the Illinois River it has been estimated that nearly 2/3 of sediments enter the system from erosion of valley slopes and tributary watersheds and about 1/3 originate from regional agricultural fields (Lee and Stall 1976). It is not known what relative contribution upland and watershed vs. local agricultural floodplain fields contribute to sediments in the MMRRC, but some studies estimate that 75-95% of the suspended sediment load that passes St. Louis and enters the MMRRC annually is supplied from the Missouri River (Davinroy 2006). Sediment/water mixing from the Missouri and Mississippi rivers often occurs as far south as Chester. Prior to the 1950s, sediment loads in the confluence area were as high as 250-375 million metric tons/year; after the completion of Gavin's Point Reservoir upstream on the Missouri River in the mid 1950s, this load was reduced to about 100-150 million metric tons/year and has remained relatively constant since (Fig. 28). Turbidity levels

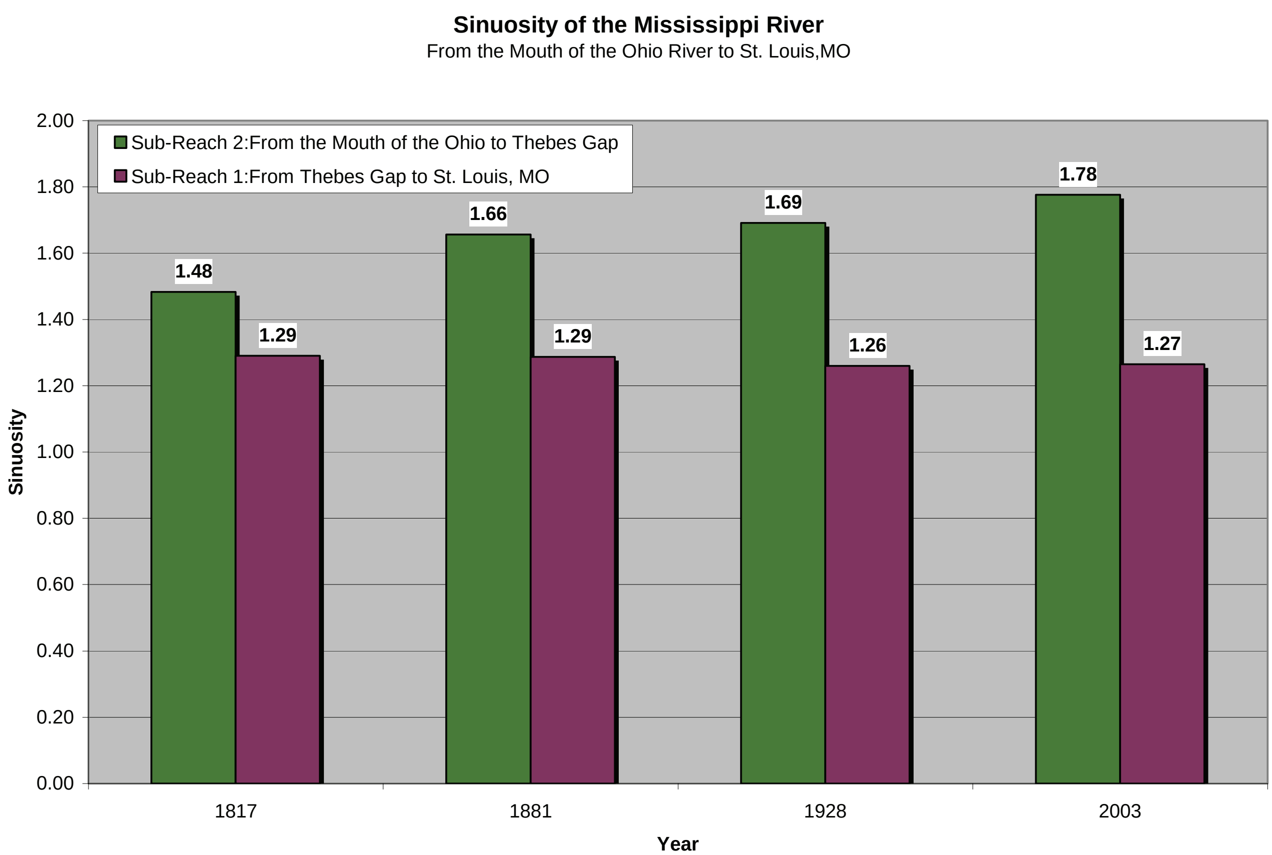
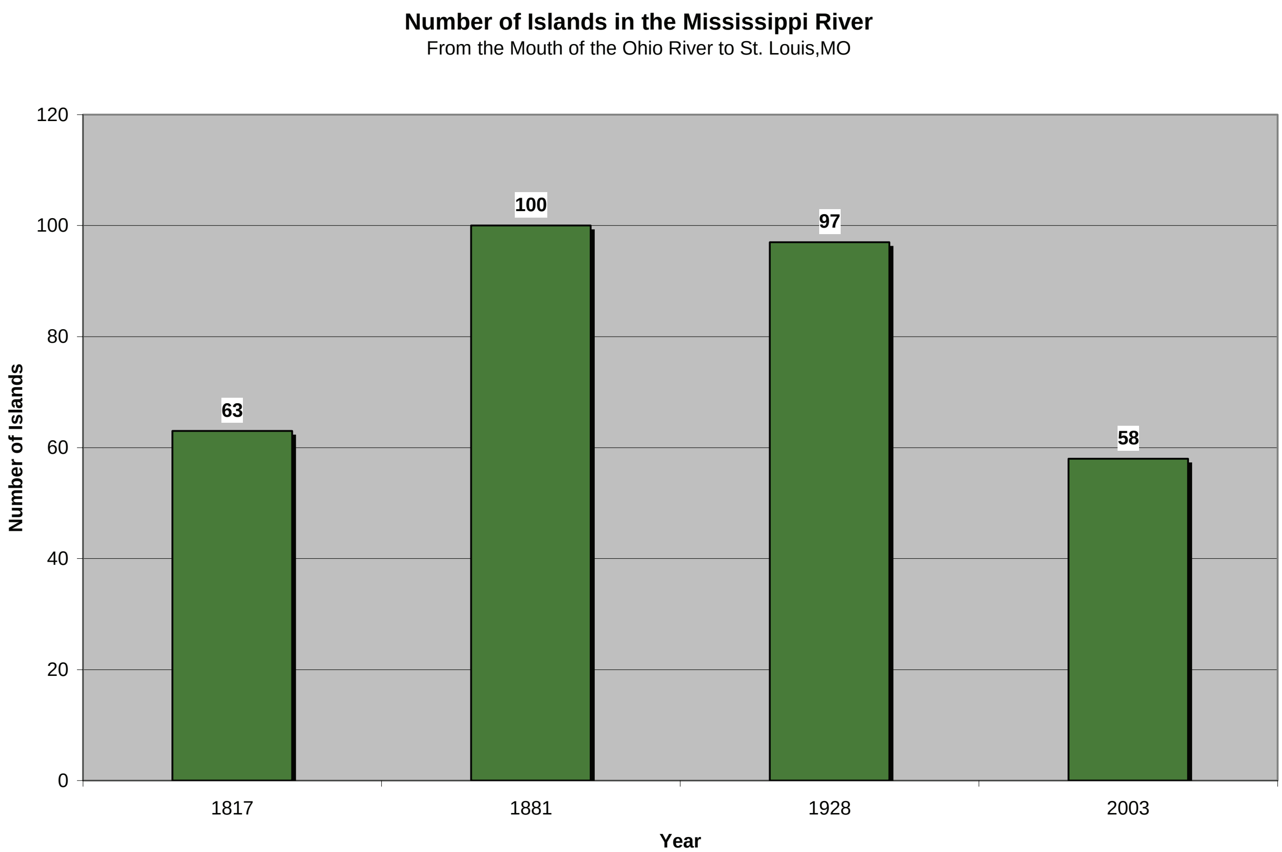



Fig. 24. Sinuosity of the Mississippi River in the Middle Mississippi River Regional Corridor 1817-2003 (from Brauer et al. 2005).



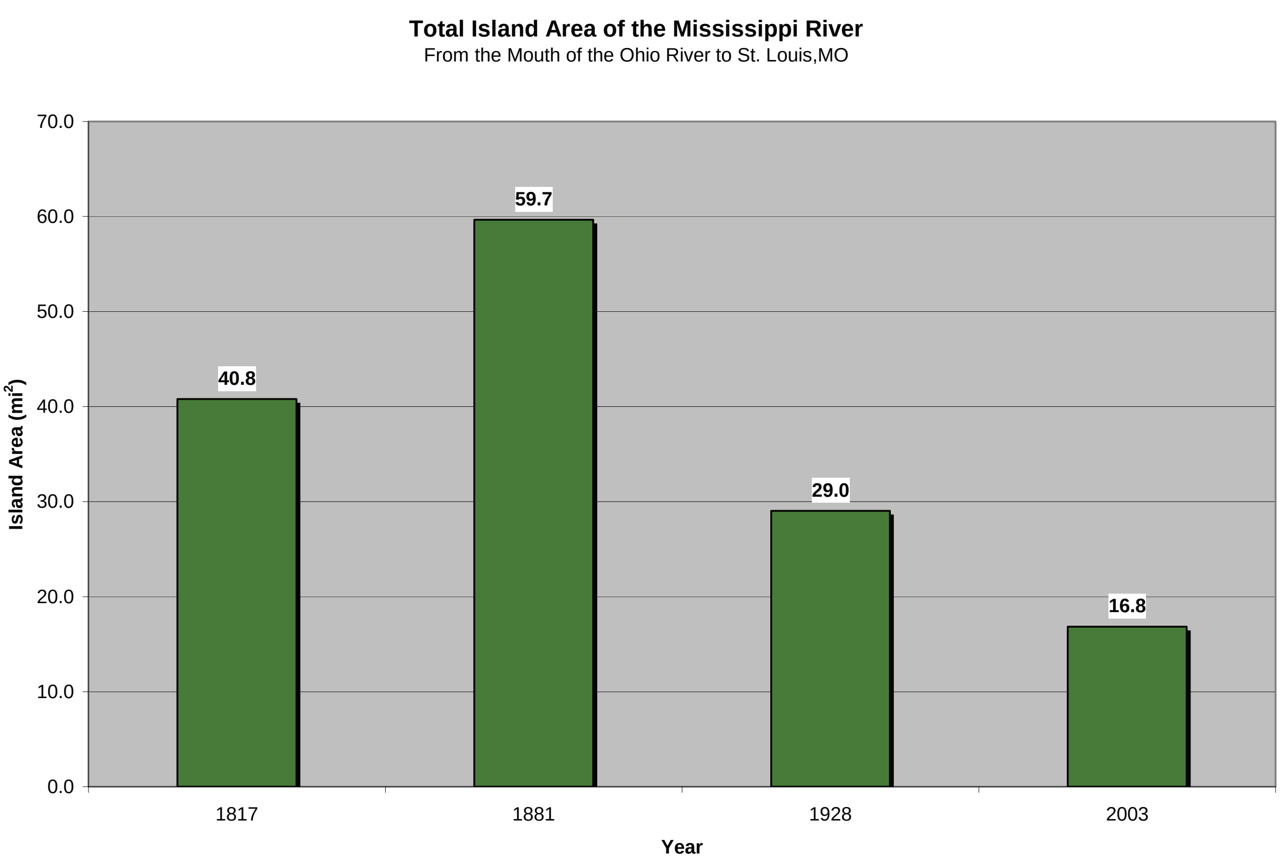




Fig. 25. Number and area (acres) of islands in the Mississippi River in the Middle Mississippi River Regional Corridor from the mouth of the Ohio River to St. Louis, Missouri 1817-2003 (from Brauer et al. 2005).

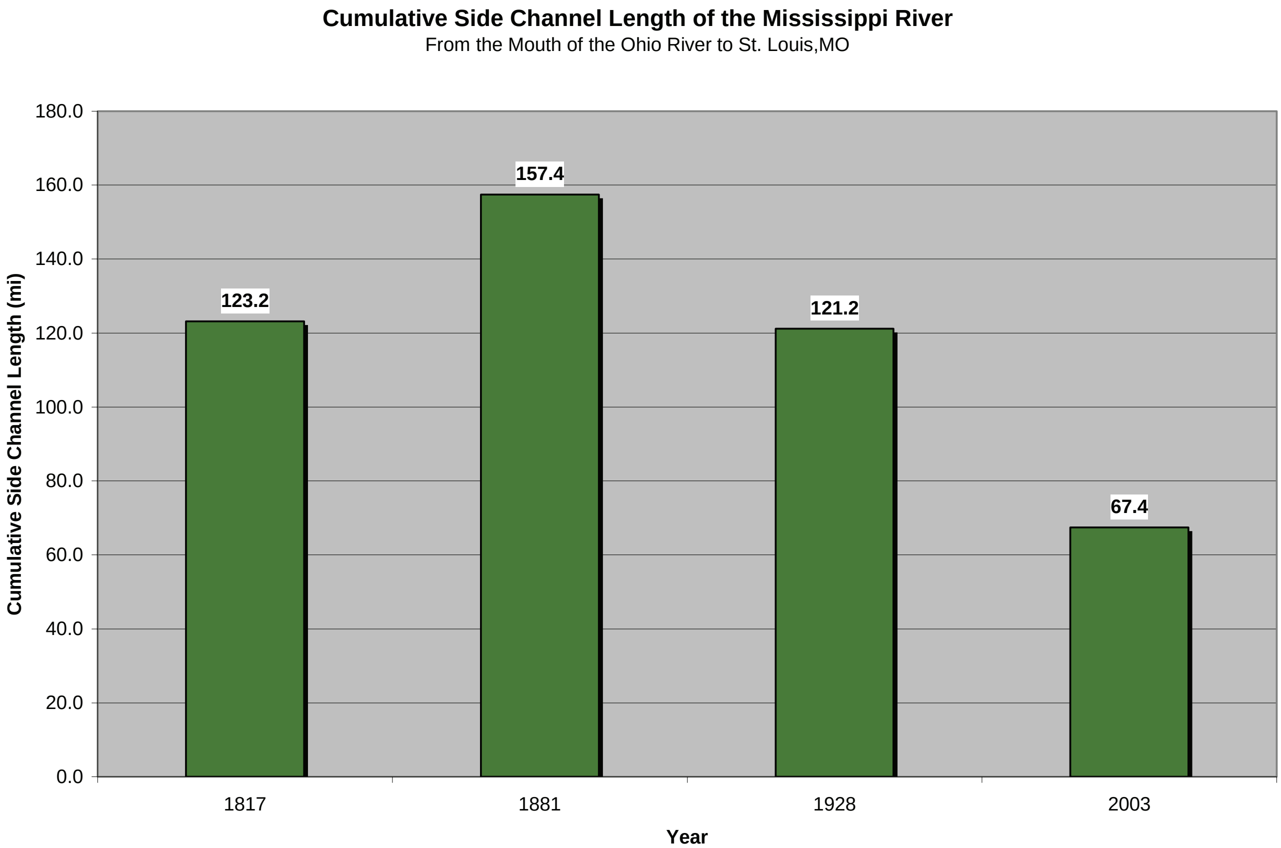



Fig. 26. Cumulative side channel length (miles) of the Mississippi River in the Middle Mississippi River Regional Corridor from the mouth of the Ohio River to St. Louis, Missouri 1817-2003 (from Brauer et al. 2005).

monitored in the middle part of the MMRRC by the Long Term Resource Monitoring Program (LTRMP) also indicate relative stability in sediment loads in the Mississippi River over time (Fig. 29). The average sediment load, post-Gavin's Point Reservoir, is about 50-100 times greater than average sediment loads in the pooled, lock-and-dam, reaches of the Mississippi River.

Sediments that enter the MMRRC from the Missouri River tend to be deposited in greater amounts during high flow events between Mississippi RM 168 and 192 in the American Bottoms. This stretch of the Mississippi River is dredged annually and an estimated 30 million cubic yards of sediment has been dredged from this stretch since 1964 (Davinroy 2006). Much of the Mississippi River in the MMRRC now is dredged annually to maintain a nine-foot navigation channel (Fig. 30). Most dredging occurs during the dry, low-flow, summer months. For example, a large amount of dredging occurred during the drought years 1988 and 1989 while little dredging occurred in the extreme flood year of 1993.

Large areas of forest and prairie were cleared for agricultural production in the late 1800s and early 1900s (Appendices F-J). This clearing was coupled with rerouting of drainages, ditching, and tile drainage. These changes affected local runoff and erosion, structure, and bulk density of soils (Davinroy 2006). Initial soil erosion and sedimentation in MMRRC floodplains, Side Channels, and Bottomland Lakes probably were caused by overland sheet and rill erosion. Later, headcutting occurred on the major tributaries, especially the Kaskaskia and Big Muddy rivers and tributary banks eroded. This bank erosion was likely the largest source of sediments within the southern parts of the MMRRC (Davinroy 2006). Collectively, large inputs of sediments and erosion from floodplains and tributaries have contributed to the changed form of the Mississippi River whereby it has gradually become a more braided canaliform system (Brauer et al. 2005).

Changes in several water quality indicators have been monitored in the Mississippi River in the MMR over the last 20 years by the LTRMP (http://usgs.gov/ltrmp/water). Unfortunately, little comparative data exist from the early 1900s to understand cumulative changes. Certain indicators suggest relatively high phosphorus, nitrogen, iron, and manganese levels in

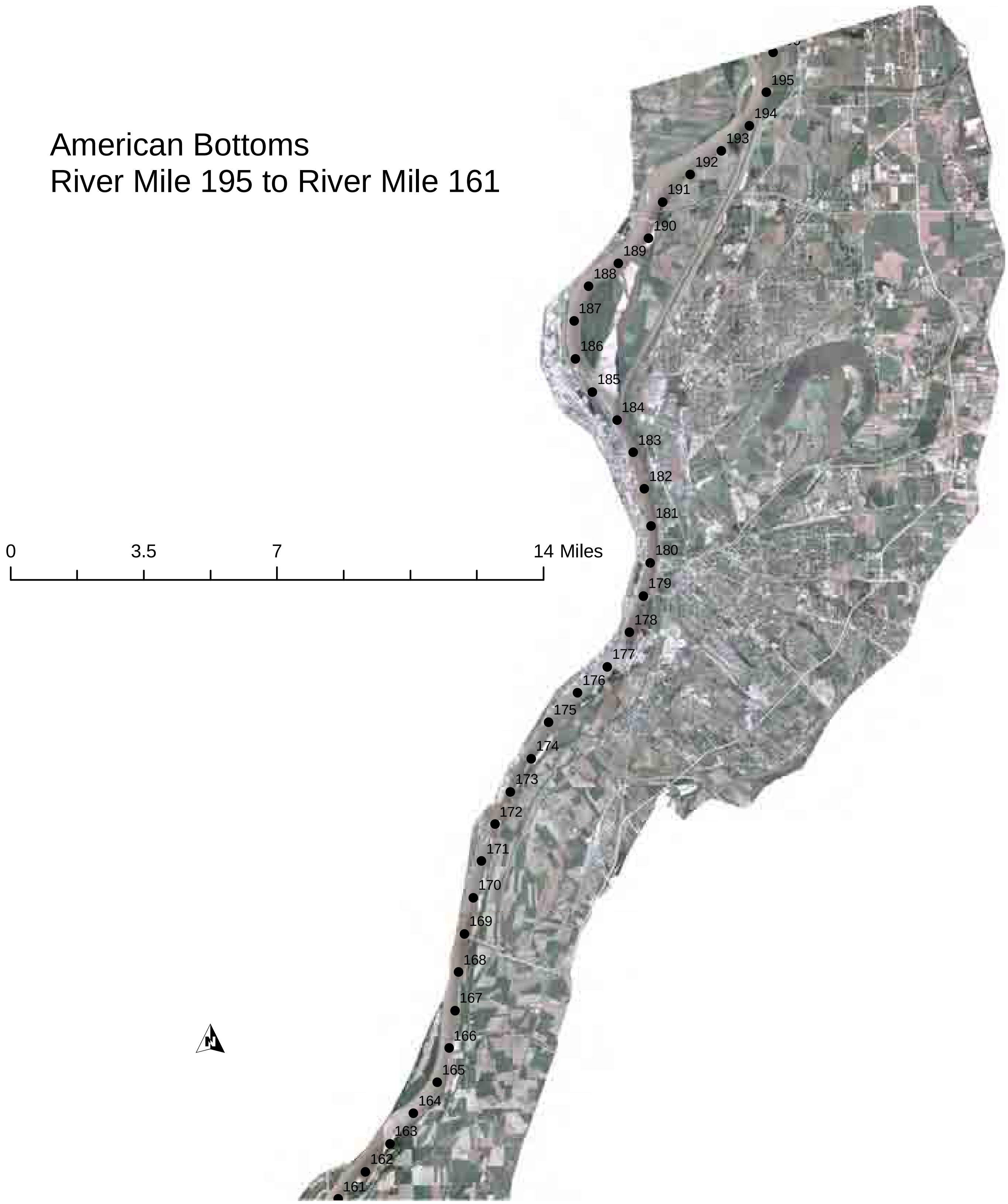



Fig. 27a. Aerial photographs of the Middle Mississippi River Regional Corridor in 2006.


Fig. 27b. Aerial photographs of the Middle Mississippi River Regional Corridor in 2006.

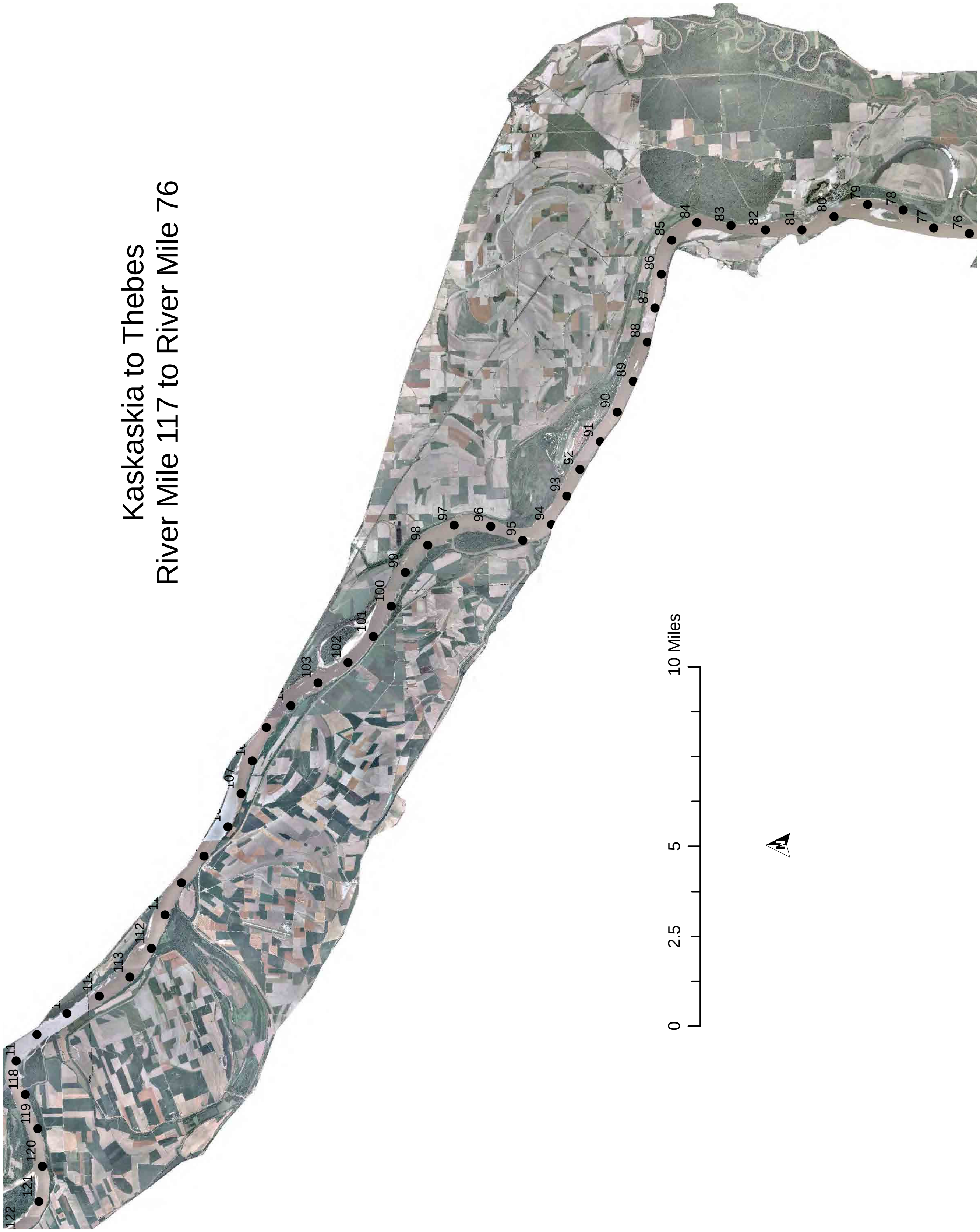



Fig. 27c. Aerial photographs of the Middle Mississippi River Regional Corridor in 2006.


Fig. 27d. Aerial photographs of the Middle Mississippi River Regional Corridor in 2006.

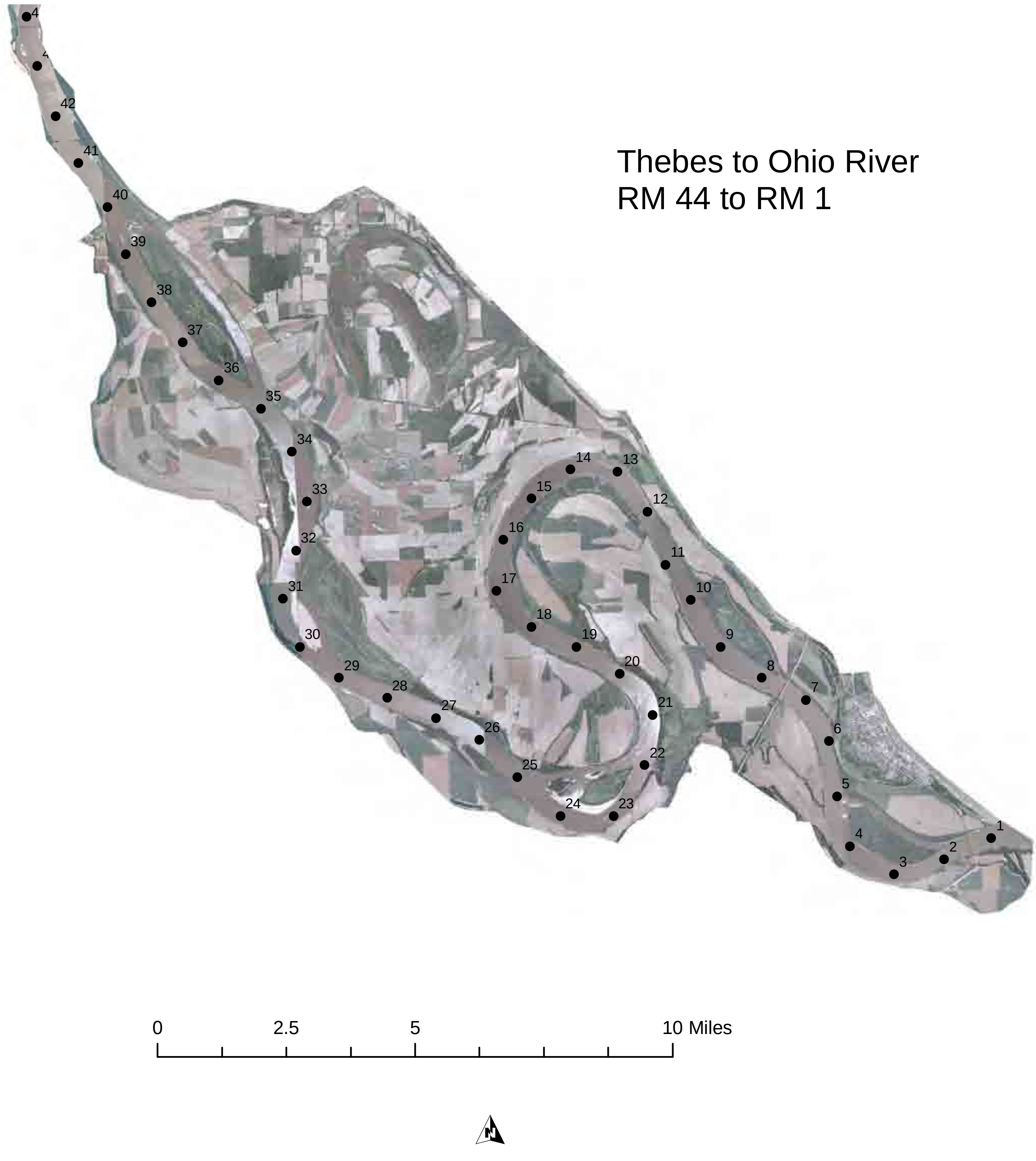



Fig. 27e. Aerial photographs of the Middle Mississippi River Regional Corridor in 2006.

the contemporary Mississippi River; these elements are mostly associated with fine clay particles in river sediments (Davinroy 2006). Undoubtedly, increased use of agri-chemicals has caused increases in residual herbicide and pesticide levels in MMRRC wetlands and waters (Goolsby and Pereira 1995) and industrial pollutants now are common, and often near toxic levels, in the Mississippi River below St. Louis (Theiling 1996).

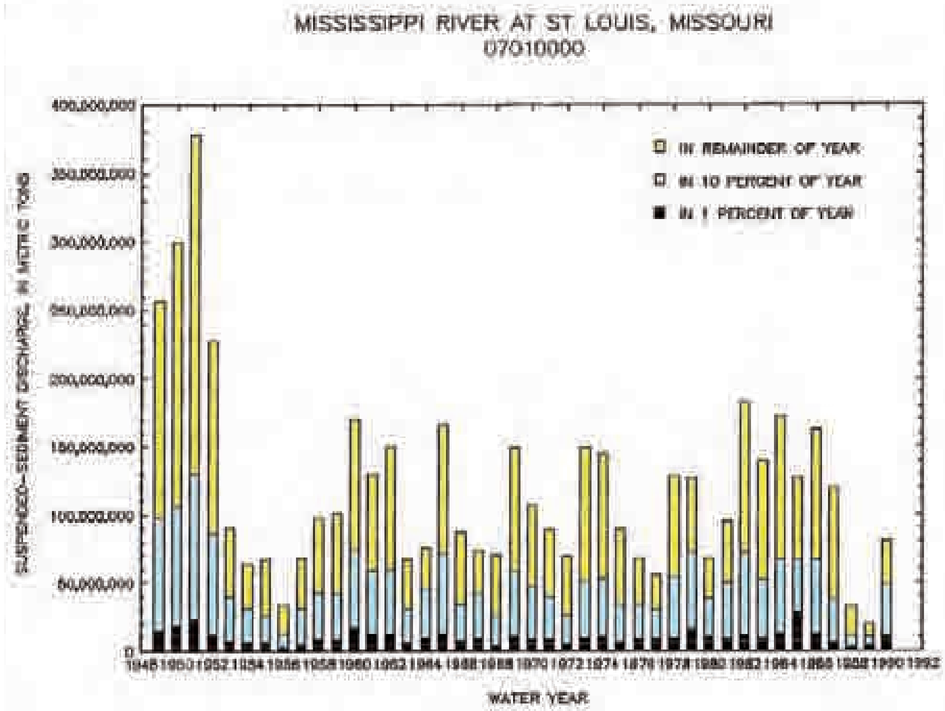



Fig. 28. Suspended sediment discharge (metric tons) in the Mississippi River at St. Louis, Missouri, 1946-1992 (from Davinroy 2006).

*Benthic Invertebrates, Fish and Wildlife Populations.* – Unfortunately, little quantitative data are available on historic invertebrate, fish, and wildlife populations in the MMRRC. The location of the MMRRC in the middle of the United States, its central position in the Mississippi River system, and the presence of diverse and highly productive vegetation communities enabled this region to support diverse and abundant fish and wildlife populations. Undoubtedly, the sites of major Native American communities at Cahokia, Linn-Helig, etc. were chosen because of abundant fish and wildlife food resources. Historical accounts of explorers and naturalists describe large and widely distributed populations of fish and wildlife throughout the MMRRC and archaeological findings at early settlements indicate a wide diversity of animal species were used as food by native people (e.g., Munson 1966, Kelly et al. 1979, Lopinot et al. 1991, Milner 1998). Early French Colonial settlers also relied heavily on the abundant fish and wildlife populations for annual food resources and it greatly influenced social patterns and histories of early settlements (e.g., Gums 1988, Brown 2005). Commercial harvest of fish and waterfowl was common in the MMRRC in the late 1800s and early 1900s and the growing population of St. Louis was a major market for these foods.

The LTRMP has monitored benthic invertebrate communities at select locations in the Mississippi River since 1985 and these data suggest relative stability in recent years. These data do not represent historic levels, however, and they are restricted to the main and side channels where aquatic invertebrate abundance and diversity generally are low because of high current velocity and constantly shifting substrates, especially sands. Undoubtedly, total invertebrate diversity and abundance have greatly declined throughout the MMRRC over time as floodplain wetlands and forests were destroyed. In general, loss of floodplain

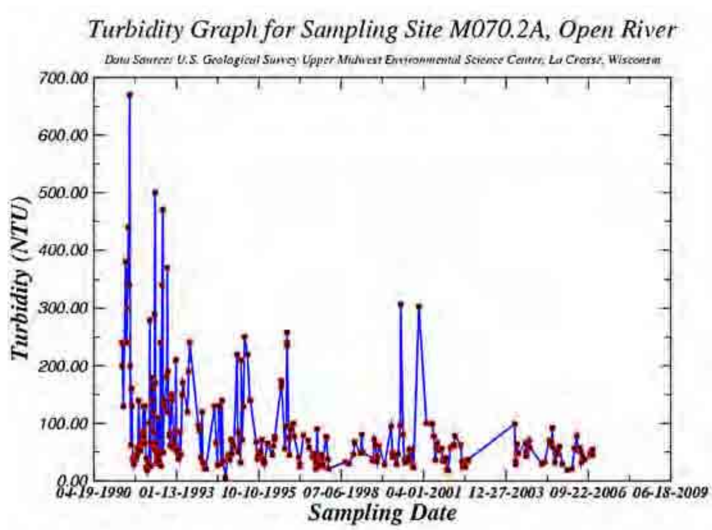



Fig. 29. Turbidity levels (National Turbidity Units) in the Mississippi River at Grand Tower, Illinois 1990-2005 (www.usgs.gov.ltrmp/waterquality).

wetlands, high sedimentation rates, contamination, and decreased water quality in Bottomland Lakes create depauperate invertebrate communities (e.g., Beckett et al. 1983, Sparks et al. 1998, West Consultants, Inc. 2000).

Native fish and mussel populations in the Mississippi River and its backwaters have declined markedly since the early 1900s (Duyvejonck 1996). Declines are especially notable for sunfish, catfish, buffalo-fishes, bass and other small species such as shiners. A major change in the fish fauna of the MMRRC occurred when common carp were introduced in the 1880s. Carp quickly became a dominant fish species in the Mississippi River and in the early and mid 1900s common carp made up about 2/3 of all commercial harvest in the Mississippi and Illinois rivers. Over time, common carp populations have declined, and in the last two decades the fish fauna of the Mississippi River and its backwaters has been dramatically altered by the increasing populations of bighead, silver, and grass carp (Koel et al. 2000).

Changes in composition and distribution of floodplain habitats in the MMRRC have affected many other animal groups including birds, mammals, amphibians, reptiles, and terrestrial insects (Duyvejonck 1996, Smith 1996). Little data are available on populations of amphibians and reptiles in the MMRRC. Trends in other Upper Mississippi River Valley ecosystems suggest declines in all of these species groups (e.g., Mills et al. 1966, West Consultants, Inc. 2000). Many amphibian and reptile species are highly associated with floodplain wetlands and declines in area and degradations to the quality of these wetlands cause decreases in populations (e.g., Knutson et al. 1999, Semlitsch 2000). Contamination from agricultural chemicals and runoffs also has been correlated with decreased amphibian and reptile populations in floodplain areas. Mammals in the MMRRC, especially those species associated with wetlands and aquatic habitats, also have been negatively affected by decreasing abundance and condition of wetlands, forests, and prairies (Smith 1996). Several larger species such as elk, bison, cougar, and black bear now are extirpated from the MMRRC.

Many neotropical migrant birds use MMRRC habitats for breeding, wintering, and during migration. Most of these birds rely on the diverse mix of floodplain forest communities for food, nesting sites, and refuge. Clearing, mortality, and changed distribution of these forests reduces resource abundance and causes declines in avian species abundance and species richness (e.g., Knutson et al. 1996). Today, the primary forest corridor that remains in the MMRRC is a relatively narrow band of Riverfront Forest along the Mississippi River. Riverfront Forest provides important food for many neotropical migrants and local residents, but other species that depended on foods and resources in the historically widely dispersed and interconnected forests now are less able to find suitable habitats to sustain annual events. This is especially true for habitat specialists, such as Swainson's warblers that are associated with patches of giant cane and area-sensitive species such as Cerulean warblers that need large connected patches of bottomland forest (e.g., Twedt and Loesch 1999, Wilson et al. 2007).

Waterfowl and waterbird populations in the MMRRC historically were large and diverse (Bellrose 1968, 1980). Market hunting of ducks and geese was common in the MMRRC in the late 1800s and the abundant wetlands throughout the region provided important resources that helped sustain continental populations (e.g., Havera 1999). Loss of wetlands and changed land uses eventually caused marked declines in MMRRC waterfowl numbers. Today, waterfowl are highly concentrated, especially in fall and winter, in remnant wetland complexes such as state and federal wildlife management areas and U.S. Fish and Wildlife Service National Wildlife Refuges in the region. Generally, populations of diving ducks that depended on aquatic vegetation and benthic

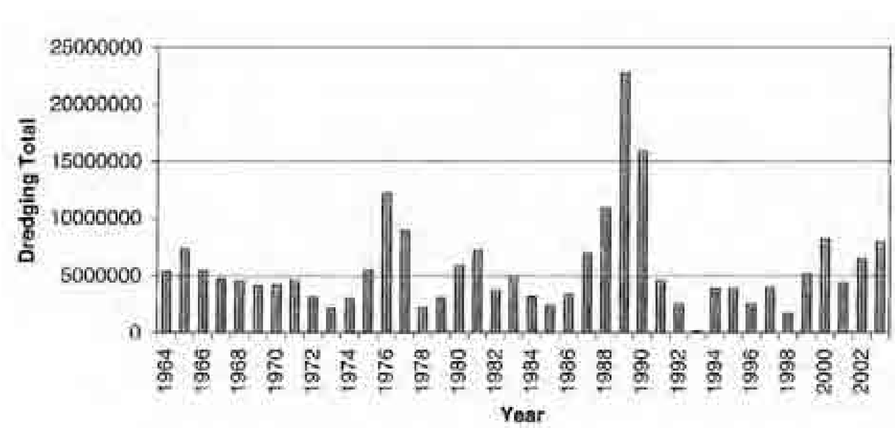



Fig. 30. Historic dredging (metric tons/year) of the Mississippi River from the mouth of the Ohio River to St. Louis, Missouri (river miles 0-200) 1964-2002 (from Davinroy 2006).

fauna in MMRRC wetlands and Mississippi River habitats are greatly reduced (e.g., Bellrose et al. 1979, Smith 1996). Populations of dabbling ducks have not declined at the same rate as diving ducks, but some species that depended on aquatic vegetation in Bottomland Lakes such as wigeon, gadwall, teal, and shoveler have been negatively influenced (Havera 1999).Large populations of geese formerly used MMRRC habitats during migration and winter. Now, distribution, abundance, and species composition of geese are greatly changed. For example, the Mississippi Valley Population of Canada geese that reached winter populations of > 250,000 in southern Illinois parts of the MMRRC (Hanson and Smith 1950) now rarely exceeds 30,000 (unpublished Illinois Department of Conservation midwinter waterfowl inventories). Conversely, snow geese that formerly were relatively scarce now often exceed 100,000 in the same area.

Many exotic plant and animal species now are present in the MMRRC. While detailed current vegetation surveys are not available for all areas in the MMRRC, the invasive species purple loosestrife, water milfoil, sericea lespedeza, Johnson grass, reed canary grass, and Japanese stiltgrass are present in at least some areas. Asian carp species are obvious exotic fish that now are present in large numbers throughout the MMRRC and European ruffe and black carp are likely new exotic introductions. Asiatic clam and European zebra mussel also now are present in the MMRRC.

# RESTORATION AND MANAGEMENT OPTIONS

## GENERAL RESTORATION GOALS

The Mississippi River Valley contains the largest ecological "corridor" of water, wetlands, and floodplain forests in North America. The MMRRC is within the central "core" part of this ecosystem and contains three ecologically distinct ecoregions. Landforms, soils, and topography in each ecoregion were created by historical geomorphic and hydrological processes of the Mississippi River and plant communities were distributed along gradients of elevation, soils, frequency of flooding, and geomorphological surfaces. Consequently, the historic distribution and juxtaposition of plant communities within the MMRRC was highly heterogeneous (Appendices A-E), and resources within these communities supported diverse and abundant animal species and populations at local, regional, and continental scales.

Restoration and sound ecological management of the MMRRC is important to sustain and provide critical natural resources and ecological functions and values that effect the entire mid-portion of the United States including floodwater transport and storage, nutrient cycling, filtration and transformation of nutrients and contaminants, groundwater recharge, carbon sequestration, quantity and quality of surface waters, fish and wildlife habitat, education, and recreational opportunities. This report identifies options and opportunities to conduct ecosystem restoration in the MMRRC and general management actions that will be needed to sustain communities and resource values.

Many changes have occurred in the MMRRC ecosystem from Presettlement to current periods. Some landscape changes are relatively permanent and are unlikely to return to former conditions, at least in the foreseeable future. These changes include the extensive urbanization of the Upper American Bottoms; large mainstem levees along the Mississippi, Big Muddy, and Kaskaskia rivers; and construction of locks-and-dams upstream on the Mississippi River. Additionally, large areas of the MMRRC have been cleared and converted to agriculture. Bottomland and Mesic Prairie, Slope Forest, and Floodplain Forest have been destroyed at high rates. Bottomland Lakes have been drained and altered in most MMRRC ecoregions. Mississippi River Side Channels and Chutes are greatly reduced in area and connectivity. Generally, seasonal floodplain hydrology is changed throughout the MMRRC and historic patterns of Mississippi River overbank flooding, depth, and duration in the MMRRC are altered with less flooding north, but more flooding south, depending on the location of levees and other flood-protection structures in various locations.

Despite the many alterations and degradations to the MMRRC ecosystem, many opportunities exist to restore at least some parts of this region. The key to understanding realistic, and sustainable, restoration opportunities and options is the basic mapping of the relationships of historic vegetation communities to topographic, soil, and geomorphic landscape position (Appendices A-E). The "HGM" process used in this report to evaluate ecosystem restoration options allows conservation interests to: 1) identify what communities "belong" in specific locations; 2) determine what ecological processes are needed to restore and sustain specific habitats; 3) determine the types and extent of alterations to historic communities, 4) determine constraints to restoration and management of specific sites, and 5) provide some sense of best opportunity or priority to restoration of specific habitats and locations.

Generally, this study evaluated restoration options, and subsequent management needs, to improve natural ecosystem processes, functions, and values rather than to manage for specific plant/animal species. This study focuses primarily on restoration of floodplain ecosystems, but recognizes the hydrological and ecological connections between the floodplain and active Mississippi River channel, and identifies basic landscape and hydrological mechanisms for both the floodplain and main channel that must be considered in restoring the integrity of the entire ecosystem. The strategic conservation basis inherent in the HGM approach used in this study is scientific information on landscape and floodplain ecology that identifies how the "complex" of communities, rather than individual parcels, ultimately provides the diversity and distribution (spatial and temporal) of resources to sustain the productivity, diversity, and integrity of the entire MMRRC ecosystem.

Based on information gathered in this study, conservation actions in the MMRRC should seek to:

1. Protect and sustain existing floodplain areas that have plant communities similar to Presettlement conditions.

2. Restore plant and animal communities in appropriate topographic and geomorphic landscape position.

3. Restore at least some sustainable "patches" of habitats that have been highly destroyed or degraded.

4. Restore habitats and areas that can serve as a "core" of critical, sometimes limiting, resources that can complement and encourage restoration and management on adjacent and regional private lands.

Attempts to meet these conservation goals will require the following considerations:

1. *Protect and sustain existing floodplain areas that have plant communities similar to Presettlement conditions.*

All remaining habitats within the MMRRC are altered to some degree, usually because of changed hydrology; size, connectivity, and interspersion with other habitats; infrequent disturbance and regeneration mechanisms; and influences of adjacent lands, especially agricultural and urban uses. Despite alterations, some areas still retain relatively unchanged composition of vegetation communities compared to Presettlement periods. These remnant patches, especially areas that contain habitats that have been destroyed at high rates and extent such as Bottomland and Mesic Prairie, Floodplain Forest, Bottomland Lakes, and High BLH deserve priority for protection. The maps of remnant habitats for the MMRRC (Appendices K-O) identify lands that currently are owned and protected by public and private conservation agencies and organizations (Fig. 31). Ownership, however, does not always guarantee restoration of historic communities or the management to sustain specific ecosystem types or complexes of historic habitats. All remnant habitats within the MMRRC (both protected and not protected) should be carefully evaluated to determine if future protection or changes in management are needed. On private lands, acquisition or securing conservation easements may be possible for some remnant patches. For other non-protected sites, discussions should begin with owners to identify conservation opportunities.

Conservation of existing habitat remnants should go beyond simply purchasing lands or securing deed/management restrictions for certain uses. Sustaining existing habitats also requires protecting or restoring the ecological processes that created, and can sustain, the habitat. Often these ecological processes are disturbance events such as flood and drought, fire, and periodic physical disruption of sediments or plant structure (Junk et al. 1989, Sparks et al. 1998, Heitmeyer and Westphall 2007). Unfortunately, most remnant habitats in the MMRRC have at least some disruption in these ecological "driving" processes and restoration of most habitats will require at least some active management, whether it be manipulation of water regimes (e.g., periodic drawdowns of Bottomland Lakes), periodic scouring or disturbance of sediments (e.g., dredging or removal of plugs in Side Channels or discing in Bottomland Prairie swales), disturbance of vegetation (e.g., fire or mechanical removal of prairie vegetation or timber management in Floodplain Forest), or reduction in contaminant inputs from adjacent lands (e.g., construction of silt basins or vegetation buffers along edges of Bottomland Lakes and other floodplain wetlands).

2. *Restore communities in appropriate topographic and geomorphic landscape position.*

The historic distribution of vegetation communities in the MMRRC was determined by regional climate, geomorphic surface, elevation, soils, and hydrological regime. The HGM matrices produced in this report provide information about

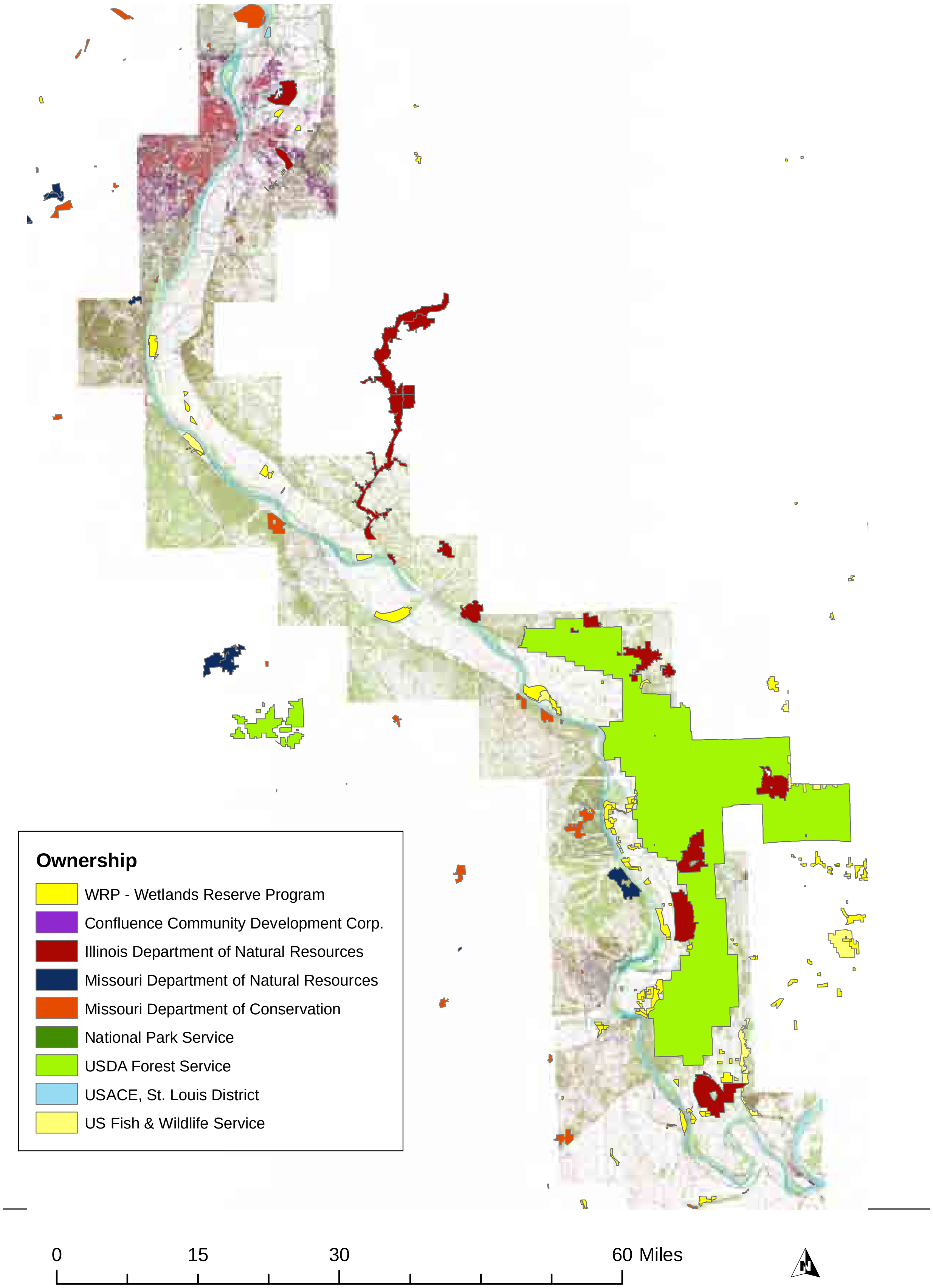



Fig. 31. Conservation lands owned or under easement within the Middle Mississippi River Regional Corridor.

the abiotic features that are associated with each community/habitat type in the three MMRRC ecoregions. Attempts to restore specific habitat types must “match” the physical attributes of a site with requirements of each community, and not try to “force” a specific habitat type to occur on a site where it can not be sustained.

This study produced maps of potential restoration sites for the major habitat communities in each MMRRC ecoregion (Appendices P-T). These maps do not imply or suggest that all areas shown could be restored to historic habitats, but rather they broadly identify which MMRRC locations have HGM characteristics that potentially could support specific communities. For many habitats, potential restoration sites essentially mirror historical distribution (Appendices A-E) because these are the only locations that have appropriate geomorphology, soils, and landform characteristics associated with the habitat. For example, Bottomland and Mesic Prairie historically were confined to areas north of Kaskaskia on higher elevation terrace and older point bar surfaces; Slope Forest was always on alluvial fan surfaces with erosional soils; Bottomland Lakes were in abandoned channels; and Riverfront Forest was present on young and highly scoured chute and bar surfaces. Potential restoration sites for other communities such as Floodplain Forest and BLH also basically mirror historic distribution but contemporary potential restoration sites also reflect systemic and local landscape changes. The most obvious change to landscapes that formerly supported Floodplain Forest and BLH communities is altered hydrology, especially alterations in river-floodplain connectivity and changed seasonal and long-term hydroperiod and flood frequency caused by extensive levees, ditches, roads, and topography changes.

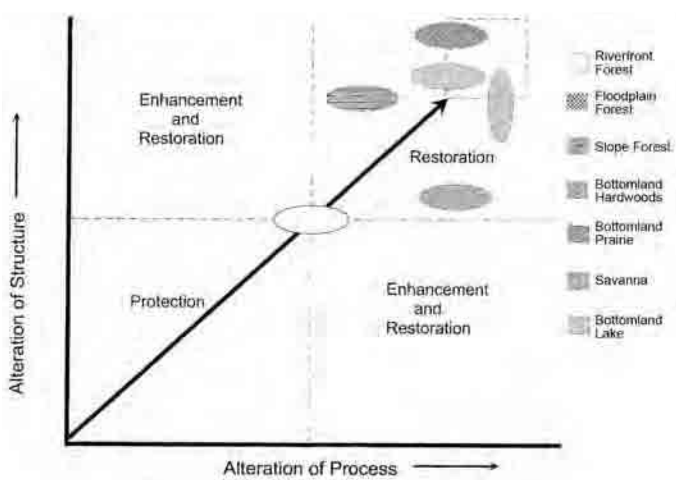



Fig. 32. Model of the conservation actions most appropriate, and intensity of management required, on sites of varying amounts of alteration from Presettlement condition for major habitat types in the Middle Mississippi River Regional Corridor.

Clearly, many sites within the MMRRC now are so highly altered that historic communities can not be restored on that site. For example, large areas that formerly supported Bottomland and Mesic Prairie in the American Bottoms now are urbanized and covered with concrete, asphalt, buildings, and roads. In other areas, changes have occurred ( e.g., lands protected behind large levees) so that historic hydrological or physical disturbance events can not occur, however the new condition of these sites may be able to support another system community type (e.g., expanded distribution of Floodplain Forest behind mainstem Mississippi River levees). Current landscape features (e.g. levees, ditches, etc.) and flood frequency data (Table 9) can be used to determine potential contemporary floodplain elevations associated with 1-, 2-, 5-, 10-, 20-year etc. flood frequencies throughout the MMRRC and to understand how current landscapes match the HGM matrix conditions for community establishment (Tables 5-7). Consequently, the maps that show the general locations of potential restoration sites (Appendices P-T) are useful to make system-wide strategic decisions about where to target restoration activities to restore functional distributions of communities throughout MMRRC ecoregions. Specific features that need to be considered at local sites and for each community are presented later in this report. Additionally, a process to identify opportunities and uncertainties about the restoration potential of individual sites is discussed in the “Application of Information (How-To)...” section of this report.

Sustainable restoration of most MMRRC communities will require a combination of works that includes revegetation (through natural or artificial means), restoring topographical features (e.g., Stratman and Barickman 2000), and recreating basic processes such as flooding, fire, soil disturbance, etc. The degree that landscapes and processes have been altered will influence the difficulty and cost of both restoring and managing the site in the future (Fig. 32). In the MMRRC, restoration of Bottomland and Mesic Prairie, Floodplain Forest, and BLH will be more difficult than restoring Riverfront Forest or Slope Forest. The geomorphic surfaces and fundamental processes that created and maintained prairie ( terraces, higher point bars, fire), Floodplain Forest (2-year overbank flood frequency, mostly non-clay soils), and BLH (backswamp, clay soils, slow backwater dormant season flooding) are more highly destroyed and degraded than the topography and processes that sustained Riverfront Forest (chute and bar surfaces that remain connected to Mississippi River overflows in batture lands) and Slope Forest (alluvial fans where upland sheetflow of water drains onto and off of these slopes).

3. *Restore at least some sustainable "patches" of habitat types that have been highly degraded or destroyed.*

This report identified the loss of Presettlement floodplain habitat types in the three MMRRC ecoregions (Table 8). Generally, the most destroyed habitats in the MMRRC are Bottomland and Mesic Prairie, Floodplain Forest, Slope Forest, Savanna, and High BLH communities. Only Riverfront Forest remains in larger contiguous patches that somewhat resemble historic distribution. The diversity and heterogeneity of habitats within the MMRRC enabled the region to provide critical ecological functions and support diverse and abundant animal populations. Many large spatial "gaps" now exist in the historic distributions of MMRRC communities (e.g., the nearly nonexistent remnant Bottomland and Mesic Prairie and Savanna), remnant habitats are highly fragmented (e.g., small disjunct patches of Floodplain Forest), seasonal or long-term connectivity to the Mississippi River is reduced or eliminated (e.g, Side Channels and Bottomland Lakes) and linear habitat and travel corridor connectivity and continuity are reduced or eliminated (e.g., the patchy distribution of BLH in the Lower MMRRC).

Where possible, habitats should restored where they can: 1) occur in larger patches, 2) connect remnant or other restored patches, 3) provide physical and hydrological connectivity, 4) emulate natural water regimes and flooding dynamics, and 5) fill critical gaps in former distribution patterns of communities (e.g., Noss and Cooperrider 1994, Shafer 1995, Gurnell 1997, Helzer and Minckler 1999, Falk et al. 2006, Heitmeyer and Westphall 2007). This will be difficult in some locations and for some habitats.

Table 9. Floodplain elevations (feet above mean sea level) related to percent exceedence probability (50% = 2-year flood frequency, 20% = 5-year flood frequency, 10% = 10 year flood frequency, 5% = 20-year flood frequency) of current Mississippi River floods at ca. five-river mile increments, and other select geographic points, within the Middle Mississippi River Regional Corridor (MMRRC). Data are from U.S. Army Corps of Engineers, St. Louis District Hydrologic Engineering Section. Complete exceedence data for all river mile stations in the MMRRC are available from the St. Louis District.

| River mile and station name | Percent Exceedence Probability 50% | 20% | 10% | 5% |
|---|---|---|---|---|
| 0.00 Ohio River | 314.0 | 319.5 | 323.0 | 325.6 |
| 2.00 Birds Point | 314.5 | 319.9 | 323.2 | 325.8 |
| 5.11 | 315.4 | 320.6 | 323.8 | 326.1 |
| 10.14 | 317.0 | 321.8 | 324.6 | 326.7 |
| 14.92 | 318.7 | 323.1 | 325.5 | 327.4 |
| 20.05 Thompson Landing | 320.5 | 324.5 | 326.4 | 328.2 |
| 24.83 | 323.4 | 327.8 | 329.8 | 331.3 |
| 28.20 Price Landing | 325.5 | 330.1 | 332.1 | 335.5 |
| 30.40 | 326.6 | 331.2 | 333.2 | 334.7 |
| 35.57 | 329.2 | 333.9 | 335.9 | 337.5 |
| 39.50 Commerce | 331.2 | 335.9 | 338.0 | 339.6 |
| 43.70 Thebes | 333.4 | 338.4 | 340.1 | 342.2 |
| 45.36 | 334.5 | 339.6 | 341.8 | 343.5 |
| 50.15 | 338.0 | 343.0 | 345.3 | 347.1 |
| 52.00 Cape Girardeau | 339.3 | 344.3 | 346.7 | 348.4 |
| 55.00 | 341.0 | 346.1 | 348.5 | 350.3 |
| 60.11 | 344.0 | 349.2 | 251.6 | 353.4 |
| 65.40 | 347.0 | 352.3 | 354.7 | 356.6 |
| 70.27 | 349.9 | 355.3 | 357.8 | 359.7 |
| 75.65 Big Muddy River | 353.2 | 358.6 | 361.2 | 363.2 |
| 80.08 | 355.9 | 361.3 | 364.0 | 366.0 |
| 81.90 Grand Tower | 357.0 | 362.4 | 365.1 | 367.2 |
| 84.96 | 358.6 | 364.2 | 366.9 | 369.0 |
| 90.23 | 361.4 | 367.3 | 370.0 | 372.2 |
| 94.10 Red Rock Landing | 363.5 | 369.5 | 372.2 | 374.5 |
| 100.80 Bishop Landing | 367.1 | 372.5 | 375.5 | 377.7 |
| 105.30 | 369.6 | 375.1 | 378.1 | 380.5 |
| 109.90 Chester | 372.2 | 377.7 | 380.8 | 383.3 |
| 115.24 | 375.1 | 380.6 | 383.6 | 386.1 |
| 117.41 Kaskaskia River | 376.3 | 381.7 | 384.7 | 387.3 |
| 120.07 | 377.7 | 382.2 | 386.1 | 388.7 |
| 125.50 Little Rock Landing | 380.7 | 386.1 | 388.9 | 391.5 |
| 130.24 | 383.3 | 399.7 | 391.5 | 394.1 |
| 136.00 Brickeys | 386.4 | 391.8 | 394.6 | 397.2 |
| 139.96 | 388.5 | 393.9 | 396.7 | 399.3 |
| 145.81 Selma | 391.6 | 396.9 | 399.8 | 402.5 |
| 150.19 | 393.6 | 399.0 | 401.9 | 404.6 |
| 155.54 | 396.1 | 401.5 | 404.5 | 407.2 |
| 160.71 Meramec River | 398.6 | 404.1 | 407.1 | 409.8 |
| 165.25 | 401.1 | 406.4 | 409.4 | 412.3 |
| 168.75 Jefferson Barracks | 403.0 | 408.2 | 411.3 | 414.2 |
| 170.15 | 403.9 | 409.2 | 412.1 | 415.0 |
| 175.33 | 407.0 | 412.8 | 415.4 | 417.0 |
| 176.96 Engineering Depot | 408.0 | 414.0 | 416.4 | 418.8 |
| 179.60 St. Louis | 409.9 | 415.7 | 418.4 | 421.0 |
| 185.18 | 412.1 | 418.2 | 421.4 | 424.4 |
| 190.37 Chain of Rocks | 414.1 | 420.1 | 423.5 | 425.8 |
| 195.55 Missouri River | 417.0 | 422.2 | 425.5 | 428.5 |

For example, prairie historically was confined to areas north of Kaskaskia in the MMRRC and the larger prairie patches in the American Bottoms have been almost entirely converted to agricultural fields or to urban areas. Despite difficulties, some priority should be given to restoring at least some functional patches of all historic habitats to restore parts of the integrity of the entire MMRRC.

The annual primary and secondary production of MMRRC habitats was among the greatest of any ecosystem in North America. This production historically depended on seasonal and long-term flooding regimes and regular fire, wind, and soil disturbances. High primary productivity in the MMRRC was created by high fertility of alluvial soils (hence the large past conversion to agriculture), a Mediterranean to subtropical climate, and regular inputs of nutrients and sediments from floodwaters of the Mississippi River and its tributaries. High secondary production in the MMRRC was sustained by a large inputs of nutrients and plant materials from diverse forest and prairie communities. Protecting and restoring both ecological structure and processes in the MMRRC ultimately is critical to creating and sustaining rich seasonal pulses of resources in this floodplain system and the many potential foods and ecological niches occupied by diverse fish and wildlife species.

Food webs in floodplains are complex and highly seasonal (e.g., Sparks 1995, Heitmeyer et al. 2005). Most animals that historically were abundant in the MMRRC relied on multiple foods during the year, or they were present only during seasons when specific resources are present (e.g., hard mast, detrital invertebrates, moist-soil seeds, arboreal insects, etc.). A basic adaptation of many of these animals was high mobility and species also relied on connected water flow and habitat patches that enabled them to move throughout the system (e.g. during floods) to exploit resources. In floodplain ecosystems, the connectivity of terrestrial and aquatic habitats is an important aspect of disbursement and distribution of nutrients, water, and energy flow. Maintaining or restoring connectivity of water flow and habitats where possible in the MMRRC is critical for sustaining "traditions" of use by seasonal animal visitors, securing critical resources to meet annual needs of resident species, and reducing predation or other mortality agents. Restoring connectivity between the Mississippi River and the MMRRC floodplain, at least in some locations, is important, yet will be difficult to achieve in many areas where large flood protection levees exist along the Mississippi River. Nonetheless, opportunities to reestablish some connectivity, and to emulate natural seasonal and long term hydroperiods, should be pursued.

4. *Restore habitats that can serve as a "core" of critical, sometimes limiting, resources that can complement and encourage restoration and management on adjacent private lands.*

Ultimately, restoring ecological functions and values of the MMRRC ecosystem will require conservation and restoration of both public and private lands throughout all three MMRRC ecoregions. Public lands often can serve as a "core" of resources within floodplains, however they are not always large enough, distributed in all "gap" areas, or contain a diversity of critical habitat types to meet needs for all species. A general goal for "core" conservation areas should be to couple existing or planned public areas with adjacent private lands to create a functional complexes of habitats and resources throughout the MMRRC (e.g., see similar conservation strategies in National Ecological Assessment Team 2006).

The historic diversity of vegetation communities in the MMRRC assured that many food types were present and abundant in all seasons (Fig. 33). Changes in distribution and extent of some habitats (e.g. the high percentage loss of Bottomland and Mesic Prairie, Floodplain Forest, and Savanna) have clearly altered amount and availability of some foods. Where declines in key resources and foods are identified for an area, attempts should be made to either restore that component of the system or replace the resource with another similar type. Managers must recognize, however, that long-term sustainability of animal communities will require restoration of key plant communities in appropriate locations throughout the MMRRC (Appendices P-T).

## RESTORATION OF SPECIFIC COMMUNITIES

This report does not attempt to prioritize specific sites that can be restored. Opportunities, and individual priorities, for restoration at a site(s) will depend on many factors including site availability, landowner and conservation objectives, financial options and assistance for landowners, resource agency budgets, mitigation or compensation needs of land or water development projects, commodity and resource markets, etc. While conservation organizations in the MMRRC may have different objectives and capabilities to restore MMRRC habitats, the collective and coordinated works of all parties offer the opportunity to restore many parts of the region. In general, the key to restoring some biodiversity, functions, values, and sustainable communities in the MMRRC is in restoring a mosaic of all habitats in natural distribution patterns and in restoring some semblance of natural hydrology and floodplain water flows in this ecosystem.

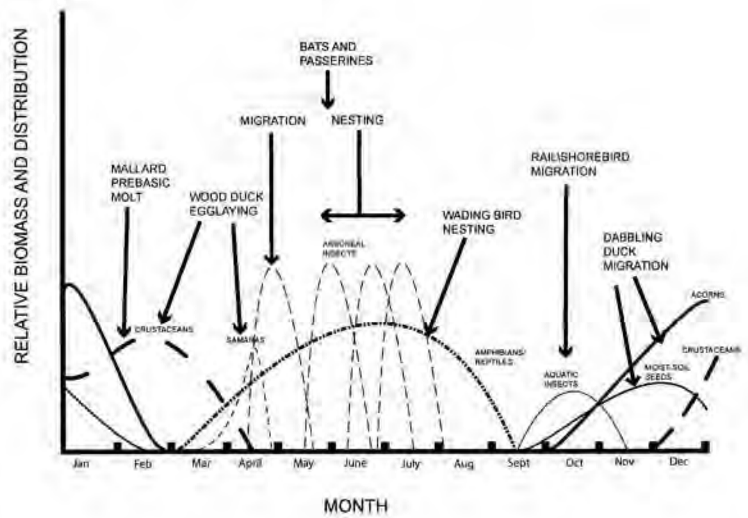



Fig. 33. Examples of seasonal pulses of food types in bottomland hardwood forests and key annual cycle events of select species that coincide with these pulses (from Heitmeyer et al. 2005).

This report identifies landscape and ecological characteristics that are needed to successfully restore specific habitats. This HGM process of identifying the matrix characteristics associated with specific habitats is useful in several contexts. For example, the HGM matrices produced in this report help decide what restoration options are most appropriate if: 1) sites are sought to restore specific habitat types including those that are greatly reduced in area and distribution (e.g., prairie), represent a key "gap" in coverage or connectivity (e.g., Floodplain Forest), provide key resources for animal species of concern (e.g., giant canebrakes within BLH forests), or are needed for mitigation; or 2) a site becomes available or offered to a resource agency and decisions must be made on what habitats can/should be restored on the site given budget, management, and development constraints. The specific HGM characteristics of the major habitat types in the MMRRC are discussed below.

*Bottomland Prairie*. – Bottomland Prairie historically occurred in large, often interconnected, patches north of Kaskaskia. The largest patches of Bottomland Prairie were in the American Bottoms north of Valmeyer. Unfortunately, most of this habitat type was quickly converted to agriculture and urban areas following European settlement and today only a few very small prairie patches exist as small linear strips along roads, ditches, and rail beds and in isolated pasture sites. Consequently, restoration is the only conservation option available to provide a significant Bottomland Prairie component to the MMRRC landscape. Because Bottomland Prairie was such a large part of the Presettlement American Bottoms (and on what is now Kaskaskia Island); restoration of at least some Bottomland Prairie should be a high priority for the region.

Bottomland Prairie restoration should be attempted only on sites that previously were prairie during the Presettlement period (Appendices A-C). Many of the historic prairie sites have changed dramatically and can not be restored because of urbanization, altered topography and soils, and the inability to use regular disturbance events, especially fire. Furthermore, the cost of converting agricultural land to prairie and the level of management intensity that will be required to maintain smaller prairie patches will be high. Despite difficulties, restoring at least a few larger patches that contain both ridge and swale prairie vegetation will help the MMRRC ecosystem regain a critical, now essentially absent, part of its ecological values and functions. Generally, the best areas for restoration of Bottomland Prairie will be highest elevations on the tops of point bar surfaces in the American Bottoms from Valmeyer to Dupo. Prairie restoration should be discouraged adjacent to, or in, former (or current) forested areas because soil types, surface water drainage, and lack of fire will favor encroachment by trees and compromise long-term sustainability of prairie. Some restoration of Bottomland Prairie communities can be conducted by restoring natural topography in small swales and using water-control structures to effectively mimic short duration seasonal flooding. In effect, creating small moist-soil impoundments in these areas can replicate, to at least some degree, wet Bottomland Prairie communities if they contain appropriate vegetation species.

The best sites to restore complexes of Bottomland Prairie "ridges" and "swales" are:

- north of Kaskaskia Island
- on older Point Bar surfaces that retain topographic complexes of narrow swales and broader ridges
- at elevations at least above the 2-year flood frequency zone (swales in Bottomland Prairies were in the 2-5 year flood frequency zone and higher ridges were above the 5-year flood frequency zone)
- non-clay soils on ridges and clay soils in swales
- locations with few dissecting drainages or ditches
- at least 100 acres and preferably at least 1/4-mile wide (see Helzer and Jelinski 1999)
- areas that can be actively managed with fire, plantings, and perhaps occasional grazing
- owned, managed, or controlled by a conservation entity

*Mesic Prairie*. – Mesic Prairie was mostly confined to the northeast part of the American Bottoms, mostly on the Savanna Terrace, and on higher elevation point bar ridges. Most historic Mesic Prairies have been converted to agriculture or urban communities; a few very small remnant patches occur east of Horseshoe Lake State Park. Restoring Mesic Prairie will require most of the same considerations as restoring Bottomland Prairie, except that the opportunity to obtain larger sites and to use fire as a regular disturbance mechanism will be more constrained because of the extreme urbanization in former Mesic Prairie sites. Undoubtedly, fire was common on the higher terraces that supported Mesic Prairie and fires probably burned from adjacent upland forests along terrace edges and bluffs into Bottomland Prairie areas until it was extinguished by wetter conditions in low floodplain areas.

As with Bottomland Prairie, some Mesic Prairie may be able to be restored in small linear patches along roads, ditches, and rail beds and borders along agricultural fields or pastures if periodic disturbance can occur. Sites immediately adjacent to existing forest will be difficult to maintain as Mesic Prairie because of persistent encroachment by woody species.

Areas that seem most suitable for restoring Mesic Prairie include sites that are:

- higher elevations on the Savanna Terrace and point bar ridges in the northern part of the American Bottoms
- > 20-year flood frequency zone
- silt loam and sandy loam soils
- gently sloping topography with few internal drainages or ditches
- owned or managed by conservation interests
- capable of having at least some regular disturbance from fire, mowing, or grazing

*Savanna*. – Savanna habitats were present in some MMRRC locations, mostly in narrow bands adjacent to Bottomland and Mesic Prairie areas that transitioned to Slope or Floodplain Forests. Mapping the historic distribution of Savanna is difficult (Appendices A-C) because the distribution of this mixture of grass vs. trees was temporally dynamic and expanded or contracted as flooding and drought cycles occurred in the region. The ecological factors that created Savanna were the actively competing forces that sustained relatively equal amounts of prairie (fire, herbivory, higher sloping elevations) and forest (drainage, more frequent flooding, erosion or scouring of soils, ponding of surface water for extended periods, etc.). Consequently, restoration of Savanna in the MMRRC will require careful site selection and regular disturbance including fire or mowing. Interestingly, most small remnant Savannas in the MMRRC occur near dwellings or towns, on historic school lands, and at rural church sites on the edge of former prairie sites where some sort of regular disturbance (usually mowing) has helped maintain an interspersion of grass and trees.

Sites most suited to restoring savanna include areas:

- at the ecotone of former prairie edges
- that have silt loam soils
- in pasturelands

- near alluvial fans and other floodplain edge sites with 3-5% slopes

- near the edges of towns or farmsteads

*Slope Forest*. – Slope Forests in the MMRRC historically were confined to alluvial fans and the highest elevations on the edge of the Savanna Terrace. In areas where alluvial fans graded to Bottomland or Mesic Prairie in the American Bottoms, Slope Forest often had a Savanna-type mix of grass and upland trees (see preceding section on Savannas). Where alluvial fans graded to Floodplain Forest or BLH, the Slope Forest contained a mix of Upland Forest, Floodplain Forest, or BLH species. Most alluvial fans in the MMRRC have been cleared for agriculture or are sites of small rural communities. A few remnant Slope Forest patches are present throughout the MMRRC (Appendices K-O). Restoring Slope Forest seems possible wherever the topography and soils of alluvial fans and terraces have not been highly disturbed. In some alluvial fans where adjacent stands of upland forest remains on the top part of the slope, natural regeneration and expansion of these upland-type trees onto the slope may occur. In contrast, most of the bottom parts of alluvial fan slopes now are cleared and are in agricultural production. Consequently, reintroduction of Floodplain Forest or BLH species back onto at least the bottom parts of alluvial fans and terrace slopes probably will require direct planting.

Sites where Slope Forest should be restored include:

- alluvial fans and colluvial aprons

- high elevation edges of the Savanna Terrace

- > 20-year flood frequency elevations

- areas with mixed erosional type soils

- sites with few, or no, roads, ditches and levees that disrupt overland sheetflow of water over the alluvial fan and slope

- sites adjacent to remnant upland forests

*Floodplain Forest*. – Floodplain Forest historically was present throughout the MMRRC; the largest amount of this habitat type was in the Kaskaskia ecoregion. Unfortunately, this habitat type has been widely destroyed and only small scattered patches remain. Floodplain Forest occupied an intermediate elevation position between Riverfront Forests located on chute and bar surfaces next to the Mississippi River and BLH or prairie communities on floodplain backswamp and point bar surfaces. Generally, Floodplain Forest was located at 2-5 year flood frequency elevations and was regularly inundated for some periods in late winter and spring, however it did not incur the regular scouring and large deposition of coarse-sediment alluvium associated with the Riverfront Forest chute and bar environment. Occasional prolonged growing season flooding in Floodplain Forest sites discouraged widespread encroachment of most BLH species, especially pin oak, in these communities. In the American Bottoms, swales within Floodplain Forest often contained a mix of S/S and annual herbaceous plants along with water tolerant trees similar to those found in Riverfront Forest. Ridges in these northern MMRRC areas contained some hard mast species, most commonly pecan and pin oak. South of Kaskaskia, swales in Floodplain Forest contained S/S species and some baldcypress, willow, cottonwood, maple, and ash. Ridges in these areas contained a mix of many species including an increasing amount of oaks and pecan. Riparian areas along river tributaries in the MMRRC also contained Floodplain Forest with some mixed pecan and oaks.

Restoration of Floodplain Forest is possible on sites that historically had this community. Also, some chute and bar surfaces (historically Riverfront Forest) that now are protected from annual Mississippi River overflow and scouring may be restorable to Floodplain Forest if soils and elevations are suitable. Ideally, restoration of Floodplain Forest could occur throughout the MMRRC as an integral part of restoring complexes of all historic communities. Floodplain Forest historically were important habitat corridors from uplands along the edges of MMRRC floodplain to the Mississippi River and were conduits for movement and dispersal of water, nutrients, plants, and animals. Afforestation of Floodplain Forest should carefully plant higher zone less water tolerant species (including elm, oaks, and pecan) on the highest ridges and lower zone wetter species (including baldcypress, cottonwood, ash, sugarberry, and sycamore) in swales.

Generally, locations that are most suitable for restoring Floodplain Forest are:

- point bar surfaces and tributary riparian zones
- high elevation ridges on chute and bar surfaces, especially if they are protected by mainstem Mississippi River levees
- 2-5 year flood frequency elevations
- mixed sandy to loam soils on ridges and mixed clay-silt soils in swales
- sites that can enlarge and connect remnant, or restored, Floodplain Forest patches
- sites that have few ditches, levees, or roads that disrupt overland sheetflow of water across the floodplain and that do not cause excessive ponding of water in swales or depressions.

*BLH*. – BLH communities within the MMRRC ranged from Cypress/Tupelo stands to oak-dominated forests along elevation and flooding gradients. All BLH communities, excepting the cypress/tupelo zone, were relatively intolerant of growing season flooding and became established in floodplain depressions where short duration backwater flooding was the usual seasonal water source. Consequently, BLH developed mostly in southern MMRRC areas where backswamp depressions were present along the bluff side of floodplains and on Holocene stream terraces.

Cypress/Tupelo habitats historically were present in older abandoned channels and larger floodplain swales and depressions south of Kaskaskia. Restoration of Cypress/Tupelo habitat is appropriate and probably can be accomplished relatively easily in many abandoned channels and swales that have been drained or cleared. Restoration of Cypress/Tupelo will require reestablishment of dominant trees and restoring semipermanent water regimes to a site. In some locations, simply planting seedlings may be sufficient to restore trees; a few areas in swales and abandoned channels north of Fountain Bluff were planted to baldcypress in the 1960s and now have excellent stands of baldcypress (Fig. 34). In sites that have been partly drained, regular flooding that persists at least 3 months of most years must be restored. Conversely, some former cypress/tupelo sites have been converted to open water habitats because water is present year round and soils never dry. In these wet areas, periodic drawdowns that expose soils and allow germination of baldcypress and tupelo seedlings will be needed to maintain and regenerate cypress/tupelo habitats.

Restoration of Cypress/Tupelo communities seems possible where the following combination of factors occurs:

- low elevation depressions, backswamps, swales, and abandoned channels south of Kaskaskia
- 1-5 year flood frequency zones
- wherever fringes of abandoned channels and swales have been cleared or drained
- clay or silt-clay soils
- in low depressions and water-logged sites some of which may be created by man
- where surface water stands 3-9 months of the year on average, especially in backswamp deposits, and has the capability of being periodically drained during late summer.

Low, Intermediate, and High BLH communities were present south of Kaskaskia in backswamp, braided river channel, and depressional surfaces. A gradation of species occurred from the lowest to highest elevations within these sites. Restoration of Low BLH in some sites may be accomplished simply by planting appropriate tree species. These sites include some low elevation areas south of Thebes and in old backswamp surfaces. In some areas, hydrology will need to be restored in addition to planting trees so that growing season flooding is avoided and that up to 3 months of dormant season flooding can occur in most years. Water management in BLH sites should emulate natural regimes and avoid stagnant and repeated-year flooding especially in greentree reservoir sites like Oakwood Bottoms WMA (Fredrickson and Laubhan1990, Fredrickson and Batema 1991, King and Fredrickson 1998). Additionally, water management in BLH communities must provide inter-annual dynamics of depth, duration, and timing of flooding and provide occasional extended dry periods to emulate natural droughts.

Where possible, the natural hydrology in all BLH habitats should be restored using the least amount of structural modifications possible and with water management infrastructure designed on natural contours (e.g., King and Fredrickson 1998).

Fig. 34. Baldcypress planted in an abandoned channel northwest of Gorham, Illinois

Some structural modifications may be needed in highly altered sites such as reconnecting sloughs and swales; filling of ditches; removing levees and roads in low areas; and restoring drains to major outlets in lower elevations. Wherever levees, ditches, and water-control structures are needed to restore and manage BLH hydrology they must be designed carefully so that they do not further fragment existing forests or disrupt sheet and backwater flood flows in the area. Additional levees and water-control structures have the potential to create pockets of standing water for extended periods that cannot be drained easily, thus further degrading BLH composition and functions. New ditches, roads, and levees can further fragment existing BLH forest areas and create entry corridors for exotic species, predators, and cowbirds that can impact local populations of plants and animals.

Excellent locations to restore Low BLH include:

- areas south of Kaskaskia
- swales in backswamps, braided stream surfaces, and isolated point bar surfaces
- sites that are inundated for an average of 1-3 months annually
- flood prone areas along tributaries
- areas with clay and silt-clay soils

Intermediate BLH occurred south of Kaskaskia, especially in the backswamp east of Fountain Bluff and areas within the 2-5 year flood frequency braided stream terrace south of Thebes. Sites most suited to restoring Intermediate BLH are:

- backswamp and braided stream terraces south of Kaskaskia, with some local natural levee veneers in point bar surfaces
- 2-5 year flood frequency zones
- clay and silt clay to silt-loam-clay soils
- sites that are flooded up to 2-3 months annually only during the dormant season
- non laser-leveled fields
- sites that enlarge existing BLH forest patches

High BLH is the highest elevation zone within BLH communities and represents the transition area between BLH and upland forests. Consequently, most High BLH within the MMR has been converted to agriculture and lands have been extensively drained, leveled, and cleared. Sites most suited for High BLH restoration include:

- high elevation backswamp, braided stream terrace, and edges of alluvial fans or bluff margins south of Kaskaskia
- > 5 but < 10-year flood frequency zones
- high elevation natural levee veneer ridges in isolated point bar surfaces

- silty-clay to silt loam soils
- areas that are not highly ditched or leveed and that retain (or can be restored with) at least some surface sheetflow of water from local floodplain watersheds
- non laser-leveled agricultural fields
- sites that can enlarge existing BLH patches or that connect with remnant slope or upland forests

*Riverfront Forest.* – Riverfront Forest historically was distributed as an almost continuous band of habitat along the Mississippi River in the MMRRC where chute and bar geomorphic surfaces were present. This forest type contained early successional trees and shrubs that are adapted to extended growing season flooding and coarse-grained soils that were regularly scoured and reshaped by river flooding. Riverfront Forest also occurred on the edges of larger tributary channels and the ends of older abandoned channels where coarse sediments were deposited. Riverfront Forests have not been destroyed as extensively as other MMRRC habitats, partly because of their position next to the Mississippi River, the underlying sandy soils, and because much of this remnant habitat is within batture lands on the inside of mainstem levees that remain subject to periodic high flows and deposition/scouring of sediments.

Riverfront Forests are not monotypic and they include a diversity of species stratified by elevation and flooding duration. Low elevation sites immediately next to river Side channels and Chutes are occupied primarily by willow and silver maple along with some shrubs. Higher ridges and the low, newly formed, natural levees along the Mississippi River contain mostly cottonwood, sycamore, silver maple and occasional sugarberry, ash, and pecan. Oaks rarely occur in Riverfront Forest, but historically some of the highest ridges and older natural levees supported scattered pockets of pin oak; few if any of these areas remain today.

Restoration of Riverfront Forest may not be as high of a priority for the MMRRC simply because larger amounts of the historic distribution of this habitat type remains in place. However, in chute and bar areas that have been cleared, reestablishment of this community is desirable and probably can be done relatively easily. Tree species in Riverfront Forest are aggressive early successional varieties that have high dispersal capabilities and germinate on newly deposited or scoured surfaces. Consequently, Riverfront species can quickly populate an area. The challenge in many areas will be to reestablish a diversity of species in Riverfront Forest and to sustain at least some higher elevation “ridge” species such as cottonwood and pecan. Planting of these higher zone species will require careful site selection.

Restoration of Riverfront Forest is possible:

- throughout the MMRRC on chute and bar surfaces, especially within batture lands
- on sandy or sandy-loam soils (with silt veneers in swales)
- within the 1-2 year flood frequency zone for more water tolerant species and on ridges with 2-5 year flood frequencies for less water tolerant species such as pecan
- any cleared area immediately adjacent to the Mississippi River

*Bottomland Lakes.* – Most Bottomland Lakes in the MMRRC were formed from abandoned channels of the Mississippi River. The Horseshoe Lake WMA complex in southern Illinois was formed by abandoned channels of the Ohio and Mississippi rivers. Other smaller abandoned channels were formed along the Big Muddy River. Some abandoned channels, especially newer ones, still retain at least some of their original topography, however, many have been at least partly filled with sediments and have altered hydrology. Many remnant Bottomland Lakes now are “islands” within wide expanses of agricultural lands and urban fringes (Appendices K-O). In many cases, the edges of Bottomland Lakes are highly developed and cleared and inputs of nutrients, chemicals, sediments, and sewage into the lakes have degraded their productivity and water quality. Restoration of water regimes, water quality, and fringe vegetation communities of some Bottomland Lakes may not be possible.

Bottomland Lakes in the MMRRC historically included both prairie-wetland and forest-edge types. Many Bottomland Lakes in the American Bottoms historically were surrounded, at least in part, by bottomland prairie and the edges of these lakes was dominated by emergent and herbaceous vegetation that essentially formed a “marsh” ecosystem. Other Bottomland Lakes were within forested areas of the MMRRC, especially those south of Kaskaskia. The edges of these lakes supported diverse forest communities ranging from Riverfront Forest species in the American Bottoms to Cypress/Tupelo communities in southern areas. Restoration of Bottomland Lakes should attempt to restore the appropriate surrounding vegetation that historically occurred at a site. Consequently, prairie-type lakes should be restored in conjunction with restoring Bottomland Prairie tracts along their edges. Restoration of forest-edge Bottomland Lakes should include restoration of Floodplain Forest or BLH along their edges and watersheds. Restoring more natural nutrient and water inputs to Bottomland Lakes may require restoration of watershed drainages and enhancing river connectivity during flood events. Restoring buffers (preferably at least 300 feet wide) of grassland or forest along the edges of these lakes also will be important to filter upland runoff and provide organic material for edge habitats.

Some Bottomland Lakes may need physical modifications to emulate more natural seasonal and long term water regimes. Most Bottomland Lakes historically had seasonal water regimes that created maximum flooding in late winter and early spring followed by gradual drying of edges during summer. Summer drawdowns allowed germination of both prairie herbaceous/emergent species and woody encroachment. Currently, most Bottomland Lakes in the American Bottoms have shifted to forest-edge communities because formerly adjacent prairies have been converted to agriculture or urban areas and fires can not burn into lake edges during drawdown periods. Additionally, most larger remnant Bottomland Lakes throughout the MMRRC now are seldom drawn down because of recreational uses and public demands for fishing or other activity (e.g., Horseshoe Lake State Park in the American Bottoms and Horseshoe Lake WMA in Alexander County, Illinois). Eventually, permanent water regimes in Bottomland Lakes will degrade diversity of plant communities and bind nutrients in emergent or woody vegetation. Food webs and fish community structure in Bottomland Lakes also becomes highly altered in permanent water regimes if invasive plants and animals become present. Generally, management of Bottomland Lakes should incorporate regular drawdowns that emulate both seasonal and long-term dynamics.

In contrast to more permanent flooding of larger remnant Bottomland Lakes, most smaller lakes have been at least partly drained and ditched. In these smaller Bottomland Lake areas, restoration will require restoring water flow into, and holding capacity of, the basin. Construction of perpendicular "cross-levees" within degraded Bottomland Lakes usually is not desirable because it disrupts water flow through the old abandoned channel, stagnates water behind levees, often reduces drainage capabilities of the respective pools, and sometimes cuts through soil restrictive layers or veneers of clay and silt in the lake bottom to expose underlying sand deposits that will drain, rather than flood, a former lake. Nonetheless, sometimes, levees may be needed to restore hydrology of the Bottomland Lake if it simply can not continue to hold water without them. For example, if a large drainage ditch is present at the end of a former Bottomland Lake then some type of water-control structure, and perhaps a levee, may be needed to restore the hydrology to the site. Generally, restoration of Bottomland Lakes should be conducted with the least amount of physical development within the former channel bed as possible and in all cases extensive soil coring should be done to understand depth, permeability, and constituency of abandoned channel sediments.

Restoration of Bottomland Lakes can occur if:

- hydraulic connectivity with watersheds (direct drainage systems or overland sheetflow) or periodic flooding sources (such as the Mississippi or tributary rivers) is restored
- water regimes can be managed for natural dynamics of periodic flooding and at least partial drainage (e.g., USACE 2003b)
- sediments, nutrients, and contaminant inputs are reduced or filtered (e.g, silt basins in watersheds)
- some portions of the bottoms of filled depressions are reshaped to more natural contours
- ditches that drain abandoned channels are removed and cuts that expose lower sandy soils under lakes are filled in with clay or water restrictive materials
- developments along the edges of lakes are reduced or restricted

- fringe vegetation communities are restored to historic conditions (prairie or forest types) and buffers of 100-300 feet wide surround the lake. Preferably, wider buffers and entire watershed patches, especially in main drainage input areas, could be restored.

*Side Channels and Chutes.* – The number, length, and connectivity of Side Channels and Chutes along the Mississippi River have been greatly reduced. These habitats are extremely valuable for many aquatic species and some opportunities for reestablishing connectivity to the Side Channels have been identified by conservation interests in the MMRRC (USACE 2001). In some cases, plans are being developed to create "new" Side Channels. The physics, hydraulics and basic science of creation of new channels is less known that reestablishment of connectivity to former Side Channels and will require careful planning to avoid excessive and artificial flow and sediment conditions. In most older Side Channels, the combination of river channel migration and sediment deposition dynamics tends to create plugs of sediment at the upstream end, and gradual siltation and filling of the mid and downstream sections, of the Side Channel. The challenge for restoration of highly filled and disconnected Side Channels is both physical and biological. If dredging is used to reopen the Side Channel, river flow patterns and sediment movements must be understood and accounted for so that the reopening can be more sustainable and not become a regular recurring "maintenance" problem and expense. Further, the dynamics of water entry, flow through, and depth is a function of river stage and flooding frequency both seasonally and long term. Where the river has become more entrained or entrenched from navigation developments and levees, the stages and duration curves of the Mississippi River are changed from historic patterns and must be considered when planning Side Channel restoration. In these cases, reentry of the river into chutes can be created, but if natural dynamics of flooding are not emulated then both plant and animal responses to these developments will not be as intended.

Generally, restoration of Side Channels and Chutes will be most successful if:

- efforts are focused on reconnecting recent Side Channels and Chutes

- river entry locations and elevations emulate historic seasonal and long-term dynamics of Mississippi River stage and discharge. Most river entry points in older Chutes were from downstream backwaters rather than upstream headwaters except during high flow seasons and years

- engineering is used to dredge and divert water into and through Side Channels in the above manner.

## RESTORING COMPLEXES

The key to ultimately improving ecological functions and values in the MMRRC ecosystem will be the restoration of at least some sustainable areas or patches of all habitat types that historically occurred in the region. The best restoration locations will be areas where "complexes" of habitats and landscape linkages between communities can be created. In reality, most restoration opportunities in the MMRRC likely will occur where a specific parcel of land becomes available for acquisition or conservation easement (e.g., WRP) and then a restoration plan can be developed for the tract given constraints of the specific site. The previous section of this report provided the guidance to understand what specific communities can be restored on a site given its geomorphic surface, soils, topography, hydrology, and land modifications. Size, location, neighboring land uses, etc. will all be constraints to restorations, but if the HGM evaluation for a site is done correctly, then the most sustainable habitat complex can be planned and restored for the site. Each site will be unique and require site-specific evaluation. The temptation for some conservation interests or landowners will be to try to over-develop a site and include habitat types that did not historically occur on the site or that cannot now be restored or be sustained given current conditions (Fredrickson and Reid 1988). Each site must be viewed as a potential contributor to eventually restoring components of the historic MMR ecosystem. All restoration sites in the MMRRC will be important, but their respective role and contribution must be clearly understood within this larger spatial-scale context.

A productive strategy for ecosystem restoration within the MMRRC will be to proactively seek sites that offer potential for restoration of habitat complexes that: 1) include habitat types that have been highly destroyed or degraded, 2) fill spatial "gaps" in both habitat type and area , 3) provide physical and ecological connectivity among habitats and patches, and 4) include restoration of the basic ecological processes needed to establish and sustain the respective vegetation or aquatic community. With this in mind, it is recommended that the following items be incorporated into a comprehensive ecosystem restoration and conservation strategy for the MMRRC.

1. Restore at least some functional areas of the most destroyed habitat types, especially Bottomland and Mesic Prairie, Savanna, Bottomland Lake, and Floodplain Forest.

2. Expand remnant BLH patches and restore natural hydrological regimes that match natural dynamics of respective Low to High BLH communities.

3. Expand and diversify Riverfront Forest communities to create functional corridors along the Mississippi River and include some hard mast tree species on the highest ridges and natural levee elevations.

4. Reconnect select Side Channels and Chutes along the Mississippi River.

5. Create buffers of habitat complexes around wetlands especially Bottomland Lakes, point bar swales, and backswamp depressions.

6. Identify possibilities for restoring hydraulic connectivity between MMRRC rivers and their floodplains, especially backwater flows into sloughs, swales, abandoned channels, and backswamp depressions.

# APPLICATION OF INFORMATION (HOW-TO) FROM THIS REPORT

This report used the basic principles of HGM methodology to evaluate landscape-scale options for restoration of ecosystems in the MMRRC. The HGM process asks four basic sets of questions that guide decisions about what communities can/should be restored at spatial scales ranging from broad ecoregions and regional floodplain corridors to specific tracts of land. These four sets of questions are:

1. What was the historic (pre-European settlement) community, what landscape features were associated with this community, and what abiotic and biotic mechanisms sustained it?

2. What changes have occurred from the historic conditions, both in landform and mechanisms?

3. What potential communities can be restored and sustained on the site or region now? In other words, what is the "new desired state?"

4. What physical and biological changes are needed to create and sustain the new desired community?

Information in this report provides most, but not all, of the answers to these questions to help conservation planners in the MMRRC make restoration decisions. At a broad landscape scale, Appendices A-E identify the historic types and distribution of communities in the MMRRC, Appendices K-O identify what communities currently exist, and Appendices P-T suggest the current suitability of areas for restoring each community. This regional information can be used by conservation partners to understand which communities have been most lost in ecoregions (Table 8) and where they may wish to work to restore basic parts of the MMRRC ecosystem.

At the site-specific scale, this report provides much of the information needed to determine what communities potentially could be restored at a site. For example, the digital GIS databases assembled for this report provide detailed information on the geomorphology, soils, and to some degree the topography and current flood frequency elevation contours for a site. This GIS information now is available to all conservation organizations and can be sorted and analyzed at any spatial scale. The development of HGM community matrices in this report for the three MMRRC ecoregions help planners identify what physical features and ecological processes sustained historic communities at a site, and that must be present if the community is to be restored. This report can not identify all of the physical or biological changes that have occurred at each site in the MMRRC, but it does describe the general types of landscape alterations that must be identified before decisions can be made about restoration options. This report suggests the following procedure to determine optimal restoration options at a site.

1. Ask what the historic community types were on the site. This is provided in Appendices A-E.

2. Ask what the physical and biological features of the community were and what the controlling biological mechanisms were. This is provided in the HGM matrices (Tables 5-7) and text for each community type.

3. Ask what changes have occurred to the site. Some of this information is provided in Appendices K-O (where existing habitats are) and general information about ecological effects of various landscape changes is provided in tables, figures and text of the report. Obtaining information about detailed changes in landform, hydrology,

and community composition usually will require site-specific investigations.

4. Ask what communities are appropriate and ultimately can be sustained for the site given current alterations. The suggestions for general community restoration on sites are provided in Appendices P-T of this report. Refinements of determining the new desired state and detailed distribution of species within a community will require information on specific topography and flood frequency at the site.

5. Ask what physical and biological changes will be needed to restore the desired community.

The following is an example of this "How-To" process for Wilkinson Island, which is a site now owned in part by the U.S. Fish and Wildlife Service.

1. *What was the historic community?*

Answer: The site was covered by Riverfront Forest with interspersed sloughs and chutes that were seasonally connected with Mississippi River flows (Appendix C).

2. *What were the physical and biological features of this community?*

Answer: The site was a recent chute and bar geomorphic surface that had diverse ridge and swale topography (Fig. 6). Swales contained a thin veneer of silts over underlying sands (Fig. 7). Ridges had predominantly sandy-silt soils. Swales were within the 1-year flood frequency zone and had seasonal inundation from Mississippi River flows. Ridges were mostly within the 2-5 year flood frequency zone and were flooded for short durations, mostly during higher stage flood events of the Mississippi River (Table 9). Swales contained mainly early successional tree and shrub species such as willow, silver maple, and buttonbush (Table 6). Ridges contained less water tolerant trees including green ash, cottonwood, sycamore, and scattered sugarberry, box elder, pecan and pin oak in the highest elevations. Deeper chutes that were highly connected with the Mississippi River for most of the year contained S/S edges and some aquatic submergent and herbaceous "moist-soil" plants.

3. *What changes have occurred on the site?*

Answer: Part of the site was cleared for agricultural production by the late 1800s (Appendix G) and subsequent clearing converted up to 50% of the site to farmland by the mid 1900s. Merchantable timber on the site was harvested initially for fuel for steamboats traveling the Mississippi River in the late 1800s and later for lumber and pulp in the 1900s. Remnant forest vegetation is relatively young and dominated by willow, silver maple, and cottonwood with a few scattered pecan (Appendix M). A large mainstem levee was built along the Mississippi River in the 1930s and separated most of the site into mostly batture lands within the levee and a small fringe area outside, or behind, the levee. Drainage ditches were dug in parts of the site to facilitate farming. Some interior roads and levees were constructed to provide access and protect parts of the site from regular Mississippi River floods. Systemic changes in Mississippi River flows throughout the MMRRC have dampened spring and summer flood events in this region. A former connected side channel in the site now is closed from siltation.

4. *What is the new desired state?*

Answer: The site is best suited for restoration to a Riverfront Forest complex (Appendix R). A detailed topographic survey is needed to determine which species should be restored at specific locations. Early successional species such as willow, silver maple, and some cottonwood and sycamore will be the most sustainable tree species for most of the site in the future because of regular growing season flooding and sandy soils next to the Mississippi River. However, higher elevations that are > 2-year flood frequency contour (see Table 9) potentially can be restored to a mix of less water tolerant trees including cottonwood, sycamore, elm, ash, and pecan. Also, sites behind the mainstem levee now have infrequent flooding, compared to the interior "batture" part of the site, and may also support "higher zone" tree species that resemble Floodplain Forest communities. Chutes and swales should be reconnected to high Mississippi River flows.

5. *What is needed to achieve the desired state?*

Answer: Older interior levees and roads that obstruct water flow across the site should be removed and water flow paths in historic chutes and swales should be restored. Reforestation using both planted seedlings and natural regeneration should be done to restore appropriate tree species in relation to soils and elevation (see above).

This single example demonstrates how this report can be used to provide the fundamental information to determine restoration objectives for individual sites within the MMRRC. The degree that more detailed site-specific information will be needed at any site depends on what information exists for that site. The most common data deficiency for sites within the MMRRC is the lack of topographic surveys that map surfaces to at least a 1-foot contour, and preferably to < 0.5-foot contours. Additionally, the degree of alteration of former hydrology caused by site changes (e.g., levees, ditches, roads) and systemic alterations (e.g. lock and dam effects upstream) often is uncertain and flood frequency maps currently are not available for most MMRRC sites behind the mainstem Mississippi River levees. Despite some gaps and uncertainties, this report provides the basic information and tools to plan regional conservation and restoration actions in the MMRRC and to conduct much of site-specific evaluations. Undoubtedly, some refinement of predicted communities, both past and future, will occur as new information is acquired and existing data are refined.

# MONITORING AND EVALUATION

Restoring components of the historic MMRRC ecosystem will require many physical and biological strategies. Engineering and science information is available to inform, design, and implement these strategies, but some uncertainties remain about specific techniques, hydrological variables, community responses, and larger-scale interactions of habitats and sites. Future restoration and management of ecosystems in the MMRRC can be done in an adaptive management framework where predictions about specific management or restoration actions can be made and then select biotic and abiotic features and variables are monitored and evaluated to determine system responses and to suggest changes in management or strategies that are needed to achieve desired results. In most cases, the most important features that need monitoring are the primary abiotic features and ecological mechanisms that sustain communities and their productivity. These features include: 1) hydrological regimes including routes and interactions of surface and subsurface water flows, 2) sediment and nutrient loads and contamination rates, and 3) occurrence and effect of soil and vegetation disturbances. Key biotic features that must be monitored include: 1) composition, distribution, survival, and regeneration of plant species expected in the restored community; 2) invertebrate diversity and distribution, both detrital and terrestrial; and 3) vertebrate occurrence, distribution, and abundance. Specific monitoring and evaluation needs are identified below.

## EFFICACY OF RESTORING BOTTOMLAND PRAIRIE

Restoring patches of Bottomland Prairie in the American Bottoms of the MMRRC is important because this habitat type historically was extensive and supported unique communities of both plants and animals that contributed to the overall diversity and nutrient flow within the region. Restoring prairie will require reestablishment of appropriate grass, forb, and herb species and reintroduction of critical disturbance regimes, most notably fire. Certain data suggest sustainability of restored prairies is related to size of patch, with larger areas being preferable (e.g., Helzer and Jelinski 1999). Unfortunately, obtaining large prairie restoration sites in the American Bottom may be difficult. Opportunities for restoring smaller patches of prairie may be possible in small linear areas such as road and rail rights-of-way, ditch and canal banks, and field borders. Wherever prairie restoration is attempted, vegetation response must be regularly monitored to determine the best species mix for planting, effects of various disturbances if they can be used (e.g., mowing or chemical application), and encroachment of woody species. Also, if restoration sites can not be occasionally flooded, then experiments should be conducted to determine if Mesic Prairie might be a better restoration goal than Bottomland Prairie for the site. Conversely, if a site is occasionally flooded or has saturated soils, water regimes should be monitored to determine if they emulate historic seasonal and long term hydroperiods.

## REINTRODUCTION OF HARD MAST SPECIES WITHIN FLOODPLAIN AND RIVERFRONT FORESTS

The abundance and distribution of trees that produce hard mast (i.e. oaks and pecan) have declined throughout the Upper Mississippi River system. These declines have been caused by extended growing season inundation of sites from raised water levels in lock-and-dam pools, large flood events such as in 1993 and 1995, and physical developments such as levee and road construction in floodplain depressions that impounded water for longer periods and prohibit or slow drainage from a site. The HGM evaluation in this report suggests that some hard mast tree species, especially pecan, can be reestablished on the higher elevation ridges of point bar and the highest chute and bar surfaces. Afforestation of oaks and pecan in the MMRRC to date has had mixed results, most likely because of poor site selection and/or planting methods. Many afforestation methods have been used in the MMRRC including direct planting of bare root seedlings, planting container-grown trees, direct seeding of acorns, and natural regeneration from adjacent forests. New planting of pecan and oak species should be stratified by elevation, soil, and flood frequency relative to tolerance of each species. For example, pecan is best suited for sandy high ridges within bar and chute surfaces, overcup oak or baldcypress is most suitable for lower swales and depressions such as edges of southern abandoned channels, and pin oak is most appropriate for high point bar ridges and within higher braided stream channel and backswamp surfaces. In all afforestation sites, monitoring is needed to document species responses to methods and location.

## WATER FLOW PATTERNS, GROUNDWATER DYNAMICS, SILTATION, AND CONTAMINANTS

This report recommends changes to water flow patterns and seasonal hydrology associated with specific locations and habitats. Most changes involve some attempt to more closely emulate natural dynamics and natural drainage or flow routes including removal of artificial drainages on abandoned channels; restoring connectivity between the Mississippi River and side channels and other non-leveed floodplain sloughs and swales; and active management of water in swales, Bottomland Lakes, and backswamp depressions. Wherever water regimes are managed, or attempts are made to restore natural water flow patterns (either drainage or entry), monitoring should be done to document: 1) surface water movements including measures of discharge and storage in specific locations, 2) water quality including measures of contaminants and silt loads, and 3) groundwater levels. The interactions of ground and surface water within the MMRRC floodplain are especially unknown, but it seems probable that substantial interchanges occur between ground and surface waters where stratified subsurface layers of coarse-grain sediments are present. For example, most point bar surfaces have sand deposits underneath silt or loam soils on ridges. Subsurface sands and gravel are conduits for groundwater movement between the Mississippi River and often distant point bar swales when river levels are high. A series of permanent monitoring locations with piezometers should be established in areas of active restoration and analyses should include both groundwater level and water quality should be measured. Also, permanent monitoring stations should be established in key MMRRC floodplain wetland sites to determine sedimentation rates. LTRMP monitoring records much information on water quality and turbidity on the Mississippi River channel, but not floodplain habitats, and this monitoring should be expanded.

## ENDEMIC AND INVASIVE PLANT AND ANIMAL SPECIES

Baseline inventory data are needed on the distribution and abundance of both native and non-native plant and animal species the MMRRC, especially for sites that are targeted for restoration. Certain data are maintained on animal populations in the Mississippi River channel by the LTRMP, but unfortunately little monitoring is done within floodplain habitats or for certain species such as amphibians and reptiles. Further monitoring is needed to document animal responses to actual restoration sites to determine effects of restoration methods, habitats, and landscape features such as size, complexity, configuration, proximity to other habitats and refuges, public use, etc. Many invasive plant and animal species now occur in the MMRRC and their abundance and distribution must be monitored regularly to determine changes and impacts on ecosystems.

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Montagnes Pelées
F S. Louis
Fort Crevecoeur
Caoquias
Cascaquias
Ft de Chartres
Oyo
R. des anciens Chouanons
Rw. des Cheraquis
Mine
R. a la Mine de Fer
Fort Fr. commencé depuis les Anglois
le Fort Prudhome
les Acansas
les Chicachas
les Tchatas
Alibamous
dodaquios
les Natchitoches
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