AN EVALUATION OF TERRESTRIAL ECOSYSTEM RESTORATION OPTIONS FOR THE CHIPPEWA RIVER ECOREGION OF THE UPPER MISSISSIPPI RIVER SYSTEM

Prepared For:

U. S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

Report 10-06

Mickey E. Heitmeyer

July 2010

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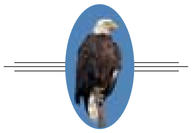

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Alan Stankevitz - FUMRR contest

EXECUTIVE SUMMARY


David Schulz - FUMRR contest

The Chippewa River ecoregion (CRE) of the Upper Mississippi River System (UMRS) includes the Mississippi River and its floodplain from river mile (RM) 634 to RM 763. The 132 miles of the CRE extends from the confluence of the Chippewa and Mississippi rivers in Lower Navigation Pool 4 to the confluence of the Wisconsin and Mississippi rivers in Upper Pool 10. A primary conservation goal for the CRE is to protect and restore at least some areas of historic terrestrial communities in non-impounded pool areas, especially those types that have been extensively lost or degraded such as prairie, savanna, wet meadow, and floodplain forest. This goal depends on understanding both the historic and contemporary vegetation community types and distribution in the CRE and the ecological attributes that are associated with each type.

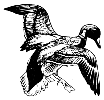
This report uses hydrogeomorphic methodology (HGM) to evaluate ecosystem restoration and management options for the CRE related to three objectives:

1. Identify the pre-European settlement ecosystem condition and ecological processes in the CRE.

2. Evaluate changes in the CRE from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.

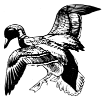
3. Identify restoration options and ecological attributes needed to successfully restore specific terrestrial habitats and conditions within the CRE.

The HGM approach used in this study obtained and analyzed historic and current information about: 1) geology



and geomorphology, 2) soils, 3) topography and elevation, 4) hydrological regimes, 5) plant and animal communities, and 6) physical anthropogenic features of landscapes in the CRE. A primary part of the HGM approach was the development of a matrix of understanding, and prediction, of potential historic vegetation communities in the CRE using comprehensive scientific data discovery and field validation using published literature, vegetation community reference sites, and state-of-the-art understanding of plant species relationships (i.e., botanical correlation) to geomorphology, soil, topography and elevation, hydrological regimes, and ecosystem disturbances. Geospatial maps of all HGM data sets in the CRE are provided in the Appendix to this report.

Major vegetation communities in the CRE, arrayed in order of water tolerance, includes: 1) open water/aquatic, 2) persistent emergent wetland (PEM), 3) herbaceous wet meadow, 4) shrub/scrub (S/S), 5) early succession riverfront forest, 6) floodplain forest, and 7) prairie/savanna. When all HGM variables were considered, the most powerful predictor of the distribution of these communities in the CRE in Presettlement times was geomorphic surface. For example, several geomorphic surfaces apparently supported only a single major community type, with some minor inclusions of other species associations. For example, glacial stream scarps and terraces supported prairie and savanna communities, main channel lateral accretion surfaces and islands contained only riverfront forest, tributary meander belts contained floodplain forest, and colluvial slopes contained slope forest communities. Other geomorphic surfaces supported multiple communities with vegetation species distribution largely determined by elevation and associated flood frequency. For example, tributary fans/deltas contained a mixture of floodplain forest on higher elevation ridges and levees with a > 2-year flood frequency and PEM or wet meadow along drainages where seasonal inundation occurred. PEM occupied sites where semipermanent to permanent water regimes occurred, while wet meadow was in seasonally flooded elevation bands. Maps of potential Presettlement



vegetation community distribution in the CRE are provided in Appendix L of this report.

Many studies have documented the extensive changes to the terrestrial and aquatic ecosystem components of the UMRS including the CRE. This report analyzed the major ecosystem changes in land form, hydrology, and vegetation communities to understand how Presettlement community distribution and extent have changed and to identify options and opportunities for restoration. Conservation plans for the UMRS and the CRE generally recommend that future conservation efforts include attempts to restore communities and resources, especially those types that have been highly destroyed in the non-impounded parts of navigation pools. The key to restoring native communities in the CRE is identifying sites that are appropriate for, and have the best chance for sustaining, specific communities. In other words, to design sustainable restoration programs for an individual site it is critical to first understand what communities historically were present and whether the site still has the capability of providing basic landform attributes (e.g., soils, geomorphic surface, topography) and driving ecological processes (e.g., inter- and intra-annual dynamics of hydrological regimes) that created and sustained the communities.

The HGM analyses in this study provides an understanding of not only where historic communities were located, but also the basic physical and ecological attributes that were associated with specific communities. This understanding helps to identify general locations where restoration of each community can occur and likely be successful. Once the general locations for potential restoration are identified, then site-specific analyses can help design detailed plans for restoration projects at individual locations.

Generally, terrestrial community restoration in the CRE will necessarily be at elevations above mean water levels maintained in navigation pools that provide a 9-foot navigation channel. Consequently, locations upstream of impounded areas in navigation pools, and higher surfaces such as floodplain ridges, natural levees, tributary fans and deltas, and colluvial slopes offer the greatest potential for restoration sites. Main and side channels, sloughs, and floodplain lakes will continue to support open water/aquatic habitats and many actions have been proposed, and are being implemented (such as island construction), to improve these habitats. This report provides two maps (Appendices P and Q) that identify general locations in the CRE where terrestrial community restoration has the best potential, related to specific community type. Further a summary of the most appropriate restoration sites, by community type is provided. The report also provides guidance in application of study results to evaluate landscape-scale options for restoration and identifies important monitoring and evaluation needs.


David Schulz - FUMRR contest

INTRODUCTION

The Chippewa River ecoregion (CRE) of the Upper Mississippi River System (UMRS) includes the Mississippi River and its floodplain from river mile (RM) 634 to RM 763 (Appendix A). The ca. 132 miles of the CRE extends from the confluence of the Chippewa and Mississippi Rivers in Lower Navigation Pool 4 to the confluence of the Wisconsin and Mississippi Rivers in Upper Pool 10. Other major tributaries to the Mississippi River in this ecoregion from north to south include the Zumbro, Whitewater, Trempealeau, Black, LaCrosse, Root, Upper Iowa, and Yellow rivers. The floodplain of the CRE is bounded by the Paleozoic Plateau on the west in Minnesota and Iowa and the nonglaciated "Driftless" physiographic region to the east in Wisconsin (Fig. 1).

The entire UMRS, including the CRE, has been extensively altered from the Pre-European settlement (hereafter "Presettlement") condition in the late 1700s by conversion of native vegetation communities to agricultural production; numerous urban and industrial developments in and adjacent to the floodplain; construction of flood protection and navigation infrastructure; altered drainage systems including ditches, stream channelization, tile, and water diversions; contaminants from sediments and various chemical compounds, and introduction and expansion of exotic and invasive plant and animal species (e.g., Theiling 1996, WEST Consultants, Inc. 2000, U.S. Fish and Wildlife Service (USFWS) 2006). Undoubtedly, the most significant change to the UMRS and the CRE has been the con-

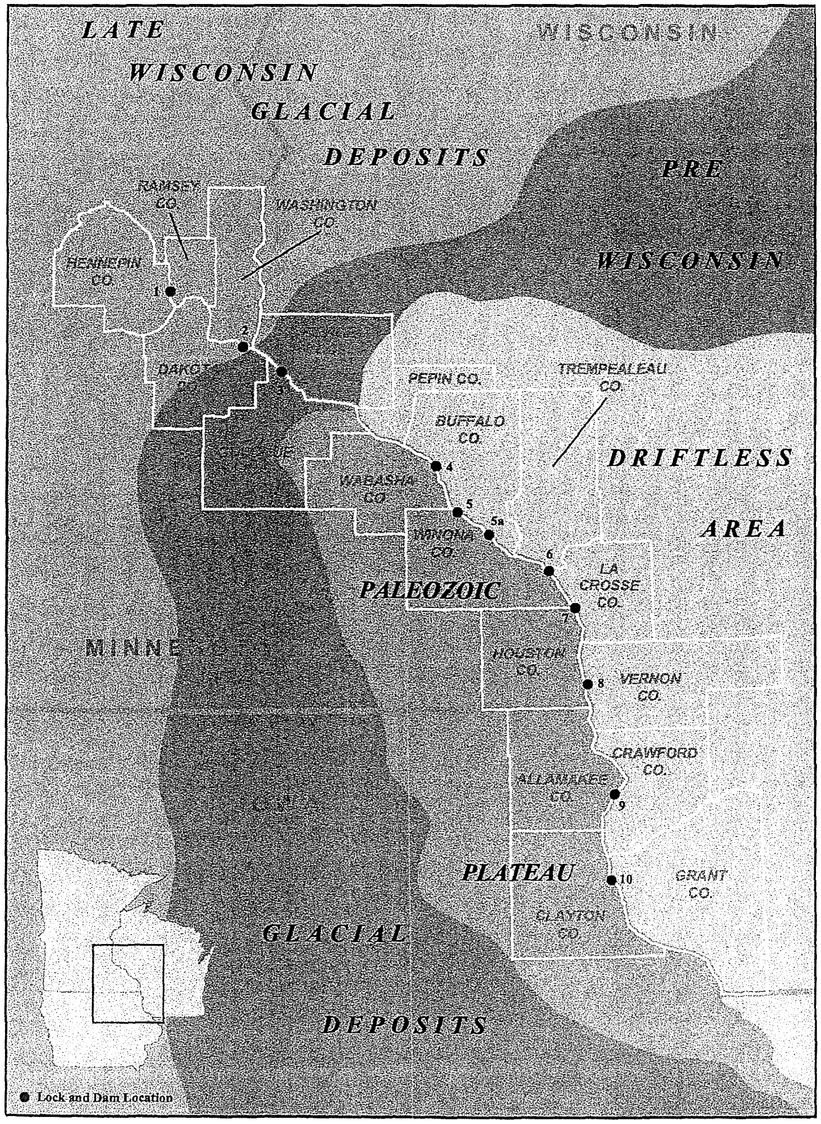


Figure 1. Physiographic regions of the Chippewa River ecoregion (from Madigan et al. 1998).

struction of locks and dams on the Mississippi River starting in the early 1930s and subsequent management of water levels upstream of dams (Theiling et al. 2000). These navigation dams are used to increase low and moderate discharge water surface elevations to a nine-foot depth necessary for modern commercial towboats and barges. Most dams do not hold back flood water during high flows and therefore they have relatively little effect on high stage flood discharges. Essentially, the dams remove the low seasonal Mississippi River flows, prevent summer-fall drying of many floodplain areas, and have created a series of impounded lakes immediately upstream of respective dams.

Prior to impoundment, the Mississippi River in the CRE exhibited an island-braided river channel form (WEST Consultants, Inc. 2000). Many wing dams and substantial dredging helped maintain deeper river channels for navigation from the late 1800s until construction of locks and dams. After locks and dams were built, lower portions of the navigation pools became permanently inundated and submerged pre-dam river channels, islands, and floodplains. Some high elevation floodplain areas, and relict glacial terraces, remained as islands, but post-dam wind erosion has now eliminated most small riverine-type islands in the lower part of the pools. After locks and dams were built, the middle portions of pools continued to provide broad island-braided floodplains, but with more extended annual hydroperiods compared to pre-dam periods. Upper parts of pools retained narrower river channels and more extensive floodplains. These areas have dampened hydrographs with reduced flood pulses where high flow water surfaces are not as high, and low flow water surfaces are not as low, as pre-dam conditions (Theiling 1996). The lock and dam impoundments have created wetter hydrology throughout the CRE and caused mortality of many floodplain forest communities and increased open water and aquatic habitats (Yin and Nelson 1996, Theiling et al. 2000, WEST Consultants, Inc. 2000). Further, land use changes in the CRE, especially agricultural and urban developments, have caused extensive loss of native prairie, savanna, wet meadow, and forest habitats.

A primary conservation goal for the UMRS, including the CRE, is to protect and restore at least some areas of historic terrestrial communities in non-impounded pool areas, especially those types that have been extensively lost or degraded such as prairie, savanna, wet meadow, and forest (Theiling et al. 2000, River Resources Forum 2004, USFWS 2006). This conservation goal depends on understanding both the historic and contemporary vegetation community type and distribution and the ecological attributes that are associated with each community type in the CRE. Recently, hydrogeomorphic methodology (HGM) has been used to evaluate ecosystem restoration and management options for large river ecosystems in North America including those impacted by dams and reservoirs (e.g., Heitmeyer 2008a, b; Heitmeyer et al. 2009a,b; Heitmeyer and Fredrickson 2005; Heitmeyer and Westphall 2007, Degenhardt and Heitmeyer 2009). HGM evaluations obtain and analyze historic and current information about: 1) geology and geomorphology, 2) soils, 3) topography and elevation, 4) hydrological regimes; 5) plant and animal communities, and 6) physical anthropogenic features of landscapes ranging in scale from site-specific tracts to large watersheds. Examples of both site-specific (Heitmeyer et al. 2009a, b) and ecoregion-wide (Heitmeyer 2008a) hydrogeomorphic evaluations have been conducted within the UMRS. In 2007,a feasibility investigation was conducted that concluded that adequate geospatial and ecological data were available to conduct HGM evaluations throughout the UMRS and it recommended that evaluations should be divided into work products by spatially-defined ecoregions that had distinct hydrogeomorphic and associated ecological characteristics (Heitmeyer 2007a). Recent analyses of hydrogeomorphic data for the UMRS defined the CRE in Pools 4-10 as such an ecologically distinct ecoregion (Theiling 2010).

This report provides HGM data and analyses to meet three objectives:

1. Identify the Presettlement ecosystem condition and ecological processes in the CRE.

2. Evaluate changes in the CRE from the Presettlement period with specific reference to alterations in hydrology, vegetation community structure and distribution, and resource availability to key fish and wildlife species.

3. Identify restoration options and ecological attributes needed to successfully restore specific terrestrial habitats and conditions within the CRE.

THE HISTORIC
CHIPPEWA RIVER ECOSYSTEM

GEOLOGY, GEOMORPHOLOGY, SOILS, TOPOGRAPHY

The Mississippi River and its tributaries drain much of the north-central U.S. and their courses have been formed and moved by erosion and glacial events over the last million years. Prior to the first glaciers that occurred in the UMRS about one million years before the present (BP), three major drainage systems were present in the UMRS region including the Upper Mississippi River that originated in northern Minnesota (Horberg 1956, Thornbury 1965, Simons et al. 1974). Sequential changes in the course and morphology of the Mississippi River that eventually created its current position and configuration occurred in response to Nebraskan, Kansan, Illinoian, and Wisconsin glacial advances (Frye et al. 1965). Prior to the Nebraskan glacial advance into central Minnesota, the Mississippi River drained southeast through Minnesota and Iowa to the present channel at Muscatine, Iowa (Fremling 2005). The Nebraskan and Kansan glaciers moved the river east into its present course on the edge of unglaciated “Driftless” area of west Wisconsin where it flowed as a glacier margin stream over resistant Cambrian and Ordovician deposited rock rather than following a path of less resistant soil and rock surfaces (Evans 2003). As the Mississippi River crossed the resistant Paleozoic bedrock, it carved relatively narrow valley gorges in dolomite limestone and widened where less resistant sandstone occurred (Halberg et al. 1984). The Mississippi River through the CRE subsequently was affected by glacial sequences that scoured and filled the river valley several times (Madigan et al. 1998, Bettis et al. 2008). Eventually the Mississippi River Valley became deeply incised and bounded by steep-sided hills capped with a veneer of loess deposited during the late Wisconsin period (Madigan et al. 1998). Tributary streams draining to the Mississippi River also deeply dissected the Paleozoic bedrock and created a well-developed dendritic network that extends into the uplands away from the river.

The Wisconsin glacier ice advance and recession created much of the post-glacial geomorphic template in the UMRS and the CRE (Madigan et al. 1998). The Wisconsin ice sheet reached its maximum extent in the Southern Great Lakes region about 21,000 BP, while the western margin of the ice sheet reached maximum extent about 14-17,000 BP. The course of the Mississippi River north of St. Paul, Minnesota changed repeatedly during the Pleistocene in response to advance and retreat of glacial ice lobes. The Superior Lobe culminated at about 15,500 BP and formed the St. Croix moraine at its margin. The Mississippi River presently occupies a prominent gap eroded through this moraine and then drains through the CRE. Silts and sand deflated from the last-glacial Mississippi River braid plain and upland erosion surfaces accumulated as loess and Aeolian sand on uplands and high terraces east and west of the valley. The Mississippi River floodplain began to aggrade by 21,000 BP as massive amounts of sediment entered the valley via tributaries that drained the various ice sheets. A braided channel pattern developed in the UMRS during this time and extensive aprons of colluviums accumulated along valley margins where they interfingered with valley alluvium. The depth of alluvial fill currently present in the Mississippi River Valley in the CRE extends 300+ feet deep in some locations.

As the Wisconsin ice sheet began to degrade, large discharges with low sediment concentrations spilled into the valley from glacial lakes that formed along the ice margin (Madigan et al. 1998). These flood waters deposited clay beds sometimes over 40 feet higher than modern floodplains. Proglacial lake drainage caused down cutting in the UMRS, altered the gradient of the river, and left various full glacial terrace surfaces elevated above the late-glacial floodplain, such as the Savanna Terrace that formed between 9,500 and 13,000 years BP. Lake Agassiz, the largest of the proglacial lakes discharged large amounts of water into the UMRS and these flows sculpted a series of late-glacial terraces in the CRE. Colluvial slopes formed during full glacial periods were then truncated by the down cutting discharges of the river. Loess and sand dune fields formed on some glacial terraces. The Mississippi River channel occupied several positions south of the area covered by late Wisconsin glacial deposits and various paleochannels dissected glacial terraces (Trowbridge 1959). Two of the highest glacial terraces developed along the Black River where it enters the current Pool 7 area suggesting that the two rivers must have graded to each other during Late Wisconsin time (Madigan et al. 1998). Lower terraces appear to be erosional remnants of glacial terraces formed at this time that was planed off by discharge of meltwater down the Mississippi River. All of these surfaces exhibit channel scars that have been modified by eolian processes. Further south in Pool 10, two other well defined terrace levels have been identified and were formed by glacial outwash materials. One final advance of ice blocked eastern outlets of the ancient Mississippi River and caused renewed down cutting within the Mississippi Valley between 9,900 and 9,500 years BP. This final glaciations episode is the last time that meltwater from glacial lakes flowed down the UMRS north of Illinois and played an important role in the Holocene evolution of the Mississippi Valley. When climate warmed and dried during the late glacial Holocene transition period about 9,500 BP, coniferous-dominated forest in the UMRS changed to mesic-type deciduous oak (*Quercus* sp.) forests (Delcourt and Delcourt 1981, Baker et al. 2000). In the Central Plains, prairie expanded on uplands and into higher elevations of the UMRS floodplain in the mid Holocene “Altithermal” period from 4,500 to 8,000 BP. During this drier period the UMRS underwent major changes in fluvial style. By about 10,500 BP the Mississippi River channel had changed from a braided coarse-grain substrate to an island-braided channel system dominated by fine-grain sediments (Bettis et al. 2008). High frequency bankfull, and low frequency overbank, flooding in the UMRS were responsive to climate changes with few flood events during the Altithermal, but increasing floods thereafter to the present. Flooding in the early and mid Holocene created many episodic events that caused widespread erosion/deposition and destabilized channels. Between 7,000 and 10,500 BP, avulsions in wider valley reaches and channel migration in narrower valley reaches, formed a series of abandoned channel belts. Channel positions began to stabilize about 7,000 BP except at and just above large tributary confluences.

Fine grained alluvium accumulated in the UMRS floodplain during the early and mid Holocene period and natural levees and crevasse splay complexes began to form adjacent to channels in wider valley reaches. Alluvial fans and colluvial slopes also accumulated along the margins of the Mississippi River Valley about 8,500 BP but their development slowed during the end of the Althithermal following a shift to wetter conditions and greater vegetation cover that reduced sediment erosion from valley slopes and small stream valleys. After about 3,000 BP, Arctic air flow increased across the UMRS and forest expanded back into floodplains and some terrace areas (Baker et al. 1992, 1996). Overbank flooding also increased after this time and tributary valleys began to aggrade. Fan-head trenches developed and most alluvial fans and colluvial slopes stabilized about 2,500 BP. Tributary fans also expanded at confluence areas and became more stabilized surfaces during the late Holocene as tributary rivers settled into more stable meander belts that crossed fluvial fans. At these tributary confluences, broad tributary fans developed; the fan where the Chippewa River entered the Mississippi River floodplain was especially extensive and effectively dammed the river and created Lake Pepin upstream of the confluence in what is now Pool 4. Some episodic aggradations continued into the Mississippi River floodplain with valley-wide periods of slower sedimentation and soil formation from 800 to 1,800 BP.

Maps of geomorphic surfaces and geological age of the CRE are provided in Appendices B and C. These and other HGM appendix maps are presented in eight CRE areas to provide a smaller scale presentation related to current navigation pools. The geomorphic land sediment assemblage (LSA) categories displayed in Appendix B represent the formation of the deposition/scour surfaces from lateral or vertical deposition during glaciofluvial and fluvial drainage, stream entrenchment, cut banks and scarps, eolian deposition, and mass wasting/slope processes (Madigan et al. 1998). In general, vertical accretion deposits occur in low energy environments in backwater areas where deposition of fine-grained sediments occurs. Conversely, lateral accretion deposits are laid down in high energy environments dominated by channel migration and deposition of coarse-grained sediment.

Most glacial terraces in the CRE accumulated between 14,000 and 10,000 BP and remnant terraces are present throughout the pools. Eolian dunes cover extensive terrace areas in Pools 5 and 7. The terrace groups correlate with the Langdon Terrace in Pool 2 and the Savanna and Kingston Terraces in the Mississippi River floodplain in the U.S. Army Corps of Engineers (USACE) Rock Island District (Madigan et al. 1998). Many terraces in the CRE are separated from the river valley wall by paleochannel systems and essentially form islands within the Mississippi River floodplain such as Red Oak Ridge, Dresbach, French, and Bell Islands, Isle La Plume and other unnamed terrace sites. Soils on glacial terraces contain mostly sandy loam types, especially in northern parts of the CRE (Appendix D). The large terrace near Prairie du Chein contains a mixture of sand and silt loam. Common soils on the terraces include Sparta sands, Burkhardt and Dakota sandy loam, Gotham and Finchford loamy sand, and Chaseburg and Arenaville silt loam. These sandy terrace soils are very well drained and reflect prairie soils with deep A horizons (Overstreet et al. 1986). Elevations on terraces in the CRE range from about 680 feet above mean sea level (amsl) near Wabasha, Minnesota to about 620 feet amsl near Prairie du Chein, Wisconsin (Appendices A, E). Terraces are often 20-40 feet higher than adjacent floodplain areas. Generally, the terraces have relatively flat-lying surface tops with some relict channel patterns on some surfaces. Sedimentary deposits underlying terraces vary in depth and material but often have about 100 feet of cross-bedded sand gravel overlying planar-bedded sand and pebbly sand (Madigan et al. 1998)

Glacial stream channels mark the course of the meltwater draining through the Mississippi River during the late Wisconsin period; most formation took place between 9,200 and 14,000 BP (Madigan et al. 1998). Most of these channels appear as narrow relatively well defined channels cut into terraces or passing through bedrock lowlands separated from the main river valley; they often contain small wetland depressions within their boundaries. Channels that lie within the floodplain are now filled with alluvial sediment deposited during the Holocene period and soils are mainly Newalbin silt loam, Duelm fine sandy loam, and Hubbard soil types (Appendix D). Glacial stream scarps are steep abrupt slopes bounding the outer margins of the glacial stream channels. These scarps contain more sand than relict channels.

Minor/inactive channel LSA's mark the position of paleochannels and distributary channels within the floodplain active during the early to middle Holocene. These LSA's are present below Lock and Dam 5 and appear as a series of anastomosing channels containing closed depressions, cutoff channels, oxbows, lakes, and sloughs. Lateral accretion deposits consist of meander scrolls and point bars with ridge-and-swale topography (Appendices E, F). They are most common below the confluence of tributary streams and tributary fans. Vertical accretion deposits consist of undifferentiated floodplain deposits, marshes, and sloughs. Formation of these LSA's is attributed to fluvial activity on paleofloodplains of the Mississippi River where the amount of sediment added to the Mississippi River was greater than it could carry, resulting in an island-braided stream type of environment. These deposits have been extensively reworked by lateral channel migration during the early to middle Holocene period. Sediments of these LSA's are highly variable depending on location in the floodplain but usually have 3-6 feet of loamy soil veneer over underlying sands and gravel. Common soils in minor lateral accretion surfaces are Comfrey, Shiloh, and Caneek silt loams while minor vertical accretion sites have more clay soils including Shandup, Shiloh, Caneek, and Orion types (Appendix D).

Main channel LSA's include both vertical and lateral accretion deposits on low relief, gently rolling, moderately to poorly drained surfaces about 1-3 meters above the level of the active river channel. These surfaces are associated with fluvial processes operating on the main channel during the late Holocene period. Because of their proximity to the current river channel, they are regularly overtopped by floodwaters during high stages of the Mississippi River. These surfaces are inset below other LSA groups and may cut through or interfinger with Minor/inactive LSA units and low terraces on both sides of the Mississippi River in the CRE (e.g., Appendix F). Main channel islands are present in some pools and represent a combination of lateral and vertical accretion deposits. Lateral accretion deposits contain marked ridge-and-swale topography with some ridges being quite elongated. Soils in main channel lateral accretion surfaces are dominated by sandy alluvium. Main channel vertical accretion sites were created by fine-grained sediments being deposited in floodplain sites not reworked by the main channel such as natural levees, crevasse splays, sloughs, marshes, and lakes. These sites have predominantly Comfrey, Shiloh, and Caneek silt loam soils (Appendix D). Main channel islands are covered with sand.

Many tributary-derived LSA surfaces are present in the CRE including tributary floodplains, marshes, scarps, channels, meander belt deposits, and fans/deltas. Tributary streams are responsible for increasing sediment loading and water discharge into the Mississippi River and its floodplain and they cause changes in channel configuration and blocking of river drainage, which form floodplain lakes and influence geomorphology of valley edges. Many of these surfaces extend far into the floodplain of the Mississippi River such as the large tributary fans associated with the Chippewa, Trempealeau, Root, Upper Iowa, Black, and Wisconsin rivers. These fans/deltas prograde into standing water in the floodplain and vertical deposition is largely a function of stream velocity and the base level of the Mississippi River. Certain data suggest tributary fans/deltas may be expanding because of upstream erosion control and the mobilization of sediment stored in tributary streams (Knox and Faulkner 1994). Perhaps the best known tributary fan/delta is the Chippewa River Delta, where sediment damming created Lake Pepin. Topography on fans/deltas is highly heterogeneous and labyrinth like, with multiple flow channels interspersed within alluvial deposition mounds (Appendices E, F). Consequently, soils on fans/deltas are diverse ranging from Minneiska fine sandy loams on higher ridge areas to Palms muck types in depressions and channels (Appendix D). Other common soil types on fans/deltas include Caneek, Elon, Shandep, and Newalbin silt loams, Comfrey and Moundprairie silty clay loam, and Algansee-Kalmarville complex soils.

Tributary floodplain and marsh sites generally are flat low elevation surfaces that have standing water on them for extended periods of the year. In contrast, Tributary meander belts, also called Yazoo systems, are formed by streams entering the valley of another stream and flowing parallel to its floodplain. These sites have complex mosaics of ridges and swales often interspersed with abandoned channels, marshes and sloughs. Sedimentary deposits in these meander belts consist of silty clay loam and clay loam and are only seasonally flooded in most cases.

Colluvial slopes are present along the Mississippi River Valley margins throughout the CRE on both sides of the valley. These slope areas are formed by gravitational redistribution of sediment from mass erosion movement caused by water infiltration and surface runoff. The most active period of slope development was during the Late Wisconsin period (Mason and Knox 1997) when preglacial conditions existed in the river valley. Sedimentary deposits on colluvial slopes tend to be poorly sorted, containing large slabs of weathered bedrock in a matrix of fine-grained silt and silt loam derived from erosion of the upland surface. Colluvial slope surfaces often range from 30-100 feet vertical elevation difference from top to bottom of the slope and are above the flooding level of the CRE (e.g., Appendix E).

CLIMATE AND HYDROLOGY

The climate of the CRE is midcontinental, north temperate, with sub-humid to humid conditions. The region has cold, relatively dry winters and hot, moist summers. Typically, warm moist air masses from the Gulf of Mexico alternate with cold air masses from Canada. Frequent and rapid changes in weather occur along associated frontal boundaries. The average monthly temperature ranges from about 11° Fahrenheit in January to 74° Fahrenheit in July. Average frost-free growing seasons range from 130 to 160 days depending in location and elevation within the CRE. Average annual precipitation for the region is about 28-30 inches and about 75% of total annual precipitation occurs between April and September. Annual snowfall is about 40 inches. Ice covers most waters for nearly 3 months each year and reaches an average annual thickness of > 13 inches.

Discharge in the Mississippi River in the CRE is highly seasonal and reflects amount of precipitation and runoff locally and in the upper watershed with high water levels in spring and early summer followed by declines to lower, relatively stable, levels from late fall through winter (Fig. 2). Median long-term discharge is about 32,000 cubic-feet/second (cfs) at Winona, Minnesota. The seasonal dynamics of river flow influences surface flooding and groundwater levels in the CRE and is the primary factor governing hydroperiods of floodplain communities, at least prior to construction of locks and dams. Mississippi River flows are generated by snowmelt, rainfall, and various combinations of these (Knox 1999). Nearly 75% of all floods occur from March through July, with March and June being the most important. When only annual maximum flood stage is considered, March accounts for about 30% of the total, with June accounting for about 15% of the total. Relatively few floods occur during winter from December through February when moisture is temporarily stored in snow cover. Generally, annual maximum flood stages correlate best with magnitudes of snow depth and early summer rainfall and most annual floods do not have long memory of antecedent moisture conditions (Knox 1999). Stage-discharge relationships for the Mississippi River pre- and post-lock and dam are available throughout the CRE and provide information on the frequency of flooding at various elevations related to flow (Fig. 3) and percentage exceedance levels (Fig. 4).

Historic (1910-1929) pre-dam Mississippi River discharge data indicate a regular 12-14-year periodicity in annual high and low river flows in the UMRS (Franklin et al. 2003). Historically, most gauge stations in the UMRS consistently averaged about five years duration of higher flows, followed by about five years of lower flows. This pattern changed somewhat after river systemization and engineering of river developments post-1930; low flow periods now are compressed to about two years duration on average, with intervening higher

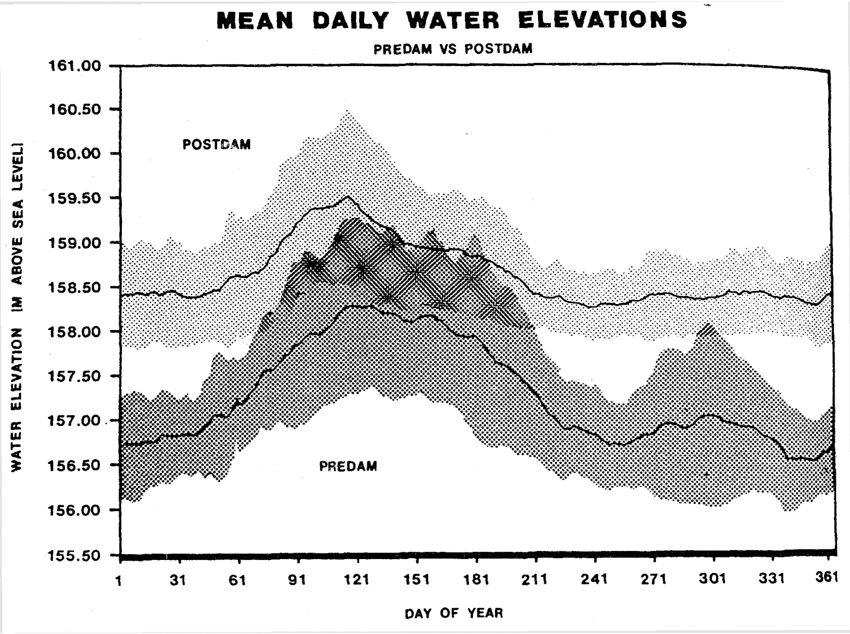


Figure 2. Generalized annual hydrographs for the pre-dam (dark shading) and post-dam (light shading) periods at LaCrosse, Wisconsin (from Grubaugh and Anderson 1988).

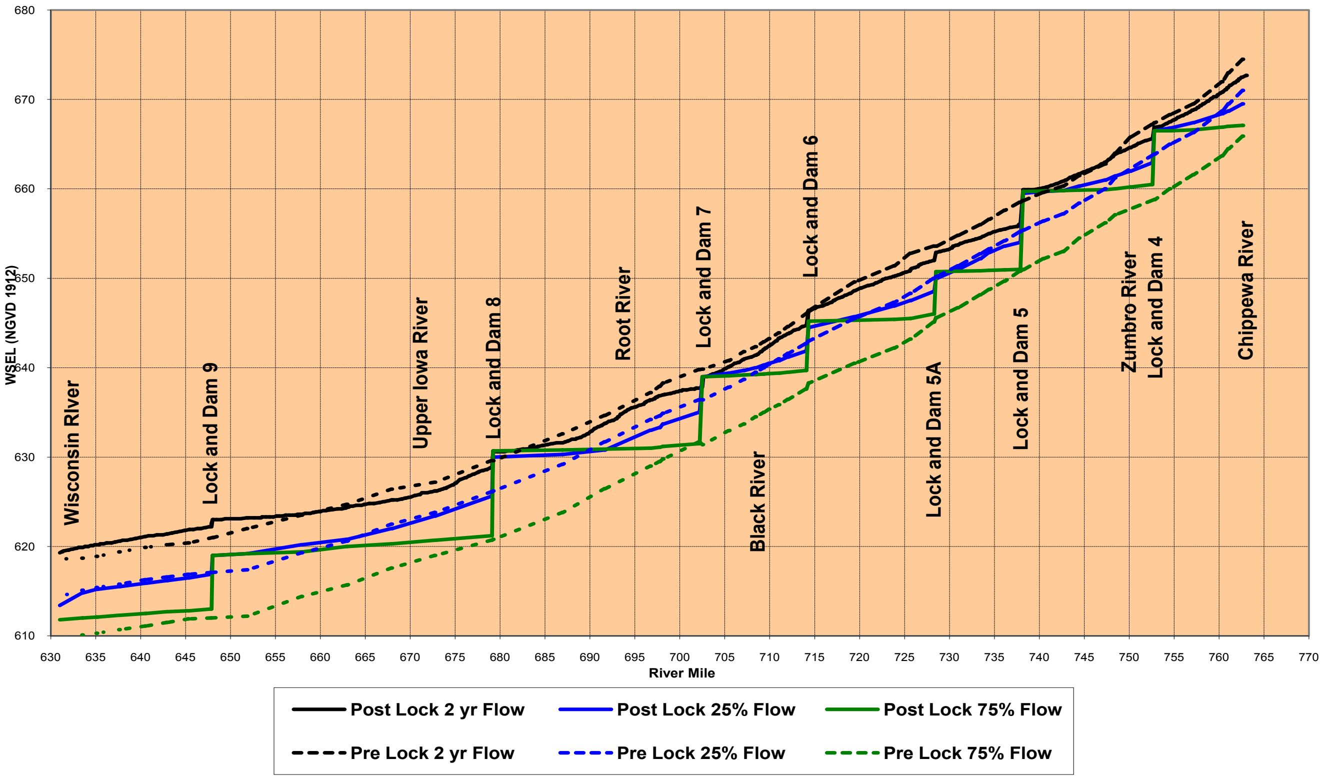


Figure 3. Surface water elevations pre- and post-dam for the Chippewa River ecoregion navigation pool areas.

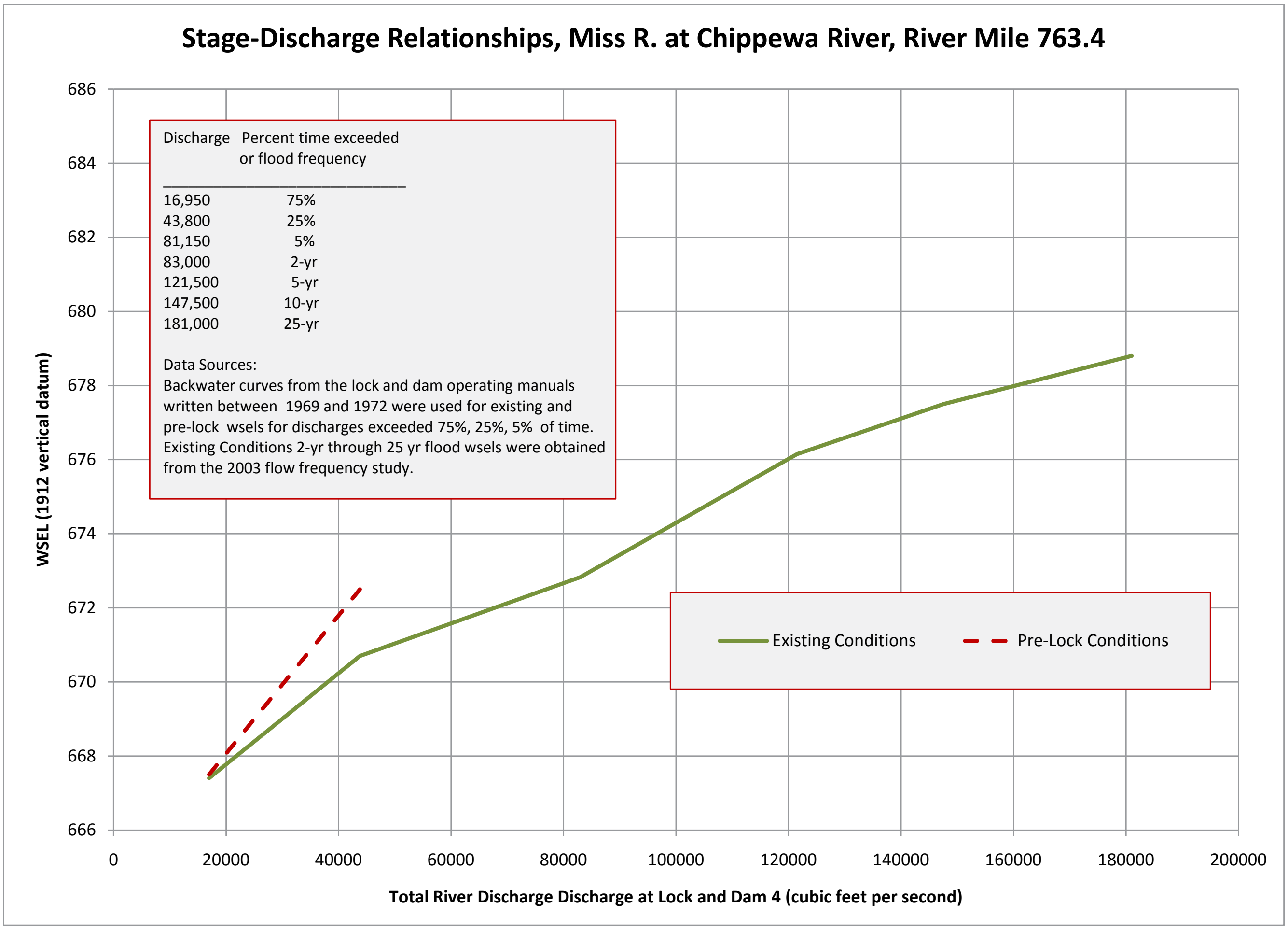


Figure 4. Mississippi River stage-discharge relationships for select gauge stations in the Chippewa River ecoregion pre-dam and existing conditions.

annual mean flows occurring at about five years duration. Some evidence links this long term periodicity to the El Nino/Southern Oscillation climate patterns where total solar irradiance affects tropical ocean temperatures, which correspondingly affects wind and precipitation in the Upper Midwest of North America. Mississippi River discharge at McGregor, IA also indicates a gradual increase over time, suggesting the UMRS is becoming wetter (Fig. 5, see also Knox 1999, WEST Consultants, Inc. 2000).

Precipitation and river flooding patterns in the UMRS have changed several times in the Holocene period. A relatively warm climatic period occurred in the CRE region between 3,000 and 5,500 BP and caused about 15% less annual precipitation and 20-30% lower flows in the Mississippi River compared to the present (Knox 1988, 1999). This warm period was followed by a shift to cooler and wetter conditions from 1,000 to 3,000 BP and included several larger floods at approximate modern 500-year floods (Knox 1993). In recent times, the magnitude of 50-year flood events in the UMRS was 40-47% less during 1896 to 1949 than in the one thousand years prior to the late 1800s. Extreme floods were especially likely to occur when a wet year was followed by another wet year, such as in 1912, 1927, 1973, and 1993.

Historic water flow patterns in the CRE were complex and included a variety of pathways such as main Mississippi and tributary river channels, side and abandoned channels, distributary channels, interconnected sloughs and depressions, and overland sheetflow across colluvial slopes, alluvial fans, and upland bluffs (Theiling 1999a). As waters rose in the Mississippi River following snowmelt and increased precipitation in spring and early summer, water first "backed" up drainages and began to inundate lower elevation floodplain surfaces and sloughs including relict glacial stream channels, swales in lateral accretion surfaces, and lower elevations on tributary fans/deltas (Lubinski 1993). Eventually, as waters continued to rise, headwater pulses of discharge caused overbank headwater flooding of ridges, natural levees, and terraces. In high flood events, most of the CRE floodplain was inundated with depth and duration being less on higher elevation terraces, low parts of colluvial slopes, and ridges and greater in other floodplain depressions and flats.

The combination of seasonal and long-term flooding patterns in the CRE ultimately created heterogeneous hydroperiods for various geomorphic surfaces related to their elevation and soil constituency. For example, high elevation glacial terraces with well drained sandy-type soils were infrequently inundated for short periods in spring (> 10 year growing season flood frequency) in wet years. In contrast, low elevation tributary floodplain surfaces and labyrinth sloughs in tributary fans were flooded for extended periods each spring and summer and only occasionally dried in early summer in very dry years. These heterogeneous hydroperiods ultimately dictated which terrestrial and aquatic communities were present in various surfaces and elevations.

HISTORIC LAND COVER AND COMMUNITIES

As previously discussed, the advance and retreat of the Wisconsin glacier, and subsequent climate changes in the Holocene period, caused dramatic shifts in vegetation communities in the UMRS and the CRE (Delcourt and Delcourt 1981). During full glacial periods, tundra and forest-tundra extended south to about the Des Moines River. Boreal forest occupied the Mississippi River Valley, including the Driftless region, south to about Cape Girardeau, Missouri (Delcourt et al. 1999). As continental warming occurred in the late glacial periods, ice sheets retreated north and the

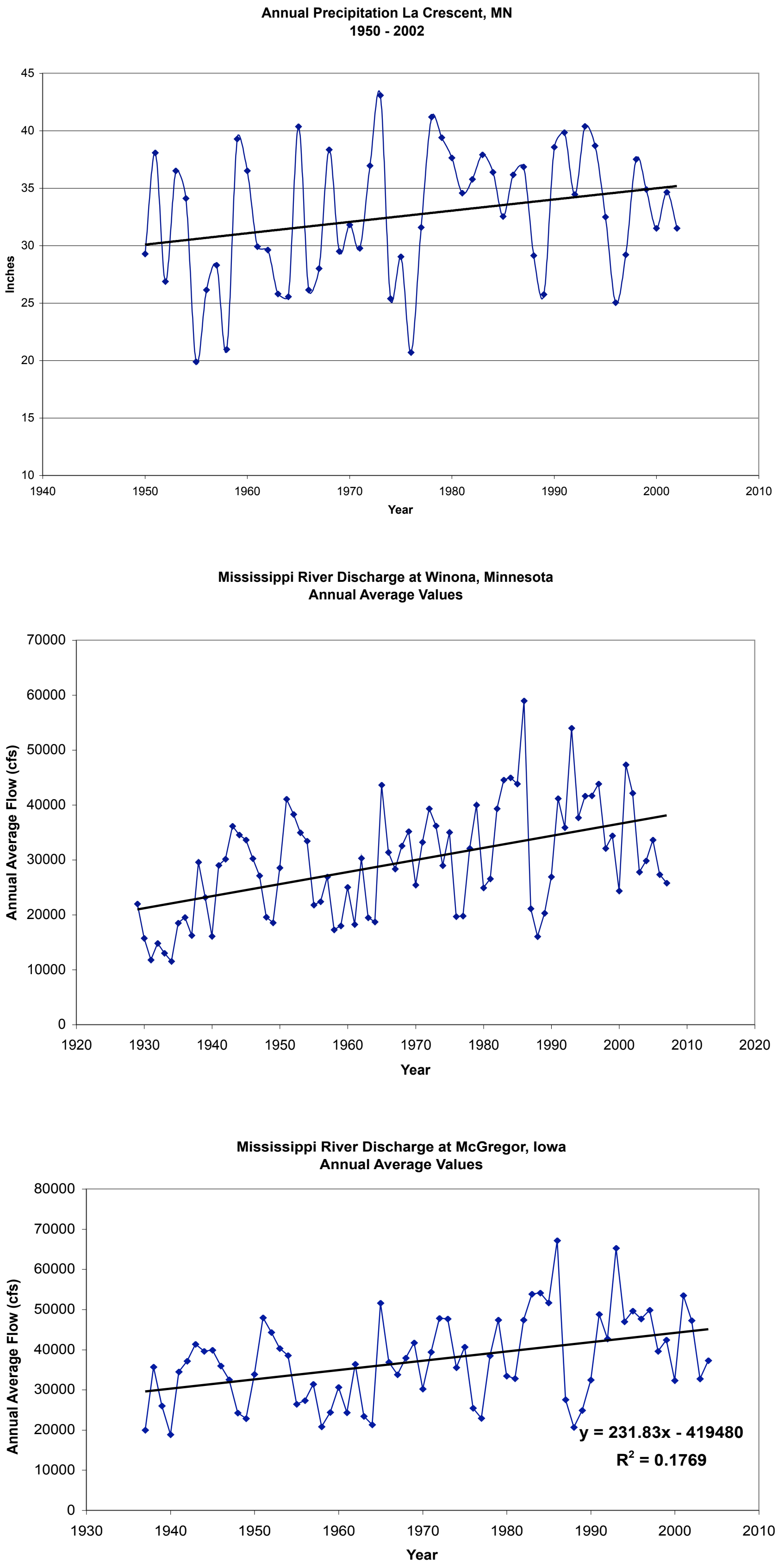


Figure 5. Long-term trends in annual precipitation at La Crescent, Minnesota (a), Mississippi River discharge at Winona, Minnesota (b), and Mississippi River discharge at McGregor, Iowa.

spruce-larch boreal forest that occupied the CRE during most of this period moved north and was replaced by mixed conifer-hardwood forest by about 11,000 BP. By about 9,500 BP mesic deciduous forest, with a large oak component, became established in much of the southern UMRS. Prairie became established in the Central and Eastern Plains of North America as early as 10,000 BP and as climate continued to warm and dry during the Altithermal period from 4,500 to 8,000 BP.

Dry Pacific air allowed expansion of prairie east of the Mississippi River into Illinois and Wisconsin between 3,000 and 5,500 BP. Often referred to as the "Prairie Peninsula", extensive mesic and some bottomland prairie was present from the CRE southward to about the Kaskaskia River (Transeau 1935, Heitmeyer 2008a). Mesic-type prairie occupied higher elevation glacial terraces and colluvial/alluvial slopes and fans; bottomland prairie covered extensive parts of paleo-channels, low terraces, and some point bar lateral accretion surfaces. Deciduous forest was confined to wetter areas along the Mississippi River channel and chutes, in tributary valleys, and in some abandoned channel and floodplain depression areas during this dry period (Delcourt et al. 1999). In the last 3,000 years, Arctic air flow increased across the central part of the Mississippi River Basin and deciduous forest expanded from valleys and bluffs into many low elevation floodplain surfaces. Mesic prairie simultaneously retreated to higher elevation terraces and bottomland prairie occupied certain floodplain areas where surface sheetflow and permeable soils occurred (e.g., Baker et al. 2002, Heitmeyer 2008a, b). The Presettlement UMRS and CRE landscape occupied a north-central continental position between grassland biomes to the west and southwest, conifer forests to the north, and deciduous forests to the east and south. As indicated above, post-glacial climatic fluctuations caused the invasion and retreat of many different plant and animal associations and created a rich biological diversity in the region. HGM matrices of the historic distribution of major vegetation communities/habitats in other UMRS and Lower Missouri River areas demonstrate that community type and distribution is strongly correlated with geomorphic surface, soils, elevation, and flood frequency (Heitmeyer 2008a,b; Heitmeyer et al. 2009a,b; Degenhardt and Heitmeyer 2009, Thogmartin et al. 2009).

Major vegetation communities in the CRE from the Presettlement to current times, arrayed in order of water tolerance, includes: 1) open water/aquatic, 2) persistent emergent wetland (PEM), 3) herbaceous wet meadow, 4) shrub/scrub (S/S), 5) riverfront forest, 6) floodplain forest, and 7) prairie/savanna (Fig. 6, Curtis 1959, Kuchler 1964, Mohlenbrock 1975, Galatowitsch and McAdams 1994, Theiling 1999b, USFWS 2006) Basic descriptions of these habitats are provided below and lists of fauna and flora for these habitats are provided in Galatowitsch and McAdams (1994) and USFWS (2006). The historic main channels of the Mississippi River and its major tributaries (e.g., Chippewa, Black, Wisconsin, Upper Iowa, and Root) 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., Janvrin 2005), and these habitats also were used by many amphibians, a few aquatic mammals, and some water and shorebirds (Theiling 1996).

Islands" historically occurred within the Mississippi River or tributary channels in the CRE, and "bars" were common on the edges of channels, especially on the downward side of major bends (Mississippi River Commission 1881, Collins and Knox 2003). Most historic "islands" in the CRE actually were extensions of lateral accretion 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. High elevation surfaces such as remnant glacial terraces and the higher portions of the lateral accretion geomorphic surfaces were not submerged after lock and dam construction and remained as islands. Examples of the "new" glacial terrace islands include Rosebud and Red Oak Ridge islands (Boszhardt and Theler 1991, Rodell 1989, Overstreet et al. 1986) Vegetation on historic river 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 main channel islands and bars historically were 1-4 feet higher than adjoining floodplain elevations and were overtopped only 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 (*Populus deltoides*) and willow (*Salix* sp.) were the most common plants. Larger main channel islands contained riverfront forest communities with some aquatic and moist-soil plants in interior swales and sloughs. In contrast, the new glacial terrace islands formed by lock-and-dam inundation historically contained prairie and some oak-savanna (Overstreet et al. 1986).

Floodplain lakes and sloughs were present throughout CRE floodplains and they occupied abandoned channels and drainages, both recent and older (e.g., Appendix F). The location, age, and size of lakes and sloughs determined depth, slopes, and consequently composition and distribution of vegetation communities. Some lakes and sloughs associated with glacial terraces, stream channels, and tributary fans were surrounded by PEM, wet meadow, or prairie communities and essentially were "marshes" with little or no woody vegetation on their edges (Green 1947). The sparse woody vegetation along theses marsh-type lakes was mostly scattered willow and shrubs such as buttonbush (*Cephalanthus occidentalis*). Persistent emergent vegetation such as cattail (*Typha latifolia*) and river bulrush (*Scirpus fluviatilis*) dominated plant composition along the edges of these lakes (Galstoff 1924). Other floodplain lakes and sloughs associated with main and minor channel vertical and lateral accretion surfaces, and tributary floodplain flats, were surrounded by either riverfront or floodplain forest. These lakes and sloughs usually contained a narrow band of S/S vegetation along their edges (Heitmeyer et al. 2009b). S/S communities represent the transition area from more herbaceous and emergent vegetation in the aquatic part of lakes and sloughs to

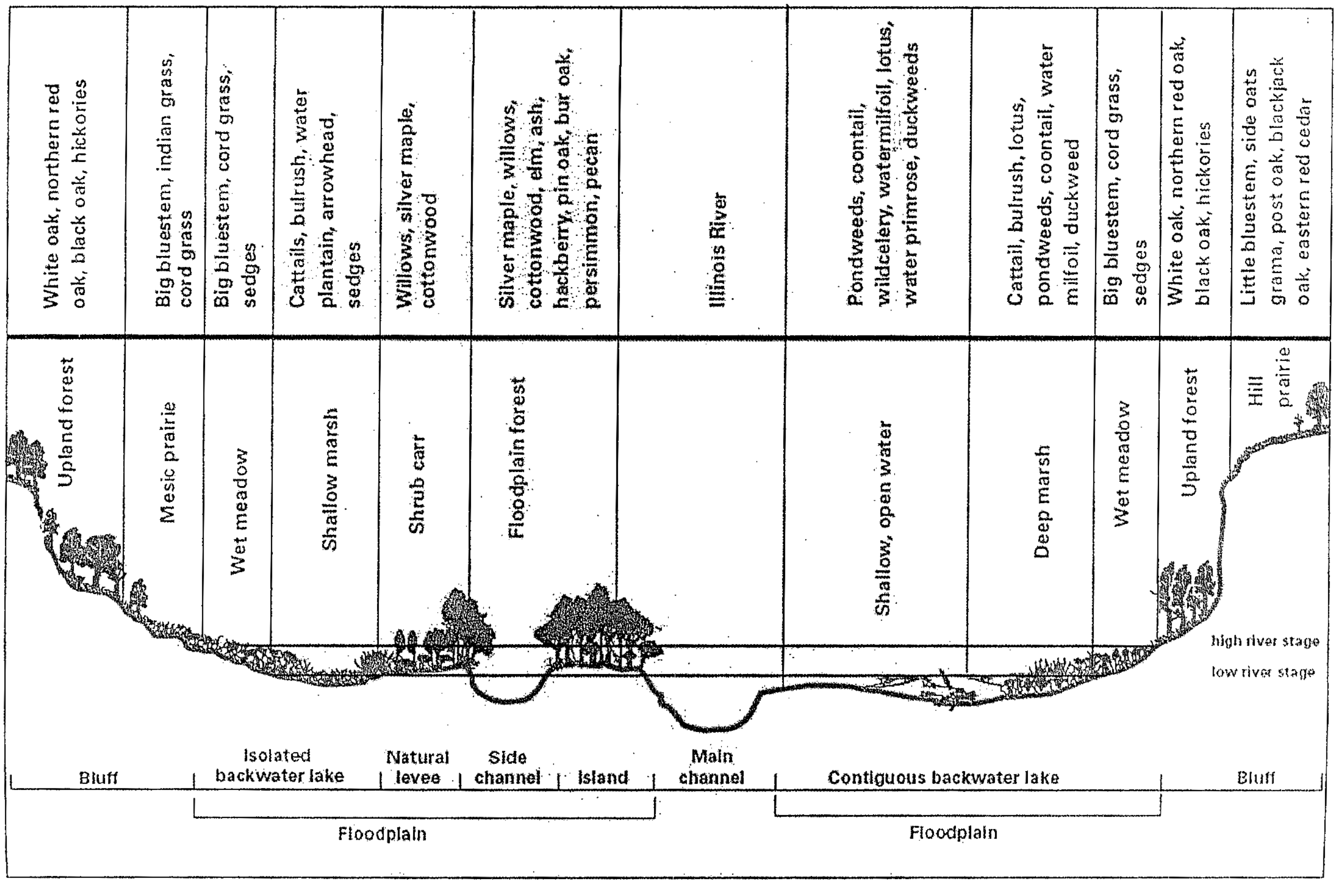


Fig. 6. Typical floodplain and bluff habitats of the Upper Mississippi River (from Theiling 1999b).

higher floodplain surfaces that supported trees. S/S habitats typically are flooded a few inches to 2-3 feet deep for extended periods of each year except in extremely dry periods. S/S habitats are dominated by buttonbush, and willow. Often a natural levee was present along the edges of floodplain lakes and these areas supported floodplain forests. Many newer and deeper floodplain lakes and some backwater sloughs historically had central areas of permanent "open water" that contained abundant aquatic "submergent" and "floating-leaved" vascular species such as pondweed (*Potamogeton* sp.), coontail (*Ceratophyllum demersum*), water milfoil (*Myriophyllum verticillatum*), American lotus (*Nelumbo lutea*), spatterdock (*Nuphar luteum*), and duckweeds (e.g., Nelson 1999). The edges of these lakes typically dried for short periods during summer and contained emergent and herbaceous vegetation. Emergent vegetation included arrowhead (*Sagittaria latifolia*), cattail, various rush (*Juncus* sp.) species, river bulrush, sedges, and spikerush (*Eleocharis* sp.). Herbaceous vegetation was dominated by smartweed (*Polygonum* sp.), millet (*Echinochloa* sp.), panic grass (*Panicum* sp.), sedges, spikerush, beggarticks (*Bidens* sp.), and many other perennial and annual "moist-soil" species. The distribution of emergent and herbaceous communities in lakes and sloughs 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 lakes, while in wetter periods herbaceous plants were confined to narrow bands along the edges of deeper open water.

Floodplain lakes and sloughs, both "marsh" and "forest-edge" types, supported a high diversity of animal species (USFWS 2006). Historically, fish moved into these lakes for foraging and spawning when they became connected with the Mississippi River during flood events (e.g., Janvrin 2005). 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). Floodplain 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, USFWS 2006). Aquatic mammals regularly used floodplain 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 (USFWS 2006).

Extensive areas of PEM and wet meadow occurred throughout the CRE floodplain in areas that had semipermanent seasonal water regimes. In lower elevations with more regular and prolonged seasonal inundation, PEM was present, while slightly higher elevations with more seasonal inundation contained wet meadow and some bottomland prairie habitats. Wet Meadows were found interspersed between forest and PEM, on fine textured soils along protected backwater areas, often near or at the edges of floodplain lakes (Galatowitsch and McAdams 1994, Duranal et al. 2007). These meadows were populated mainly with graminoids and sedges such as panic grass, prairie cordgrass (*Spartina pectinata*), smartweed, many *Carex* and *Juncus* species, iris (*Iris* sp.), and milkweed (*Asclepias* sp.) (Lammers 1977, Swanson and Sohmers 1978, Langrehr 1992, Peck and Smart 1976). Occasional willow and buttonbush were found on the edges of meadows. Many of these former meadow sites now are heavily infested with reed canary grass (*Phalaris arundinacea*).

PEM communities typically were located in protected bays and floodplain sites that had shallow and prolonged flooding for much, if not all of most years (Swanson and Sohmer 1978, Nelson 1999). Sites with the most extensive areas of PEM included tributary fans and deltas and tributary floodplain flats. Common plants in PEM areas included cattail, arrowhead, bulrush, spikerush, smartweed, wild rice (*Zizania aquatic*), giant bur-reed (*Sparganium eurycarpum*), Hibiscus (*Hisbiscus* sp.), dock (*Rumex* sp.), and water plantain (*Alisma plantago-aquatica*) (Galatowitsch and McAdams 1994, USFWS 2006). Most emergents are perennial and regrow from thick rootstocks each spring. However wild rice, some smartweeds, and other herbaceous plants are annuals. PEM often had dense beds of submersed aquatic plants where water persisted throughout much of the year, or throughout the year, during wet periods. Most of these submergents are rooted, but a few species such as coontail, can entangle with other plants (Eckblad 1986). Common submergent plants in these habitats were naiads (*Najas* sp.), waterweed (*Elodea* sp.), wild celery (*Vallisneria americana*), water milfoil, and pondweed (Lammers 1977). In stagnant water, the surface is commonly covered with duckweed (*Lemna* sp.), watermeal

(*Wolffia columbiana*), ducksmeat (*Spirodela* sp.), and submersed aquatics such as water primrose and buttercup. Floating-leaved aquatic plants commonly occur in deeper water within and on the edges of PEM and contain beds of American lotus, white water lily (*Nymphaea odorata*), and yellow water lily (*Nuphar variegate*). Limited watershield (*Brasenia schreberi*) also is present in some areas of the CRE.

Wet meadow and PEM provided diverse resources used by a rich diversity of birds, mammals, fish, and amphibians/reptiles (USFWS 2006). These habitats are used throughout the year by species that breed, migrate, and winter in the CRE. Waterbirds are especially abundant in these habitats and include waterfowl, wading birds, shorebirds, and rails. Many neotropical bird species use these habitats during migration, and some species nest locally. Fish move into and out of PEM during high water periods and these habitats serve as spawning and nursery sites.

Aquatic mammals are common in PEM and other more terrestrial species move into PEM during dry periods. Many rodents and some other mammals regularly use wet meadow habitats. Riverfront forest (also called "river-edge forest" in some older botanical literature) was present on lateral accretion geomorphic surfaces, some point bar areas near the current channel of the Mississippi River, and along the edges of some abandoned channels in the UMRS (Hus 1908, Curtis 1959, Chmurny 1973, Gregg 1975, Yin and Nelson 1996, Nelson 1997, Galatowitsch and McAdams 1994). 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 forests, especially on chute and bar surfaces, are young, annually overtopped by flood waters, highly drained, influenced by groundwater dynamics as the Mississippi River rose and fell, and contain thin veneers of silt over sands and gravel. Riverfront forest communities are dominated by early succession tree species and varied from water tolerant species such as willow and silver maple (*Acer saccharinum*) in low elevations and swales to intermediate water tolerant species such as American elm (*Ulmus americana*), green ash (*Fraxinus pennsylvanica*), river birch (*Betula nigra*), cottonwood, and hackberry (*Celtis occidentalis*) on ridges. Swamp white oak (*Quercus bicolor*) and bur oak (*Quercus macrocarpa*) 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 forests 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. 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 sometimes became large mature stands (e.g., Hosner and Minckler 1963).

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

Floodplain forests historically covered large expanses of the UMRS and CRE floodplains primarily on higher elevations of tributary fans/deltas, tributary meander belts and their natural levees, and vertical accretion surfaces (Hus 1908, Gregg 1975, Yin and Nelson 1996, Yin et al. 1997, Yin 1999, Nelson 1999, USFWS 2006). This forest type represents a transition zone from early succession riverfront forest located on coarse-sediment main channel lateral accretion surfaces to the diverse species forests that occur in silt-clay soils in vertical accretion and minor channel lateral accretion surfaces. The most expansive floodplain forests are located on vertical accretion surfaces and tributary fans within the 1-2 year flood frequency zone. These floodplain forests in the CRE are dominated by American elm, green ash, hackberry, and box elder (*Acer negundo*) but include many other species depending on elevation and soil type. Higher elevations and older remnant natural levees often contain swamp white oak. Floodplain forests on minor channel lateral accretion surfaces have marked species differences on the parallel bands of ridges and swales. These "ridge-and-swale" (RSF) floodplain forests usually contain a mix of more water tolerant species such as willow, cottonwood, and silver maple on coarser soil sediments and in swales and American elm, green ash, box elder, and some oak on ridges and in sites with thicker layers of silt and clay. Larger, deeper, swales in floodplain forests often contain surface water for extended periods of the year and support gradients of vegetation similar to forest-edge floodplain lakes but at a smaller spatial scale. Consequently, RSF sites often have heterogeneous patterns of adjacent sloughs and forest. Dense understory layers of shrubs and many vines often are present in floodplain forests. Early explorers often commented on the relatively "impenetrable" nature of these forests (e.g., Collot 1826). Herbaceous cover is extensive in higher elevations of floodplain forests (Galatowitsch and McAdams 1994). Some authors have described floodplain forests as bottomland hardwood forest (e.g., Yin et al. 1997); however, CRE floodplain forests are ecologically distinct from more southern bottomland forest communities that are dominated by oaks (e.g., Conner and Sharitz 2005).

The floral and elevation diversity of floodplain forests provides abundant resources to many animal species. Many mammals, including rodents, ungulates, and canids are present as are amphibians and reptiles. Bird abundance in floodplain forests is high and includes species that bred, winter, and migrate through the area (Knutson et al. 1996, Papon 2002). During flood events, floodplain forests often become refuge for species that typically occupy lower elevation riverfront forest. When flooded, fish move into floodplain forests for spawning and foraging. Slope forest occupied colluvial slopes along the edges of UMRS floodplains (Munson 1974, Chmurny 1973, Gregg 1975, Moore 1988, USFWS 2006). Slope forests contain a unique mix of trees representing both upland and bottomland communities that occur in higher (upland) and lower (floodplain) elevations adjacent to the slope. 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 forests included hickory (*Carya* sp.), hackberry, swamp white oak, white oak (*Quercus alba*), bur oak, northern red oak (*Quercus rubra*), black walnut (*Juglans nigra*), black ash (*Fraxinus nigra*), red mulberry (*Morus rubra*), red maple (*Acer rubrum*), box elder, hawthorn (*Crataegus* sp.), honey locust (*Gleditsia triancanthos*), and slippery elm (*Ulmus rubra*). Many other woody species occur in the understory and as occasional canopy trees. Herbaceous cover often is extensive, especially on the lowest elevations (Zawacki and Hausfater 1969).

Slope forests historically 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 are bounded by slightly larger drainages that originate in bluffs and uplands. Some slope areas in the CRE were bounded by prairie where they adjoined glacial terraces. 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.

Many animals used slope forests 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 CRE floodplain on glacial terraces and glacial stream scarps. Most of these prairies apparently were mesic type prairies on higher elevation glacial terraces (Allen 1870, Hus 1908, Sampson 1921, Turner 1934, Chmurny 1973, Gregg 1975, Nelson et al. 1994, Nelson and Sparks 1998, Nelson 1999, USACE 2006). Bottomland prairie also was present in many lower terrace elevation sites and often is 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 prairies occupied older terrace surfaces where elevations were at 2-5-year flood frequencies. Soils under bottomland prairies 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 (*Andropogon gerardii*), blue joint (*Calamagrostis canadensis*), prairie cordgrass, and switch grass (*Panicum virgtum*). Bottomland Prairie "swales" included many sedges and wetland-type plants such as river bulrush, bur reed, sweetflag (*Acorus calamus*), duck potato (*Sagittaria* sp.), water parsnip (*Sium suave*), pickerelweed (*Pontederia cordata*), mud plantain (*Heterantheria limosa*), dock, smartweed, spikerush, and yellow water crowfoot (*Ranunculus flabellaris*). They also contained abundant prairie cordgrass, marsh elder (*Iva annua*), and asters (*Aster* sp.) at the transition zones between "ridge" and "swale."

At the higher elevations of the CRE floodplain, especially on terraces (such as the Savanna Terrace in Pool 7), prairie changed into zones or patches of savanna and then to slope forests on alluvial fans and upland/bluff margins. Mesic prairie was dominated by perennial upland type grasses including big bluestem, Indian grass (*Sorghastrum nutans*), switchgrass, and panic grasses. Vegetation in mesic prairies 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 scattered hazelnut, box elder, hickory, elm, and some slope forest shrub and tree species were common. Savannas often had considerable northern pin oak and red oak stands. Given the geographic 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

The distribution of prairie and savanna in the UMRS was determined largely by the distribution of relict glacial terraces and 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 (see e.g., Nelson and Sparks 1998, Heitmeyer and Westphall 2007, Heitmeyer 2008a,b). Historically, prairie and savanna vegetation was partly maintained by seasonal burning by native people and by herbivory from elk (*Cervus canadensis*), bison (*Bison bison*), white-tailed deer (*Odoocoileus virginianus*) , and many rodents. This herbivory cropped and recycled prairie vegetation and also browsed invading woody shrubs and plants. Prairies 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. Distribution and Extent of Presettlement Habitats

The exact distribution of vegetation communities (habitat types) in the CRE 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 UMRS and the CRE and they include historic cartography, photographs, botanical data and accounts, and general descriptions of landscapes from early explorers and naturalists (e.g., Laustrup and Lowenberg 1994, Anfinson 1997, Sickley and Mladenoff 2007, Appendices G-I, L, M). 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 UMRS were made during French governance of the region by the French cartographers Franquelin (produced in 1682), 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 UMRS 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 UMRS; 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 the most accurate map of the southern UMRS region 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 UMRS 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. This "Collot" map provided expanded notes and coverage of vegetation and larger wetlands in the UMRS floodplain and became the basis for additional maps and naturalist accounts of Nicolas de Finiels in the early 1800s (Ekberg and Foley 1989).

In the early 1800s, following American occupation and rule, the CRE 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, Appendix L). Consequently, the GLO maps and surveys established a "georeference" of locations and distribution of CRE features including general habitat types. GLO surveyors usually described vegetation communities in broad categories (e.g., forest, bottomland, and 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 (Brugam and Patterson 1996, Schulte and Mladenoff 2001). Most likely, the "black oaks" described in GLO notes for the CRE floodplains were "red oak" species such as northern pin oak and northern red and the "white oaks" probably were swamp white and bur 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 in the CRE probably mapped many savannas as forest, but this is unclear because many savanna areas may have contained larger amounts of prairie or other grasses. In the CRE, GLO notes and maps often mix the terms "bottomland", "woodland", and "forest". Most "bottomland" appears to have been wet meadow 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 some CRE areas (Hutchins 1784, Brackenridge 1814, Flint 1828, Flagg 1838, Wild 1841, Oliver 1843, Warren 1869, Allen 1870). 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 (Appendix G).

Collectively, the above maps, historical accounts, and published literature suggest historical vegetation communities in the CRE were distributed along elevation, geomorphology, and hydrological gradients. Similar community distribution associations also occur in other UMRS floodplain areas and help validate information from the CRE (e.g., Sparks 1993, Theiling 1999b, Heitmeyer and Westphall 2007, Heitmeyer 2008a, b; Heitmeyer et al. 2009a, b). 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 CRE (Table 1). The Hydrogeomorphic matrix of understanding, and prediction, of potential historic vegetation communities is developed using comprehensive scientific data discovery and field validation using published literature, vegetation community reference sites, and state-of-the-art understanding of plant species relationships (i.e., botanical correlation) to geomorphology, soil, topography and elevation, hydrological regimes, and ecosystem disturbances (e.g., Galatowitsch and McAdams 1994). These plant-abiotic correlations are in effect the basis of plant biogeography and physiography whereby information is sought on where plant species, and community assemblages, occur throughout the world relative to geology and geomorphic setting, soils, topographic and aspect position, and hydrology (e.g., Barbour and Billings 1991). The HGM matrix allows understanding of potential historic vegetation community distribution in the CRE in an objective manner based on the botanical correlations that identify community type and distribution, juxtaposition, and "driving" ecological processes that created and sustained them. The predictions of type and historic distribution of communities are only as good as the understanding and documentation of plant-abiotic relationships and the geospatial data for the abiotic variables for a location and period of interest, such as Presettlement period.

In the UMRS, including the CRE, the major vegetation communities that were present during the Presettlement period are known (e.g., Appendix L) and the botanical relationships of these communities with abiotic factors also are extensively documented and robust (see e.g. soil-vegetation relationships in Whitson et al. 1917, Edwards et al. 1927 and reviews of abiotic-plant correlation in Galatowitsch and McAdams 1994). For example, prairie and savanna were extensively present wherever relict glacial terraces were present. The interrelationships among abiotic factors for the UMRS also are well understood and documented (e.g., Heitmeyer 2008a, b; Heitmeyer et al. 2009a, b; Theiling 2010). For example, the type and spatial position of soils generally are closely related to geomorphic surface and formation. As a specific example, Sparta, Finchford, and Gotham fine sandy soils are present only on glacial terraces.

The robust vegetation community relationships in the UMRS enable a well-validated understanding of where historic major plant communities in the CRE were located relative to geomorphic setting, soils,

Table 1. Hydrogeomorphic (HGM) matrix of historical distribution of major vegetation communities/habitat types in the Chippewa River ecoregion in relationship to geomorphic surface, soils, and hydrological regime. Relationships were determined from land cover maps prepared for the Government Land Office survey notes taken in the early 1800s, historic maps and photographs, U.S. Department of Agriculture soil maps, land sediment assemblage maps, flood frequency data provided by the U.S. Army Corps of Engineers, St. Paul District; and various naturalist/botanical accounts and literature.

Habitat Type	Geomorphic Surface[a]	Soil type[b]	Flood Frequency
Open Water/Aquatic	SC, TC, SL	Sand-gravel	Permanent
Persistent Emergent	TF, TFM, MCV	Silt loam, muck	Semi-permanent
Shrub/scrub	Edges of TC, SC, and SL	Silt clay	Semi-permanent
Wet Meadow	GSC, TFM, MNV	Loam – muck	Spring-summer
seasonal			
Mesic Prairie/Savanna	GT, GSS, MNV[c]	Sandy loam	> 10 year
Bottomland Prairie	GSC, TF	Loam	> 5 year
Riverfront Forest	MCL, MCI, MNL[d]	Sandy-silt	1 year
Floodplain Forest	TSS, TF, MCV, TMB MNL[d], MCV, MNV	Silt loam-clay	2-5 year
Floodplain Forest – Oak[e]	MCV	Silt clay	> 5 year
Slope Forest	CS	Mixed erosional	> 20

[a] CS – colluvial slope, GSC – glacial stream channel, GSS – glacial stream scarp, GT – glacial terrace, MCI – main channel island, MCL – main channel lateral accretion, MCV – main channel vertical accretion, MNL – minor channel lateral accretion, MNV – minor channel vertical accretion, SC – side channel, SL – sloughs-lakes-river channels, TC – tributary channel, TF – tributary fan, TFM – Tributary floodplain and marsh, TMB – tributary meander belt, TSS – tributary stream scarp.

[b] See Appendix D for list of soils associated with vegetation communities and geomorphic surfaces.

[c] Prairie found in MNV only in the Winona Flats area.

[d] Minor channel lateral surfaces contain ridge-and-swale communities with Floodplain Forest typically on ridges and Riverfront Forest typically in swales.

[e] Sites with relatively small amounts of oak interspersed in a diverse Floodplain Forest with relatively water-intolerant species.

and hydrological regime. Consequently, even though Presettlement hydrology data area not available for the region, the confirmed relationships of species to other abiotic variables provides strong inference as to what the historic hydrological regime was for various locations. The primary terrestrial communities in the CRE are riverfront and floodplain forest, PEM, wet meadow, and prairie/savanna. These communities have relatively long generation cycles and their occurrence at sites indicates long-term response and adaptation to repetitive inter-annual and seasonal patterns of hydrology. If confidence is reached in understanding the position of a historic community type based on historic maps and botanical correlation with other abiotic variables including specific geomorphology, soils, and topography, then by default, the historic hydrological regime for a site also can be safely predicted. For example, if a historic site supported floodplain forest, then the site undoubtedly had (long-term average) short duration dormant season flooding within a > 2-year growing season flood frequency zone. The sequence of methodology used to prepare the Hydrogeomorphic matrix of potential historic communities for the CRE was:

1. The general distribution of major vegetation community/habitat types including forest, prairie, floodplain lakes and sloughs, PEM, and wet meadow was determined from GLO surveys (General Land Office 1817-1860), historic cartography (e.g., Hutchins 1784, Collot 1826, Warren 1869, Mississippi River Commission 1881, and early settlement/naturalist accounts (e.g., Brackenridge 1814, Flint 1828, Flagg 1838, Wild 1841). A generalized map of the historic distribution of communities (e.g., Appendices L, M) using the above collective information was then overlain on contemporary geomorphology (Appendices C, D), soils (Appendix D), flood frequency (data from USACE, St. Paul District), and topography maps (e.g., Appendix E, F).

2. The general correspondence of Presettlement vegetation communities from the above map sources with contemporary abiotic geomorphology, soils, and 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 are used. Despite the imprecision of some older maps and accounts, analyzing habitat information from these sources provides 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 or two factors. For example, in the CRE all main channel islands and lateral accretion surfaces with recently deposited and scoured sandy soils along the current Mississippi River channel historically were riverfront forest. In other cases, however, it was necessary to use multiple abiotic variables to understand botanical relationships, for example the complex PEM, bottomland prairie, and floodplain forest distribution in the Winona Flats area.

3. Remnant native vegetation communities in the CRE were identified from aerial photographs and other sources (e.g., USFWS 2006). Select sites were visited in 2009 and 2010 to document vegetation characteristics, such as species composition, and to determine if the sites matched the community types predicted from step #2. If the historic maps and contemporary field data were consistent, then the field sites were considered a reference site of former community types (e.g., Nestler et al. 2010).

4. 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.

6. The position of predicted communities from the Hydrogeomorphic matrix on the composite digital geo-referenced maps of geomorphology, soils, topography, and flood frequency was mapped,
7. Aerial photographs were used to identify remnant habitats of the map predicted types (i.e. prairie, PEM, floodplain forest, floodplain lakes, etc.) and reference sites and remnant habitats were revisited to determine the vegetation that was present. This field data collection was similar to step #3 in finding reference sites that represented and verified various communities.

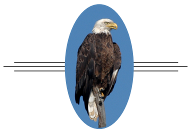
8. Based on field and map data developed in steps 6 and 7, the matrix was refined and areas or communities were identified where correspondence

with various abiotic factors were weaker. For example, GLO information suggests more prairie and/or savanna and an interesting mixture of PEM and both floodplain and riverfront forest on the Winona Flats area (Appendix L, Pool 6 map) than would have been suggested based solely on its minor channel vertical accretion geomorphic surface. The minor channel vertical accretion surface as Winona Flats lies between two larger relict glacial terraces (which would have supported prairie/savanna) and also has a relict glacial stream channel and scarp bisecting the area. Consequently, it is likely that the accretion surface lies above a degraded terrace and that adjacent glacial terraces supplied prairie species stock to the site. Also, the Winona Flats contains significant elevation heterogeneity that likely contributed to diverse, local, vegetation communities.

When all HGM variables were considered, the most powerful predictor of Presettlement communities in the CRE was geomorphic surface. For example, several geomorphic surfaces apparently supported only a single major community, with perhaps some minor inclusions of other species associations. These included prairies on glacial stream scarps and terraces, riverfront forest on main channel lateral accretion surfaces and Islands, floodplain forest on tributary meander belts, and slope forest on colluvial slopes. Other geomorphic surfaces supported multiple communities with the community distribution largely being related to elevation and associated flood frequency. The lack of flood frequency/hydrology data for the Presettlement period prohibits precise mapping of this variation, but generally distribution patterns are understood. For example, tributary fans/deltas contained a mixture of floodplain forest on higher ridges and levees with a > 2-year flood frequency, and PEM or wet meadow along labyrinth drainages where seasonal inundation occurred (Table 1). PEM occupied sites where semipermanent to permanent water regimes occurred, while wet meadow was in seasonally flooded elevations. Similarly, minor channel vertical accretion surfaces contained a mixture of floodplain forest and PEM depending on elevation and frequency and duration of flooding (e.g., Heitmeyer et al. 2009a).


LIGHT HOUSE DISTRICT
LILY
MER DU NORD
RIVIERE DE MISSISIPI
FLORIDE
GOLPHE de MEXIQUE
THE MISSISSIPPI by Franquelin. About 1682.


Old Pontoon Bridge at Prairie du chien, Wis.



CHANGES TO THE CHIPPEWA RIVER ECOSYSTEM

SETTLEMENT AND EARLY LANDSCAPE CHANGES

Native people apparently first occupied the UMRS and the CRE about 10,000 years BP (Stoltman 1983). Early people in the region apparently were nomadic; little archaeological evidence exists for more permanent village and camp sites. These PaleoIndian and Early Archaic people had a hunter-gather lifestyle. The continued glacial outwash and active fluvial processes in the region likely caused seasonal movements of people in response to large spring-summer flooding events. By ca. 8,000 BP early people may have penetrated most of the UMRS and the remains of a bison kill indicate they reached Lake Itasca, the head of the Mississippi River by about 7,000 BP (Shay 1971). During the Altithermal 4,000 to 8,000 years BP, the CRE became warmer and drier and prairie and savanna expanded onto glacial terraces and other higher elevations in the CRE. At this time native people appear to have congregated at a limited number of high elevation locations near permanent water areas of floodplain lakes and river channels.

The Late Archaic period (3,000 to 500 years BP) was a time of great expansion of native human populations at numerous UMRS sites as the climate ameliorated. At this time, cultural elaboration caused settlements to become more specialized to exploit certain resources at specific times of the year and likely CRE sites became occupied seasonally as populations shifted from dispersed to aggregated settlements. The end of this period also marks the development of horticulture and the introduction of pottery into the CRE. Many animals were utilized including white-tailed deer, small mammals, migratory birds, fish, and amphibians (Arzigian et al. 1989). Ridge locations were usually chosen for camps and settlements because surrounding floodplain areas were seasonally inundated and contained dense swamp-type vegetation. Evidence suggests that people were highly mobile hunter-gathers well adapted to seasonal floodplain resource availability through the Late Archaic period and likely had little effect on vegetation community distribution or disturbances.

During the Woodland period, horticulture intensified on the higher ridges and terraces of the UMRS and other developments included construction of earthworks, reorganization of social structure, and elaboration of artistic expression and burial rituals (Griffin 1967). The Early Woodland period (2,100 to 2,500 years BP) marked initial use of ceramics and some expansion of horticulture including more expansive maize production. By the Middle Woodland time, burial ceremonialism and artistic expression were elaborated and "mound" construction apparently occurred in some more permanently settled areas. The Black Sand culture was among the first to intensively exploit floodplains in the UMRS from about 2,100 to 2,400 BP. The Havana culture, which existed from about 2,400 to 1,600 BP was strongly established along the Illinois River, but also reached up the Mississippi River to its confluence with the Minnesota River (Streuver 1977). It was part of a vast trade network that dealt in copper from the Lake Superior region, conch shells from the Gulf of Mexico, mica from the Appalachian Mountains in North Carolina and obsidian and grizzly bear (*Ursus* horribilus) teeth from Wyoming (Carlson and Collins 1980). By the Late Woodland period (1,600 to 1,200 years BP) many cultural shifts began occurring including substructure mound-and-plaza complexes, two-tiered social hierarchy, formation of territorial units, increased reliance of maize production, new technologies such as the bow and arrow, and tempered ceramics. It is possible that this time period represented the maximum prehistory occupation of the UMRS by native people and that some areas on higher ridges, natural levees, and terraces were converted to agriculture and settlements with regular disturbance of surrounding habitats using fire and perhaps limited clearing.

During the Mississippian period the final climax of native cultural development occurred in the UMRS region and the region supported large populations, albeit small compared to the huge population center at Cahokia (Milner 1998). At this time populations expanded in the region, intense settlements occurred on high ridges in the floodplain, more emphasis was placed on agricultural production, earthworks were constructed based on celestial alignments, inter-regional exchange of items occurred, shell-tempered ceramics were made, and some region warfare was present to protect territories (Streuver 1977). These developments led to the conscripted, complex socio-political system known as chiefdoms in southern parts of the UMRS (e.g., Milner 1998). One pervasive cultures of the period was the Oneota culture which appeared about 950 BP and reach from Lake Michigan to the Great Plains (Stoltman 1983, Glenn 1974). Oneota culture people lived in large permanent villages, grew corn, and supplemented their diet with hunting and gathering. This culture lasted until about 1650; some large settlements had fragmented into small dispersed communities by 1400. Undoubtedly larger occupation sites caused anthropogenic effects on local ecosystems and plant communities including more widespread clearing and maintenance of agricultural fields and local high exploitation of fish and wildlife populations. A general abandonment of the Mississippian ceremonial centers and villages throughout the Mississippi River Valley after 1550. While the region may not have been completely vacant, it appears populations dispersed and relocated (Brose 1978).

The Protohistory period 1540-1673 is generally considered to have the first appearance of Europeans in the southeastern U.S. and eventually into the UMRS. French explorers first reached the Great Lakes in 1615 and reached western Lake Superior by the 1660s bringing with them missionaries and markets for furs (Lanegran and Mosher-Sheridan 1983). When Marquette and Jolliet descended the Mississippi River in summer 1673, few native people were encountered in the UMRS (Marquette 1954). Forts and trading posts established around the Great Lakes region greatly influenced sparse settlements of native people in the UMRS in the late 1600s and Jesuit missions became economic and social centers (Stone and Chaput 1978). French traders erected and occupied 10 forts on the Upper Mississippi River and its tributaries (Lanegran and Mosher-Sheridan 1983), but France eventually lost influence in the UMRS during the 1750s during the French and Indian War and in Europe during the Seven Years' War. By the early 1760s, France had lost its territory east of the Mississippi River to Britain and its territory west of the Mississippi River to Spain. France regained the Louisiana Territory west of the Mississippi River in 1800 by treaty, but sold the territory in 1803 to the United States as the Louisiana Purchase.

In 1805 Zebulon Pike, a lieutenant in the U.S. Army, made one of the first attempts to assert jurisdiction over the UMRS and he traveled to the confluence of the Mississippi and Minnesota rivers and bought land from local Sioux tribes. Western lands were considered "conquered" and available for settlement by U.S. citizens, although some land was allotted to conquered Indian inhabitants (Stone and Chaput 1978). Agreements between the U.S. government and native people usually were in the form of treaties and land cessions. Among these agreements was an 1804 treaty in which the Sauk and Fox tribes relinquished claims to land east of the Mississippi River, a treaty which prompted an unsuccessful Indian rebellion – the Black Hawk War – in 1832. Treaties of 1837 and 1842 between the U.S. and the Ojibwa tribes involved major land cessions in Wisconsin and in the 1851 treaty of Traverse des Sioux, Dakota land in Minnesota was ceded to the U.S. Government (Bauxar 1983).

During the 1800s, many of the settlers that moved into the UMRS and CRE followed the ancient Mississippi River valley gorge to Fort Snelling and settled nearby in the communities of St. Paul and St. Anthony. Others settled in forest lands and higher floodplain terrace locations of the CRE. This mid- to late-1800s settlement marked the beginning of conversion of historic prairies to agriculture, clearing of forests, grain markets, and eventual establishment of larger communities and associated roads, rail lines, and commercial travel and trade on the Mississippi River (e.g. Godfrey 1990).

During the 1840s and 1850s, the cities of St. Paul, St. Anthony, and Minneapolis began to draw river traffic north through the CRE. Steamboat traffic created a need for wood fuel and major forest sites along the Mississippi River were harvested. Steamboat business on the Upper Mississippi River thrived during the 1850s and waves of immigrant people moved into Iowa, western Wisconsin, and eastern Minnesota. This immigration swelled after the Traverse des Sioux treaty and effectively opened the UMRS and CRE for settlement. For example, in 1850, the population of the territory of Minnesota was about 6,000, but by 1860 the population had grown to more than 170,000 (Hartsough 1924). Agriculture was the primary economic use of the region at this time, especially wheat production. By the late 1850s, hundreds of thousands of bushels of wheat were being shipped south using the Mississippi River; at that time Minnesota had no rail connections with the eastern U.S. CRE river towns that prospered in the wheat trade were Wabasha, Winona, and Brownsville in Minnesota and McGregor, Iowa. The wheat trade on the Mississippi River existed mainly between these river ports and railheads along the east bank of the river south of LaCrosse, Wisconsin. This trade was lively during the Civil War, but weakened after 1867, when railroads began to cross the Mississippi River and taped farm fields of Iowa and Minnesota.

As early as the 1830s, snags and other local obstructions such as shoals, sandbars, and rocks were removed from the main-stem Mississippi River to ensure a safe passage for steamboats (Upper Mississippi River Basin Commission 1982). As steamboat traffic increased and competition from railroads increased Congress made 16 appropriations for river and harbor projects in the UMRS between 1866 and 1883 (Hoops 1993). These projects were intended to improve the Mississippi River's efficiency for commercial navigation and they stimulated many future attempts to improve the system for navigation (Brunet 1977, Anfinson 1993). In 1878, Congress authorized the USACE to develop and maintain a 4.5-foot deep navigation channel between St. Paul and St. Louis. To divert river flows into the main channel, wing dams were constructed perpendicular to the riverbanks. Side channels were cut off with closing dams and many riverbanks were stabilized by revetments.

In 1907, Congress authorized a deeper 6-foot channel and subsequent river modifications consisted of further river contraction and bank protection and the construction of the first lock and dam at Keokuk, Iowa in 1913. In 1927, Congress authorized the development of a navigation channel of 9 feet deep and 300 feet wide from the mouth of the Missouri and Mississippi rivers near St. Louis to the mouth of the Ohio River at Cairo, Illinois. This 9-foot channel project resulted in more extensive flow constriction and more bank stabilization structures, but no construction of locks and dams in the region. In 1930, the 9-foot channel was extended north from St. Louis to St. Paul and during the 1930s, a series of 27 locks and dams were constructed. Each dam was intended to impound water during low river flows to maintain a minimum 9 foot navigation channel.

Landscape changes in the CRE prior to construction of locks and dams are chronicled by data from the GLO surveys conducted in the region in the mid 1800s (Appendix L), maps of the Mississippi River floodplain prepared by the Mississippi River Commission in the 1880s (Appendices G, M), 1929 aerial photographs (Appendix I), and maps prepared by Brown in 1930 (Appendix H). Collectively, these sources of information identify the relatively rapid: 1) conversion of glacial terrace prairies and savannas to agriculture and residential/urban communities; 2) clearing of floodplain forest, especially on higher elevation ridges, natural levees, and terrace edges, for agriculture and some urban uses; 3) clearing of slope forest for agriculture and pasture; and 4) marked changes in other floodplain areas including conversion to agriculture, levees and drainage developments, alterations in sloughs, side channels, and the main stem Mississippi River. Consequently, by the 1930s, about 50% of Presettlement natural communities, and over 80% of historic prairie and savanna, had been lost. By 1929 farmland and urban areas covered 22% of the UMRS floodplain and forest had declined to 29% of its former extent (Peck and Smith 1986).

In 1924, Congress passed the Upper Mississippi River Wild Life and Fish Refuge Act that authorized acquisition of land for a USFWS NWR between Rock Island, Illinois and Wabasha, Minnesota. This Act, and the subsequent establishment of the Upper Mississippi River NWR was largely promoted by the Izaak Walton League, and in particular, the efforts of its founder and leader Will Dilg, after proposals were made to drain a larger portion of the river backwaters and floodplain areas in the region. Consent for land acquisition was granted by the states of Minnesota, Wisconsin, Iowa, and Illinois, with varying conditions, in 1925, and land acquisition proceeded rapidly thereafter. About 90,000 acres were acquired by the U.S. Bureau of Biological Survey (precursor to the current USFWS) for the NWR, much of which was in the CRE, by 1930. With authorization of the 9-foot channel and impending construction of locks and dams in the UMRS, the Biological Survey suspended acquisition for the NWR, but the USACE subsequently acquired about 106,000 acres within the generally accepted boundary of the NWR that was needed for construction of the locks and dams and subsequent raising of water levels for navigation purposes.

POST LOCK-AND-DAM HYDROLOGICAL AND LANDSCAPE CHANGES

Locks and Dams on the Mississippi River in the CRE were constructed between 1935 and 1939 (WEST Consultants, Inc. 2000). The immediate effect of the locks and dams was significant change in hydrographs of the Mississippi River and its floodplain communities (e.g., Fig. 7) and impoundment of lower parts of each pool. The pre-dam era was characterized by an average pattern of high river stage during snowmelt and spring rains that tapered to summer low flow river stages, rose with fall rains, and froze at a moderate river stage in winter. Navigation dams increased average water surface elevations by about two to three feet and eliminated natural low-flow river stages during late summer (Theiling 1996). The post-dam change in water surface profiles for the discharge exceeded 75% of the time (i.e., low flow conditions) is especially marked (Fig. 3). Stage-discharge relationships also have changed in all CRE navigation pools (Fig. 4) with headwater (immediately above the dam in the impounded section of the pool) differences being 6 to 12 feet higher for existing vs. pre-dam low flow conditions. In contrast, tailwater areas immediately downstream of dams have stage-discharge relationships that indicate water surface elevations up to one to two feet higher for low flow conditions and up to two feet lower for high flow conditions depending on the dam. High flow conditions are represented on Figure 3 by the 2-year flood. Mid-pool relationships generally have two to three feet higher stages now than during pre-dam periods (e.g., Heitmeyer et al. 2009a)

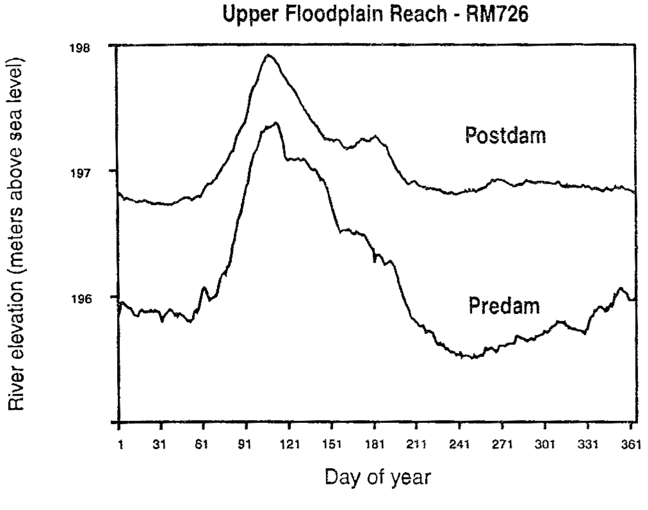


Fig. 7. Mean annual hydrographs of the Mississippi River at river mile 726 near Winona, Minnesota pre- and post-dam (from Franklin et al. 2003).

Land use in the CRE continued to change from the late 1920s (Appendix I) to the present (see e.g., Appendices J, K, N, O). By 1989, Presettlement habitats in Pools 4 and 8 had shifted to greater amounts of open water, urban and developed land, and agriculture and lesser amounts of forest and marsh (Table 2). Prairie/savanna area remained relatively similar between the late 1880s and late 1900s, primarily because most prairie and savanna already had been converted to agriculture and urban development by the late 1880s (see above). Loss of forest was largely caused by impoundment of the lower one-half of most navigation pools. For example, the proportion of timber in Pool 8 dropped 38% post-dam through 1989, and subsequently has declined even further (e.g., Heitmeyer et al. 2009b). In 1989, forests covered about 1,233 square kilometers (14.3%) of the UMRS (Laustrup and Lowenberg 1994). This loss of forest is considerable, but less than other Lower Mississippi River Valley areas largely because of public land acquisitions for navigation pools and the Upper Mississippi River National Wildlife and Fish Refuge.

Combined timber harvest (largely prior to locks and dams), water level regulation, bank stabilization structures, dredging, island erosion, sedimentation and expansion of invasive and exotic plant and animal species have collectively greatly altered the historic community distribution, extent, and composition in the CRE (e.g., Theiling et al 2000, WEST Consultants, Inc. 2000, USFWS 2006). The cumulative impacts of alterations to the CRE, especially since implementation of measures to maintain a 9-foot navigation channel, including construction of locks and dams, is extensively documented (WEST Consultants, Inc. 2000). Historically, the CRE was highly influenced by the large bed load supply of sediment from the Chippewa and other tributary rivers and the region had high physical and ecological complexity including large areas of secondary channels, isolated backwaters, and number of islands (Keown et al. 1986, Knox 1987). Because of water impoundment, the navigation pools now have large open water areas and erosion of island in lower portions of the pools has occurred. This island erosion is attributed to reduced bed load sediment transport to the lower portions of pools and wind-driven wave action. In contrast, main channel and secondary channel area has increased because of impoundment. Backwater areas have decreased in some areas due to sediment deposition.

Table 2. Percentage composition of land cover types in Pool 8 of the Chippewa River ecoregion in the early 1800s Presettlement and 1989 periods (from Theiling et al. 2000).

Habitat type	Presettlement	1989
Open water	21.0	52.8
Marsh[a]	14.8	8.1
Prairie	8.0	9.8
Forest[b]	55.5	17.7
Swamp[c]	0.6	0.0
Developed	0.0	11.1
Agriculture	0.0	0.5

[a] Presumably combined Persistent Emergent, Wet Meadow, and Bottomland Prairie (see text).
[b] Combined Riverfront, Floodplain, and Slope Forest types (see text).
[c] Presumably Shrub/Scrub (see text).

Forest habitats in the CRE have been especially altered in the post-dam period (e.g., Yin and Nelson 1996, Knutson and Klaas 1998, Appendices K, O). Declines in all forest types have occurred, with remnant forest sites now confined to the higher elevations where historic forest communities were present (USFWS 1944). Obviously, impoundment post-dam in lower portions of the navigation pools quickly killed all forest present. Forest mortality in middle and upper parts of pools has been more delayed, yet the latent persistent higher levels of surface water inundation and soil saturation have prevented regeneration of floodplain forest seedlings for most species and gradually weakened, and eventually killed, large areas of green ash, American elm, box elder, swamp white oak, and hackberry (Urich 1995). Significant loss of floodplain forest, especially remnant elm and ash has occurred even in the last 10 years. Floodplain forest species are adapted to seasonal flooding in the UMRS, but they need drying periods in summer and fall to maintain root systems and allow regeneration of seedlings. Further, long-term sustainability of these species requires periodic periods of extended drying, that historically occurred for 2-4 consecutive years during dry periods of long-term climatic patterns (see earlier discussion of Climate characteristics of the CRE). For example, the continued loss of floodplain forest at Reno Bottoms is associated with the ca. 2-foot higher water levels now present in Upper Pool 9 during the driest part of the pool managed hydrograph (Heitmeyer et al. 2009a).

Remnant areas of riverfront forest have been impacted less than floodplain forest because they contain silver maple, willow, and cottonwood, which have greater water tolerance. Nonetheless, species diversity in riverfront forest areas has been reduced and is quickly becoming more monocultures of silver maple and willow. Most of the dead and/or dying forest area has converted to S/S, PEM, wet meadow, or open water habitats.

In addition to large loss of forest area in the CRE, large changes in prairie/savanna, wet meadow, PEM, and aquatic habitats also have occurred (e.g., Theiling et al. 2000, WEST Consultants, Inc. 2000, River Resources Forum 2004, USFWS 2006). Generally, all habitats have continued to shift to wetter regimes causing a transition in community distribution and composition. Many former wet meadow sites now are PEM or open water, while conversely some former floodplain forest sites now are wet meadow. Wet meadow areas also have become heavily infested with reed canary grass as water regimes have become wetter and sedimentation has increased in floodplain depressions and flats. PEM is becoming reduced in area as permanent water gradually eliminated emergent plant occurrence and persistence. Open water now is deeper and often more turbid and submergent plant communities are reduced or degraded. Prairie and savanna areas are now rare in the CRE because glacial terraces are highly developed or farmed, fire is controlled, and non-native grass and forb species are invading former prairie/savanna remnants.

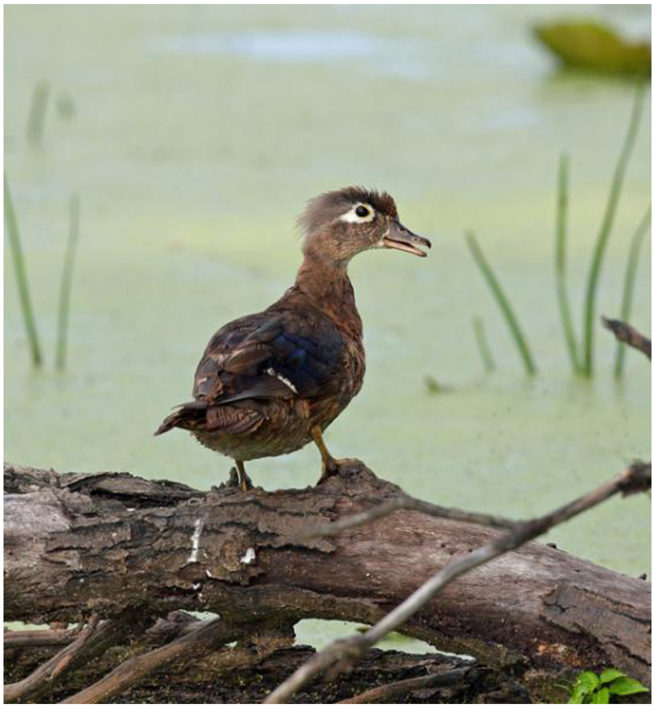
USFWS

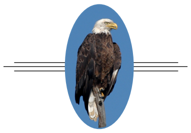
Koppie; Craig/USFWS

Land and water use in the CRE is more intense in most areas than during the pre-dam period. Locks and dams have created more permanent water areas, which increase both navigation and recreation use. Residential and urban developments have continued to expand in the CRE. Regional land use changes, especially conversion of watershed areas to agriculture and urban areas, increased sediment loading in the CRE through the 1900s (e.g., Eckblad 1977, Knox and Faulkner 1994), although sediment input into the CRE now apparently has stabilized (Fitzpatrick et al. 2007, 2009).

After locks and dams were constructed in the UMRS, and within the CRE, management jurisdiction over much of the USACE-acquired land within the boundaries of the Upper Mississippi River NWR was transferred to the USFWS with reservations, through a series of agreements in 1945, 1954, and 1963. A 2001 Amendment further modified and simplified earlier agreements. Certain conflicts between navigation, fish and wildlife conservation, and recreation influenced cooperative agreements and long-range management strategies for the UMRS have been developed over time.

Sue Fletcher - FUMMR contest





ECOSYSTEM RESTORATION OPTIONS

COMMUNITY DISTRIBUTION

Many studies have documented the extensive changes to the terrestrial and aquatic ecosystem components of the UMRS including the CRE (e.g., USACE 1978, Bhowmik and Adams 1989, WEST Consultants, Inc. 2000, Theiling et al. 2000, Wiener and Sandheinrich 2010) and conservation plans for the region generally recommend that future conservation efforts for the region include attempts to restore communities and resources, especially those types that have been highly destroyed in non-impounded areas of the CRE (e.g., Theiling et al. 2000, River Resources Forum 2004, USFWS 2006, USFWS and USACE 2009). The key to restoring native communities in the CRE is identifying sites that are appropriate for, and have the best chance for sustaining, specific communities. In other words, to design sustainable restoration programs for an individual site it is critical to first understand what communities historically were present and whether the site still has the driving ecological processes that created and sustained the communities. The temptation is often to try and establish many historic communities on a site, irrespective of its historical condition, but the long term sustainability of these restored/created communities will inevitably be compromised if the site is not appropriate for the new/restored community (Heitmeyer 2007b).

The collective efforts to document the historical Presettlement composition and distribution of community/habitat types using GLO records (e.g., Yin and Nelson 1996, Appendix L), old maps and aerial photographs (e.g., Appendices G, M), and now HGM analyses (this study, Table 1) provide the baseline for understanding what community types were present and their distribution and extent. Aerial photographs and land cover maps (e.g., Appendices I, J, K, N, O) provide understanding of changes from the Presettlement conditions and identify areas where remnant communities are present. These data provide the template to identify areas that may be most suitable for restoring specific community types in the contemporary, highly modified, CRE environment.

The HGM analyses in this study provide an understanding of not only where historic communities were located, but also the basic physical attributes and ecological processes that created and sustained these communities. This understanding can identify general locations that community restoration potentially could occur and be successful. Once general locations for potential community restoration are identified, then site-specific analyses can help design specific details for restoration projects at individual locations. For example, determining the potential restoration locations for floodplain forest in minor vertical accretion surfaces will require detailed information on inundation frequency and seasonal duration (e.g., Wlosinski and Wlosinski 2001) related to elevation (e.g., Heitmeyer et al. 2009a,b).

Generally, in the CRE, terrestrial community restoration will necessarily be at elevations above mean water levels maintained for the 9-foot navigation channel. Consequently, locations upstream of impounded areas of navigation pools, and higher surfaces such as floodplain ridges, natural levees, terraces, tributary fans/deltas, and colluvial slopes offer the greatest potential for restoration sites. Main and side channels, sloughs, and floodplain lakes will continue to support open water/aquatic habitats and many actions have been proposed, and are being implemented, such as island construction, etc. to improve these habitats and the resources they provide to fish and wildlife species, recreational opportunities, and other ecological functions and values (e.g., UMRBC 1981, USFWS 1982, USACE 1997, River Resources Forum 2004, Nelson 1998).

Two maps are provided in this report (Appendices P, Q) that identify general locations where terrestrial communities have the best potential to be maintained and restored. As previously mentioned, the geomorphic surface data layer was the most predictive data related to Presettlement community distribution. Obviously, geomorphic surfaces also influence soils and topography on a site, and by default its general hydrological regime. Some geomorphic surfaces, such as tributary fans/deltas, tributary floodplains, and minor channel lateral accretion areas can support more than one community, and for these areas more detailed site specific elevation information will be needed to delineate precise locations for specific community restoration potential. This study could not provide this detailed information for all CRE areas, but provides the basic foundation for subsequent site-specific evaluations and restoration plans, such as was done recently for the Reno Bottoms area of Upper Pool 9 (Heitmeyer et al. 2009) and the Root River Tract in Pool 8 (Heitmeyer et al. 2010).

A summary of the most appropriate restoration sites by community type is provided below:

Shrub/Scrub

S/S historically was present in the CRE in narrow bands along the edges of side channels, sloughs, lakes, and tributary channels. A few very low elevation minor channel vertical accretion sites also contained S/S. These sites had silty clay soils and semipermanent water regimes. Currently, higher more prolonged water regimes in navigation pools has expanded S/S into some formerly less flooded floodplain areas, and simultaneously eliminated much S/S in lower elevations. Restoration of S/S appears possible in these geomorphic surfaces if silt clay soils are present and water regimes can become semipermanent with at least occasional drying periods during summer in some years.

Persistent Emergent Marsh

PEM includes wetlands that are dominated by annual and perennial emergent plants with some aquatic plants such as submersed or floating species in deeper more permanent water areas, and herbaceous species on higher edges that have more seasonal water regimes. PEM historically was present in more protected bays and floodplain depressions with semipermanent water regimes such as tributary fans, tributary floodplain/marsh, and minor channel vertical accretion geomorphology. PEM soils were silt loam and muck types with deep organic material formed from accumulated detritus masses of decayed persistent vegetation material. These HGM characteristics remain throughout the CRE on select tributary fan, tributary floodplain, and some minor channel vertical accretion sites. The key to restoring PEM will be providing and sustaining semipermanent water regimes on the appropriate geomorphic surfaces.

Wet Meadow

Wet meadow was a transitional habitat type between PEM and forested communities. These sites were dominated by sedges, rushes, and graminoids and had semipermanent to seasonal flooding regimes during late spring and early summer. Wet meadows typically were on similar geomorphic surfaces and had similar soils to PEM, except that wet meadow also was found on relict glacial stream channels but seldom on tributary fans. The most appropriate sites for restoration and maintenance of wet meadow habitats in the CRE are on glacial stream channel, tributary floodplain, and some minor channel vertical accretion sites where silt loam and loam-muck soils are present, and water regimes are seasonal with spring-early summer flooding. A challenge for restoration of native species composition in wet meadows will be maintaining a seasonal spring-dominated water regime and controlling invasion of reed canary grass. Future studies of reed canary grass should map its extent and determine overlap with the HGM-predicted wet meadow community to understand distributional issues and more effectively target control measures.

Prairie and Savanna

Prairie and savanna occupied large areas of the Presettlement CRE on glacial terraces and glacial stream scarps. These sites had sandy loam soils and were above the 5-10 year growing seasonal flood frequency elevation. The highest elevations on the middles of these terraces and scarps were apparently almost solely grass and forb dominated mesic prairie, while slightly lower elevations and sites adjoining more upland areas, such as colluvial slopes, contained significant amounts of scattered northern red and northern pin oak that formed an oak-savanna. Some bottomland prairie dominated by prairie cordgrass and annual and perennial herbaceous vegetation also was present in the CRE, especially in relict glacial stream channels. These bottomland prairies often are included in wet meadow communities in vegetation classifications and this study did not attempt to separate the two communities. The more appropriate sites for restoration of prairie and savanna in the CRE today are the relict glacial terraces that have not become small islands in lower impounded portions of navigation pools. Edges of these terraces, especially where they adjoin colluvial slopes seem appropriate sites to try and establish savanna. Keys to restoring prairie and savanna will be restoring native species, providing regular disturbance from fire, or possibly grazing, and selecting sites high enough in elevation to prevent regular inundation at < 5 year frequencies.

Riverfront Forest

Riverfront forest is comprised of early succession, pioneering, tree species that are adapted to, and can tolerate regular scouring and deposition of coarse-grained river sediments. Typical riverfront forest species are willow, silver maple, cottonwood, and river birch with some shrubs, but little herbaceous ground cover. Presettlement sites in the CRE that contained riverfront forest were main channel islands and main and minor channel lateral accretion surfaces. These sites contained sandy-silt soils and were flooded annually, often several times during high flow events. Regeneration of riverfront forest species required newly scoured or deposited sandy surfaces where wind-blown seeds could settle and germinate/grow in full sunlight and non-plant competition environments. Many riverfront forest areas remain in the CRE, but most have shifted to nearly monocultures of silver maple and willow. Wind and wave action in lower parts of navigation pools often prohibits establishment of riverfront forest, mainly because the island is actively being eroded and eliminated. Some larger islands retain the capability to sustain riverfront forest, but generally the active process of repetitive scouring and deposition on lateral accretion and island surfaces is now absent or greatly reduced because alternating high flow flood events with scouring action and alternating low flow periods when cottonwood and sycamore can become established are absent or greatly attenuated by water management of navigation pools. Riverfront forest can be restored on lateral accretion surfaces and some larger islands, but restoring a greater diversity, especially regeneration of cottonwood probably will require more intensive management to provide regularly scoured and/or deposited sandy materials on these sites.

Floodplain Forest

Floodplain forest was historically present throughout the CRE and provided important resources to many animal species and also contributed vital functions and values to the entire UMRS ecosystem. This community occupied several geomorphic surfaces where silt loam and silt clay soils were present and flooding regimes were > 2-year growing seasonal flood frequency and with extended drying periods during summer and early fall. The diversity of species in floodplain forest was maintained by slight elevation and hydrology differences and the periodic drying of the sites. This study mapped the variation in floodplain forest related to whether it occurred on minor channel lateral accretion sites (ridge-and-swale forest) vs. vertical accretion, tributary fan and tributary meander belts and scarps (floodplain forest) (Appendices P, Q). Floodplain forests have been highly destroyed in the CRE because of wetter water regimes caused by navigation pool management and remnant forests now generally are small, highly fragmented, reduced species diversity and with wetter-type species, and suspect to disease (e.g., Dutch elm and emerald ash borer mortality of elm and ash trees). Restoration of floodplain forest should target appropriate higher elevation sites on tributary fans/deltas, tributary stream scarps, tributary meander belt natural levees, main and minor channel vertical accretion, and select low swale sites in minor channel vertical accretion geomorphic surfaces. These restoration sites must have silt loam and silt clay soils and be at elevations where regular summer-early fall drying can occur. The species composition of restored floodplain forests probably will continue to be dominated by slightly more water tolerant species such as American elm, green ash, box elder, and interspersed cottonwood, river birch, and willow. Swamp white oak historically was present in higher elevations of floodplain forest areas in the CRE; its distribution appears to have been restricted to elevations with > 2-5 year growing season flood frequency and regular extended periods of drying in summer. Consequently, restoring and expanding swamp white oak in floodplain forests in the CRE will need to carefully evaluate elevations and flooding regimes and target plantings of these species to the very highest elevations in former floodplain forest locations/geomorphic surfaces.

Slope Forest

Slope forest contains an interesting mixture of tree species from both floodplain and upland communities on colluvial slope geomorphic surfaces. Soils on these slopes are mixed erosion types with constituency dictated by the parent materials of the adjoining uplands and floodplain bluffs. These slopes seldom flooded during Presettlement periods. Currently, most colluvial slopes in the CRE are highly modified for urban/residential developments or agricultural uses. Restoration of slope forest on these colluvial slopes is possible wherever conversion back to non-developed or non-agricultural use can occur and flood regimes are greater than 10-year growing season flood frequency.

Areas of Less Certain Community Distribution

Four areas in the CRE have potential community restoration that was not predicted well by the HGM matrix provided in Table 1. Two of these areas are at the transition between tributary fan and adjoining geomorphic surfaces. The first area is in the Black River delta area in Pool 7. In this area geomorphic mapping identifies a sharp transition between tributary floodplain/marsh and tributary fan surfaces at the north end of the floodplain area covered in this report (Appendix B). Tributary fan surfaces can support both floodplain forest, PEM, and wet meadow habitats and indeed both habitats historically and currently were/are in this location (Table 1, Appendices O, P). In contrast, tributary floodplain/marsh surfaces in all other CRE sites support primarily PEM and wet meadow habitats and have little forest cover. However, in the Pool 7 area of the Black River Delta, this tributary floodplain/marsh surface has extensive floodplain forest present (Appendix O). Appendices P and Q identify PEM and wet meadow as the best potential community for this site using the Table 1 HGM matrix, however, it is recognized that extensive floodplain forest occurs here. The reason for the discrepancy in geomorphology-community correlation for this area is unknown, but it may be that the Black River tributary fan actually extends farther upstream in the Black River corridor than is currently mapped (e.g., Appendix B).

The second area where geomorphology-community correlation was weak is at the north end of the Root River tributary fan in Pool 8 (Appendix B). In this site, tributary fan transitions sharply into a minor channel vertical accretion surface. Historic and current habitats in the tributary fan site are well predicted by the HGM community matrix (Table 1, Appendices O, P, Q). In contrast, the minor channel vertical accretion surface historically and currently had/has extensive PEM and wet meadow communities present, but the HGM matrix predicts that the site should be predominantly floodplain forest. Floodplain forest is present in this area, but appears to be limited to the highest elevations, which corresponds to the HGM matrix of 2-5 year flood frequency. Detailed elevation information is needed in this site to confirm the community distributions related to flood frequency and restoration potential.

The third area where community-geomorphic surface correlations were complex was in the upper end of Pool 6 northwest of Winona. Termed the "Winona Flats" area, this location has a mixture of glacial terrace, minor channel vertical accretion, sloughs and lakes, and glacial stream channel surfaces. GLO maps indicate that prairie and perhaps some small edges of savanna were present on what is mapped as minor channel vertical accretion. This is the only area in the CRE where prairie ever is indicated on a surface other than glacial terrace. Glacial terraces in this area appear dissected by older glacial stream channels, sloughs and lakes, and minor channel vertical accretion surfaces. Consequently, the historic prairie distribution in this location may migrated onto the high elevations in non-terrace surfaces, or perhaps mapping of the glacial terrace should have extended farther into the currently mapped minor channel vertical accretion area. Regardless, more detailed soil, elevation, and hydrology information should be obtained before making restoration decisions for this area.

The fourth area where HGM matrix predictions of potential community restoration differs from current community distribution is on small remnant glacial terrace "islands" now present in impounded areas. These remnant glacial terraces formerly supported prairie and oak savanna, but impoundment inundated the lowest parts of the terraces and left only relatively small high elevation tops of the terrace exposed. Currently, these islands contain mostly riverfront forest although the HGM matrix mapping (Appendix P) indicates these have potential for prairie. Clearly, the soil and geomorphic surface is correct for prairie distribution, but regular inundation from waters above locks and dams has effectively converted these sites to main channel islands that can only support riverfront forest because of their size and inability to have regular vegetation disturbance from fire or grazing that formerly sustain prairie and savanna communities.

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 CRE. The HGM process helps address four basic questions that can 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. The four questions are:

1. What was the historic (Presettlement) 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 physical structure and ecological processes.

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 CRE make restoration decisions. At a broad landscape scale, this report identifies the historic types and distribution of communities in the CRE (e.g., Appendices L, M, Table 1), the current land cover (Appendix O) and the current suitability of areas for restoring community types (Appendices P, Q). This regional information can be used by conservation partners to understand which communities have been most lost in the CRE and where they may wish to work to restore basic parts of the CRE 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 elevations of 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 the HGM community matrix in this report (Table 1) can 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 cannot identify all of the physical or biological changes that have occurred at each site in the CRE, but it does describe the general types of landscape alterations that must be identified before decisions can be made about restoration options. The following sequence of questions may be helpful for determining the best restoration potential for specific CRE sites:

1. Ask what the historic community types were on the site. This is provided in Appendices L and M and in Table 1.

2. Ask what the physical and biological features of the community were and what the controlling biological mechanisms were. This is provided in the text description of communities and in Table 1.

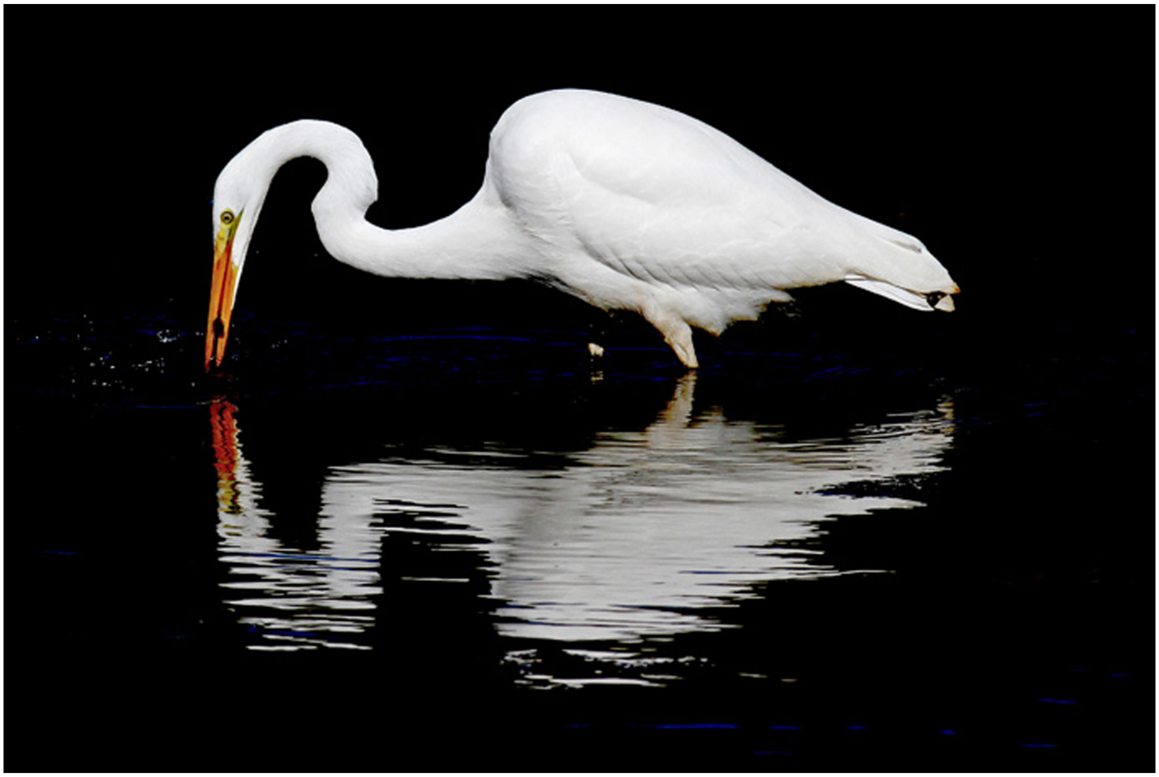
3. Ask what changes have occurred to the site. Some of this information is provided in Appendix O (where existing habitats are) and general information about ecological effects of various landscape changes is provided in tables, figures and text of the report. Obtaining information about detailed changes 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 and Q. In some areas, more than one community type may occur, such as in tributary fan, ridge-and-swale, and tributary floodplain areas. For these sites specific information will be required about elevation and flood frequency to determine the new desired state and detailed distribution of species within the site. For example, Tributary fans can support both floodplain forest and PEM/wet meadow

habitats. Sites on the fan that have elevations high enough to provide 2-5 year flood frequency hydrology will support floodplain forest, while lower elevations with more frequent and prolonged flooding will be suitable only for PEM or wet meadow.

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

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 CRE is the lack of site-specific flood frequency information and in some cases topographic information 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. Despite some gaps and uncertainties, this report provides the basic information and tools to plan regional conservation and restoration actions in the CRE 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.



Alan Stankevitz - FUMRR contest

MONITORING AND EVALUATION

The success of community, and ultimately partial, ecosystem restoration depends not only on the first requisite step of identifying the appropriate locations for restoration works in the contemporary or future planned CRE area, but also on regular monitoring and evaluation of ecosystem-wide and site-specific HGM attributes that will influence the suitability and sustainability of the area for such restoration. Also, undoubtedly, new and improved information hopefully will become available to refine and update the HGM matrix of community relationships (Table 1) and therefore the predictive success in identifying restoration sites for all community types.

This HGM report provides information about critical landscape attributes and processes that will need to be incorporated into restoration plans. Nonetheless, some uncertainty exists about the short- and long-term ecosystem effects of some current land and water uses. Consequently, future restoration efforts that incorporate recommendations in this report should be done in an adaptive management framework where: 1) predictions about community restoration are made (e.g., oak reestablishment will occur primarily on silty-clay soils in vertical accretion and terrace edge surfaces) and then 2) follow-up systematic monitoring and evaluation are implemented to measure ecosystem responses to various management actions and to suggest future changes or strategies based on the monitoring data. Specific ecosystem attributes that require additional investigation and monitoring/evaluation are provided below:

NAVIGATION POOLS

Monitoring surface water levels in CRE navigation pools is conducted daily, and extensive analyses of stage-discharge relationships have been conducted for select pool locations (e.g., U.S. Geological Survey 1999). Additional hydrological analyses likely will be needed for site-specific planning and if pool water management or infrastructure changes are made. For example, certain Habitat Rehabilitation Enhancement Project developments have the potential to change water depth, duration, and timing for some pool areas (e.g., Heitmeyer et al. 2009a). In addition to surface water monitoring, more data are needed about subsurface/groundwater levels in non-impounded areas. For example, the success of restoring floodplain forest will depend on having sites with regular summer-early fall drying windows that dewater soil surfaces and the upper parts of tree root zones. These groundwater data also are important for understanding species composition, and invasive species expansion, in other habitats especially wet meadow sites that are subject to reed canary grass invasion. Water quality measurements also are needed for restoration sites, especially siltation and contamination levels.

LONG TERM VEGETATION CHANGES

Considerable evidence indicates that remnant native terrestrial vegetation communities in the CRE are continuing to have long-term changes in species composition. Unfortunately, for some communities, the trend is toward less diversity and more monotypic stands of more water tolerant species. Also, as indicated, invasive and exotic plant species now have expanded in some habitats and locations. Continued monitoring and systematic inventory of remnant, and future restored, communities is needed to determine sustainability of community diversity and historic composition and the resource functions and values provided by this diversity. This information also will feed-back into understanding of HGM-community relationships and refine definition of the best potential restoration sites and management actions that will be needed to restore and maintain the ecological processes that sustain the community and entire CRE ecosystem.

RESTORATION TECHNIQUES

Restoration of CRE community types likely will occur using many techniques, both site-specific and more systemic. For example, restoration of floodplain forest could use direct seeding, planting bare root or root-production method (RPM) stock, and/or natural seed rain and restocking from adjacent forests. Also, forest restoration might use weed or animal control to reduce competition or browsing on seedlings. And, some topographic or hydrological modification might be used to change flooding duration and timing and soil surface suitability. Restoration of other communities also likely will require multiple approaches and techniques that will require monitoring to determine the efficiency and effectiveness of the technique in relation to cost-benefits, desired results, and public expectations.

Gloria Pollena - FUMRR contest

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Frank Nelson - MDC

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