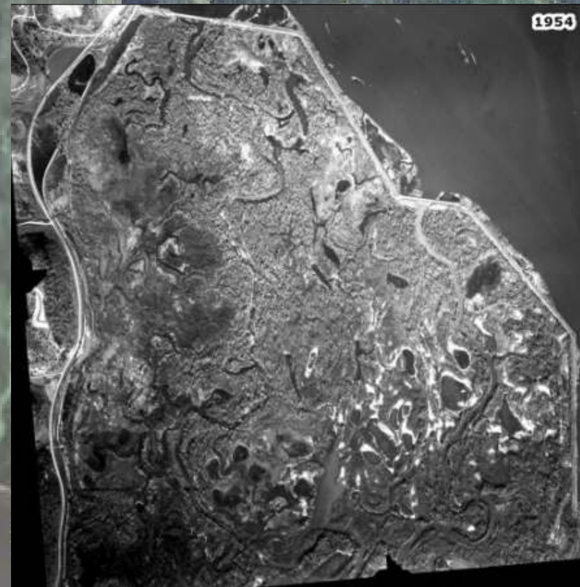

SUMMARY OF A HYDROGEOMORPHIC (HGM) WORKSHOP FOR THE
RENO BOTTOMS AREA OF POOL 9 UPPER MISSISSIPPI RIVER SYSTEM

28–29 SEPTEMBER, 2009

AND POST-WORKSHOP EVALUATION OF POTENTIAL WATER/FOREST PROJECT OPTIONS

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Introduction and Workshop Agenda

A workshop was held in New Albin, IA on 28-29 September, 2009 to develop a hydrogeomorphic (HGM) evaluation of ecosystem restoration and management options for the Reno Bottoms area of Pool 9 of the Mississippi River including possible physical and water management alterations to the Pool 8 Embankment and other Reno Bottoms locations. The purpose of the workshop was to assemble HGM data on geology/geomorphology, soils, topography, hydrology, historic and contemporary land cover, animal communities, and past management of the area. Presentation of this information allowed workshop participants from cooperating resource agencies to better understand how HGM data assists evaluation of the historical and current condition of floodplain landscapes and helps managers of the Reno Bottoms area in evaluating options for future management. A list of attendees and the agenda for the workshop are presented in Appendices A1 and A2.

Key Management issues for Reno Bottoms

The Reno Bottoms area includes over 4,000 acres of floodplain between Mississippi River miles 671 and 681 (Appendix A3). This area is the far northwest part of Pool 9 and is bordered on the north end by the Pool 8 Lock and Dam Embankment (LD8 Embankment). After closure of Lock and Dams 8 and 9, the Reno Bottoms area has been altered by changed hydrology that has gradually shifted the ecological attributes and composition of primary floodplain communities in the area. Historically, this area contained extensive floodplain forest interspersed with numerous sloughs and side channels of the Mississippi River and tributaries including Winnebago Creek and the Upper Iowa River.

Two resource enhancement projects have been proposed for Reno Bottoms under the U.S. Army Corps of Engineers (USACE) Navigation and Ecosystem Sustainability Program (NESP). The Reno Bottoms Forest Restoration Project seeks to enhance forest communities on up to 1,112 acres within the Pool Slough Closed Area of the Upper Mississippi River National Wildlife Refuge by reforesting lands formerly cleared for agriculture, enhancing natural topographic features of the floodplain, improving health and composition of existing forest, and controlling invasive plants, especially reed canary grass. The most intensive reforestation would occur on a 150 acre tract immediately north of New Albin, IA. A second proposed ecosystem enhancement project would potentially modify water flow through the LD8 Embankment and modify specific drainage systems in the Reno Bottoms area. This project would seek to improve river flow conveyance through the LD8 Embankment, improve downstream habitat in secondary and tertiary channels, and protect off-channel areas, especially forest communities, from further degradation.

Specific management/ecosystem concerns for the Reno Bottoms area include:

- Extensive mortality and reduced health, diversity, and areal coverage of floodplain forest
- Gradual shifting of floodplain communities to wetter types, with large expansion of aquatic-type communities

- Siltation, and other obstructions in sloughs and drainages, that are altering drainage, water pathways, and bathymetry capacity
- Enlargement and head cutting of main side channels into the Reno Bottoms area below Twin Islands
- Generally altered seasonal and long-term hydrology of the region
- Channelization of Winnebago Creek and the Upper Iowa River
- Potential loss of deep-water overwintering habitat for fish
- Expansion of invasive plant species, especially reed canary grass
- Potential invasion of the region by Emerald ash borer

Despite concerns, the Reno Bottoms area still retains one of the more extensive areas of floodplain forest, and diverse, interspersed floodplain vegetation communities in the Upper Mississippi River System of Pools 5-9. This area traditionally has retained abundant fish and wildlife populations and certain floodplain ecological processes and functions. Consequently, any potential modifications to the region must be carefully considered to provide enhancements without further degrading the site.

Settlement History

Kristin Moe provided a brief history of settlement in the Reno Bottoms area (Appendix A4). The region was occupied by several tribes of native people until the early 1800s; these people used the area for hunting and fishing and built encampments on higher elevation ridges and edges of the floodplain. Steamboats began traveling the Upper Mississippi River near Reno in the 1820s and the first European settlers arrived in the area in 1847. The early settlement of Jefferson was built on the banks of Minnesota Slough and paddle-wheel boats traversed the slough to the harbor at Jefferson. Early commerce in the area was cutting lumber to fuel steamboats and for railroad ties and dimensional lumber. Most of the Reno Bottoms area was low “swampy” alluvium and only the highest elevations on the edge of the floodplain were farmed. The first farm site appears to have been a historic prairie or wet meadow site immediately north of New Albin. Additional settlement occurred in the area from the mid 1800s to the 1870s, when the Chicago, Dubuque and Minnesota railroad was built in the region.

Geology/Geomorphology

The Mississippi River ecosystem at Reno Bottoms was formed primarily by fluvial and climate dynamics from the late Wisconsin glacial period to the present. The geomorphology and sedimentology of the area were main “drivers” of the contemporary landscape form, alluvial architecture, and environmental history. Key geomorphic features (Appendices A5, A6) of the site were:

- Evidence of river migrations over time that left old abandoned course/channel (AC) in west-central part of Reno
- Large tributary fan where the Upper Iowa River enters Mississippi River floodplain
- Alluvial fans on edges of floodplain
- Evidence of remnant, higher elevation, point bar on east side of Reno

- Some old remnant ridges (of old channel migrations/scrolls) in main part of Reno Bend
- Sediment “plug” and vertical accretion in top (north) end of an old AC
- Natural levee on old Raft Channel course kept Miss River water from flowing into and through Reno Bottoms, except during high flow events – one larger connected drainage system was Bluff Slough along the NW side of Reno, which apparently conveyed some flow at least during high flow periods
- Largest water entry into Reno was from backwater flow via Minnesota Slough, and other minor sloughs, from the south end
- Some sloughs were forming across the remnant point bar, however these sloughs were probably minor

Soils

The first soil map of Reno Bottoms prepared in 1929 classified all soils in the area as “Meadow” type (Appendix A7). The term “Meadow” was used to designate lands in the Mississippi River floodplain that was comprised of recently deposited alluvium. Most soils were silt-loam or silty-clay, with Sarpy fine sand present in many higher ridge areas. More recent soil maps in Minnesota and Iowa (Appendix A8) indicate most soils were Comfrey silty clay loams and Caneek Silt loams on remnant point bar and higher elevation areas, Shiloh silty clays in lower elevation abandoned channel areas, and mixed erosion silt loams on tributary and alluvial fans. Some sand inclusions occur on older point bar ridges.

Elevation/Topography

Topography in Reno Bottoms reflects the geomorphic history of the site (Appendices A9, A10). Key elevation features of the site include:

- Most elevations range from 620-635’ above mean sea level (amsl)
- Highest elevation on alluvial and tributary fans, natural levees, and old point bar ridges
- Evidence of deeper depressions in several areas of the bottoms
- Predominant channels of Pickerel, Running, Bluff, and Minnesota sloughs

Hydrology

Hydrographs of the Mississippi River near Reno Bottoms from the early 1930s to the present (Appendices A11-A13) indicate a strong seasonal pattern of high flows, and subsequent overbank or backwater flooding into the area from April to July each year. Also, regular long-term dynamics of high flows, and more prolonged inundation of the floodplain apparently occurred about every 10-15 years with interval low flow years between peak high flow periods. The Mississippi River discharge at McGregor, IA indicates a gradual increase over time, suggesting the system in becoming wetter (Appendix A11). Stage-discharge curves for the region indicate current water levels, compared to pre-Lock and Dam periods, are higher during the low flow part of the hydrograph and conversely lower during the high flow part of the hydrograph (Appendix A14). Discrepancies in stage relationships appear strongest at the Running-Pickerel Slough confluence area and at the Hastings Spillway. Other important aspects of hydrology in the region include:

- Maybe evidence of even longer cycles, i.e. dry in 30s, wet in 90s, etc.
- Primarily backwater entry through Minnesota Slough system
- Headwater flooding over old Raft channel natural levee during high flow events
- Apparently many seeps/artesian upwelling from edges of floodplain
- High water tables likely, but seasonal declines in potentimetric surfaces
- Labyrinth pattern of water flow through the old abandoned channel (Appendix A10)
- Occasional dry windows that allowed tree germination and regeneration

Historic Vegetation Communities

Many old maps and surveys in the Reno Bottoms area indicate historic vegetation/aquatic community composition and distribution of the area and subsequent changes to this ecosystem (Appendices A15-A21). General Land Office surveys conducted in 1854 provide important spatially referenced documentation of major plant communities (Appendices A16 and A22) and the Mississippi River Commission maps of 1890 (Appendices A18 and A23) also indicate historical communities and changes that were occurring at that time. Collective data suggest:

- Reno Bottoms was primarily forested, with most forest on: 1) remnant point bar, 2) vertical accretion in north end AC plug area, 3) ridges from old channel migrations, 4) natural levees.
- Maybe some prairie on highest “terrace-type” tributary fan area
- Probably a small savanna at the above prairie-forest transition
- A narrow band of shrub/scrub (S/S) habitat occurred along sloughs where forest transitions into marsh
- Marsh-type vegetation communities in low areas-probably a mix of emergent-herbaceous-bottomland prairie-wet meadow communities
- Forest required dry windows during summer and fall periods for germination and survival of seedlings
- S/S required seasonal drying-late summer
- Prairie required some disturbance, maybe fire, on some recurrence interval
- Marshes require seasonal drying, or at least regular annual dry periods

A HGM "Matrix" of potential historic habitat community distribution related to geomorphic, soil, elevation, and flood frequency conditions, shown below, was developed from information gathered in the workshop.

Habitat type	Geomorphology	Soils	Elevation	Flood Frequency
Open Water/aquatic	Deeper sloughs, Side channels, chutes	Clay	< 620	Annual-permanent
Shrub/scrub	Edges of sloughs/ chutes	Clay	620-620.5	Annual semi-permanent
Herbaceous/ Emergent marsh	Abandoned channel Swales in point bar	Silt-clay	620.5-622	Annual semi-permanent
Wet meadow	Abandoned channel, Low elevations on tributary fan	silt-clay and silt loam	622-623	Annual seasonally flooded
Floodplain forest	Remnant point bar, Natural levee, ridges, Alluvial and tributary fans	silty loam and	>623	2-5 year
Prairie	High elevation tributary fans	loam	> 628	> 5 year

Vegetation communities began rapidly shifting to "wetter-type" communities following construction of Locks and Dams, but large shifts apparently did not become apparent until the 1970s. By the 1980s, large areas of floodplain forest had died and were replaced by "marsh-type" communities of herbaceous and robust emergent plants (Appendix A24). By 2000, the area of deeper, more permanent water had expanded further and created more extensive aquatic habitats. Forest area continued to decline, and marsh and wet meadow had correspondingly increased (Appendix A25). Remnant forest in the area in the 2000s also shifted to more water tolerant species, with extensive areas of silver maple and willow replacing formerly abundant elm, ash, and oak communities (Appendix A26).

Major Changes/Alterations to the System

Clearly, many changes have occurred in the Reno Bottoms ecosystem, especially since Locks and Dams were constructed and changed Mississippi River hydrology in the region. Critical changes include:

- Lock-and-Dam (LD) construction
- Pool 8 Embankment (LD8)
- Spillways and culverts in the LD8 Embankment
- Expanded side cuts with head cutting of channels
- Overall “wetter” condition, with more frequent, prolonged, growing season flooding and soil saturation
- Gradual shift in communities to wetter types that resulted in decreased forest and correspondingly increased marsh, wet meadow, and aquatic habitats.
- Declines in diversity of communities, at least in the forest component
- Sedimentation in some floodplain areas, including some slough channels and old depressions
- Basic shift in stage-discharge curve so that current the Reno area is wetter during the low-flow period and then conversely drier during the high-flow period. At some point in the middle of the curve, little change has occurred.

Workshop Breakout Groups

Following presentations and group discussion of HGM data sets, four breakout groups analyzed the information to answer the following questions:

1. What did the HGM data tell us about historic communities and ecosystem processes that created and sustained habitats at Reno Bottoms?

2. What are the major changes/constraints to sustaining or restoring historic communities/processes at present?

3. What are appropriate management goals/objectives for Reno Bottoms in the future?

4. What management, infrastructure, etc. will be required to restore parts of the Reno Bottoms ecosystem to meet goals stated in #3 above?

5. What major uncertainties remain about HGM data that would be helpful to understanding, and evaluating, potential changes listed under #4 above?

Breakout Group #1 (Scot Johnson, Valerie Green, Kristin Moe, Elliott Stefanik, Sharonne Baylor)

Breakout Group #1 described the historic Reno Bottoms ecosystem as:

- A heterogeneous geomorphology that included multiple Mississippi River channel movements, point bars on inside bends of channel migrations, sediment fans on floodplain edges and on the tributary fan where the Upper Iowa River entered the floodplain, sediment plugs in abandoned channel areas, and multiple sloughs/side channels
- Seasonally dynamic flooding of the floodplain and also evidence of long-term high and low flow periods
- Mainly backwater flooding into the area from the Minnesota Slough area
- Diverse floodplain forest dominated the site with interspersed wet meadow, herbaceous marsh, and aquatic habitat in lower elevations

Major changes to ecosystem were described as:

- Construction of Lock and Dams 8 and 9 and LD8 Embankment
- Rerouting of most Mississippi River flow through the main channel and less overbank and side channel flow
- Water management of pools
- Widening and deepening of side channels below Twin Islands
- Altered sediment transfer regime
- Channelization and levees of the Upper Iowa River and Winnebago Slough
- Reduced floodplain forest and less diverse forest community – corresponding increase in aquatic and marsh habitats
- Overall wetter condition of Reno Bottoms post-Lock and Dam construction

Important future goals and management needs were described as:

- Improve secondary channel habitat conditions
- Improve “backwater” flow pattern in the AC
- Reduce sediment or alter to restore natural deposition/scouring patterns
- Improve forest coverage area and diversity
- Improve river connectivity to the Reno area in more natural times and patterns
- Simulate seasonal historic hydrographs to a point

Primary actions to achieve goals were described as:

- Change water control on the upper end of the bottoms by carefully engineered changes to LD8 Embankment spillways and culverts

- Development of a water management plan for all ecosystem components in the Reno Bottoms area
- Select dredging of silted-in sloughs and side channels, especially in the southern end of the bottoms to improve topographic diversity, historic water flow, and overwintering habitat of fish
- Control of invasive plant species
- Regeneration of floodplain forest in appropriate elevation locations

Major uncertainties were:

- What type of water-control structures will be needed to create desired hydrographs and seasonal flooding/drying
- Silvicultural techniques to regenerate floodplain forest
- Current age and health of trees
- Length of time that is needed for drier conditions, both seasonal and long-term, to allow tree regeneration

Breakout Group #2 (Randy Urich, Ken Lubinski, Mark Anderson, Lisa Reid, Mike Griffin)

Breakout Group #2 described the HGM information as:

- Indication of predominance of floodplain forest present on tributary fans, point bars, ridges, natural levees, and the NW part of Reno Bottoms
- Minor prairie area north of New Albin
- Highly dynamic water regimes, both seasonally and long term
- Most flooding of area from spring/summer backwater flows in south end and occasionally headwater flow into area, across historic Raft Channel natural levee on north end
- Forests need a cyclic wet and dry hydrograph to survive and regenerate
- Importance of large Minnesota Slough and historic deeper channel

Primary changes to the system were described as:

- Lock and Dam construction and altered hydrology of the area
- Impounding action of LD8
- Increased sedimentation in Minnesota Slough and other chutes/sloughs such as Bluff Slough
- Decreased forest area and diversity and increased wetland area
- Increase in Upper Mississippi River discharge over the past 50 years

Primary future goals for the area were:

- Increase forest area and diversity
- Restore natural hydrographs as best possible
- Maintain high productivity of aquatic and herbaceous marsh habitats
- Evaluate potential to restore some minor prairie areas
- Improve variability/flexibility in water management capability

Important actions to achieve goals were described as:

- Increase water management capabilities in carefully engineered water-control structures in the LD8 Embankment and side channels
- Increase topographic integrity of natural levees and Mississippi River channel borders
- Plug side channel cuts across the historic point bar north of Twin Islands
- Design spillways in LD8 Embankment for 3-5 year flood event levels
- Design water entry through side channels south of Twin Islands at 8-10 year flow entry levels
- Evaluate dredging in the primary sloughs to create overwinter fish habitat, improve natural flow paths, and side-cast dredge material to create higher "ridge-type" elevations that could be reforested
- Emulate natural hydrographs so that periodic dry periods are provided in summer and fall
- Conduct all actions in a carefully staged adaptive management framework starting with LD8 Embankment and channel border actions

Major uncertainties included:

- Response of forest to drying periods
- Sediment levels and topographic alterations

Breakout Group #3 (Jeff Janvrin, Katie Manar, Kurt Brownell, Rebecca Soileau, Ben Vandermyde)

Breakout Group #3 described HGM data and historic conditions as important to understand:

- Heterogeneous distribution of flow channels
- Distribution of forest in higher elevation on point bars, NW corner, natural levees, alluvial and tributary fans

- Sedimentation in the head (north) end of the AC
- Historic sinuosity of the Mississippi River in Pools 7-9
- Primarily backwater flooding and high connectivity in the south end of the bottoms
- Deeper sloughs and more overwintering fish habitat in south end
- Restriction of wet meadow and marsh type habitats to deeper slough channel edges

Primary changes/constraints to the ecosystem were described as:

- Altered seasonal and long term hydrology of the site post Lock and Dam construction
- Perhaps alterations to groundwater influence on the system
- Higher flows/elevation flooding during historic dry periods of the hydrograph and conversely lower elevation flows in wet periods
- Railroad bed dissected historic path of Bluff Slough and disconnected it
- Sedimentation in many areas
- Perhaps increased beaver influence in damming and obstructing slough flows, especially in north end
- Reduced sediment dynamics throughout the system
- Infrequent high flow “bankfull” events in the system
- Increased presence of invasive plant species, especially reed canary grass
- General water management of Pools 8 and 9

Major goals for the area in the future were described as:

- Emulate natural hydrographs as much as possible
- Maintain current forest area and health and restore forest to appropriate high elevation areas
- Avoid negative impacts on fisheries and improve overwinter habitat in south end of the bottoms
- Evaluate habitat restoration opportunities throughout the region and determine which habitats area best suited for Reno Bottoms – do not attempt to restore all habitats everywhere

Important actions to achieve goals were:

- Redesign spillways on the LD8 Embankment to accommodate bankfull events
- Redesign culverts to operate only on high flow events
- Dredge silted-in sloughs and side-cast material to provide more high elevation ridge-type areas to be reforested
- Intensively manage invasive plants
- Partial fill and potential water-control structures on side channels along the historic point bar
- Restore and maintain fish overwintering sites south of Millstone Landing

- Deauthorize the Upper Iowa River Flood Control Project and restore historic channel areas by removing and breaching levees
- Active forest management and reforestation in appropriate elevations
- Restore land masses in the main Mississippi River channel
- Remove blockages in Bluff Slough and control beavers if necessary to restore natural flow paths of water, especially in the north end of the bottoms
- Staged project developments accompanied by active monitoring programs

Uncertainties were:

- Causation of past tree mortality
- Flowage easements
- Modeling of water dynamics if Bluff Slough flows were restored
- Effects of dredge material placement
- Age and current health of existing trees and identification of currently stressed sites
- More detailed soil information

Breakout Group #4 Tim Yager, Tim Loose, Charlie Deutsch, Jon Hendrickson, Jon Schultz)

Breakout Group #4 described major information items from the HGM information as:

- LD8 Embankment was built on a natural levee of a former Mississippi River channel (Raft Channel)
- Numerous migration paths of the Mississippi River created the Reno Bottoms landform including an older AC west of a point bar surface mostly north of Twin Islands – this AC is dominant low elevation surface in the central part of Reno Bottoms
- Closure of the old AC on the north end by sediment plugs created topography that caused most water to flow into the site from the south, via Minnesota Slough and other sloughs during backwater stage events. High stages crossed the old Mississippi River (Raft Channel) natural levee and through Bluff Slough
- Most of the higher elevations at Reno were forested – these forests required seasonal and long-term drying periods for the forest to liver and regenerate

Major changes/constraints to sustaining former communities and processes were:

- Lock and Dam construction and altered hydrographs: water cannot get below 620' elevation at present because of LD 9 pool operation
- Major influence of continual water flow through the LD8 Embankment culverts
- Sedimentation and blockage of internal sloughs
- Probable beaver influence on internal flow paths
- Inability to replicate historic hydrograph at present

- Reduction in forest area and diversity

Primary goals for the site should be:

- Restoration of more natural hydrographs, both seasonally and long term, especially providing periodic drying years to allow forest regeneration
- Restoration of floodplain forest communities to more historic distribution
- Enhancement of fish overwinter sites and movement corridors through sloughs, especially in the south end of the bottoms
- Control side channel deepening and head cutting
- Remove blockages to sloughs

Important actions were noted as:

- Close culverts in LD8 Embankment and redesign spillways to increase flows only during high flow events
- Evaluate at least partial closure, or water-control structures on side channels, especially south of Twin Islands
- Potential dredging in Minnesota Slough and reducing sedimentation in this area
- Restoration of flows in Bluff Slough
- Reforest high elevation sites if drying windows can be provided

Major uncertainties were:

- Length of time the site would need to dry to encourage natural reforestation
- Impacts of closing culverts in LD8 Embankment on hydrology and fish movement
-
- Impact of beaver on obstructing flow and reducing forest area in the NW part of the bottoms
- How to stage developments to understand effects

Following the Breakout Group presentations, the collective group discussed similarities and differences in group ideas. Generally, all groups identified the following items as desirable goals for the Reno Bottoms area:

1. Restore hydrology of the Reno Bottoms area to more closely emulate pre-Lock and Dam seasonal and long-term dynamics. This would include restoration of: 1) seasonal, 2) long-term, and 3) water source and flow (backwater-headwater) patterns. The intent of project developments should be to effectively “tilt” the stage-discharge curve back to pre-LD pattern.

2. Maintain and restore healthy and diverse floodplain forest communities in appropriate high elevation locations (assuming the hydrograph can reinstate seasonal and long-term drying periods sufficient for forest survival and regeneration).

3. Sustain productive herbaceous marsh, wet meadow, S/S, and aquatic communities in appropriate HGM-defined locations (again assuming more natural hydrographs can be restored).

4. Evaluate the potential to restore some limited prairie on the highest elevations on the Upper Iowa River tributary fan.

5. Improve slough systems to restore topographic and flow integrity under more natural hydrographs including provision of deeper water overwintering fish habitat.

6. Restore topographic integrity of Mississippi River channel borders and primary tributary channels and borders.

7. Ultimately develop a water/habitat management plan for the site to operate redesigned water-control structures.

8. Conduct all project developments in a carefully engineered, and temporally staged, pattern with accompanying "adaptive management" monitoring and evaluation.

Further, it was generally believed that the following restoration actions represented potential options to achieve goals:

1. At least seasonal (or complete) closure of culverts in LD8 Embankment and redesign spillways to increase flows only during high water (overbank) stages

2. Remove obstructions in all sloughs, especially Bluff Slough

3. Select dredging of sloughs to restore topographic diversity, flow capability, and overwinter fish habitat, especially in the south end of the bottoms

4. Restore the integrity/topography of Mississippi River channel borders along the historic remnant point bar

5. At least partial closure, and water-control structures, in side channels south of Twin Islands

6. Active management of invasive plants

7. Reforestation on higher elevations with direct seeding methods

8. Deauthorization of the Upper Iowa River Flood Control Project and removal or breaching of levees to restore floodplain connectivity and historic overbank flow patterns

9. Removal and breaching of levees along Winnebago Slough

Potential Impacts of Alternative Ecosystem Enhancement Projects in the Reno Bottoms area to Floodplain Forest (FF) Community Distribution

Three basic ecosystem enhancement project alternatives were analyzed to determine potential changes in water levels, and expansion of existing FF stands, at five total discharge levels and six locations in Reno Bottoms (Appendices A27, A28). The alternatives ranged from Aggressive to Minor measures to create drier conditions during low flow periods to stimulate reforestation of former FF areas. Under the Aggressive Alternative, the predicted water elevation changes assumed full closure of both side channels (Appendix A27) and no flow through the two LD8 Embankment spillways and culverts. In the Moderate Alternative, modeled outputs in water levels assumed closure of side channels, a small amount of water flow through the LD8 Embankment culverts and spillways at 20,000 cfs, and “current condition” flow through spillways at all higher discharges. For the Minor Alternative, full closure of side cuts was assumed, but flow through the spillways would be modified to more closely emulate the natural hydrograph. This could result in more flow through the spillway, relative to existing conditions, during periods of increased total river discharge.

Impacts of these alternatives on potential expansion of FF were analyzed by determining:

1. Historic distribution of FF and its relationship to water and floodplain surface elevation.

2. Current distribution of FF related to floodplain surface elevation.

3. Projected changes in flooding elevation under the three alternatives.

4. Potential expansion of FF to drier elevations as predicted by the alternative water level modeling.

Historic Distribution of FF

The HGM matrix prepared during this workshop (based on relationships with geomorphology, soils, topography, and hydrology) indicated that the historic distribution of FF (Appendix 23) essentially followed the >623 foot contour on natural levee, point bar, and alluvial/tributary fans (Appendix 29) except that some prairie was present in the southwest part of the region at > 628’ elevations on loamy tributary fans. Historically (pre-Lock and Dam), FF that extended to the ca. 623’ elevation contour had average annual seasonal drying to about 621’ (Appendix A14), or at least 2 feet below surface elevation.   Seasonal drying of > 2 feet of soil in FF sites was critical to allow root zones of FF species such as elm, ash, and oak to become dry and oxygenated during summer and early fall and also to provide seasonally dry sites for seed/acorn germination, seedling growth, and ultimately regeneration of this diverse forest community.

Current Distribution of FF

The current distribution of FF at Reno Bottoms generally follows the > 625' elevation contour (Appendix A30) except in the northwest part of the area, where FF has declined or died all the way up to the 627' elevation contour. Also, some FF extends to about 624' on the large point bar surface in the east-central part of Reno Bottoms. This current FF distribution is about two feet higher elevation than during pre-Lock and Dam periods. Interestingly, the current stage-discharge relationships at the Hastings Spillway and the confluence of Running and Pickerel Sloughs (Appendix A14) at the low discharge of 20,000 cfs are about 623', or approximately also 2 feet higher than pre-Lock and Dam periods. Apparently, current Pool 9 water management and flow through the LD8 Embankment have been responsible for shifting the FF distribution about two feet higher in most of Reno Bottoms. Causes of FF mortality and shifting of distribution up to four feet higher in the northwest part of Reno Bottoms is unknown. Possible causes of more prolonged surface inundation and/or soil saturation that caused greater tree mortality in the northwest area include constant flow of water through the LD8 Embankment culverts, disconnection and disruptions of flow in the historic Bluff Slough and other drainages in this area, blockages in some drainages from beaver, etc.

Projected changes in flooding elevations at low flows with different project alternatives

The three Reno Bottoms ecosystem enhancement project alternatives have modeled potential changes in water elevation at various discharges (Appendix A28). At the critical low flow discharge, where water elevation would be at its lowest point (and therefore determine the elevations where FF and its root zones could be seasonally dry), the Aggressive Alternative has the potential to lower stage by 1.4 to 2.7 feet north of Node 24835 (see Node locations on Appendix A27). South of this point the Aggressive Alternative has moderate (-0.5 feet) reduction in low flow water elevation at Node 20705 and relatively little change in water elevation south of that point. The Moderate and Minor alternatives have similar potential to lower stage at low flow by 0.7 to about 0.9 feet at Hastings Spillway and near the confluence of Running and Pickerel sloughs, but little change in surface water elevation elsewhere. All modeling and understanding of stage and flow patterns suggest most of the change in low flow elevation is caused by closure of Embankment spillways/culverts; closure of Side Channels further south in Reno Bottoms has minimal effects.

Potential Expansion of FF to Lower Elevations based on Project Alternative Models

The above ecosystem enhancement project alternative models generally suggest that the Aggressive Alternative might have the potential to lower water levels during low flow summer periods by up to two feet north of Running and Pickerel sloughs and thus encourage expansion of existing FF back to near the historic 623' elevation. However, current water management in Pool 9 generally cannot lower water levels below 622', which would be only one foot below the surface of potential FF restoration sites. If this minimum of two feet of dry FF root zone is critical for future reestablishment and sustainability of FF, then potential restoration of FF is probably limited to the > 624' elevation contour (Appendix A31). If this is true, then the Moderate Alternative may have some potential to move the current distribution of FF below the 625' elevation contour by about 0.5 feet, but the Minor alternative has little potential to change FF distribution. Overlays of the 624' and 625' contours on aerial photographs indicate possible areal extent of future FF distribution given project alternatives.

The potential expansion of FF to the 624-625' elevation contours, indicated above, may not occur in the northwest part of Reno Bottoms, given the uncertainty of why current FF distribution has been moved upward to about 627'. If the current nearly constant flow of water through the Pool 8 Embankment culverts is a causal factor in redistribution of FF to higher elevations in this area, then closure of these spillways/culverts under the Aggressive project alternative may be helpful to allow expansion of FF. However, if other factors such as drainage blockage, etc. are causing more prolonged water regimes in the northwest region, then they will need to be addressed (e.g., by restoring drainage flow capacity and connectivity) before restoration of FF to the 624-625' elevation contour can occur.

Little expansion of FF appears possible south of the confluence of Pickerel and Running sloughs under the current project alternatives. Further, most of the reduction in surface water elevation is attributable to closure of the LD8 Embankment culverts. Additional analyses probably are needed to determine the relative contributions of LD8 Embankment vs. side channel closures and/or other features. While closing side channels may not contribute much to the potential to expand FF distribution, these closures might have good potential to positively benefit other ecosystem attributes such as restoring more natural (i.e., pre-Lock and Dam) sediment deposition and scouring patterns, improving natural water flow patterns across and through Reno Bottoms, especially seasonal backflows through Minnesota and other southern sloughs, and providing overwinter fish habitat. These and other potential project features and benefits were identified by the Workshop work groups and are listed in the work group section of this report.

Acknowledgements

The HGM workshop for Reno Bottoms was conducted under Contract No. W912ES-07-D-0005, Task Order No. 0001, Hydrogeomorphic (HGM) modeling and analyses Upper Mississippi River System Floodplain: Pool 9 Reno Bottoms from the U.S. Army Corps of Engineers to HDR Engineering, Inc. and subcontract from HDR to Greenbrier Wetland Services. We sincerely thank the participants and their agencies for attending and supporting the workshop and for their provision of information and ideas.

Reno Bottoms Workshop Appendices

1. List of attendees, affiliation, and email addresses
2. Workshop agenda
3. FSA Orthophoto of Reno Bottoms, 2008
4. Settlement History of Reno Bottoms
5. Land Settlement Assemblages map
6. Approximate ages of geomorphic surfaces
7. 1929 Houston County, MN soil survey map
8. 2004 and 2006 soil maps for Minnesota and Iowa portions of Reno Bottoms, respectively
9. Digital elevation model of elevations
10. Bathymetry map of water depths
11. Average annual discharge of the Mississippi River at McGregor, IA 1930s to 2009
12. Stage levels of the Mississippi River at Brownsville, MN 1994-1998
13. Long-term water elevation dynamics, 1933-2003 for Pool 8 and Pool 9
14. Historic and current stage-discharge relationships for various locations, Pools 8 and 9
15. 1871 Houston County, MN plat map
16. 1854 U.S. Government Land Office maps
17. 1887-88 U.S Army Corps of Engineers Mackenzie maps
18. 1890 Mississippi River Commission maps for Reno Bottoms
19. 1930 Brown survey map
20. Aerial photograph of Reno Bottoms in 1929
21. Aerial photographs of Reno Bottoms in 1947 and 1954
22. Vegetation/habitat types recorded at section corners in the 1847-1907 GLO surveys
23. 1890 land cover transcribed from Mississippi River Commission maps
24. 1989 land cover maps
25. 2000 land cover maps
26. Dominant overstory tree species present in floodplain forest sites, 1990-2005
27. Map of sites used to model stage impacts from various ecosystem enhancement project alternatives
28. Model outputs of changes in water stage levels at various discharges under Aggressive, Moderate, and Minor Alternatives for ecosystem enhancement projects
29. Area on Reno Bottoms with ca. 623 feet elevation, mapped from LIDAR data, 2008
30. Area on Reno Bottoms with ca. 625 feet elevation, mapped from LIDAR data, 2008, overlain on current aerial photographs that identify floodplain forest distribution
31. Area on Reno Bottoms with ca. 624 and 625 feet elevations that represent approximate expansion area for floodplain forest under ecosystem enhancement project alternatives

Appendix 1. Participants in the Reno Bottoms HGM Workshop, September, 2009.

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Valiree Green – Minnesota DNR, valiree.green@state.mn.us
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Mickey Heitmeyer – Greenbrier Wetland Services, mheitmeyer@greenbrierwetland.com
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Appendix 2. Agenda for the HGM workshop of Reno Bottoms held 28-29 September, 2009, New Albin, IA.

September 28

10:00 Introduction and Overview (Stefanik and Urich)

10:10 Overview of NESP Reno Bottoms forestry and Lock and Dam 8 Embankment projects (Stefanik and Urich)

10:30 USFWS Upper Mississippi River NWR perspective on history and management goals for the Reno Bottoms area (Yager and Loose)

10:45 Overview of what HGM is (Heitmeyer

12:00 Lunch

12:30 Overview of existing hydraulic data for Reno Bottoms (Hendrickson)

1:00 Site visits to various locations in Reno Bottoms

September 29

8:00 Overview of existing data for use in the HGM analyses (Heitmeyer and Moe)

9:00 Presentation of potential alternatives for projects in the Reno Bottoms area (Stefanik)

9:30 Break-out groups to discuss HGM data and recommendations

12:00 Lunch

1:00 Presentations of break-out group discussions

2:00 General discussion of break-out group discussion of HGM applications and effects/impacts of various alternatives

0 0.25 0.5 1 Mile

Reno Bottoms 2008
Farm Service Agency Orthophoto

N

Settlement History of Reno Bottoms

Long before white settlement, both prehistoric Indians, and the later American Indian Sauk, Fox, Sioux, and Winnebago tribes used the site known as Reno Bottoms. It was the scene of many Indian battles previous to the establishment of a neutral zone by the United States government in 1824. Following the Black Hawk War, a conflict that ended in 1832 near present-day New Albin, the Sauk and Fox were forced to make their first land cessions west of the Mississippi. The tribes were ordered out of the area a year later. Regardless of the order, small bands of Winnebago and Dakota were noted in the area throughout the nineteenth century. Some trading did occur among white settlers and the Native Americans. The first log cabins in Houston County, MN, immediately north of present day New Albin, were built with the help of the Winnebago.

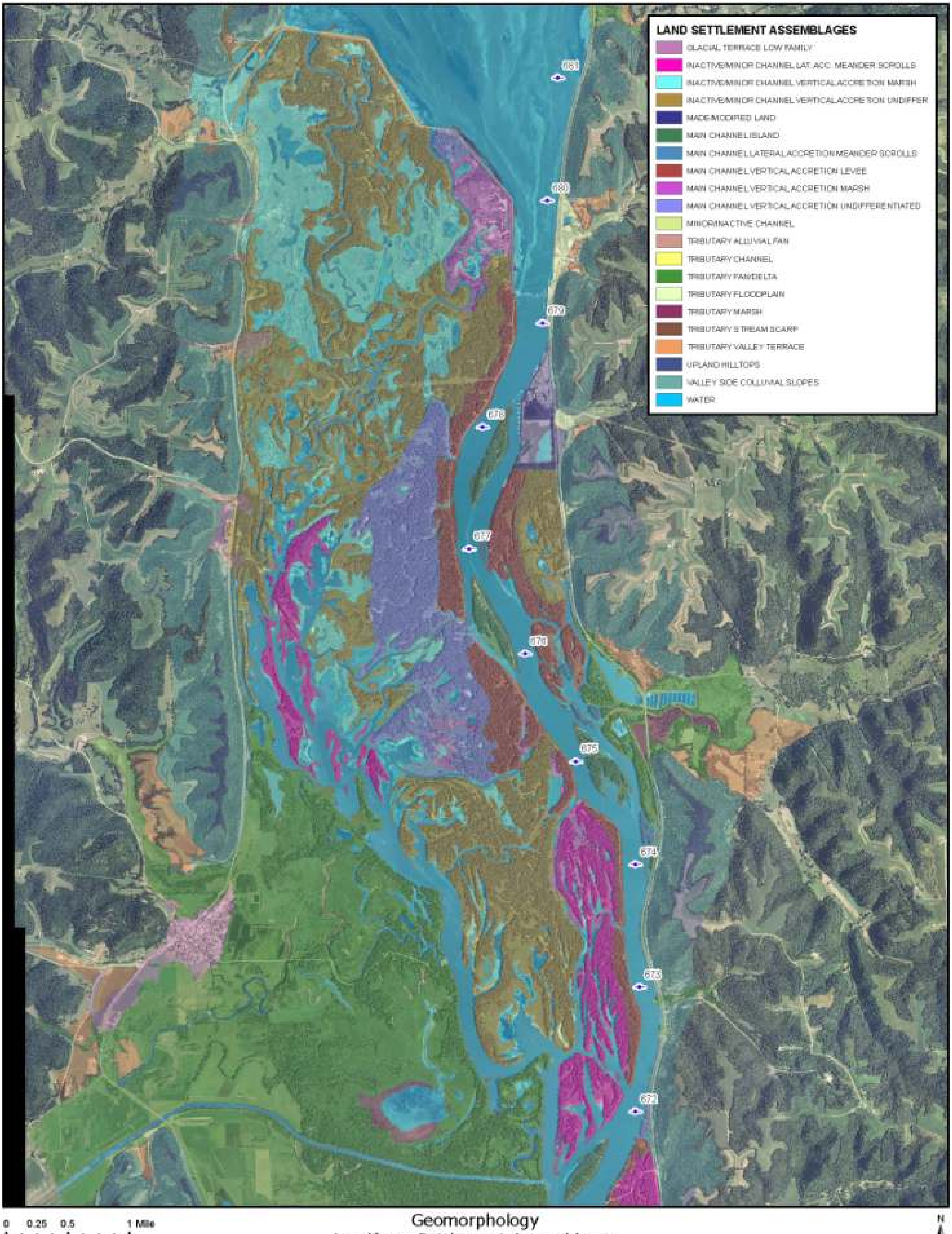
Steamboats began regularly running the Mississippi River, transporting army supplies to Fort Snelling, in 1823. In 1842, steamboats offered general freight transportation and passenger service. The first white settlers in the Reno Bottoms area were brothers John and Samuel Ross who arrived by steamboat from Galena in 1847. The Ross brothers were primarily involved in lumbering, running their timber to Galena and other points further south. They had two settlements, one in Minnesota and one in Iowa. The Minnesota site came to be known as Ross's Landing and later platted as the town of Jefferson. In 1868 a tavern, hotel, and grain warehouse were built in Jefferson along Minnesota Slough. The slough was deep enough for paddle wheelers to tie up along its banks. The town was a natural harbor and excellent fishing lured many settlers to stay in the area. The principal varieties of fish caught were sheeps head or white bass, buffalo, pickerel, pike, and enormous catfish.

Reno Bottoms was described by white settlers in 1871 as a "mass of swampy alluvium, a part of which has not been utilized for any purpose whatsoever." Land east of the Mississippi bluffs was marshy, and fit only for some varieties of timber and for hay. Timber was comprised of mostly oak with birch and maple. Some of the bottom lands along the river, where not timbered, held perennial crops and meadow hay. Despite these less than ideal conditions, plat maps and historic records show widespread settlement throughout Reno Bottoms from the bluffs east to the main channel. The majority of first settlers came to the broader area for the purpose of securing farms. In 1855, the first settler of Crooked Creek Township sold his first harvest of corn at the Brownsville market. His farm was located in the southeast corner of Crooked Creek Township, or immediately adjacent to the present day LD8 embankment.

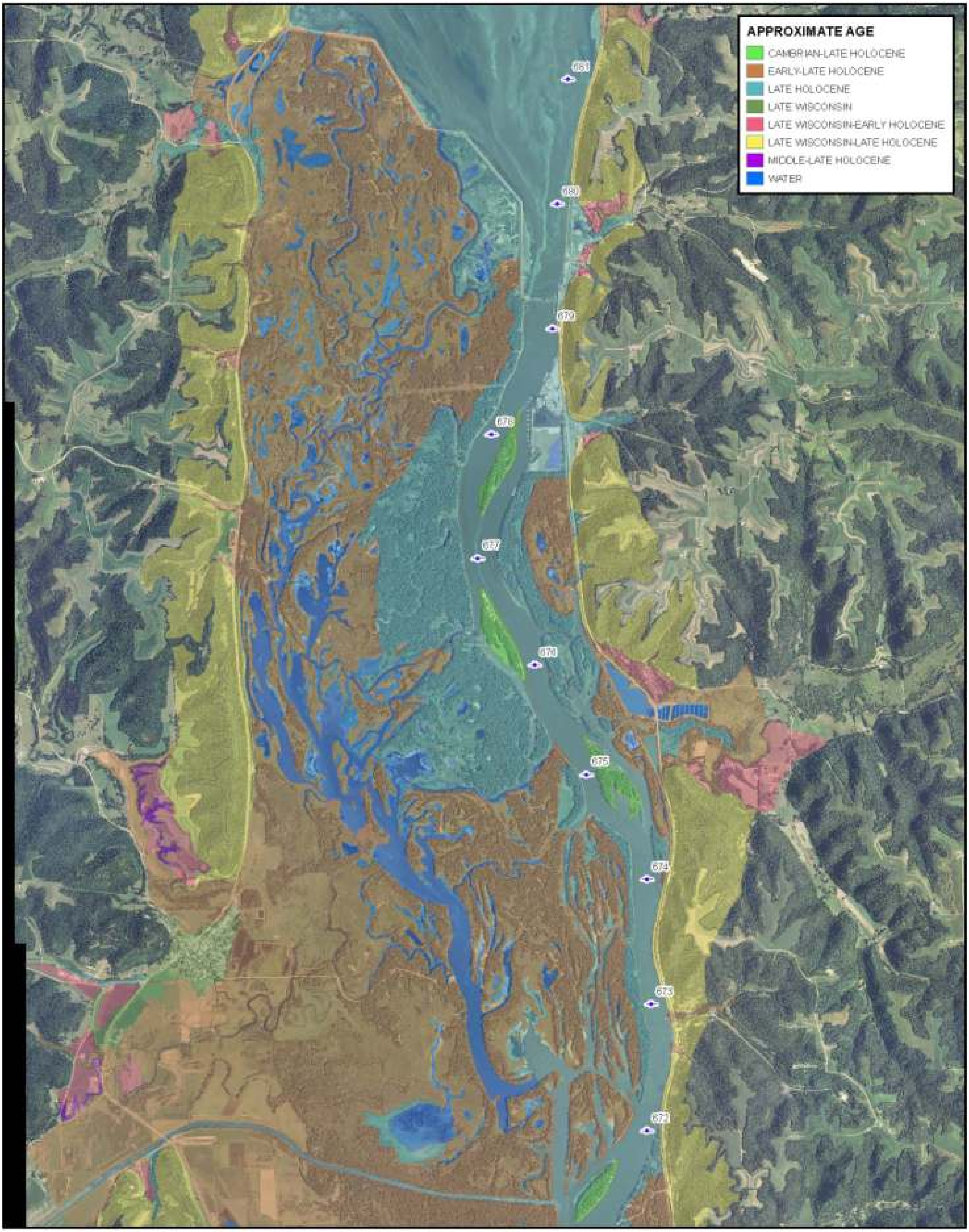
In 1872 the Chicago, Dubuque, and Minnesota railroad went through providing competition for the steamboats. The railroad platted the town of New Albin approximately one mile south of Jefferson in Iowa. A train station, grain storage facilities, and other buildings were constructed in New Albin. At this time, the area's number one cash crop was wheat. The town grew quickly as a grain-handling center and many residents moved there from Jefferson. The construction of the locks and dams in the 1930's cut Jefferson off from the river. Construction of Minnesota Highway 26 in the

1940's destroyed what was left of Jefferson except for the grain warehouse which still stands today.

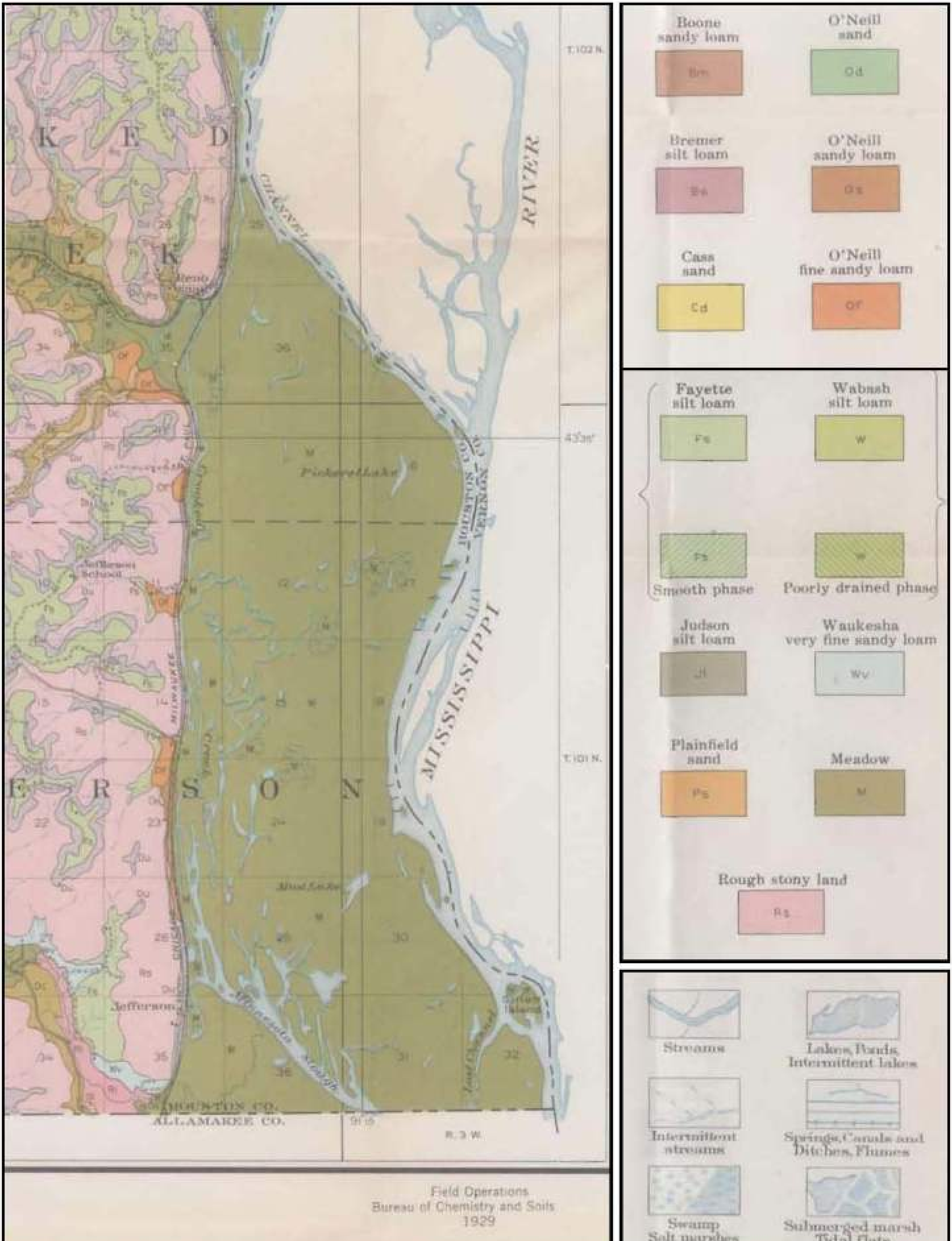
Caledonia Junction or Reno was located at the mouth of Crooked Creek on Minnesota Slough. It was the junction point of two branches of the Chicago, Milwaukee, and St. Paul Railway. Located here were several rail facilities, several dwellings, and a post office. The growth of Reno was inhibited by lack of space and extensive alluvial deposits nearby.



Geomorphology
Landform Settlement Assemblages



Geomorphology
Approximate Age



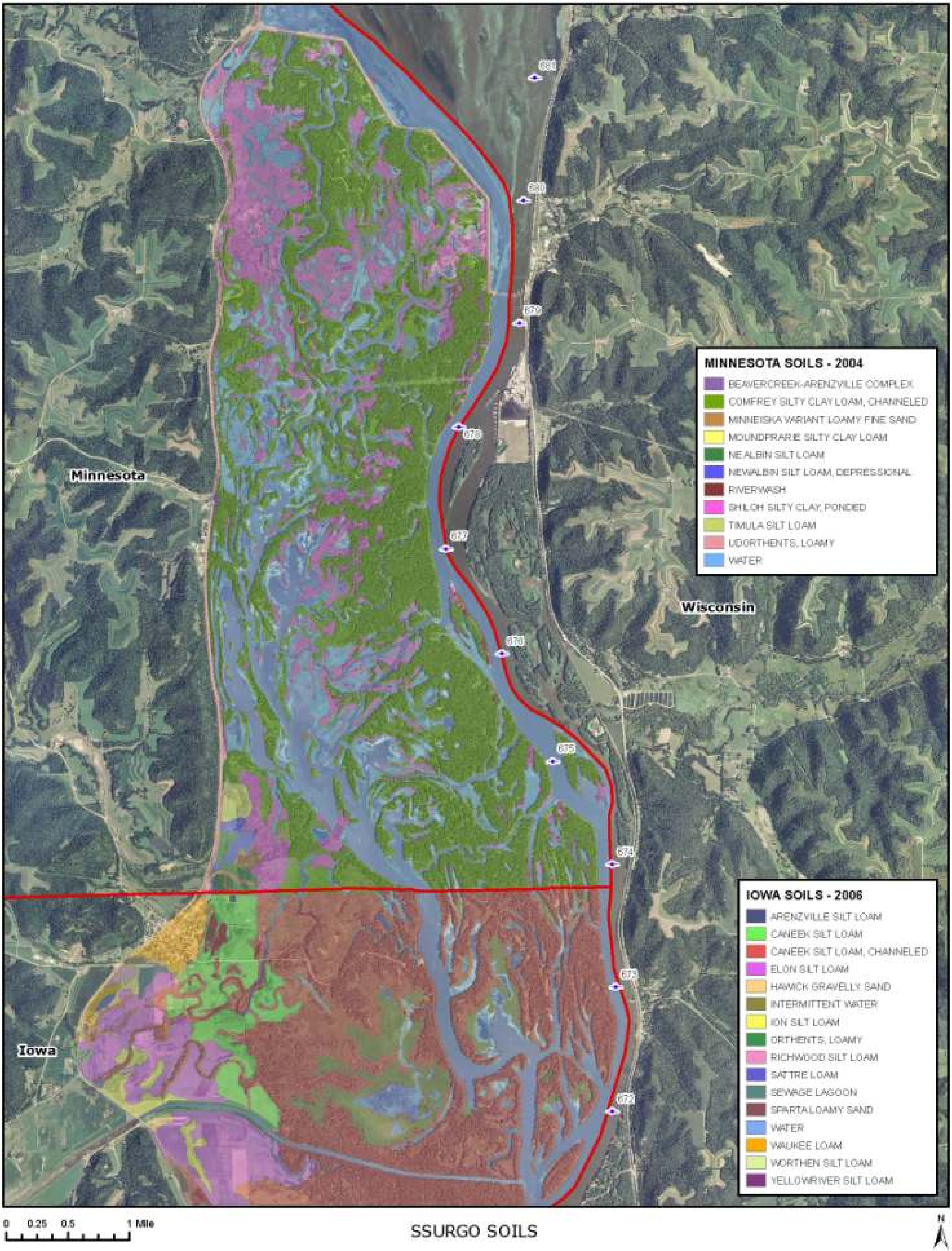
1929 Houston County Soil Survey

Meadow.—The term meadow is used to designate lands in the Mississippi bottoms, which differ widely in texture and composition. It consists not of a definite soil type but of a number of materials that make up recently deposited alluvium. Over some parts of the area the surface soil is changed or shifted with every rise of the river. In other places the material has been stationary a sufficient time to allow the development of small areas of soils similar to those in other creek and river bottoms, hence a few more or less well-developed areas of the typical bottom soils are included. In the greater part of the area, however, the alluvial deposits do not remain undisturbed long enough to develop a true soil and are constantly being modified or replaced by other materials.

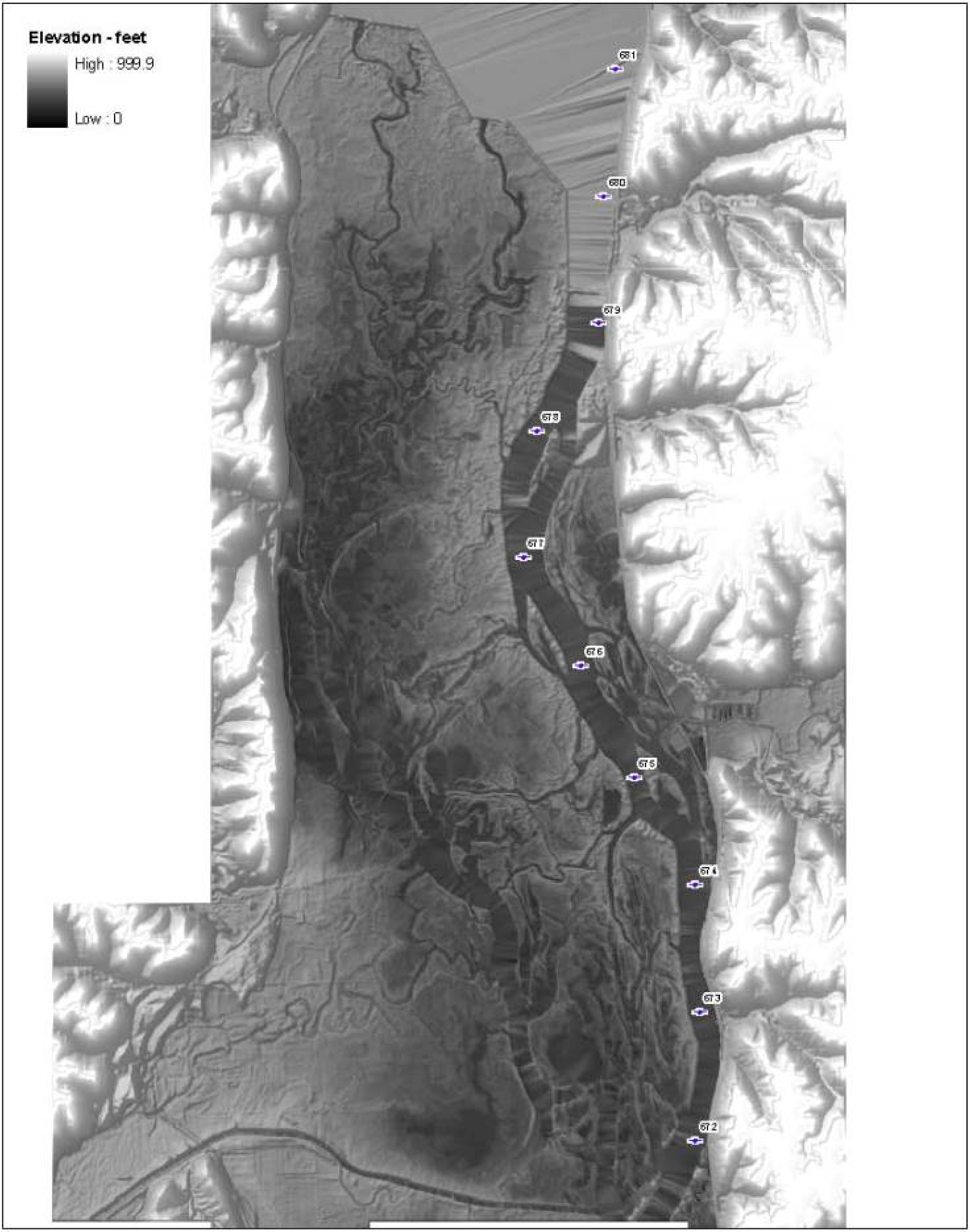
The bottoms are cut up by old channels and sloughs, with scattered areas of marshes. During overflows the water first finds its way through the old channels and sloughs, dumping the coarser sands first as it spreads out over the bottoms. Farther away in the quieter places the silt and clay are dropped, with scattered spots of sand. Old sloughs, cut-offs, and quiet backwaters have been filled with fine material, and old sand bars have been reworked and fine material mixed in, so that the areas bear little resemblance to any particular soil. In some of the lower places fairly typical Wabash silt loam has developed, in others Cass silt loam. Sarpy fine sand is present in many places but Sarpy silt loam only in spots. These soils occur all over the bottoms in small pocketlike bodies, narrow strips, and intricate meandering areas. A few areas of meadow lie along the lower ends of Crooked and Winnebago Creeks in the southeastern corner of the county. Here the valleys have been filled so recently that the soil is not uniform.

The Mississippi River bottoms in Houston County cover approximately 26 square miles, nearly all of which is classed as meadow. Very little of this land is used for cultivated crops, and wild hay is cut from most of that not in forest. A few fields of corn and one or two of oats are grown on the outer edge of the bottoms, at their juncture with the upland. In the bottoms proper, some distance from the upland, only one field of corn, including about 40 acres, was observed during the course of the survey. This was the only attempt being made to farm in the bottoms proper. Cattle are allowed to roam the bottoms, and they find very good grazing, particularly in the unforested areas. At one time large numbers of cattle were grazed, but very few are now pastured.

Until comparatively recently, attempts have been made to organize drainage districts to reclaim most of the bottoms for agriculture. These attempts have failed, owing to the uncertainty of success and to the fact that this area is included in the Federal Government's Mississippi River Fish and Game Refuge, for which large acreages have been and are to be bought by the Government. Without considering natural reasons, the expansion of these reservations will prevent most of this territory from being farmed.

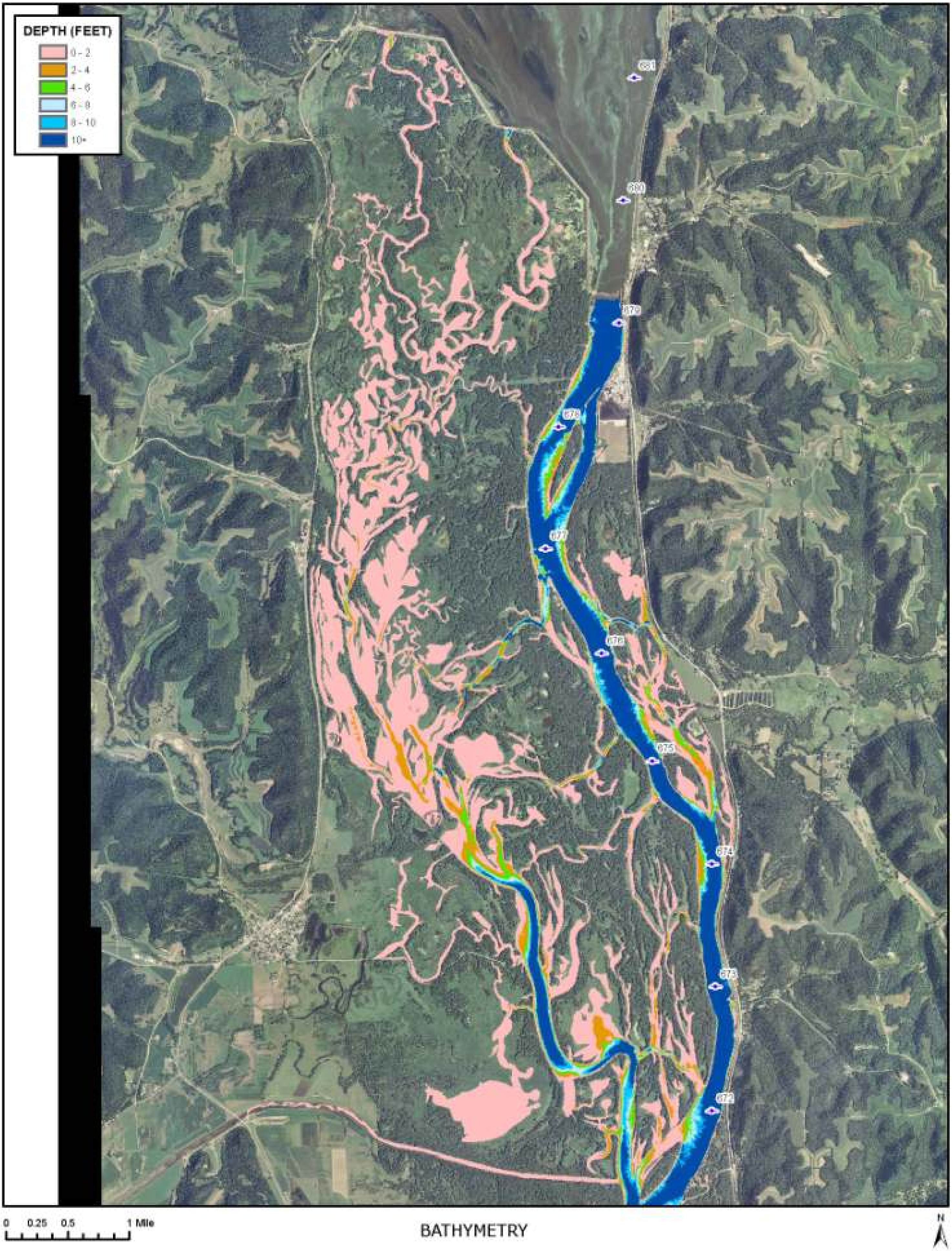


SSURGO SOILS



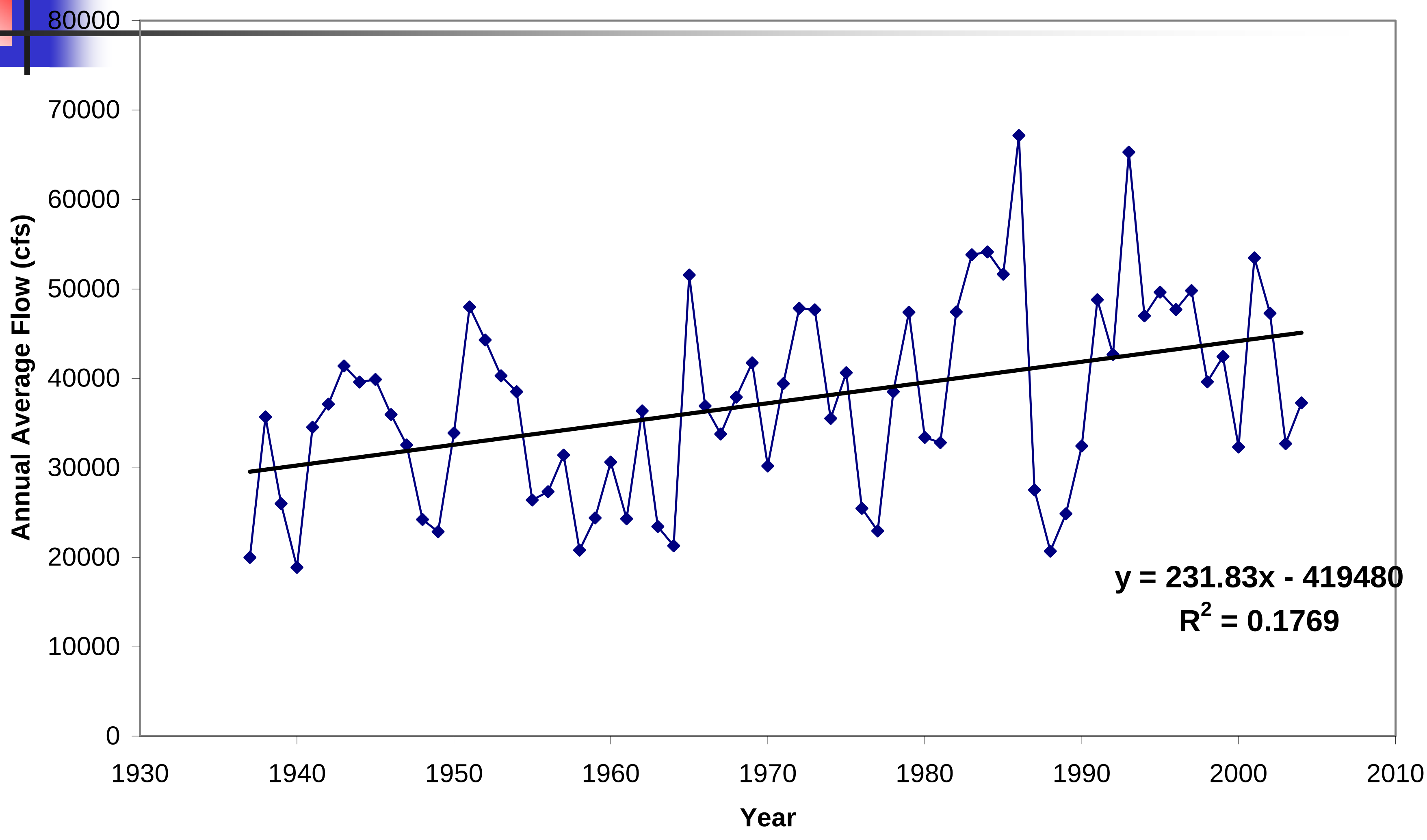
DEM developed from LiDAR data collected in 2007.

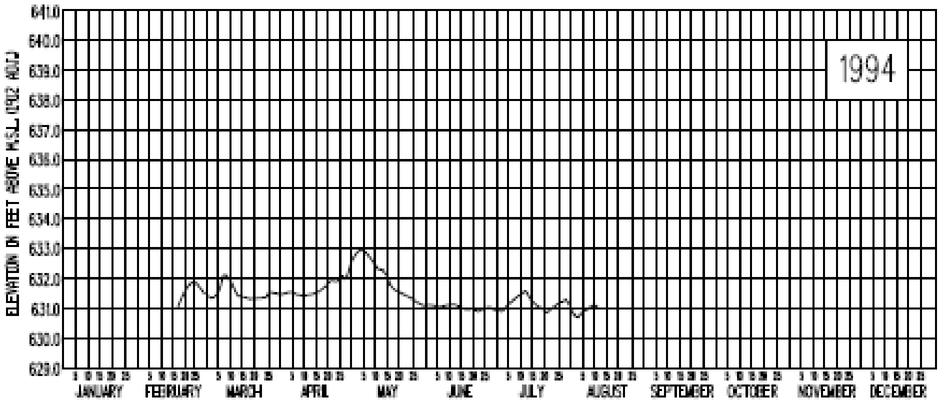
Reno Bottoms DEM

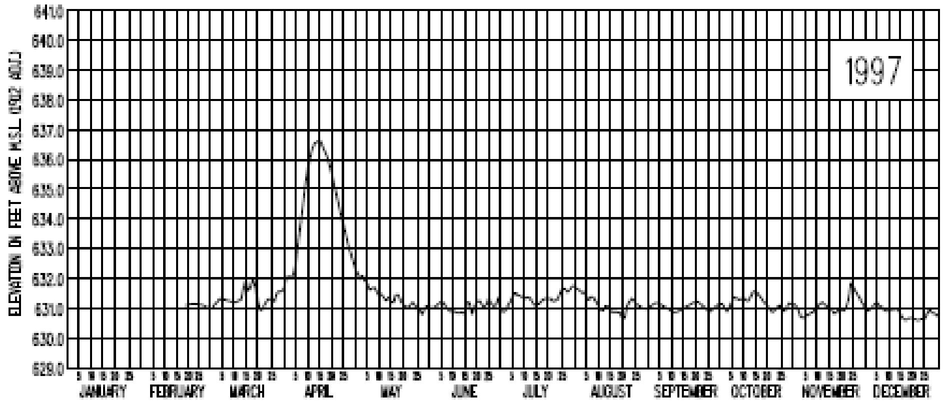

DEPTH (FEET)
0 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10+
681
680
679
678
677
676
675
674
673
672
0 0.25 0.5 1 Mile
N

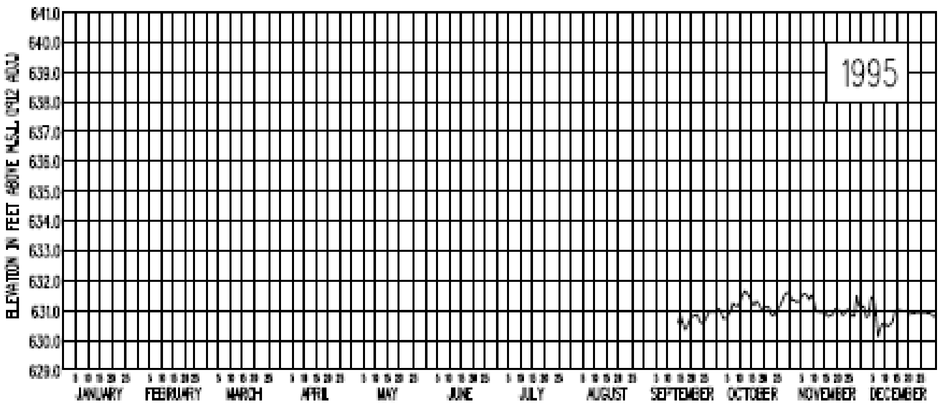
BATHYMETRY

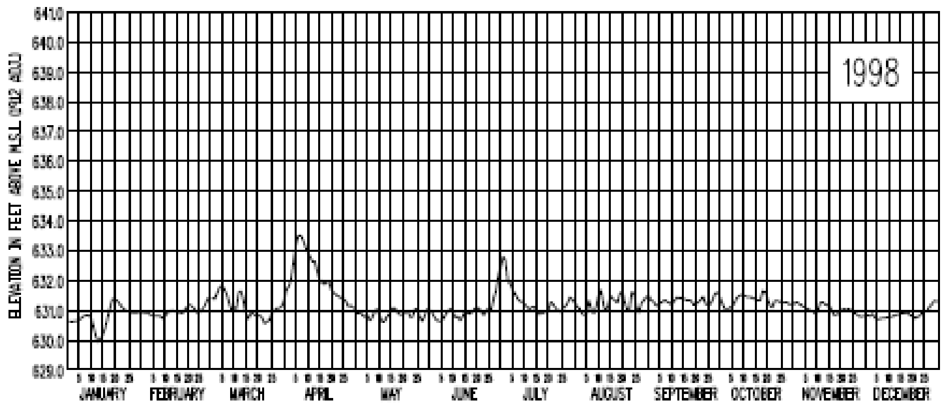
Mississippi River Discharge at McGregor, Iowa
Annual Average Values

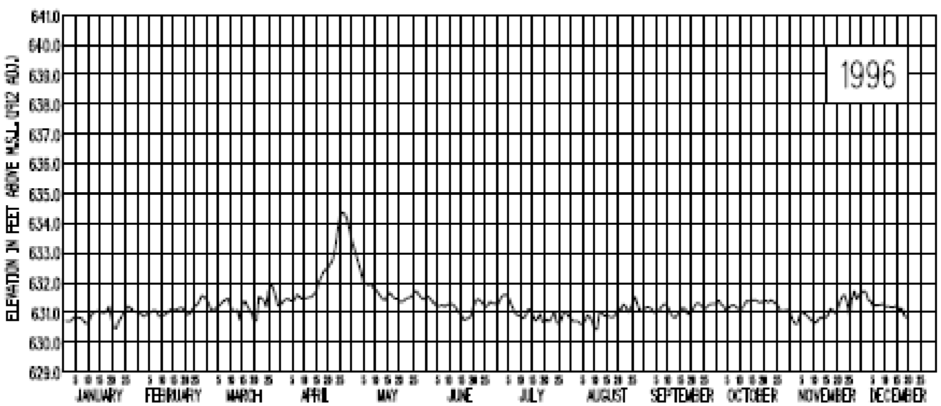












NOTES:

A. THESE ELEVATION HYDROGRAPHS WERE OBTAINED FROM U.S. ARMY CORPS OF ENGINEERS STATION AT BROWNSVILLE, MINNESOTA. THIS STATION HAS A PERIOD OF RECORD FROM 1930 TO THE PRESENT.

B. THESE HYDROGRAPHS DO NOT REPRESENT, NOR ARE THEY INTENDED TO REPRESENT, AVERAGE, TYPICAL OR FUTURE CONDITIONS. ADDITIONAL INFORMATION MAY BE OBTAINED AT THE CORPS OF ENGINEERS OFFICE IN ST. PAUL, MINNESOTA.

POOL 8 ISLANDS PHASE II STAGE 2

BROWNSVILLE, MINNESOTA

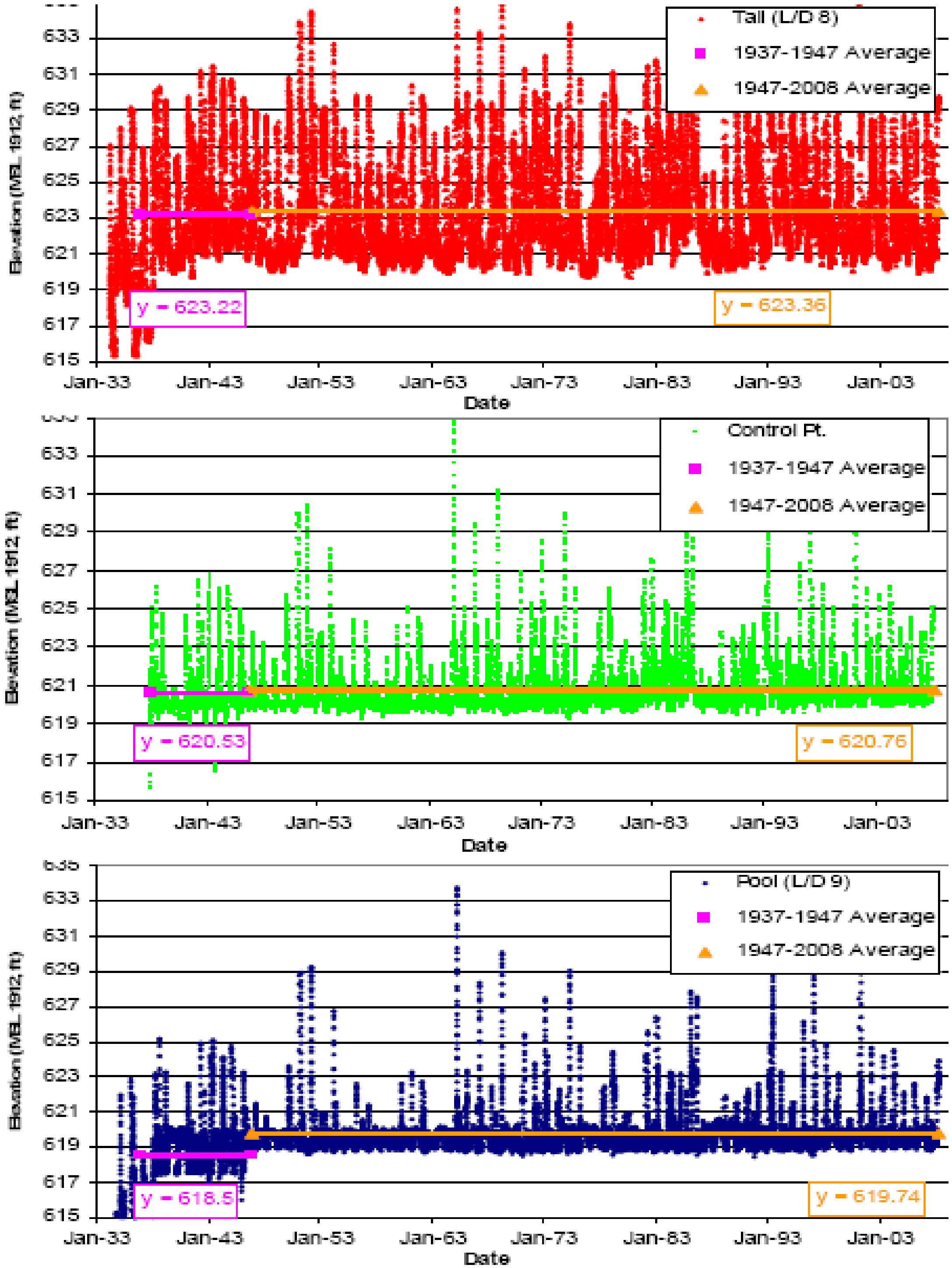
MISSISSIPPI RIVER

ELEVATION HYDROGRAPHS

1994 – 1998

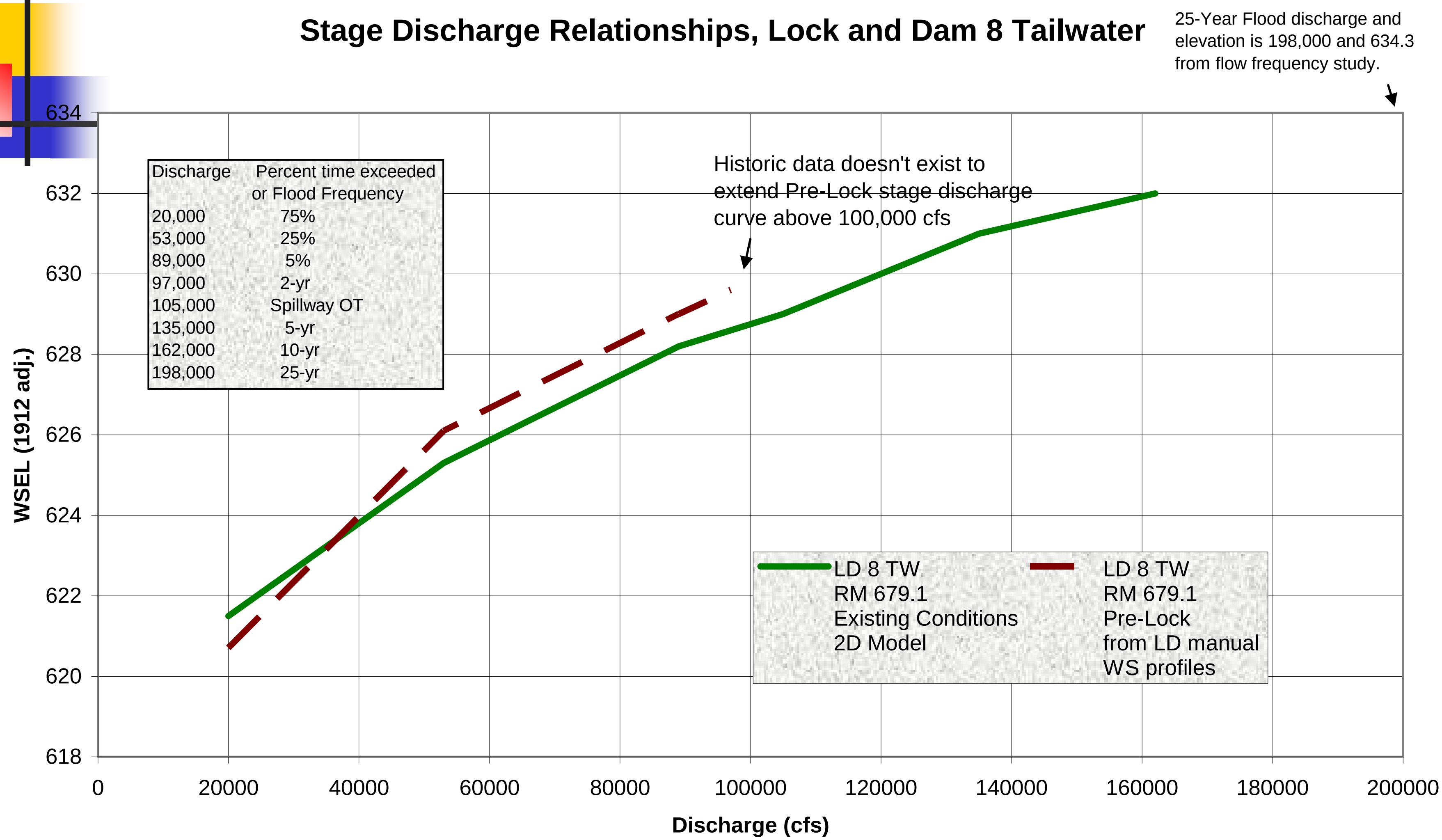
DRAWING NUMBER

BROWNHY_H1.DGN

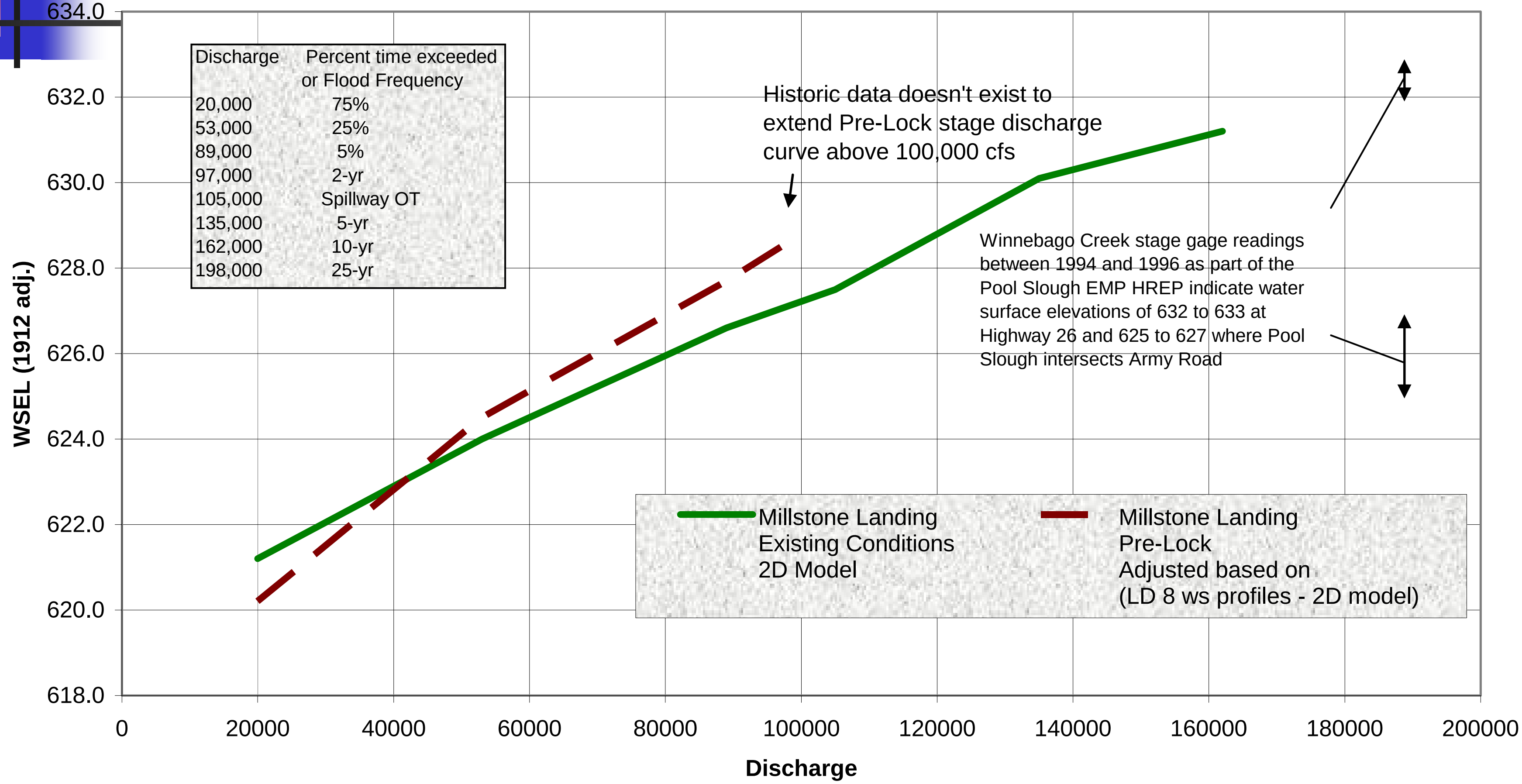


Tail (L/D 8)
1937-1947 Average
1947-2008 Average
y = 623.22
y = 623.36
Elevation (MSL 1912, ft)
633
631
629
627
625
623
621
619
617
615
Jan-33
Jan-43
Jan-53
Jan-63
Jan-73
Jan-83
Jan-93
Jan-03
Date
Control Pt.
1937-1947 Average
1947-2008 Average
y = 620.53
y = 620.76
Elevation (MSL 1912, ft)
Date
Pool (L/D 9)
1937-1947 Average
1947-2008 Average
y = 618.5
y = 619.74
Elevation (MSL 1912, ft)
Date

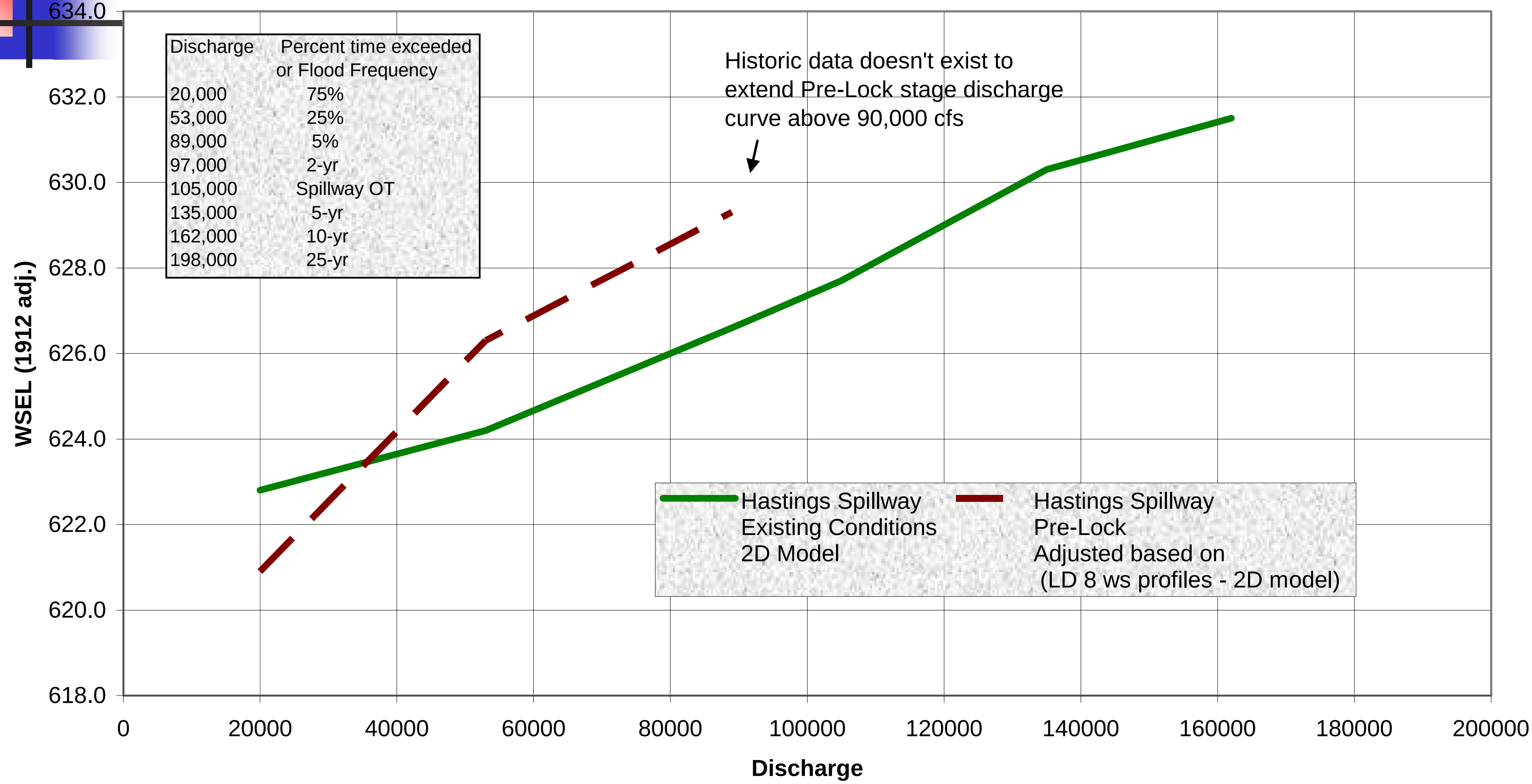
Stage Discharge Relationships, Lock and Dam 8 Tailwater



Stage Discharge Relationships, Reno Bottoms (Millstone Landing)

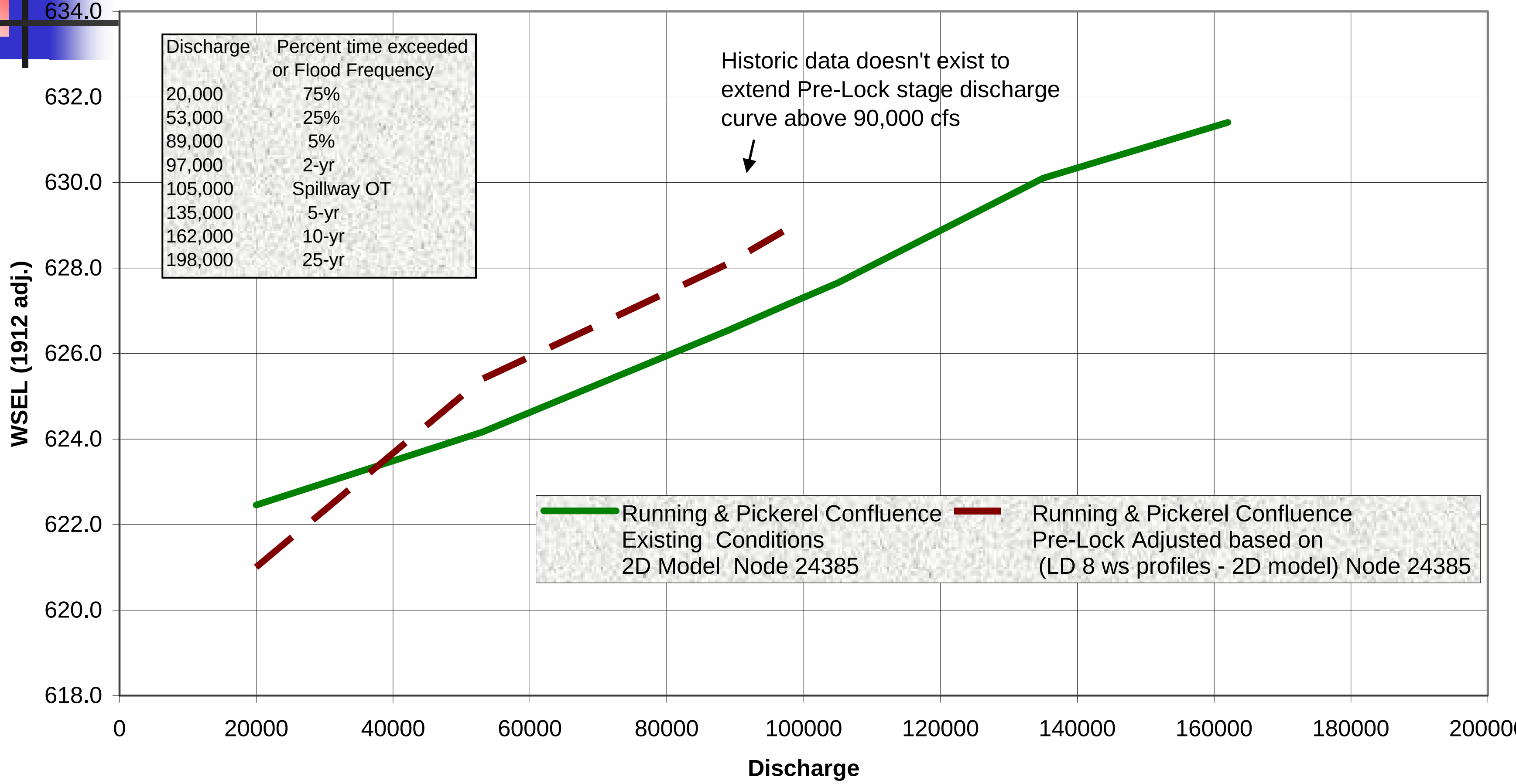


Stage Discharge Relationships, Reno Bottoms (Hastings Spillway)



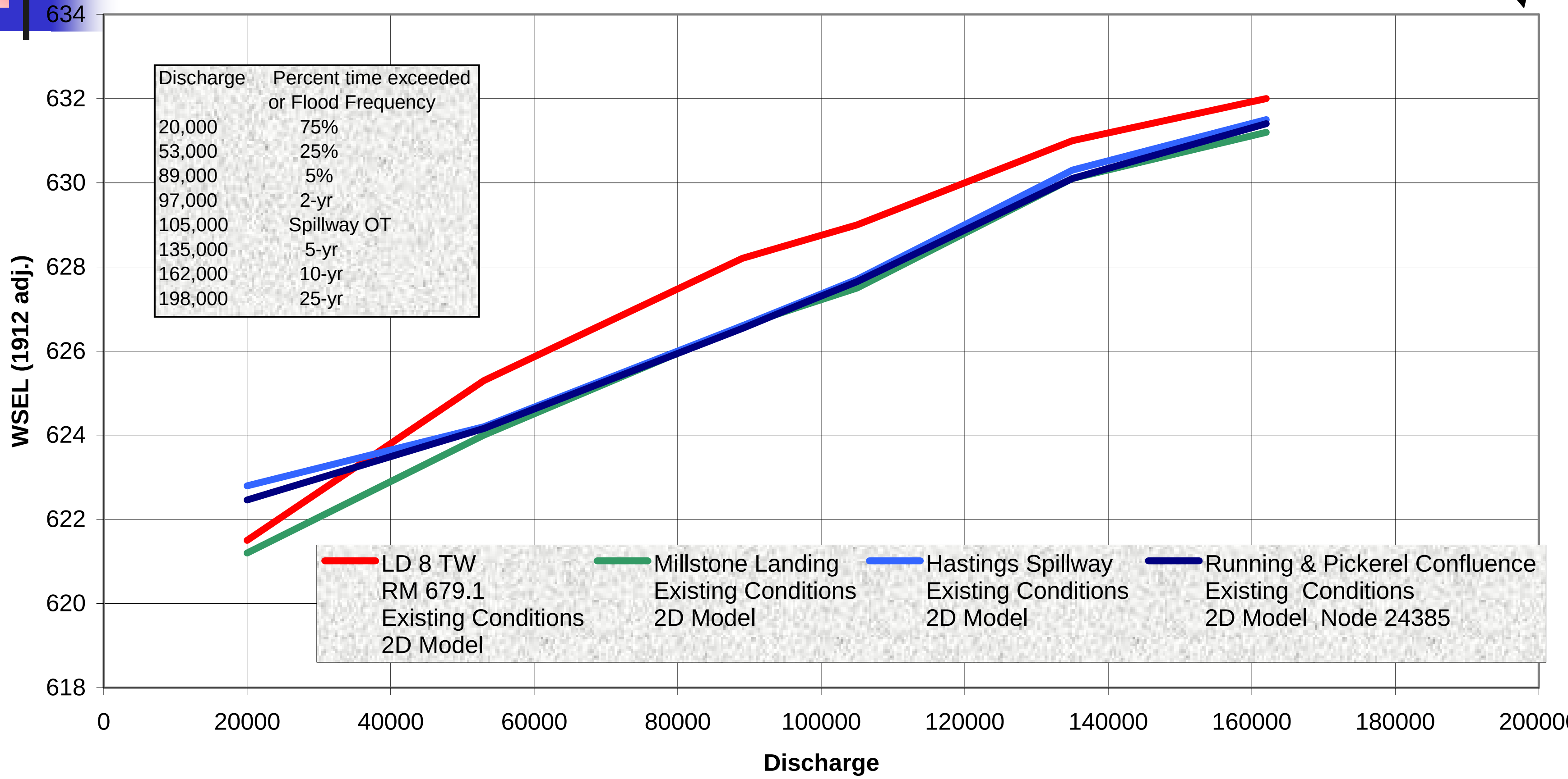
Discharge	Percent time exceeded or Flood Frequency
20,000	75%
53,000	25%
89,000	5%
97,000	2-yr
105,000	Spillway OT
135,000	5-yr
162,000	10-yr
198,000	25-yr

Stage Discharge Relationships, Reno Bottoms (Running & Pickerel Slough Confluence)

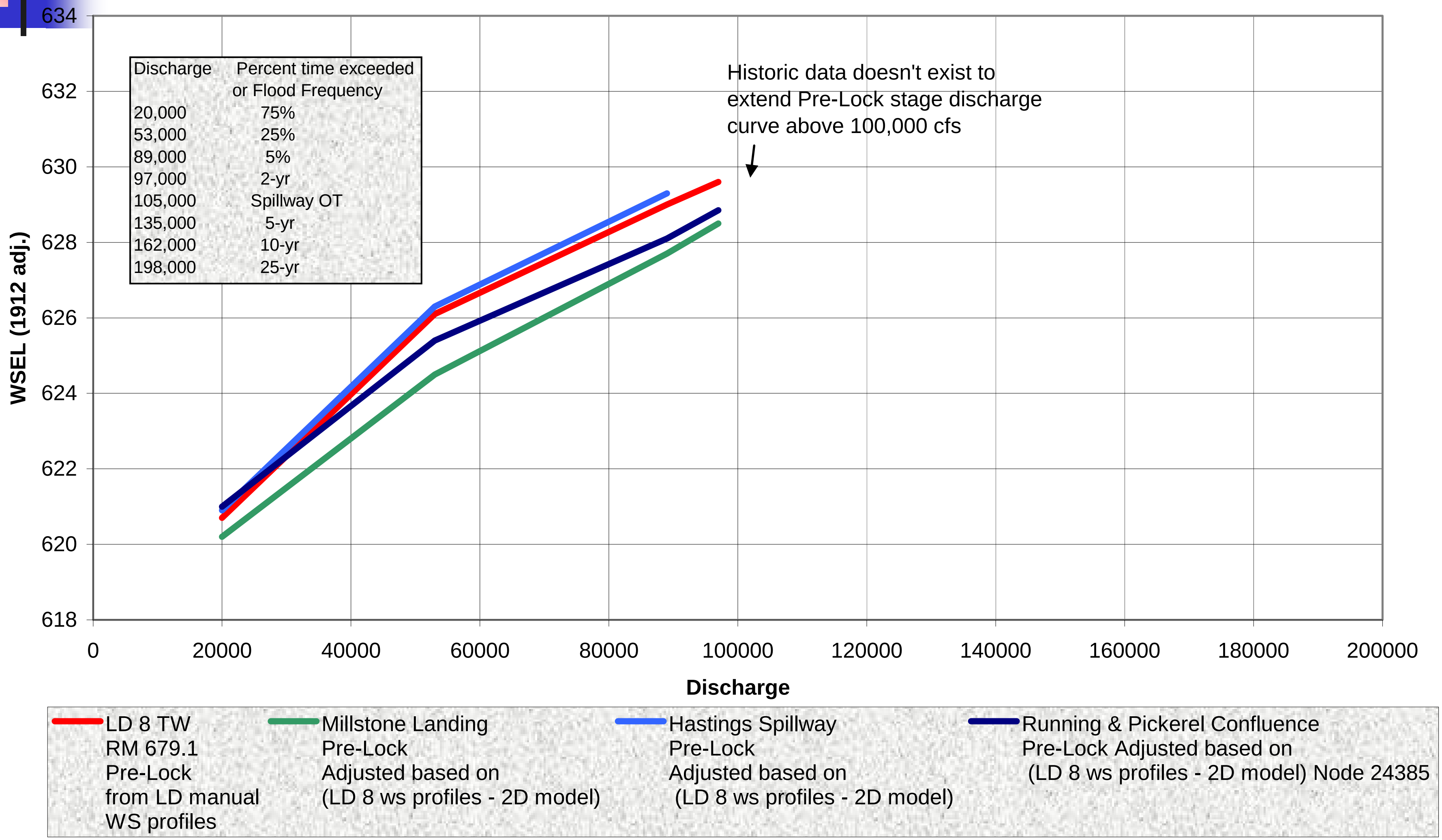


Stage Discharge Relationships, Existing Conditions
LD 8 Tailwater, Millstone Landing, and Hastings Spillway
Running and Pickerel Slough Confluence

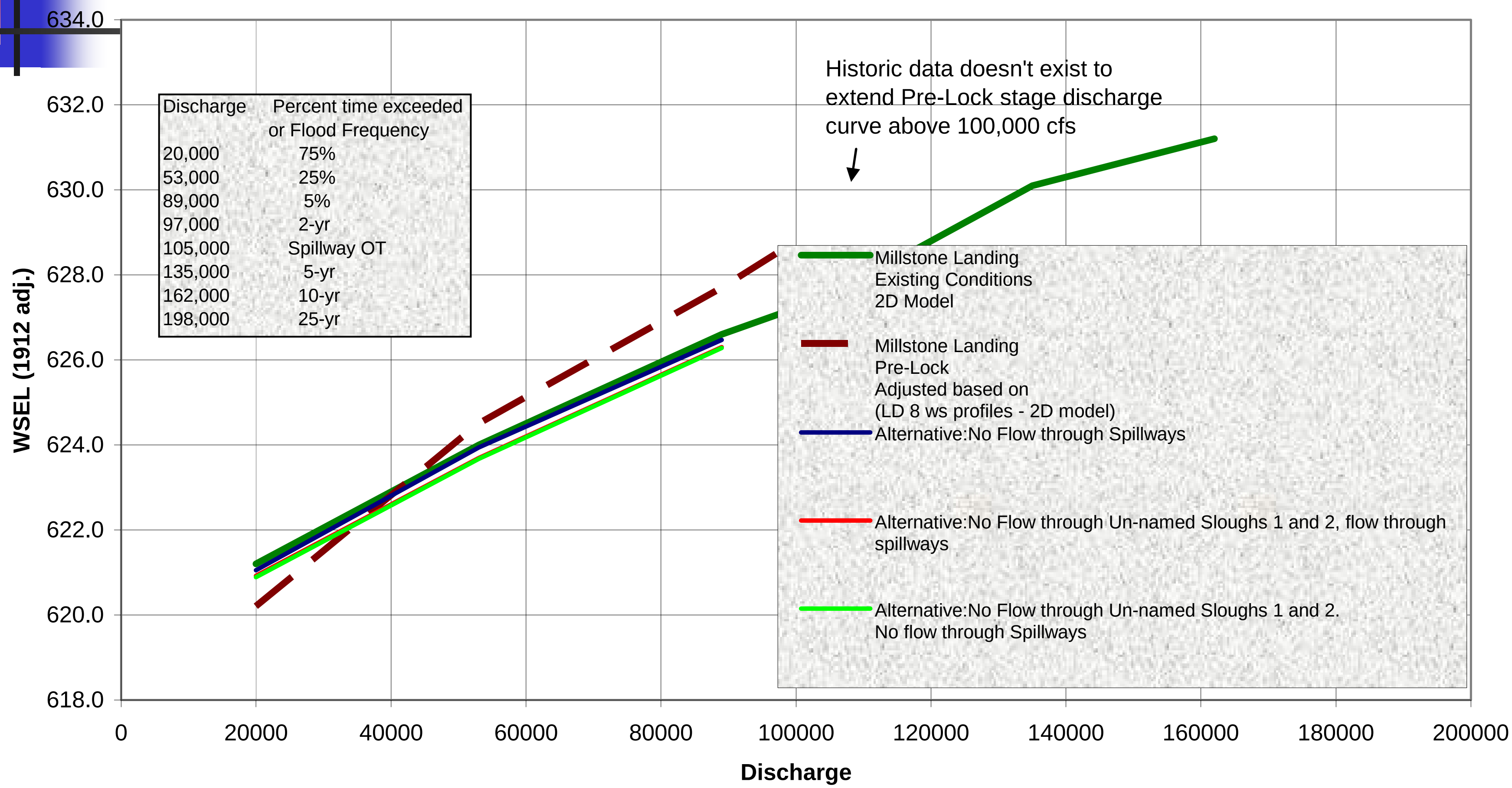
25-Year Flood discharge and elevation at LD 8 TW is 198,000 and 634.3 from flow frequency study.



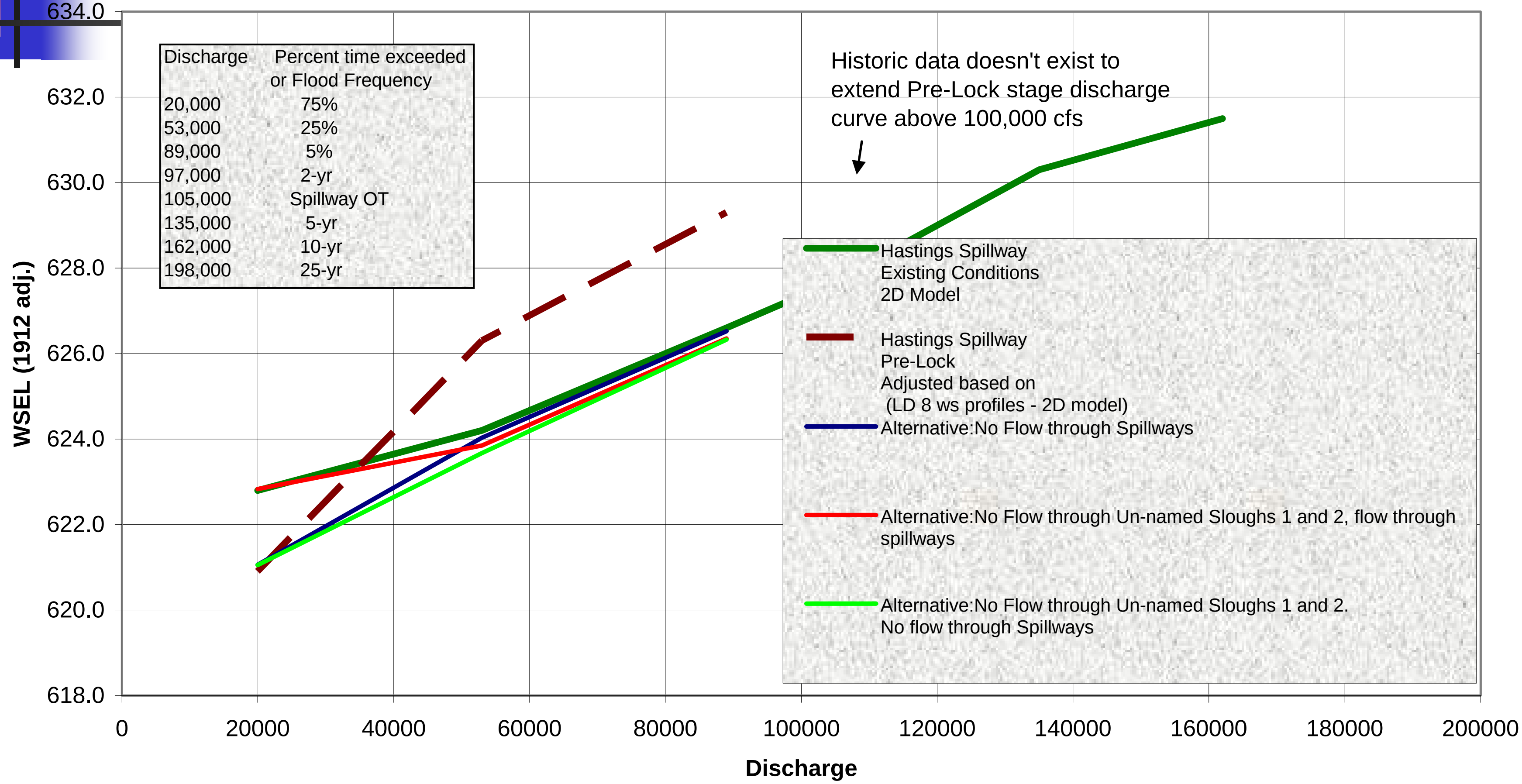
Stage Discharge Relationships, Pre-Lock Conditions
Lock and Dam 8 Tailwater, Millstone Landing, Hastings Spillway, Running and Pickerel Slough Confluence



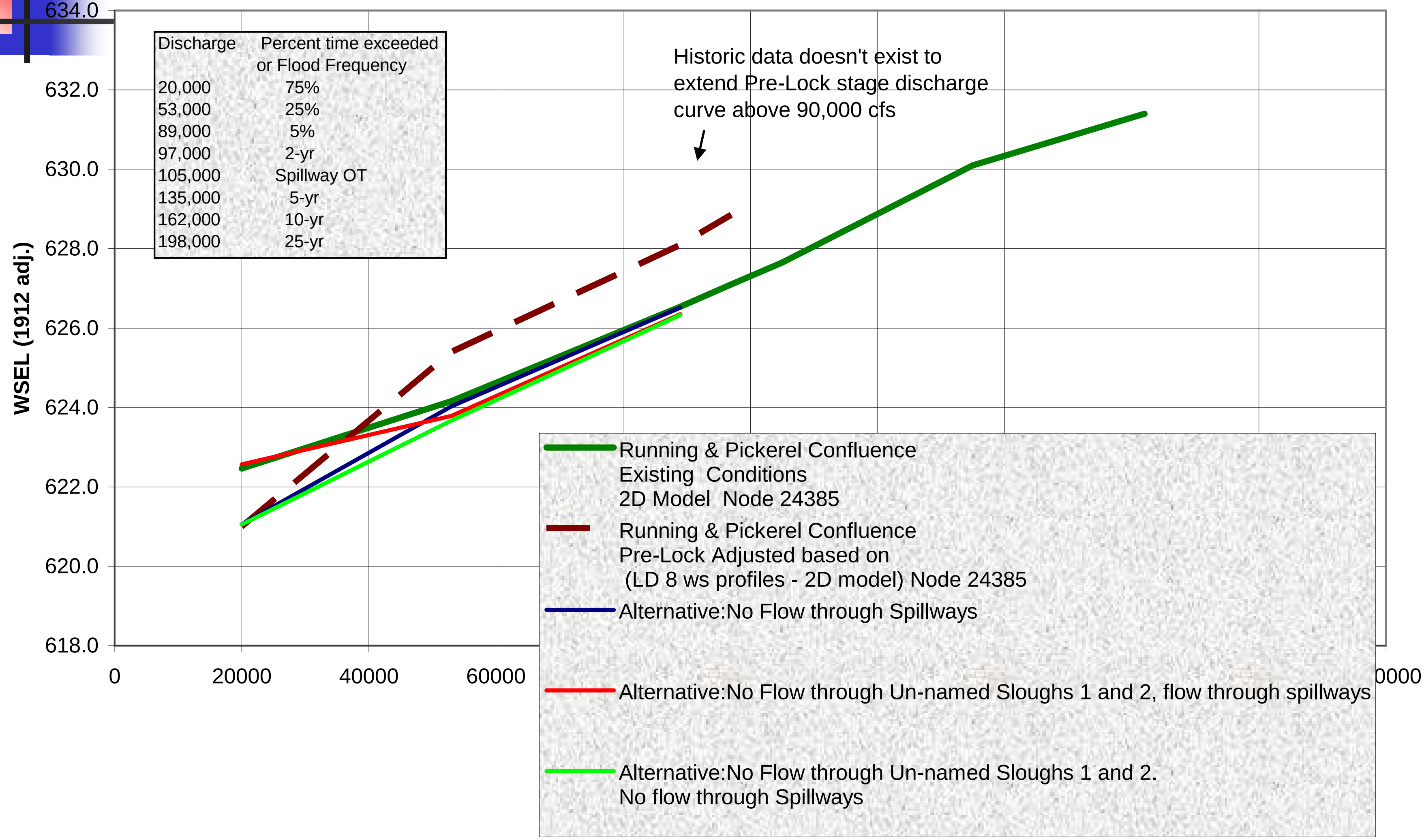
Stage Discharge Relationships, Reno Bottoms (Millstone Landing) Reduced Flow Alternatives



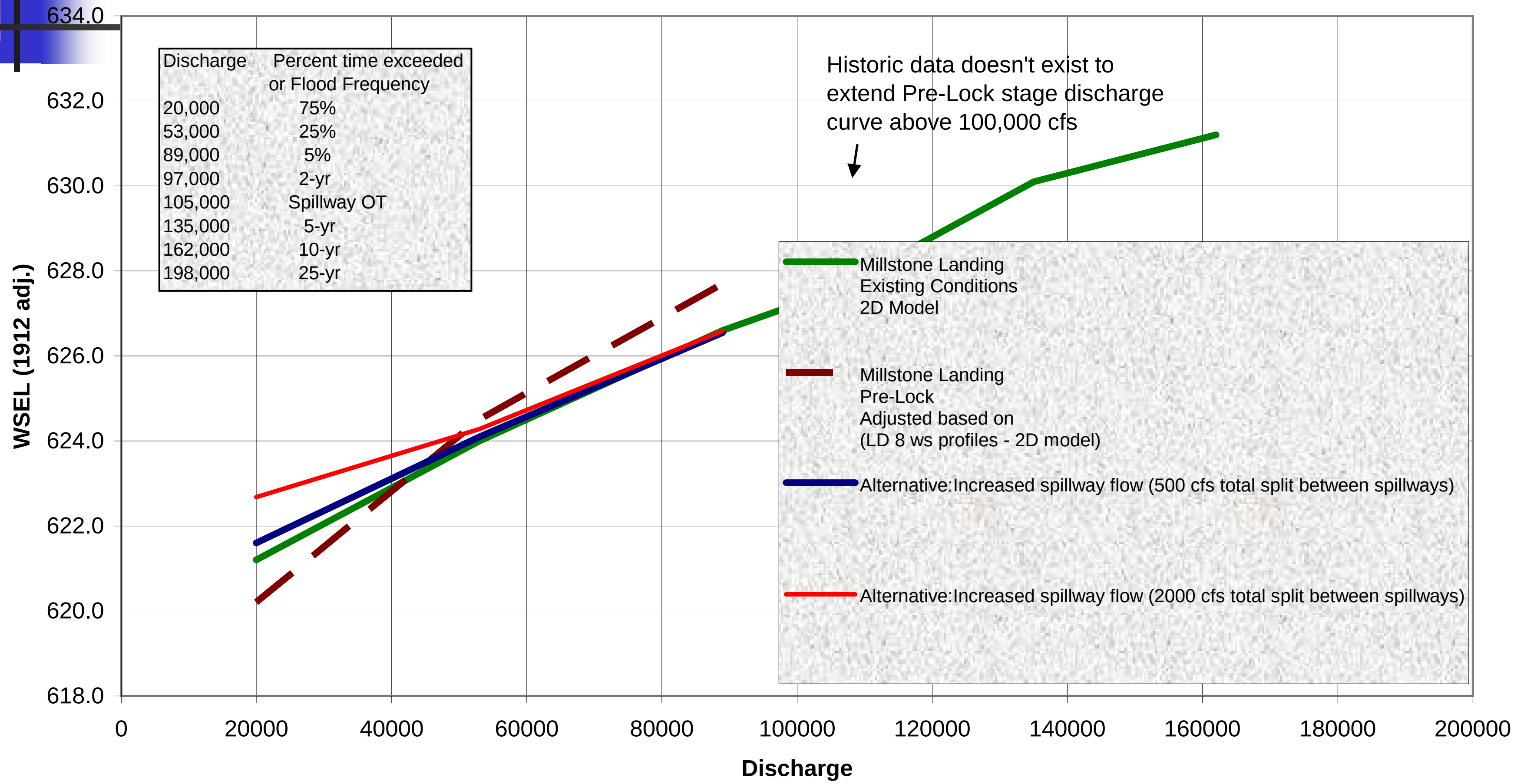
Stage Discharge Relationships, Reno Bottoms (Hastings Spillway) Reduced Flow Alternatives



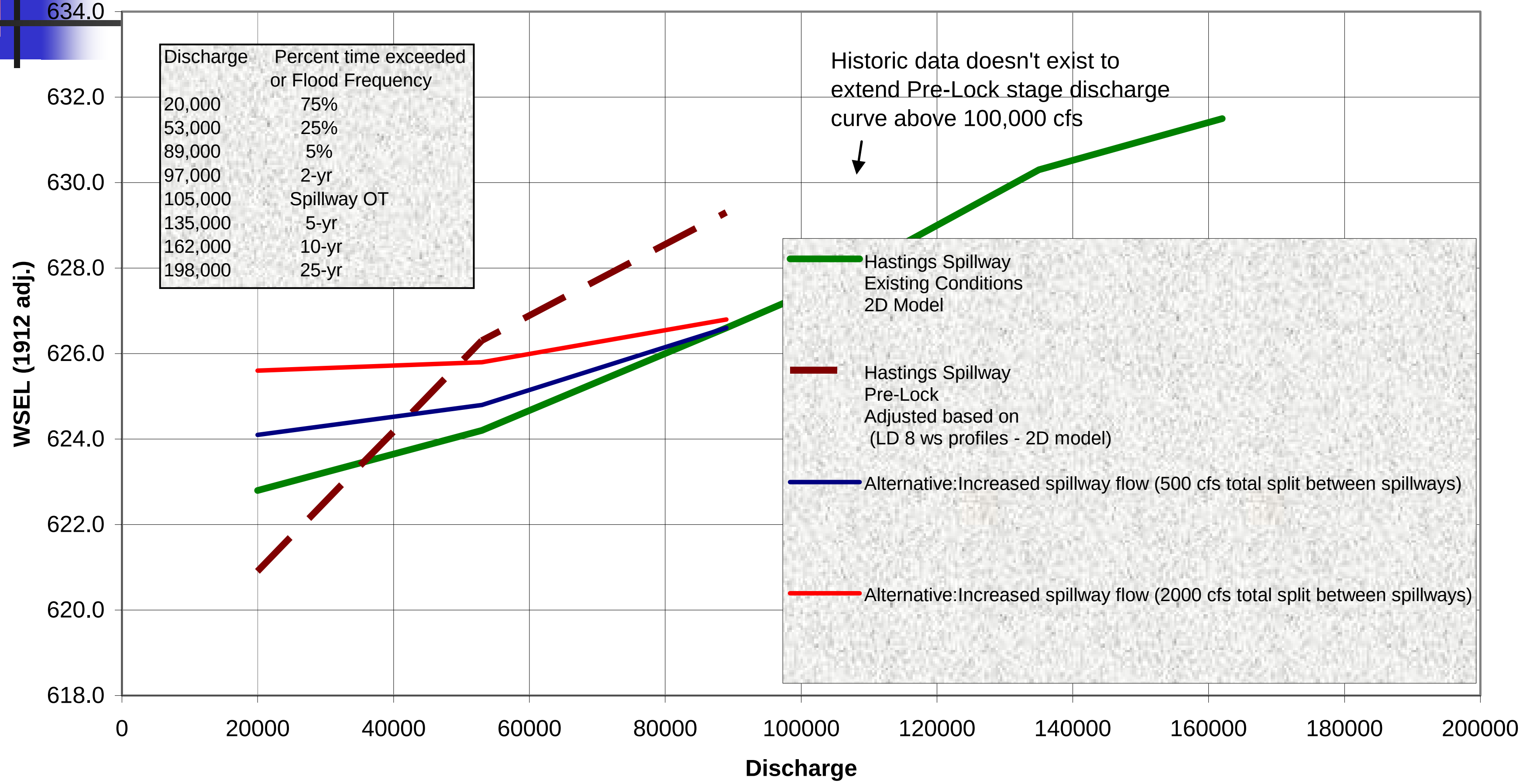
Stage Discharge Relationships, Reno Bottoms (Running & Pickerel Slough Confluence)



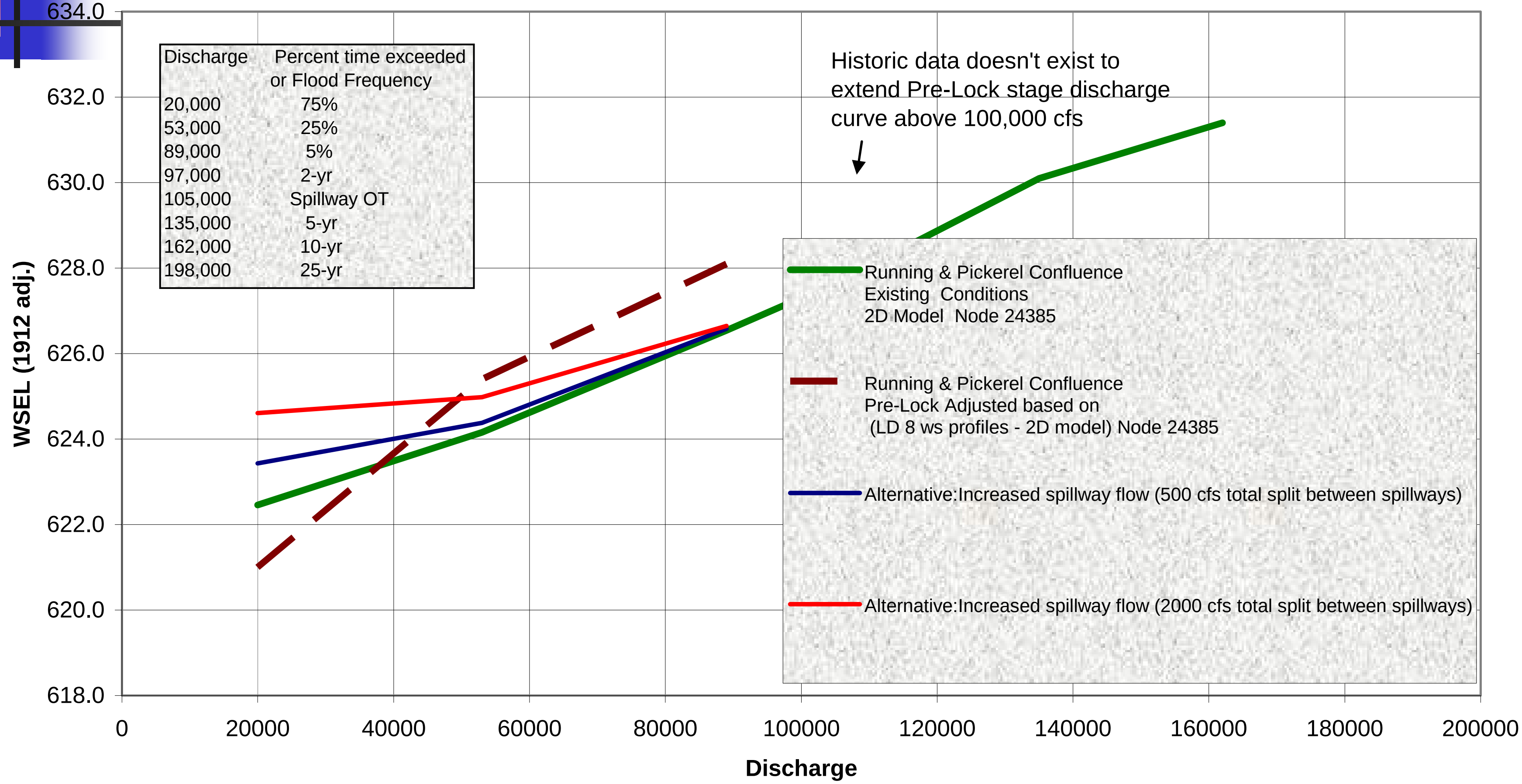
Stage Discharge Relationships, Reno Bottoms (Millstone Landing)
Increased Flow Alternatives



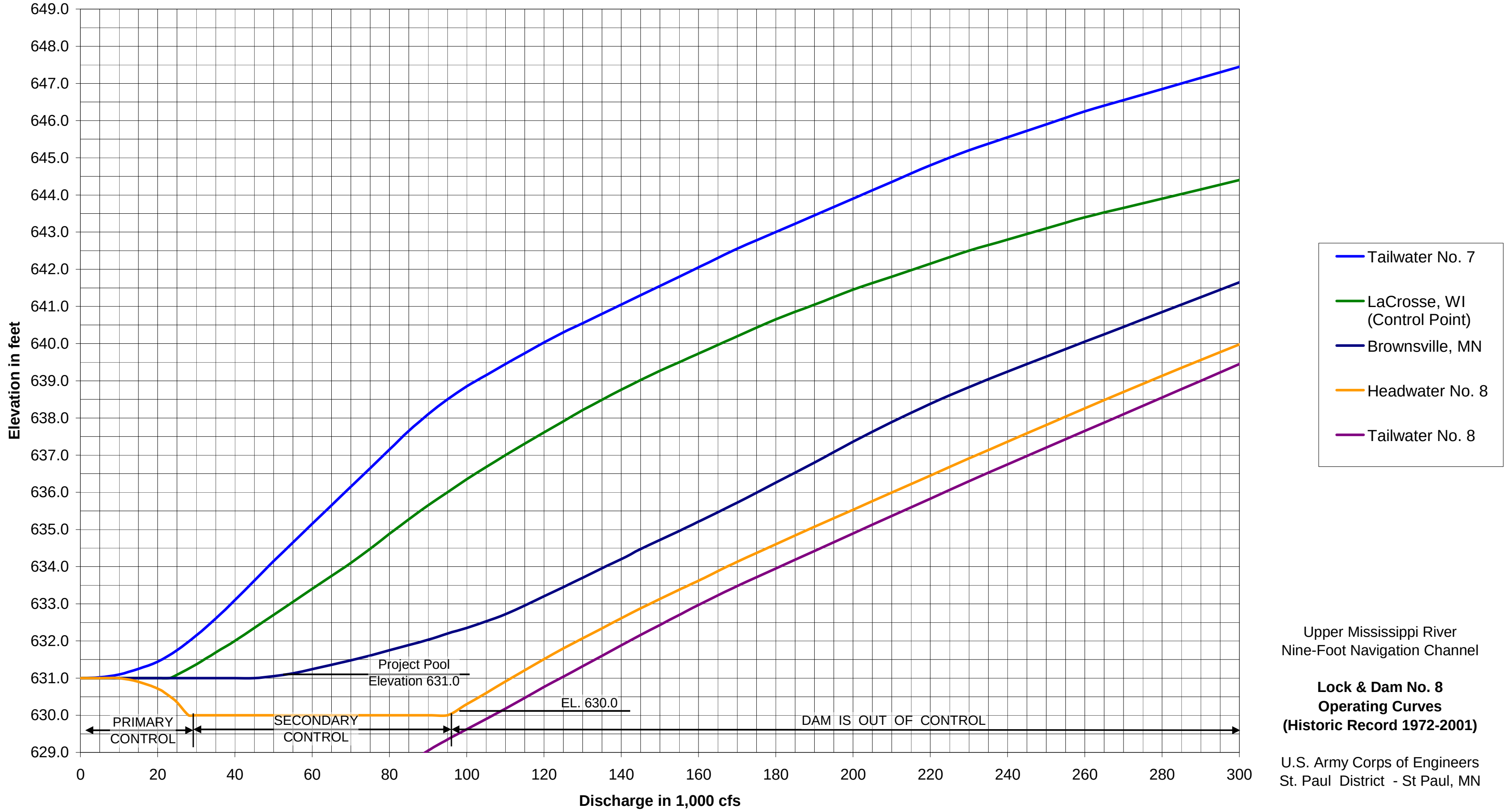
Stage Discharge Relationships, Reno Bottoms (Hastings Spillway)
Increased Flow Alternatives



Stage Discharge Relationships, Reno Bottoms (Running - Pickerel Slough Confluence) Increased Flow Alternatives



LOCK & DAM NO. 8 OPERATING CURVES

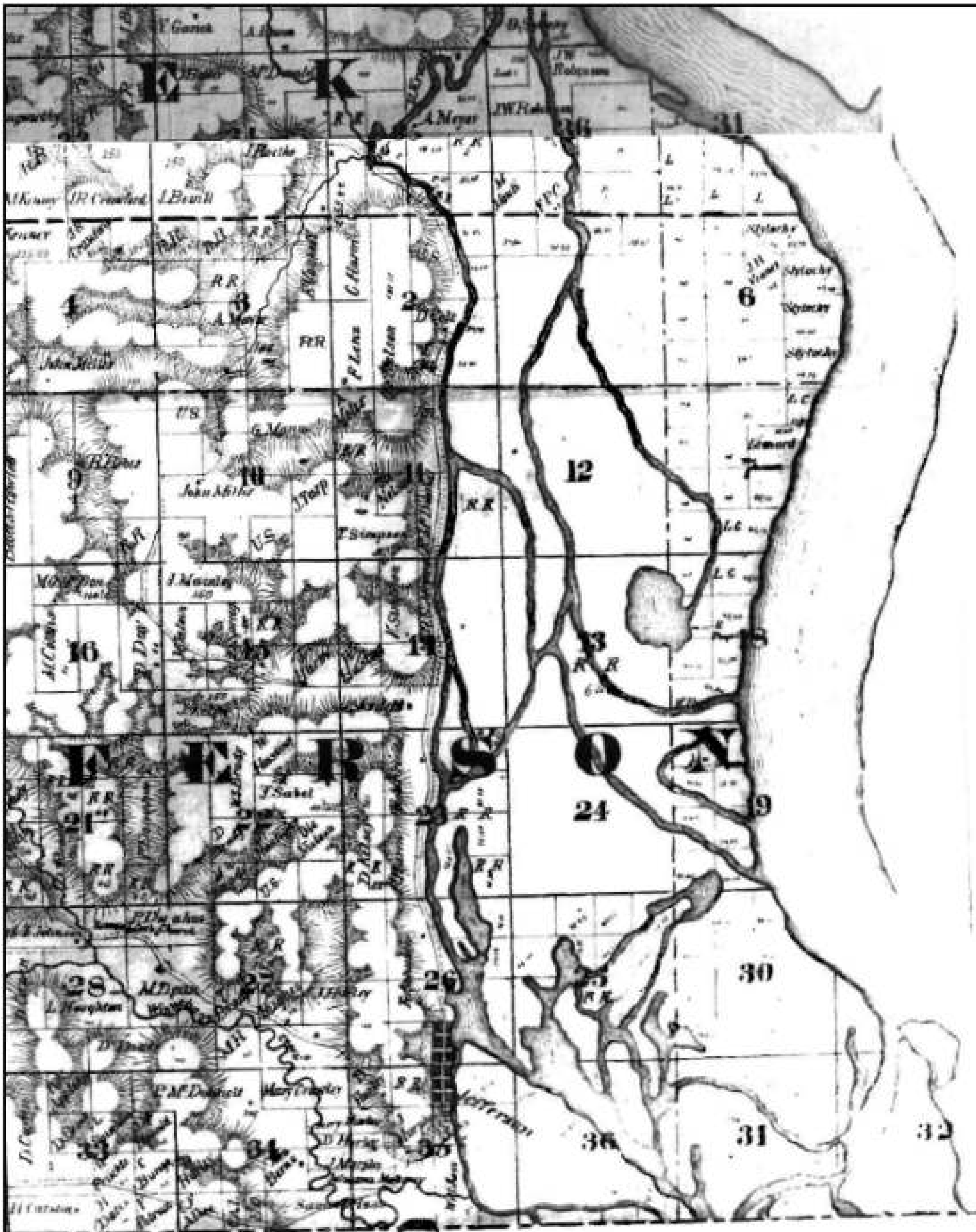


Upper Mississippi River
Nine-Foot Navigation Channel

Lock & Dam No. 8
Operating Curves
(Historic Record 1972-2001)

U.S. Army Corps of Engineers
St. Paul District - St Paul, MN

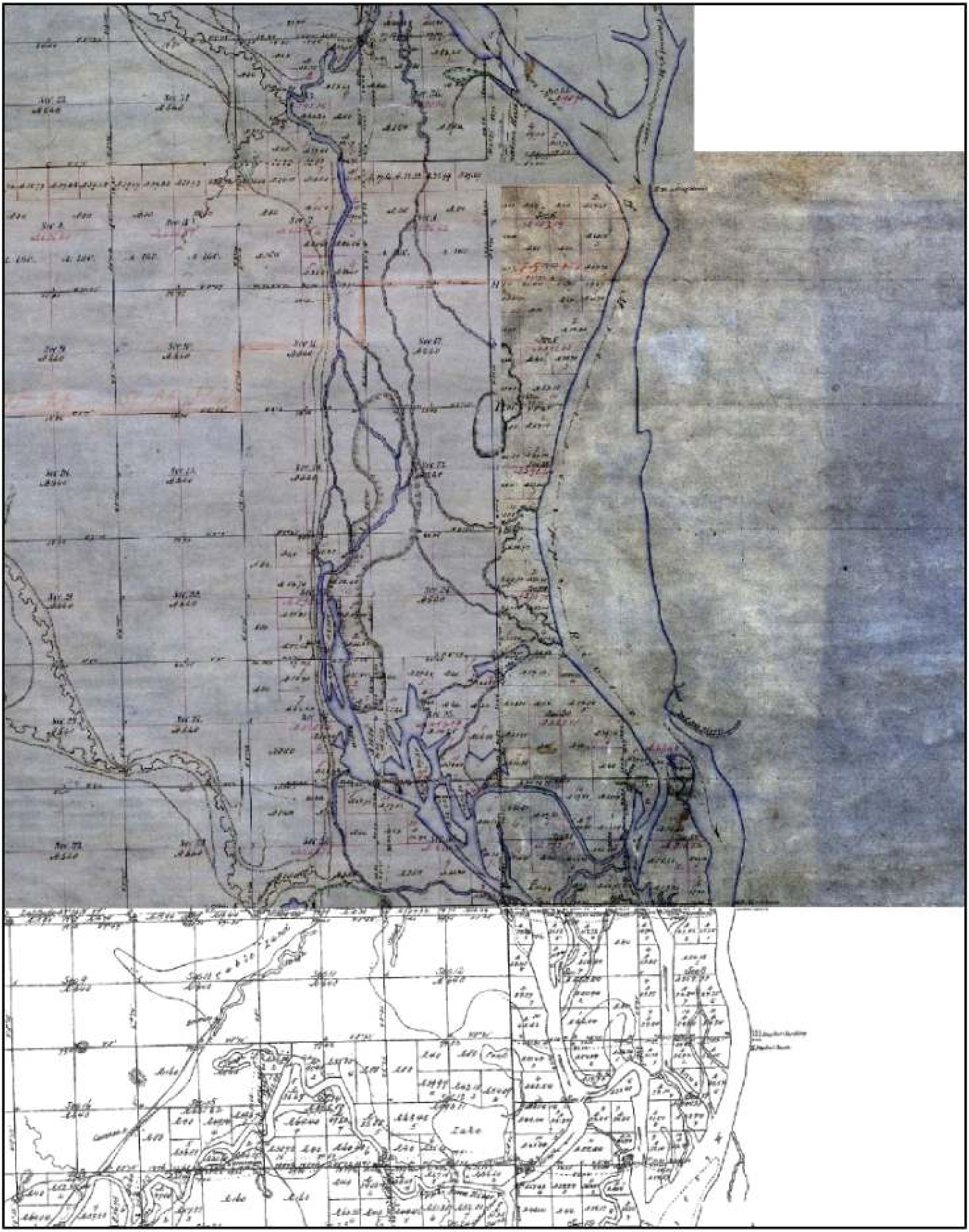
Plate 7-1



0 0.25 0.5 1 Mile

1871 HOUSTON COUNTY, MN PLAT MAPS

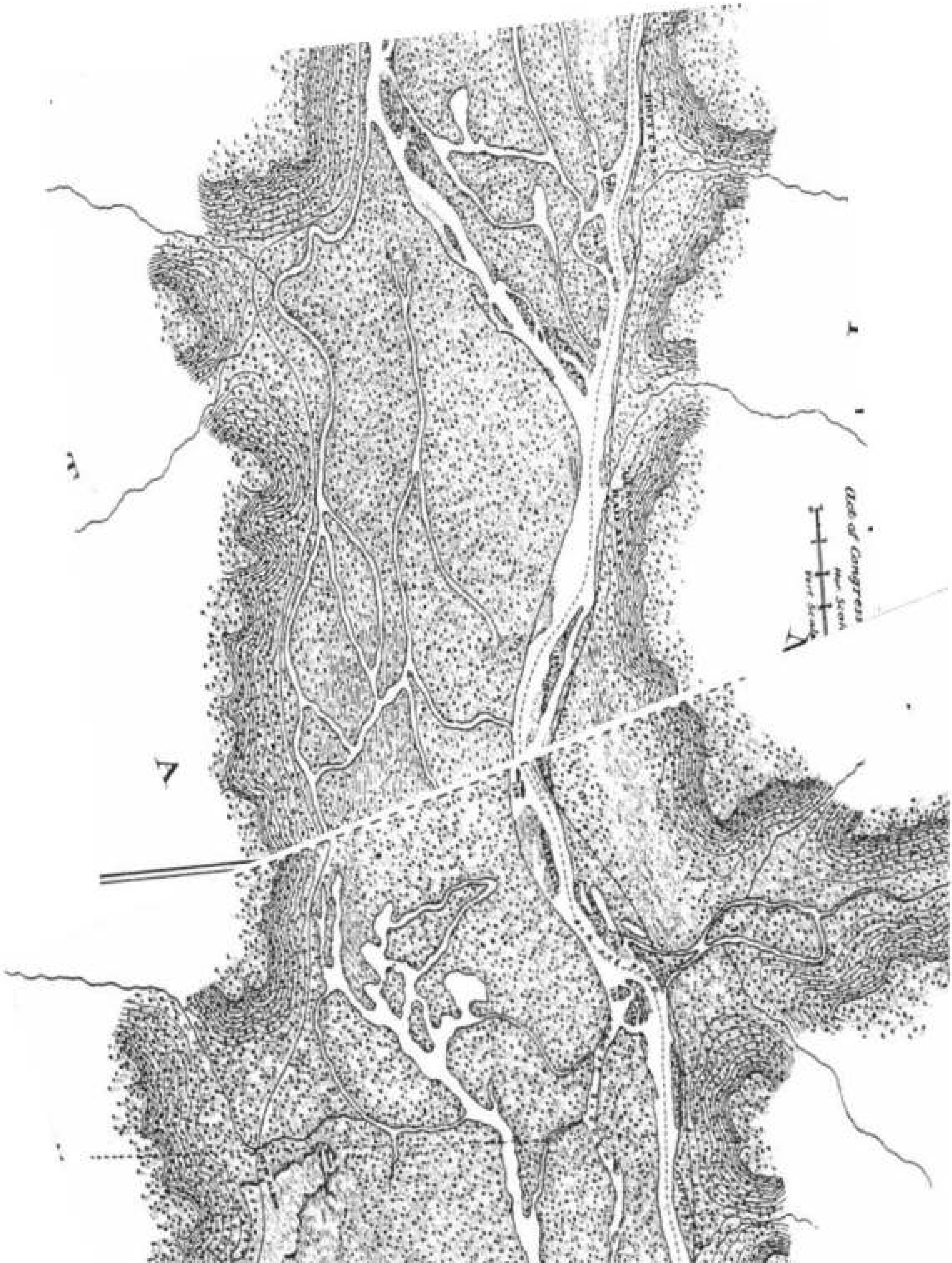
N



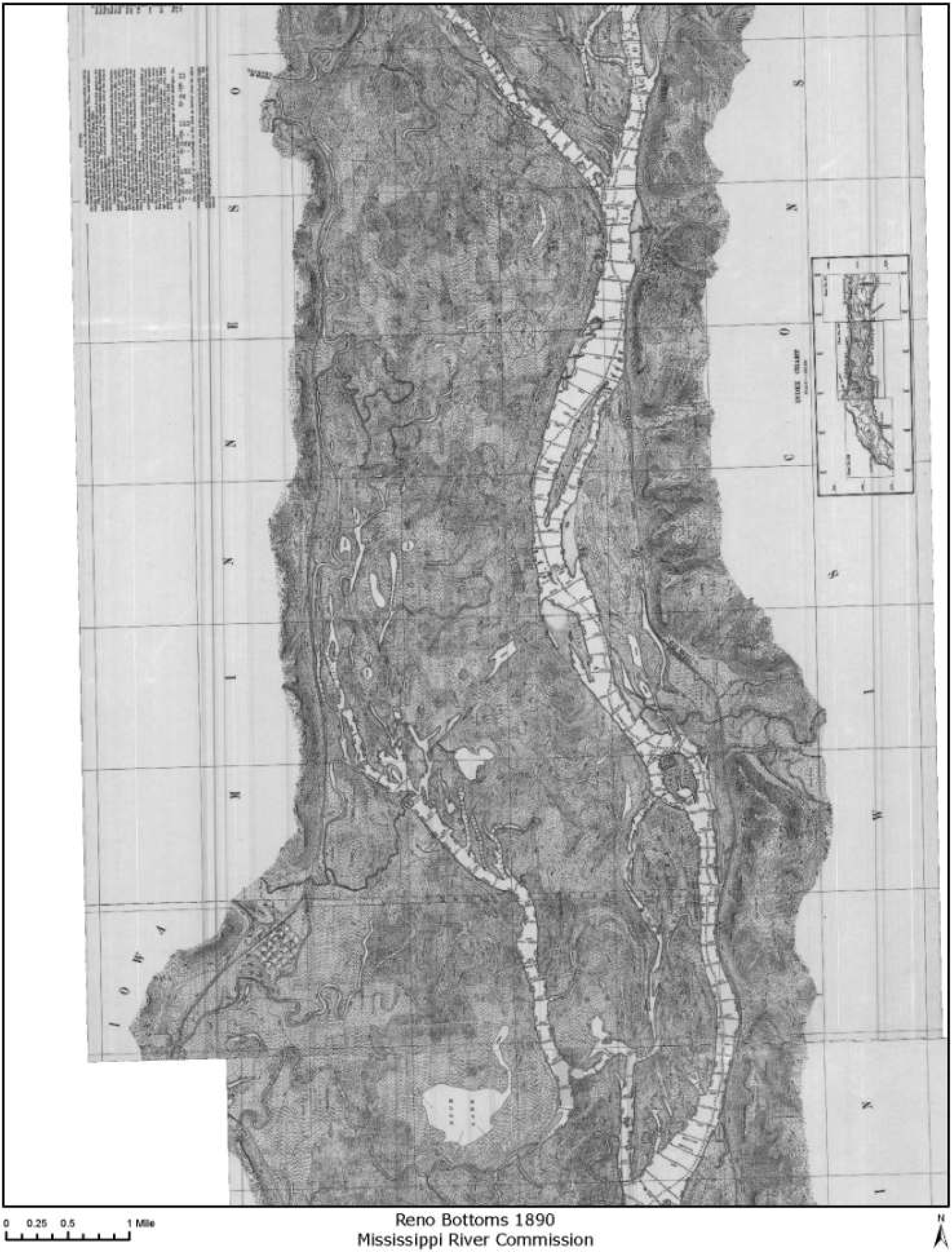
0 0.25 0.5 1 Mile

1854 GOVERNMENT LAND OFFICE MAPS

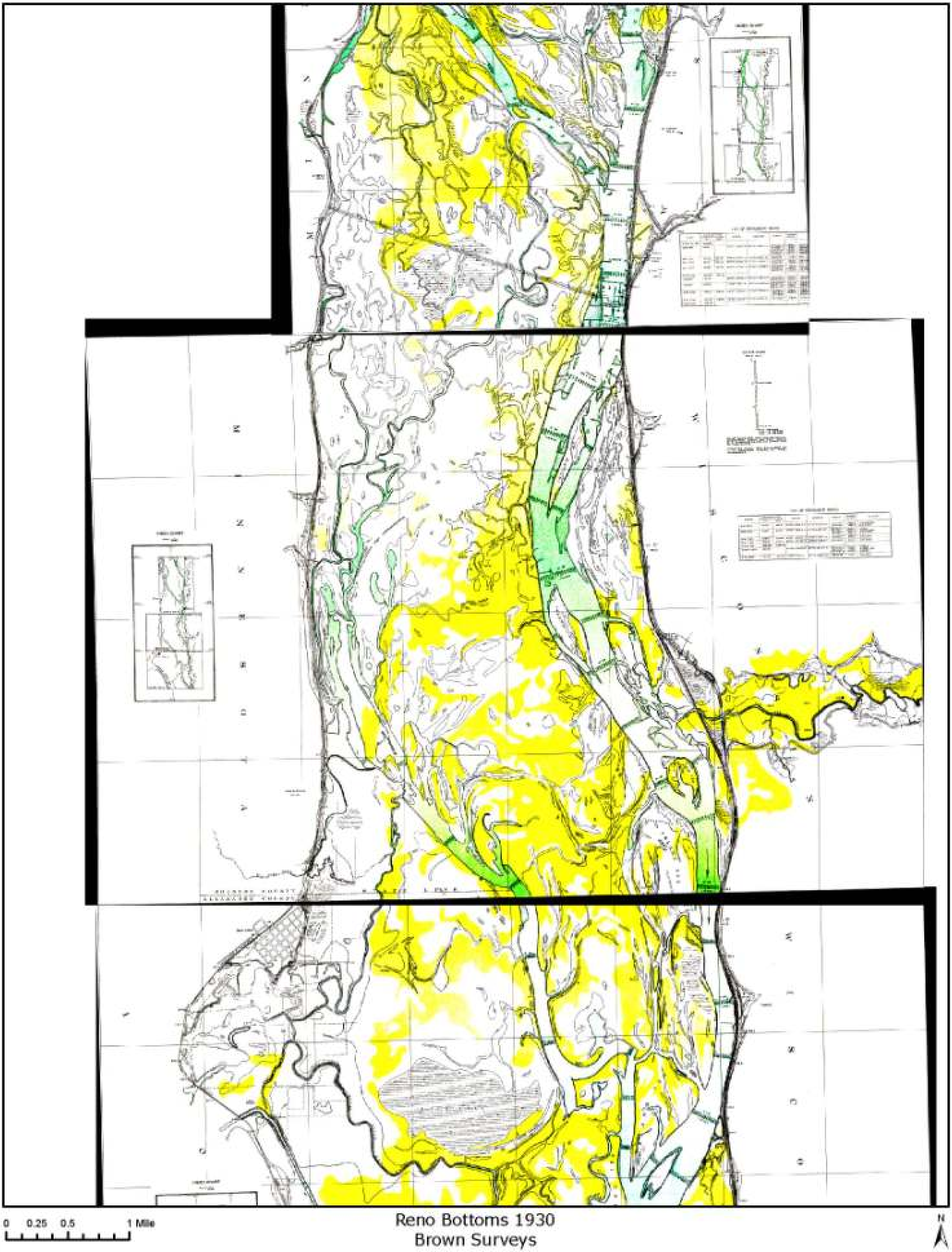
N



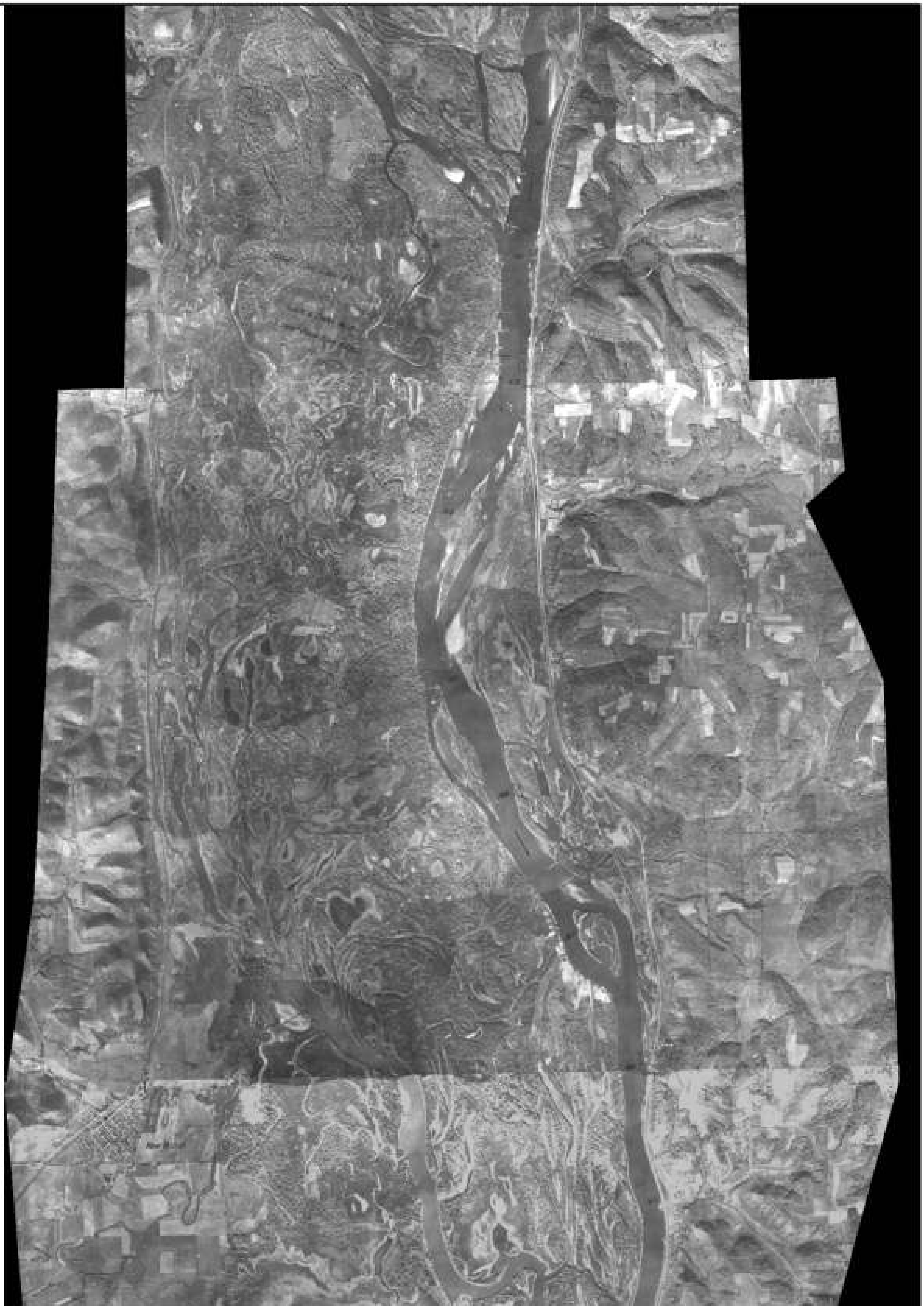
Mackenzie Maps 1887-1888
Corps of Engineers



Reno Bottoms 1890
Mississippi River Commission



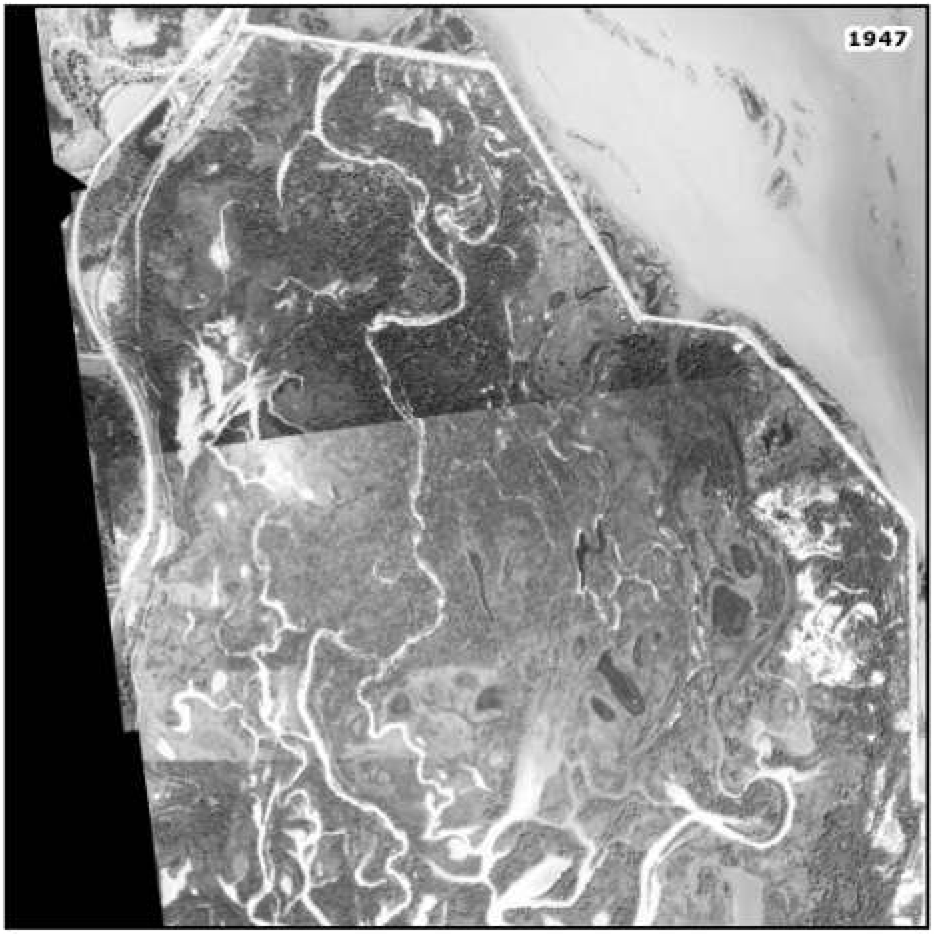
Reno Bottoms 1930
Brown Surveys

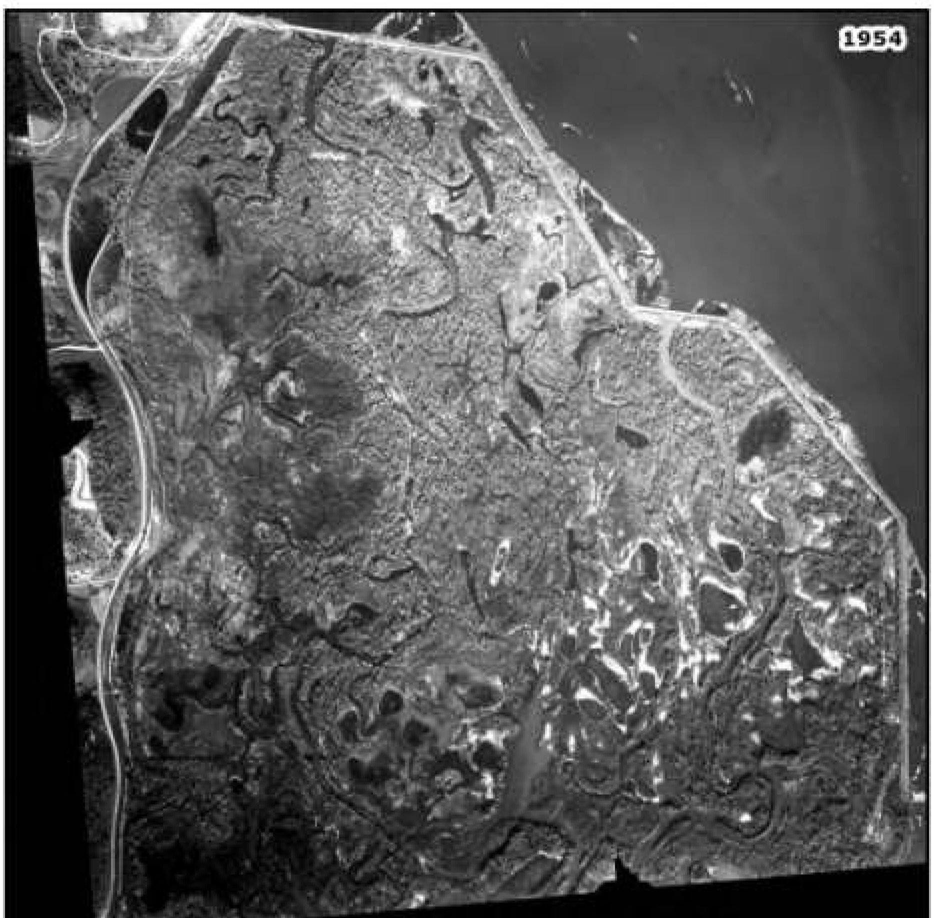


0 0.25 0.5 1 Mile

Reno Bottoms 1929

N

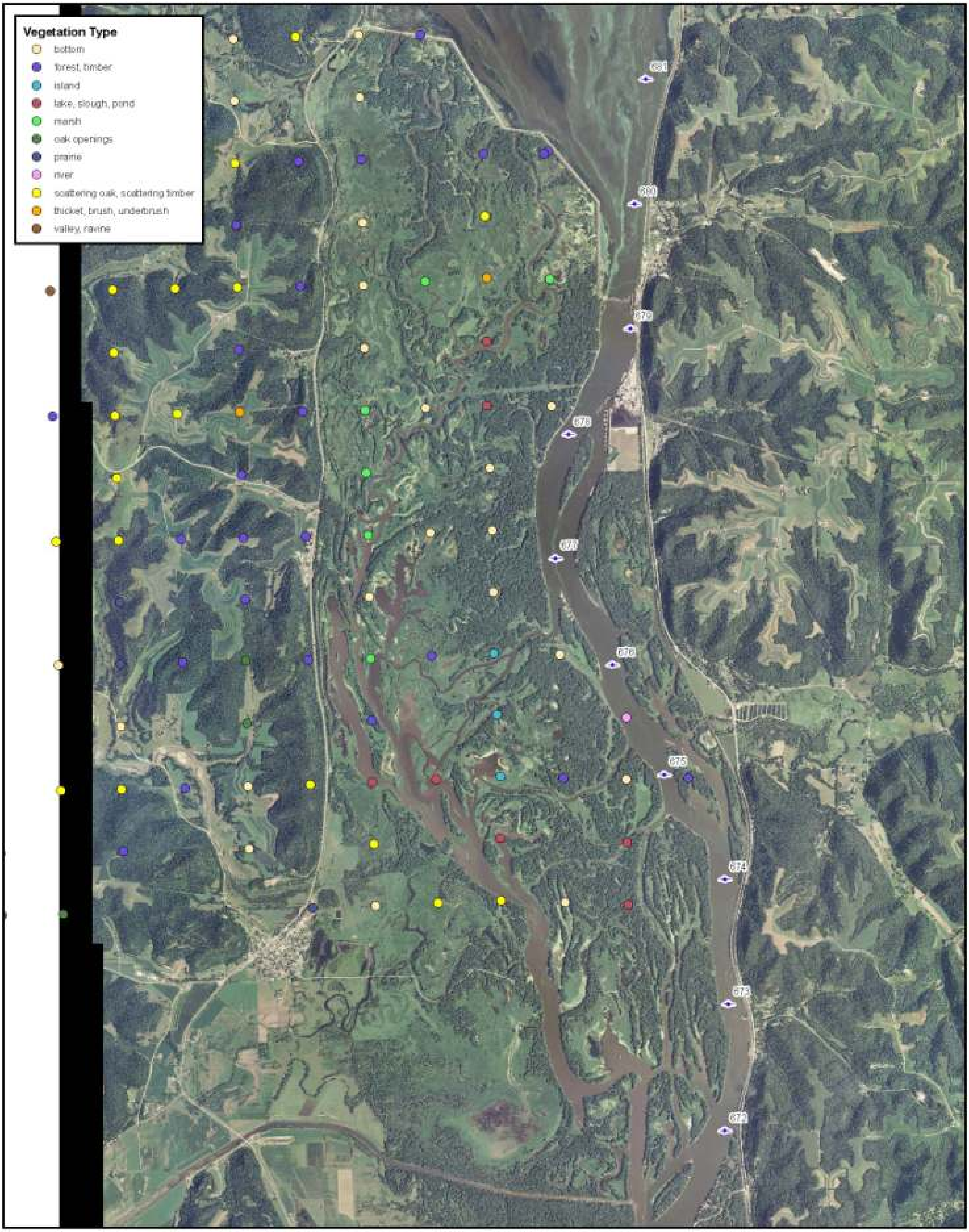




0 0.25 0.5 1 Mile

HISTORIC AIR PHOTOS

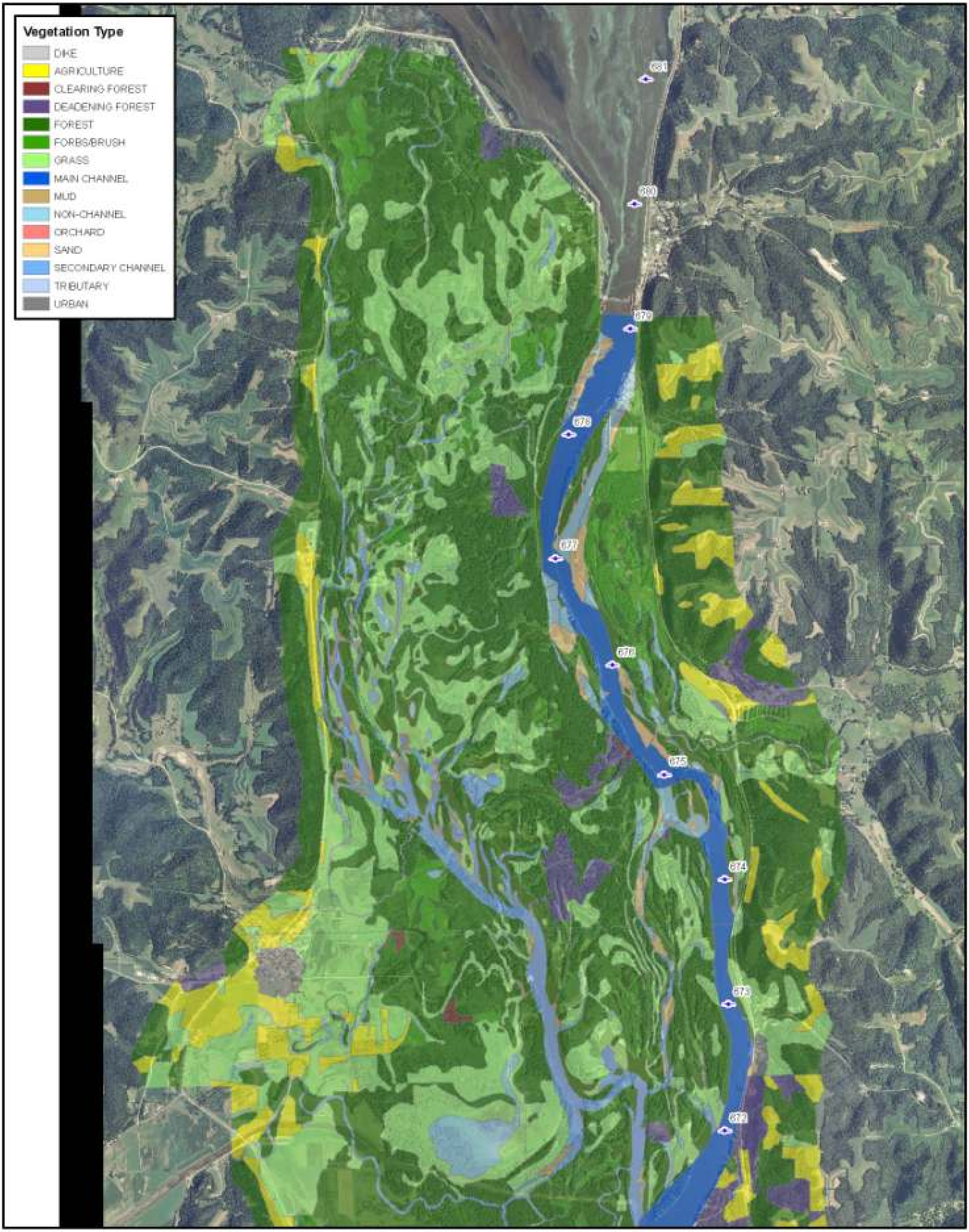
N



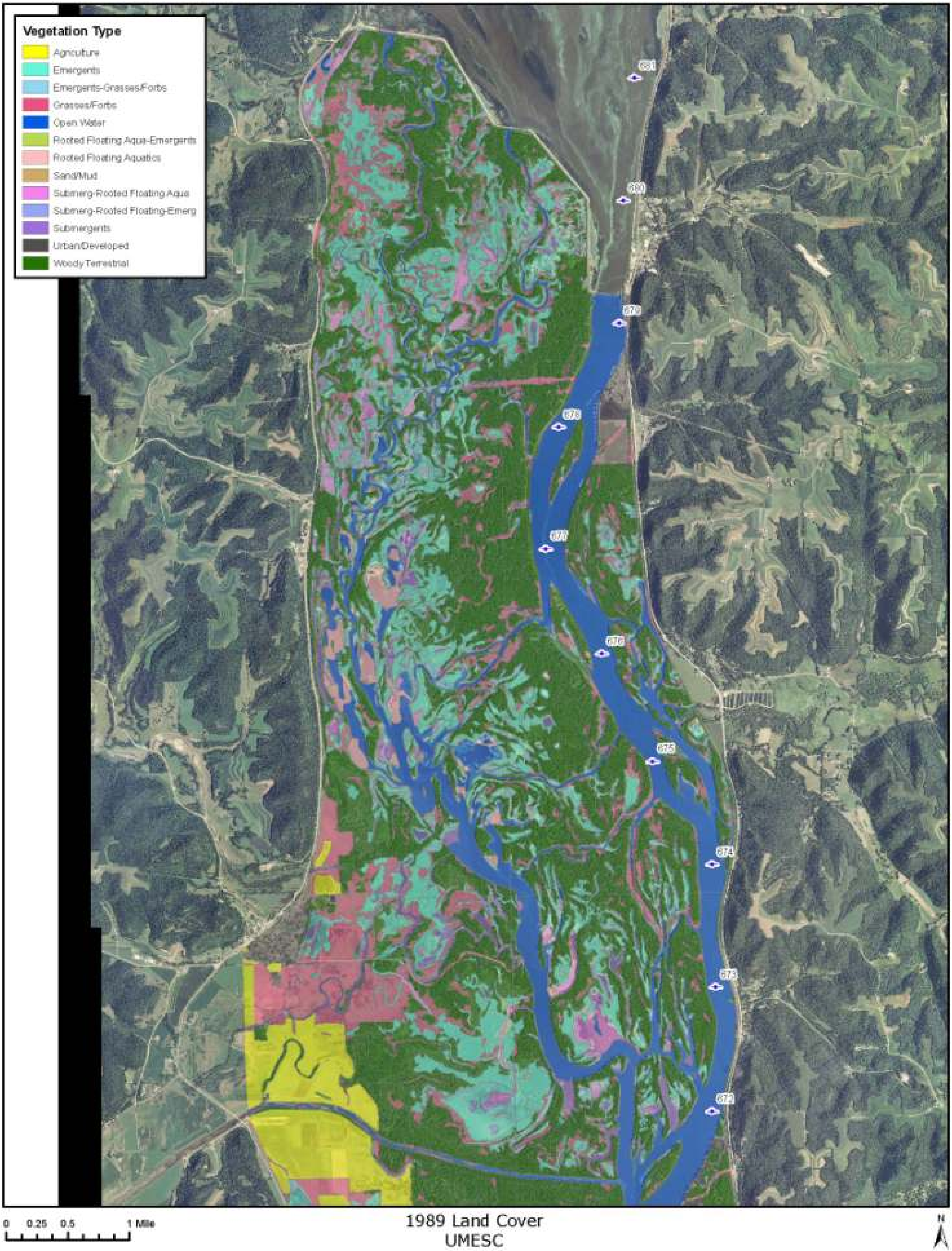
0 0.25 0.5 1 Mile

Early Settlement Vegetation
Public Land Survey 1847-1907

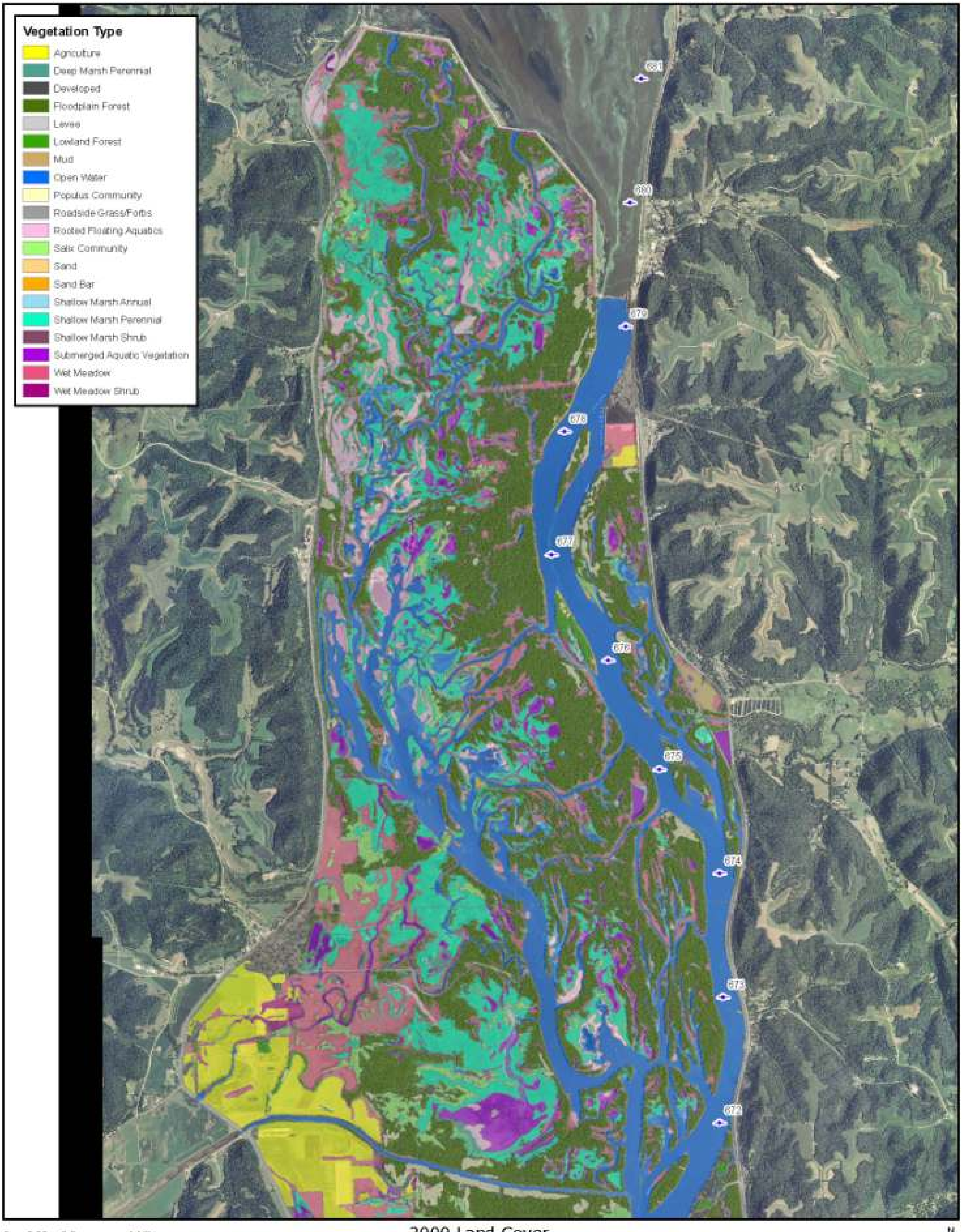
N



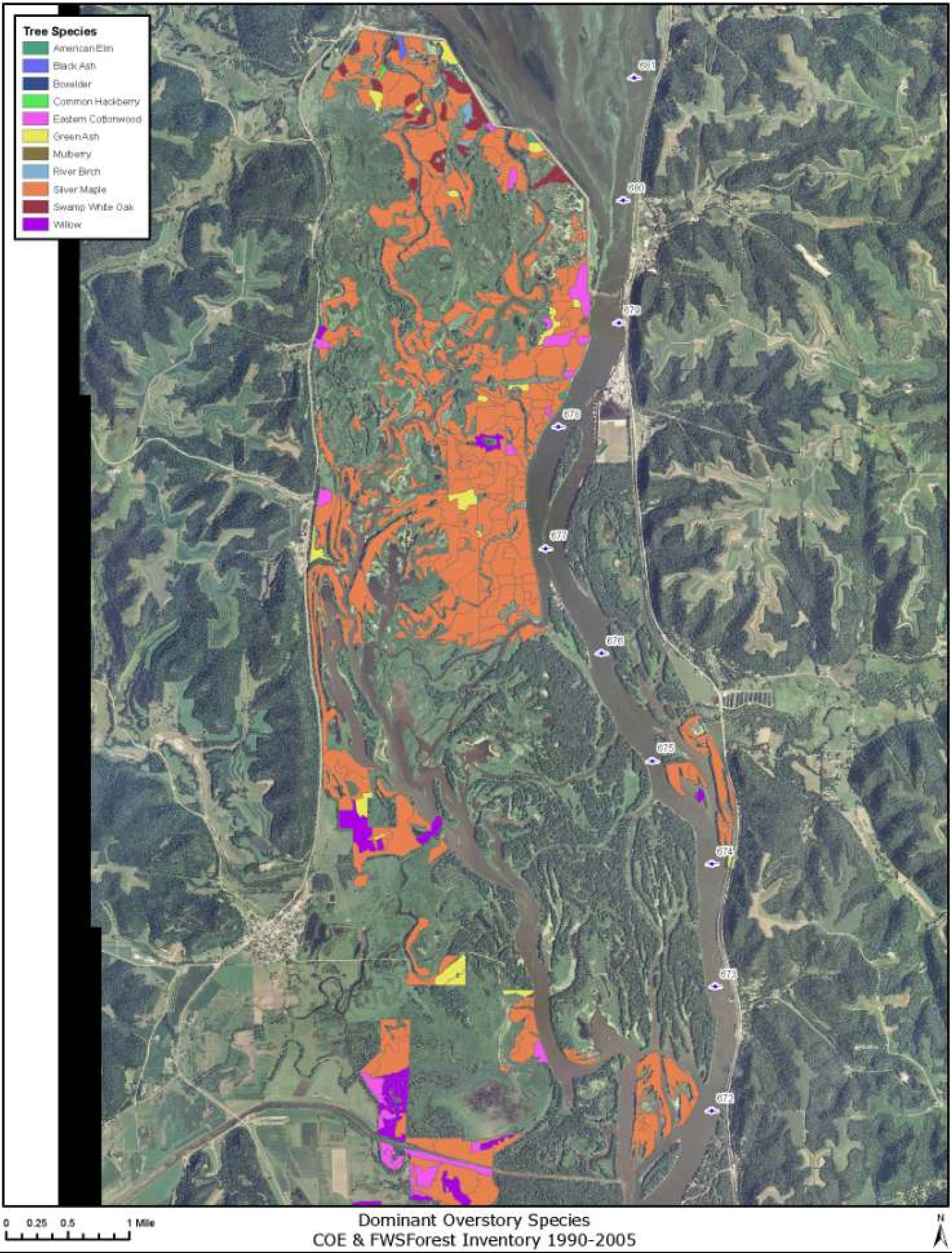
1890 Land Cover
Mississippi River Commission



1989 Land Cover
UMESC



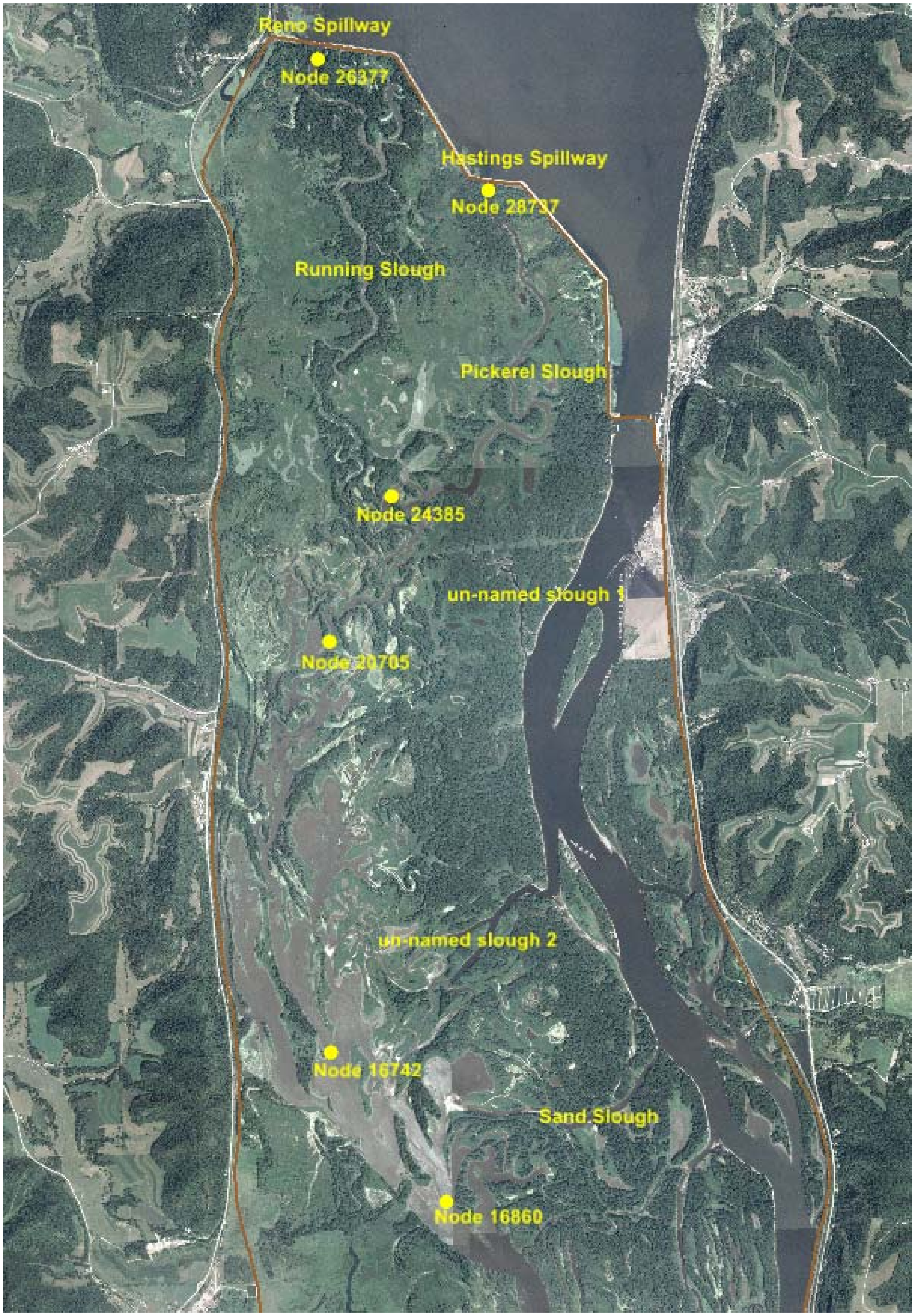
2000 Land Cover
UMESC



Dominant Overstory Species
COE & FWSForest Inventory 1990-2005

ADH Modeling of stage impacts caused by closing un-named sloughs 1 and 2 and eliminating spillway flows

Output Locations and Import Features



ADH Modeling of Stage Impacts caused by closing un-named sloughs 1 and 2 and eliminating spillway flows
Stages referenced to MSL 1912 datum

Upper Running Slough just below Reno Spillway							
Node 26377							
		No Flow through Spillways		Sloughs 1 and 2 Closed with Existing Spillway Flow		Sloughs 1 and 2 Closed with No Flow through Spillways	
Total River Discharge (cfs)	Existing Stage	Stage	Stage Change from Existing	Stage	Stage Change from Existing	Stage	Stage Change from Existing
20000	623.66	621.06	-2.60	623.68	0.02	621.05	-2.61
32000	623.74	622.19	-1.55	623.71	-0.03	621.88	-1.86
53000	624.47	624.03	-0.44	624.23	-0.24	623.67	-0.80
77000	625.79	625.68	-0.11	625.57	-0.22	625.44	-0.35
89000	626.57	626.52	-0.05	626.39	-0.18	626.33	-0.24

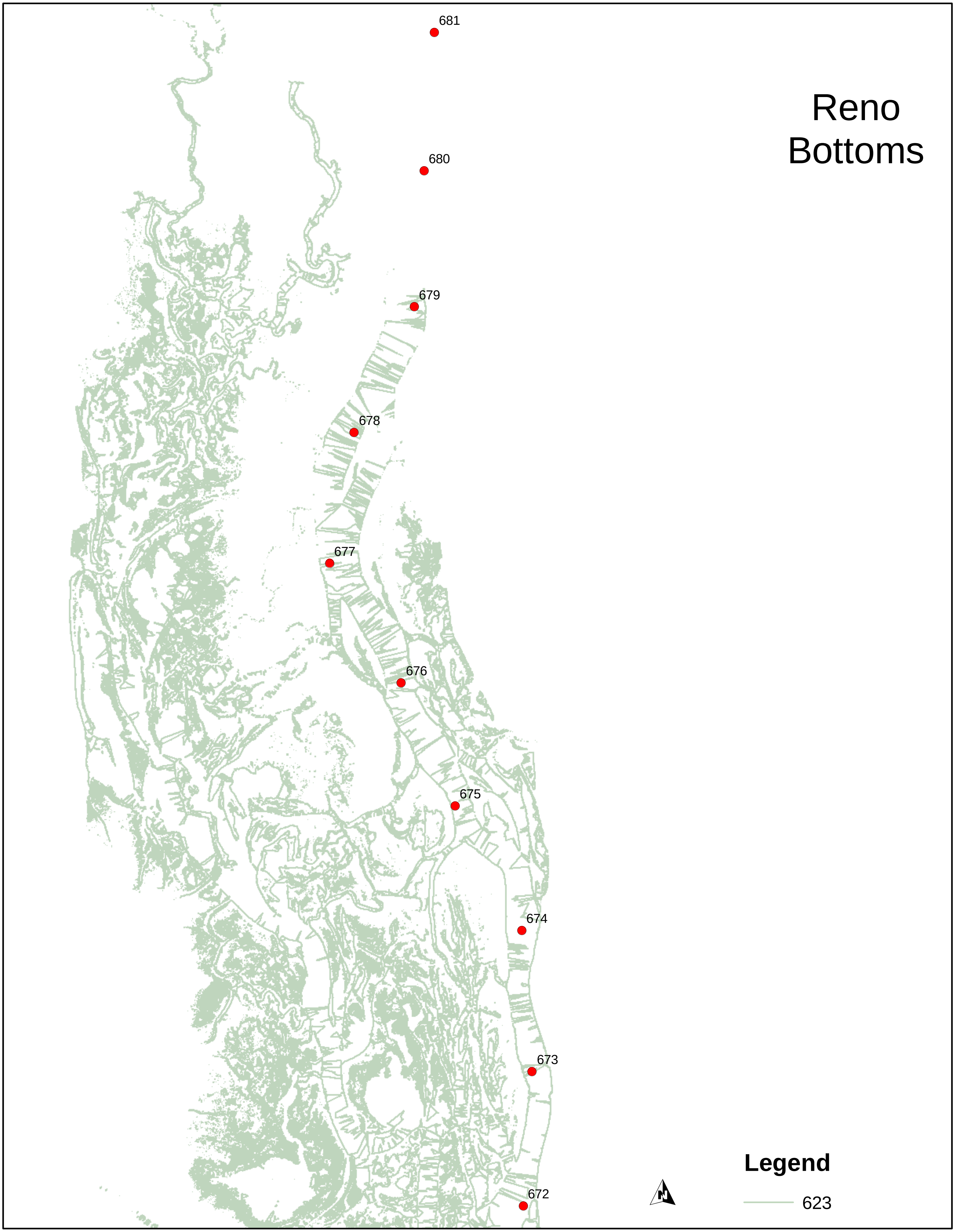
Upper Pickerel Slough just below Hastings Spillway							
Node 28737							
		No Flow through Spillways		Sloughs 1 and 2 Closed with Existing Spillway Flow		Sloughs 1 and 2 Closed with No Flow through Spillways	
Total River Discharge (cfs)	Existing Stage	Stage	Stage Change from Existing	Stage	Stage Change from Existing	Stage	Stage Change from Existing
20000	622.76	621.06	-1.70	622.83	0.07	621.05	-1.71
32000	623.01	622.19	-0.82	622.91	-0.10	621.88	-1.13
53000	624.19	624.03	-0.16	623.85	-0.34	623.67	-0.52
77000	625.71	625.68	-0.03	625.47	-0.24	625.44	-0.27
89000	626.54	626.52	-0.02	626.35	-0.19	626.33	-0.21

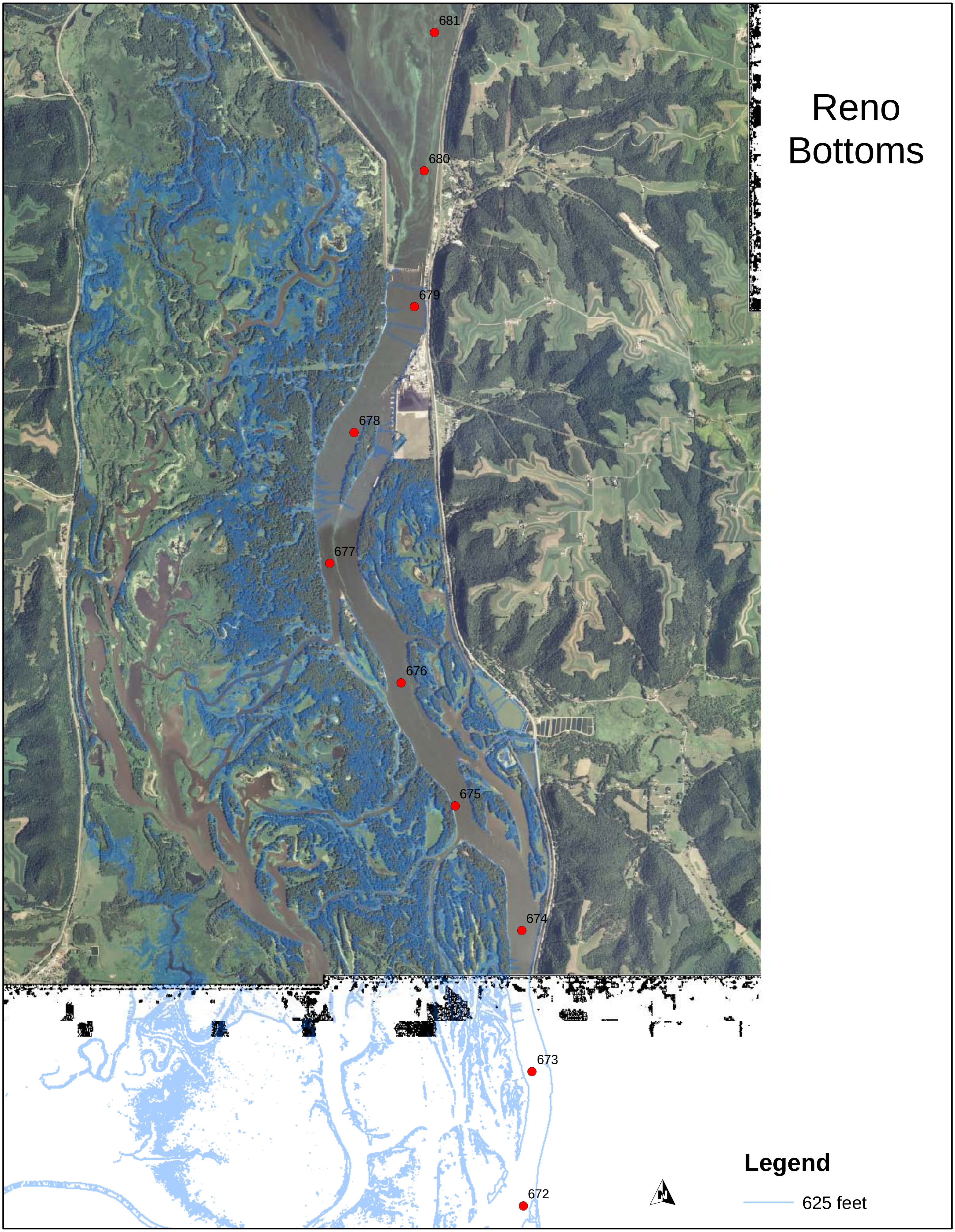
Near Convergence of Running and Pickerel Sloughs							
Node 24385							
		No Flow through Spillways		Sloughs 1 and 2 Closed with Existing Spillway Flow		Sloughs 1 and 2 Closed with No Flow through Spillways	
Total River Discharge (cfs)	Existing Stage	Stage	Stage Change from Existing	Stage	Stage Change from Existing	Stage	Stage Change from Existing
20000	622.46	621.06	-1.40	622.57	0.11	621.05	-1.41
32000	622.81	622.19	-0.62	622.68	-0.13	621.88	-0.93
53000	624.16	624.03	-0.13	623.79	-0.37	623.67	-0.49
77000	625.70	625.68	-0.02	625.47	-0.23	625.44	-0.26
89000	626.54	626.52	-0.02	626.35	-0.19	626.33	-0.21

Just below where un-named slough 1 comes in							
Node 20705							
		No Flow through Spillways		Sloughs 1 and 2 Closed with Existing Spillway Flow		Sloughs 1 and 2 Closed with No Flow through Spillways	
Total River Discharge (cfs)	Existing Stage	Stage	Stage Change from Existing	Stage	Stage Change from Existing	Stage	Stage Change from Existing
20000	621.85	621.06	-0.79	621.96	0.11	620.89	-0.96
32000	622.39	622.13	-0.26	622.22	-0.17	621.88	-0.51
53000	624.02	623.98	-0.04	623.71	-0.31	623.67	-0.35
77000	625.70	625.68	-0.02	625.45	-0.25	625.43	-0.27
89000	626.53	626.52	-0.01	626.33	-0.20	626.32	-0.21

Just below where un-named slough 2 comes in							
Node 16742							
		No Flow through Spillways		Sloughs 1 and 2 Closed with		Sloughs 1 and 2 Closed with No	
Total River Discharge (cfs)	Existing Stage	Stage	Stage Change from Existing	Stage	Stage Change from Existing	Stage	Stage Change from Existing
20000	621.11	621.05	-0.06	620.92	-0.19	620.89	-0.22
32000	622.14	622.10	-0.04	621.90	-0.24	621.88	-0.26
53000	623.96	623.94	-0.02	623.69	-0.27	623.67	-0.29
77000	625.66	625.64	-0.02	625.44	-0.22	625.42	-0.24
89000	626.48	626.47	-0.01	626.30	-0.18	626.28	-0.20

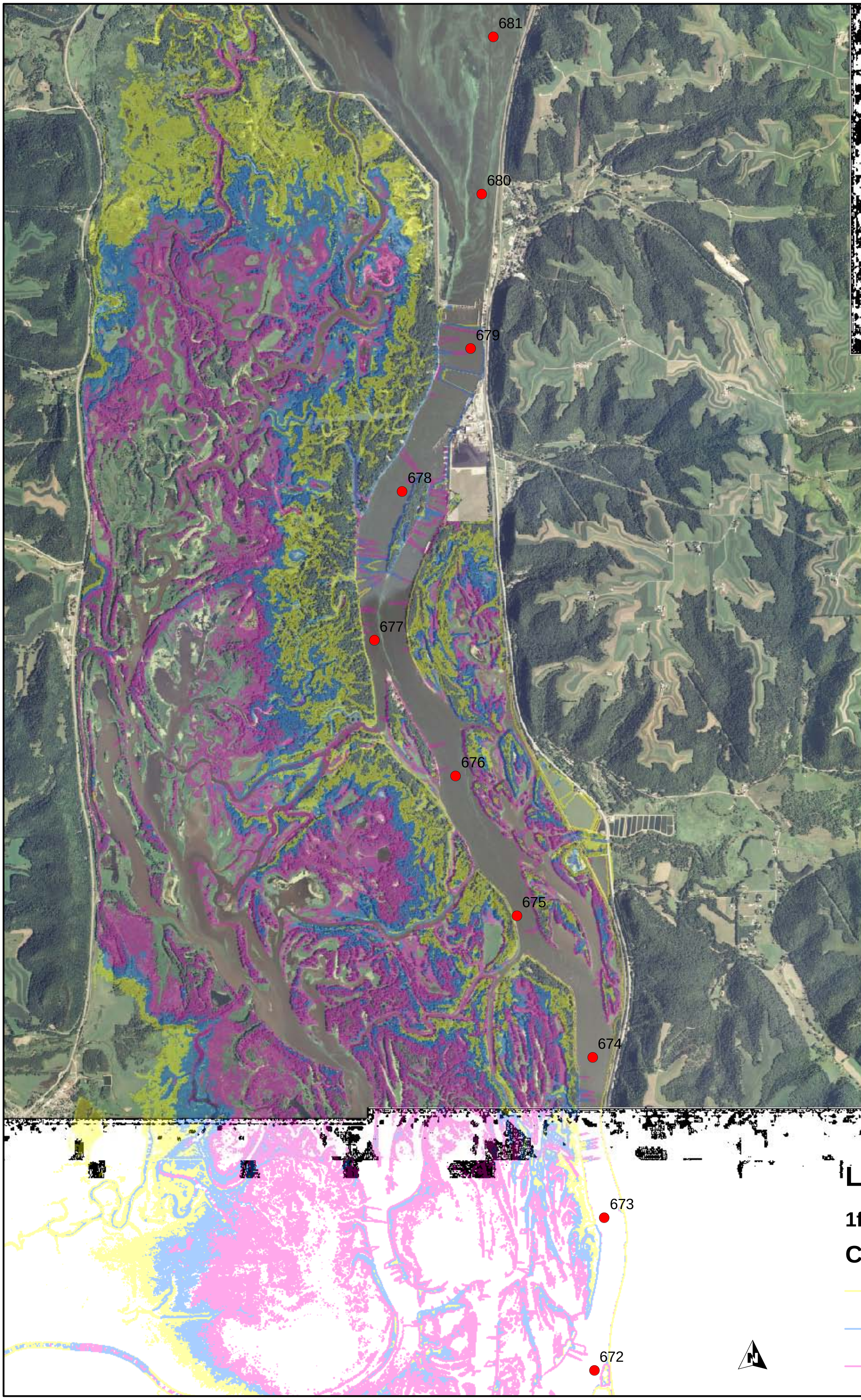
Just below where Sand Slough comes in							
Node 16860							
		No Flow through Spillways		Sloughs 1 and 2 Closed with		Sloughs 1 and 2 Closed with No	
Total River Discharge (cfs)	Existing Stage	Stage	Stage Change from Existing	Stage	Stage Change from Existing	Stage	Stage Change from Existing
20000	620.92	620.90	-0.02	620.91	-0.01	620.89	-0.03
32000	621.96	621.94	-0.02	621.90	-0.06	621.88	-0.08
53000	623.83	623.81	-0.02	623.69	-0.14	623.67	-0.16
77000	625.56	625.55	-0.01	625.42	-0.14	625.41	-0.15
89000	626.38	626.37	-0.01	626.26	-0.12	626.25	-0.13


Reno
Bottoms
681
680
679
678
677
676
675
674
673
672
Legend
623
N



Blue Heron Conservation Design | 2009

Reno Bottoms



Legend

1foot_contours_Reno

CONTOUR

626

625 feet

624 feet