National Park Service
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Natural Resource Stewardship and Science

Missouri National Recreational River

Natural Resource Condition Assessment

Natural Resource Report NPS/MNRR/NRR—2011/476

ON THE COVER
Goat Island looking west
Photograph courtesy of Missouri National Recreational River

Missouri National Recreational River

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Acronyms and Abbreviations

AOA – Area of analysis

BiOp – USFWS Biological Opinion

ESH – Emergent sandbar habitat

LCLU – Land cover / land use

MNRR - Missouri National Recreational River

NGO – Non-governmental organization

NGPC - Nebraska Game and Parks Commission

NGPN - Northern Great Plains Inventory and Monitoring Network

NLCD – National Land Cover Data

NPS – IMP – National Park Service, Inventory and Monitoring Program

NPS - National Park Service

NPS-ARD - National Park Service, Air Resources Division

NPS-WRD - National Park Service, Water Resources Division

NRCA - Natural Resource Condition Assessment

NRCS – Natural Resources Conservation Service

NU – University of Nebraska

SDGFP - South Dakota Department of Game, Fish, and Parks

SDSU – South Dakota State University

SMU GSS – Saint Mary's University of Minnesota, GeoSpatial Services

USACE - United States Army Corps of Engineers

USD – University of South Dakota

USDA – United States Department of Agriculture

USFS – United States Forest Service

USFWS - United States Fish and Wildlife Service

Acronyms and Abbreviations (continued)

USGS - United States Geological Survey

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Executive Summary

Disclaimer: Data and information presented in this report were compiled prior to the major flooding on the Missouri River in 2011; determination of resource condition did not take into account the effects of this flooding event.

As a unit in the National Park Servie (NPS), Missouri National Recreational River (MNRR) is responsible for the management and conservation of natural resources within its boundaries. This mandate is supported by the National Park Service Organic Act of 1916, which directs the NPS to:

> conserve the scenery and natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such a manner and by such means as will leave them unimpaired for the enjoyment of future generations.

In 2003, NPS Water Resources Division received funding through the Natural Resource Challenge Program to systematically assess watershed resource conditions in NPS units, establishing the Watershed Condition Assessment Program. This program, now titled the Natural Resource Condition Assessment (NRCA) Program, aims to provide documentation about the current conditions of important park resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. Findings from the NRCA, including the report and accompanying map products, will help MNRR managers to:

- develop near-term management priorities,
- engage in watershed or landscape scale partnership and education efforts,
- conduct park planning (e.g., Resource Stewardship Strategy),
- report program performance (e.g., Department of the Interior's Strategic Plan ―land health" goals, Government Performance and Results Act).

Specific project expectations and outcomes for the MNRR NRCA are listed in Chapter 3.

For the purpose of this NRCA, NPS staff identified key resources that are referred to as ―components" in the project framework and throughout the assessment. The components selected include natural resources and processes that are currently of the greatest concern to park management at MNRR. The final project framework contains nine resource components, along with measures, stressors, and reference conditions for each.

This study involved reviewing existing literature and data for each of the components in the framework and, where appropriate, analyzing the data in order to provide summaries or to create new spatial or statistical representations. After gathering data regarding current condition of component measures, those data were compared to reference conditions (when possible) and a qualitative statement of condition was developed. The discussions in Chapter 4 represent a comprehensive summary of available information regarding the current condition of these resources. These discussions represent not only the most current published literature, but also unpublished park information and, most importantly, the perspectives of park experts.

Nearly every component in MNRR is affected by the altered flow regime from the post-dam Missouri River and, with that, the conditions of most park resources (as indicated by the measures defined in the project framework) are of moderate or significant concern. These condition designations are largely a product of the ―pre-dam" reference condition assigned to nearly every MNRR component. When comparing the current condition of a resource that has been drastically altered by damming to its pre-dam condition, it is almost always worse off today. However, while the Missouri River ecosystem has endured large changes since dam construction, there are several individual components that are recovering and doing well with the given circumstances. Differing uses and interests of the Missouri River (e.g., preservation, recreation, electricity generation, navigation, etc.) further complicate MNRR's ability to restore the Missouri River to its pre-dam condition. However, several components (e.g., flow regime, aquatic and terrestrial habitats, erosional and depositional processes) are drivers of the entire ecosystem, and restoration of these components would have a cascading effect on the entire ecosystem. Overall, the Missouri River ecosystem is complex and while several components are considered to be of moderate or significant concern, their actual condition (when considering the the condition of the Missouri River ecosystem) is often times of lower concern.

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource components in national park units, hereafter ―parks". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and components emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority components for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and components.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional-issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope[1]
- employ hierarchical component frameworks[2]
- identify or develop logical reference conditions/values to compare current condition data against[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products[5]
- summarize key findings by park areas[6]
- follow national NRCA guidelines and standards for study design and reporting products.

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and components

Useful condition summaries by broader resource categories or topics, and by park areas

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study components where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors)

[1] However, the breadth of natural resources and number/type of indicators evaluated will vary by park.
[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition reporting by broader topics and park areas.
[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions.
[4] Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").
[5] As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products.
[6] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study component where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and NPS subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study components; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's Vital Signs monitoring components. They can also bring in relevant non-NPS data to help evaluate current conditions for those same Vital Signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

> ***Important NRCA Success Factors …***
>
> *Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline*
>
> *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ➯ components ➯ broader resource topics and park areas)*
>
> *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for component-level condition findings*

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study components. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks to report government accountability measures[8].

Due to their modest funding, a relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or component, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions, but in many cases their greatest value may be the documentation of known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information

NRCA Reporting Products…

Provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations ***(near-term operational planning and management)***

Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values ***(longer-term strategic planning)***

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ***("resource condition status" reporting)***

[7] NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy(RSS) but study scope can be tailored to also work well as a post-RSS project.

[8] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

MNRR was established by two acts of Congress which amended the Wild and Scenic Rivers Act of 1968. The first act (1978) created the 59-mile reach (also referred to as the Gavins Point Segment) from Gavins Point Dam to Ponca State Park, NE. The second act (1991) established a 39-mile reach (also referred to as the Fort Randall Segment) from Fort Randall Dam to Running Water, SD, 32 km (20 mi) of the lower Niobrara River, and 13km (8 mi) of Verdigre Creek (NPS 2011a). Public Law 95-625, passed on 10 November, 1978, states:

> MISSOURI RIVER, NEBRASKA, SOUTH DAKOTA. The segment from Gavins Point Dam, South Dakota, 95 km (59 mi) downstream to Ponca State Park, Nebraska, as generally depicted in the document entitled ―Review Report for Water Resources Development, South Dakota, Nebraska, North Dakota, Montana", prepared by the Division Engineer, Missouri River Division, Corps of Engineers, dated August 1977 (hereinafter in this paragraph referred to as the ―August 1977 Report"). Such segment shall be administered as a recreational river by the Secretary. The Secretary shall enter into a written cooperative agreement with the Secretary of the Army (acting through the Chief of Engineers) for construction and maintenance of bank stabilization work and appropriate recreational development.

Public Law 102-50, which established the 39-mile MNRR stretch in 1991, states:

> Niobrara, Nebraska. (A) The 40-mile segment from Borman Bridge southeast of Valentine downstream to its confluence with Chimney Creek and the 30-mile segment from the river's confluence with Rock Creek downstream to the State Highway 137 bridge, both segments to be classified as scenic and administered by the Secretary of the Interior. That portion of the 40-mile segment designated by this subparagraph located within the Fort Niobrara National Wildlife Refuge shall continue to be managed by the Secretary through the Director of the United States Fish and Wildlife Service (USFWS).
>
> (B) The 25-mile segment from the western boundary of Knox County to its confluence with the Missouri River, including that segment of the Verdigre Creek from the north municipal boundary of Verdigre, Nebraska, to its confluence with the Niobrara, to be administered by the Secretary of the Interior as a recreational river.
>
> MISSOURI RIVER, NEBRASKA AND SOUTH DAKOTA. The 39-mile segment from the headwaters of Lewis and Clark Lake to the Ft. Randall Dam, to be administered by the Secretary of the Interior as a recreational river.

2.1.2 Geographic Setting

MNRR encompasses 27,973 ha (69,123 ac). The western reach includes a 32-kilometer stretch of the Niobrara River and eight miles of Verdigre Creek (Weeks et al. 2005). MNRR is unique in that the NPS only owns a small portion of land within the park (less than 1% of the total land area); the majority of MNRR is owned by federal, state, tribal, and local jurisdictions as well as private landowners. Other well-known natural areas within MNRR include Niobrara, Ponca, Randall Creek, and Spirit Mounds State Parks, U.S. Army Corps of Engineers (USACE) properties, and the Karl Mundt National Wildlife Refuge (NPS 1999).

MNRR's climate is characterized by hot and humid summers, mild to very cold winters with rain, sleet, and snow, and moderate spring and autumn seasons (NPS 2011b). Table 1 contains temperature and precipitation averages between 1971 and 2000.

Table 1. Monthly temperature and precipitation normals (1971-2000) for MNRR (US DOC 2002).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (F)													
Max	-1.9	1.6	7.8	15.7	22.4	27.9	30.7	29.5	24.9	17.7	7.1	0.0	15.3
Min	-13.6	-10.2	-4.5	1.4	7.8	13.6	16.4	15.3	9.6	3.2	-4.3	-11.2	2.0
Average Precipitation (cm)													
Total	1.09	1.34	4.49	6.37	9.82	9.93	8.53	7.44	5.51	4.69	3.17	1.29	63.72

2.1.3 Visitation Statistics

MNRR averaged 128,972 visitors per year between 2004 and 2009, with the majority of visitation occurring during summer months (NPS 2011c). Popular visitor activities at MNRR include canoeing, boating, fishing, and wildlife viewing. Hunting and trapping are also permitted within MNRR (NPS 2009).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

The Environmental Protection Agency (EPA) classifies the United States into different ecoregion levels. MNRR lies within three level III ecoregions: Northwestern Glaciated Plains, Northern Glaciated Plains, and Western Corn Belt Plains. Bryce et al. (1998) describe the Northwestern Glaciated Plains ecoregion as

> The Northwestern Glaciated Plains ecoregion marks the westernmost extent of continental glaciation. The youthful morainal landscape has significant surface irregularity and high concentrations of wetlands. The rise in elevation along the eastern boundary defines the beginning of the Great Plains. Land use is transitional between the intensive dryland farming on Ecoregion 46i to the east and the predominance of cattle ranching and farming to the west on the Northwestern Great Plains.

Bryce et al. (1998) describes the Northern Glaciated Plains ecoregion as

> The Northern Glaciated Plains ecoregion is characterized by a flat to gently rolling landscape composed of glacial drift. The subhumid conditions foster a grassland transitional between the tall and shortgrass prairie. High concentrations of temporary and seasonal wetlands create favorable conditions for duck nesting and migration. Though the till soil is very fertile, agricultural success is subject to annual climatic fluctuations.

Bryce et al. (1998) describes Western Corn Belt Plains ecoregion as

> The high agricultural productivity of the Western Corn Belt Plains ecoregion is due to its fertile soil, temperate climate, and adequate precipitation during the growing season. This ecoregion has a relatively homogeneous topography of level to gently rolling glacial till plains with areas of morainal hills and loess deposits. The original tallgrass prairie vegetation has been converted to intensive rowcrop agriculture of corn, soybeans, and feed grains to support livestock production.

Level III ecoregions are further classified into smaller level IV ecoregions. MNRR lies within five level IV ecoregions: Southern River Breaks, Holt Tablelands, James River Lowland, Missouri Alluvial Plain, and Northeastern Nebraska Loess Hills. Bryce et al. (1998) describe the Southern River Breaks ecoregion as

> The Southern River Breaks reflect the more temperate conditions of the southern glaciated plains. Here the draws and northern aspects are heavily wooded with deciduous forest, in contrast to the River Breaks north of the Big Bend of the Missouri where the riparian woodland forms narrow stringers of juniper and green ash.

Bryce et al. (1998) describe the Holt Tablelands ecoregion as

> The Holt Tablelands ecoregion is a transitional area between the loamy, glaciated regions with loess soils to the east and the Sand Hills in the west and south. This region shares many characteristics with the Nebraska Sand Hills (44); however, climate, physiography, and land use are more similar to those of the Northwestern Glaciated Plains (42). Cropland agriculture occurs on the more level tablelands and in areas with loamy soils, whereas grassland is found in areas of greater relief.

Bryce et al. (1998) describe the James River Lowland ecoregion as

> The boundary between the James River Lowland and the Drift Plains to the north represents a broad phenological and climatic transition zone. This ecoregion is characterized by mesic soils, warmer temperatures, and a longer growing season than the Drift Plains. These differences are reflected in the crop types of the region. Winter wheat, corn, and soybeans are more prevalent in this ecoregion's milder climate.

Bryce et al. (1998) describe the Missouri Alluvial Plain as

> The human development of the Missouri Alluvial Plain over the last two centuries has separated the Missouri River from its floodplain. A system of dams, levees, and stream channelization has largely controlled the flood cycles to allow intensive agriculture in the river bottomland. Much of the northern floodplain forest has been cut, and oxbow lakes and wetlands have been drained to reclaim additional agricultural land.

Chapman et al. (2001) describe the Nebraska Loess Hills as

> The Northeastern Nebraska Loess Hills have an older, coarser loess mantle that is not as weathered as in ecoregions to the south. The climate is generally cooler with slightly less annual precipitation than in southern glaciated regions. Cropland agriculture, especially corn, is common, and there is more irrigated agriculture and pastureland, but fewer scattered woodlands than in neighboring Western Corn Belt Plains regions.

MNRR exists within the Missouri River watershed, which drains one-sixth of the United States and encompasses 1,371,010 square kilometers (529,350 square miles) (NPS 2007). Approximately 45% of the surface area within MNRR boundaries is water, mostly the Missouri River. The dominant vegetation type in MNRR is central plains riparian forest, but the unit also contains native and restored tall grass prairie, oak woodlands, pastures, plowed fields, and residential areas (Weeks et al. 2005, Stevens et al. 2010).

2.2.2 Resource Descriptions

The Missouri River is the major physical feature within MNRR. Amphibians, birds, native and non-native fish, mammals, and reptiles are abundant in and along the three major waterways of MNRR (Missouri and Niobrara Rivers and Verdigre Creek), primarily due to the diverse habitat that supports the variety of species (NPS 2010). MNRR has more federally listed endangered and threatened species than any park in the Northern Great Plains Network (NGPN) including piping plover (*Charadrius melodus*), interior least tern (*Sterna antillarum athalassos*), pallid sturgeon (*Scaphirhyncus albus*), and scaleshell mussel (*Leptodea leptodon*) (NPS n.d.).

Two major plant communities are present within MNRR, the willow (*Salix* spp.) and cottonwood (*Populus deltoides*) floodplain forest and elm (*Ulmus* spp.) and oak (*Quercus* spp.) woodlands (NPS 2011d). Plains cottonwood was historically abundant on the Missouri River floodplain, but recruitment of cottonwoods is not keeping pace with mortality due to channel modification following dam construction (Dixon et al. 2010). Sandbars and floodplains in MNRR contain a mix of annual weeds, short-lived grasses, sedges, and seedling willow and cottonwood (NPS 2011d). Larger willows and cottonwoods form floodplain forests at higher elevations along stream banks, with an understory of dogwood (*Cornus* spp.), sumac (*Rhus* spp.), wild grape (*Vitis* spp.), and poison ivy (*Toxicodendron radicans*) (NPS 2011d). The dense hardwood forests located on the adjacent bluffs are dominated by bur oak (*Quercus macrocarpa*), and also contain ash (*Fraxinus* spp.), mulberry (*Morus* spp.), and walnut (*Juglans* spp.) (NPS 2011d).

2.2.3. Resource Issues Overview

The construction of dams, levees, and the process of channelization heavily altered the Missouri River (NPS n.d.). These changes resulted in the significant alteration of aquatic and terrestrial habitat in MNRR. Two serious issues for MNRR are the reduction in sediment transport and bank erosion (Weeks et al. 2005), both a result of dam construction on the Missouri River.The resulting reservoirs eradicated miles of riparian forests and essentially stopped the meander and periodic flooding on the upper reaches of the river, greatly altering the river ecosystem (Weeks et al. 2005). Modification of the natural hydrology affected the life cycles of plants, nesting birds, aquatic insects and fish. The majority of riverine fish require high spring flows for successful reproduction (Weeks et al. 2005).

Photo 1. Gavins Point Dam (USACE n.d.).

Eight exotic invasive plants are identified as species of concern at MNRR; the most problematic include purple loosestrife (*Lythrum salicaria*), salt cedar (*Tamarix* spp.), Russian olive (*Elaeagnus angustifolia*), Canada thistle (*Cirsium arvense*), and leafy spurge (*Euphorbia esula*) (NPS 2011e). Exotic plant species often outcompete and displace native plants, altering community structure and subsequently affecting the amount and quality of available habitat for aquatic and terrestrial wildlife.

Climate change could have dramatic impacts on the ecosystems within MNRR (Gitzen et al. 2010). Temperatures in the Northern Great Plains have risen more than 1.1° C (2° F) over the past century and models predict an increase of 2.7°-6.7° C (5-12° F) during this century (National Assessment Synthesis Team 2000). While precipitation is also expected to increase, evapotranspiration will increase with higher temperatures and longer growing seasons, perhaps resulting in an overall drier climate (National Assessment Synthesis Team 2000).

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

The stretch of the Missouri River which forms MNRR is designated a National Wild and Scenic River (NPS 2011f):

> It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. The Congress declares that the

established national policy of dams and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes. (Wild and Scenic Rivers Act, October 2, 1968)

2.3.2 Status of Supporting Science

Multiple agencies are involved in research and management within MNRR, including the NPS; U.S. Fish and Wildlife Service (USFWS); U.S. Geological Survey (USGS); South Dakota Department of Game Fish and Parks (SDGFP), Nebraska Game and Parks Commission (NGPC); U.S. Army Corps of Engineers (USACE); University of South Dakota (USD); South Dakota State University (SDSU); Virginia Polytechnical University (VT); University of Nebraska (UN); and the Missouri River Recovery Group (comprised of individuals from many of the aforementioned agencies).

NGPN is responsible for developing a list of Vital Signs for each park unit based on its key resources. Table 2 shows the network Vital Signs selected for monitoring in MNRR. The following Vital Signs are currently being monitored by MNRR, another NPS program, or another federal or state agency using other funding: weather and climate, surface water dynamics, raptors, piping plovers, interior least terns, pallid sturgeon, treatments of exotic infestations, and visitor use (Gitzen et al. 2010). Other Vital Signs for MNRR have not yet been studied.

Table 2. NGPN Vital Signs selected for monitoring in MNRR (Gitzen et al. 2010). Those in bold are already monitored by the park or another NPS program while those in italics will likely be monitored in the future but there are currently no plans to develop a program.

Category	NGPN Vital Signs
Air and Climate	**Weather and climate**
Geology and Soils	Stream and river channel characteristics
Water	**Surface water dynamics**, surface water chemistry, aquatic contaminants, aquatic microorganisms, aquatic macroinvertebrates
Biological integrity	Exotic plant early detection, riparian lowland plant communities, upland plant communities, land birds, **raptors**, **piping plovers and interior least terns, pallid sturgeon**
Human use	**Treatments of exotic infestations**, **visitor use**
Landscapes (ecosystem pattern and process)	*Fire and fuel dynamics*, land cover and use, extreme disturbances, soundscape, *viewscape*, *night sky*

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Chapter 3 Study Scoping and Design

This NRCA was a collaborative effort between the NPS and Saint Mary's University of Minnesota, GeoSpatial Services (SMU GSS). Stakeholders in this project include MNRR park resource staff and the Northern Great Plains Inventory and Monitoring Network (NGPN) staff. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMU GSS. Preliminary scoping meetings were held, and a task agreement and a detailed scope of work document were created in cooperation with the NPS and SMU GSS.

3.1 Preliminary Scoping

A preliminary scoping meeting was held 21 October 2009 with SMU GSS and NPS staff. This scoping meeting determined the purpose of the MNRR NRCA, which is to evaluate and report on current conditions of key park resources, evaluate critical data and knowledge gaps and highlight selected existing and emerging resource condition influences of concern to MNRR managers.

The National NRCA Program Office provided specific guidance requirements regarding this NRCA:

- The NRCA is conducted using existing data and information;
- Identification of data needs and gaps is driven by the framework categories;
- The analysis of natural resource conditions includes a strong geospatial component;
- Resource focus and priorities are primarily driven by MNRR park resource management.

This condition assessment provides a –snapshot-in-time" evaluation of resource condition status for a select set of park natural resources, identified and agreed to by the project team. Project findings will aid MNRR resource managers in the following objectives:

- Developing near-term management priorities;
- Engaging in watershed or landscape scale partnership and education efforts;
- Conducting park planning (e.g., General Management Plan, Resource Stewardship Strategy);
- Reporting program performance (e.g., Department of the Interior Strategic Plan –land health" goals).

3.1.1 NPS Involvement

Expectations for MNRR staff involvement were detailed during project scoping. Park staff participated in project development and planning, reviewed interim and final products, and participated in condition assessments. They were also expected to participate and collaborate with SMU GSS to identify sources of information, define an appropriate resource assessment structure, identify appropriately scaled resources, threats and stressors, and identify measures for these resources.

MNRR park staff helped to identify other NPS staff that could provide guidance, technical assistance, and logistical coordination for site visits and discussions with the primary investigator, analysts, and graduate research assistants. Park staff collaborated with the SMU GSS Principle Investigator during data mining and status assessment to ensure the synthesis was consistent with the project goals. Additionally, MNRR natural resource staff assisted in developing recommendations for additional analyses to fulfill information needs that would aid in the assessment of park resource conditions. They were also expected to review and comment on draft reports and all publishable material submitted from this project in a timely fashion. Involvement of MNRR staff in this project ensured that SMU GSS efforts met the true needs of the park.

The NPS was responsible for informing the SMU GSS Principle Investigator of the specific activities required to comply with the ―NPS Interim Guidance Document Governing Code of Conduct, Peer Review, and Information Quality Correction for NPS Cultural and Natural Resource Disciplines” or any subsequent guidance issued by the NPS Director to replace this interim document.

3.2 Study Design

3.2.1 Component Framework, Focal Study Resources and Components

<u>Selection of Resources and Measures</u>

As defined by SMU GSS in the NRCA process, a ―framework” is developed for a park. This framework is a way of organizing, in a hierarchical fashion, bio-geophysical resource topics considered important in park management efforts. The primary features in the framework are key resource components, measures, stressors, and reference conditions.

Components in this process are defined as natural resources (e.g., bison), ecological processes or patterns (e.g., natural fire regime or land cover change), or specific natural features or values (e.g., geological formation, dark night skies, or viewshed) that are considered important to current park management. Each key resource component has one or more ―measures” that best define the current condition of a component being assessed in an NRCA. Measures are defined as those values or characterizations that evaluate and quantify the state of ecological health or integrity of a component. In addition to measures, current condition of components may be influenced by certain ―stressors” and thus, are considered during assessment. A ―stressor” is defined as any agent that poses a threat to a component. Stressors typically refer to anthropogenic factors that adversely affect natural ecosystems, but may also include natural processes or disturbances such as floods, fires, or predation (adapted from GLEI 2010).

During the MNRR NRCA scoping process, key resource components were identified by NPS staff and are represented as components in the NRCA framework. While this list of components is not a comprehensive list of all the resources in the park, it includes resources and processes that are unique to the park in some way, of greatest concern or of highest management priority in MNRR. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with MNRR resource staff.

Selection of Reference Conditions

A reference condition is a benchmark against which one can compare current values of a given component's measures to determine condition of that component. A reference condition may be a historical condition (e.g., flood frequency prior to dam construction on a river), an established ecological threshold (e.g., EPA standards for air quality), or a targeted management goal/objective (e.g., a bison herd no larger than 700 individuals) (adapted from Stoddard et al. 2006).

Reference conditions in this project were identified during the scoping process using input from NPS resource staff. In some cases, reference conditions represent a historical reference in which human activity and disturbance was not a major driver of ecological populations and processes, such as ―pre-exotic invasions" or ―pre-1908 establishment." In other cases, peer-reviewed literature and ecological thresholds helped to define appropriate reference conditions.

Finalizing the Framework

An initial framework was adapted from the organizational framework outlined by the H. John Heinz III Center for Science's ―State of Our Nation's Ecosystems 2008" framework (Heinz 2008). Key resources for the park were gleaned from the NGPN Vital Signs Monitoring Plan (draft form of Gitzen et al. 2010) and publicly available informational materials from MNRR. This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMU GSS analysts and NPS staff was needed to focus the scope of the NRCA project and finalize the framework of key resources to be assessed.

The NRCA framework was finalized in March 2010 following acceptance from MNRR resource staff. It contains 21 components (Table 3) and was used to drive analysis in this NRCA. This framework outlines the resources (components), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each resource.

Table 3. Final MNRR NRCA framework.

Missouri National Recreational River
Natural Resource Condition Assessment Framework

Components	Measures	Stessors	Reference Condition
Geographic Extent and Pattern			
Landscape Composition			
Land Cover & Landuse	Ownership Pattern	Invasive/exotic Vegetation; Development; Human Development and Bank Stabilization	Pre exotics and invasive
	Land Cover/Use Distribution		
	Dynamics		
Geomorphology and Hydrology			
Erosional and depositional processes	Channel elevation	Bank Stabilization; dam operations limit peak flows, increase low flows, alter temporal flows (seasonality and duration); reduction/lack of large wood in the river.	Pre-dam
	Sediment Transport and Depostion		
	Bank Erosion and Channel Migration		
	Amount, Areal Extent, and Mean Particle Size (D50) of Armored Streambed		
	Island and Sandbar Development and Maintenance Processes		
Flow Regime	Frequency of Flood Pulses (Magnitude and Rate of Change)	Bank Stabilization; dam operations limit peak flows, increase low flows, alter temporal flows (seasonality/duration); Change in climatic patterns	Pre dam construction (Ft. Randall, Gavins Point and Spencer) hydrographs
	Frequency, Timing, and Duration of Discharge		
Biological Components			
Ecosystem and Community			
Aquatic and terrestrial habitats	Distribution and abundance of diverse native plant communities.	Bank Stabilization; dam operations limit peak flows, increase low flows, alter temporal flows (seasonality and duration); exotic/invasive species; shift in climate; development; loss of natural disturbance regime.	Pre-dam
	Amount of vegetation in diverse seral stages		
	Amount of vegetated island and sandbar habitat		
	Wetland distribution, type and location		
	Depth and substrate diversity (support pallid sturgeon)		
	Amount of chutes, backwater and shallow-water habitat		
	Presence of exotics and invasives	Increase in species distribution and density	Pre exotics and invasives
Biotic Composition			
Cottonwood	Cottonwood Habitat Extent	Dam operations limit peak flows; development; loss of natural disturbance regime.	Pre-dam
	Cottonwood Age		
Pallid Sturgeon	Habitat diversity	Dam operation impact on turbidity, discharge, and micro habitat; development; loss of natural disturbance regime.	Pre-dam
	Productivity		
Piping Plover & Interior Least Tern	Available nesting habitat	Dam operations limit the natural hydrograph; development; loss of natural disturbance regime; storm flow during nesting and fledging periods.	Pre-dam
	Fledge Ratios		
	Population Size		
Land Birds	Species richness and density	Development; loss of natural disturbance regime; habitat loss.	Pre-dam
	Expected bird species		
	Species of conservation concern		
	Bald Eagles		
	Ospreys		
Native fish populations	Abundance	Change in carbon cycling due to loss of natural hydrograph; development; loss of natural disturbance regime; exotics/invasive species.	Pre-dam
Northern leopard frog	Habitat availability	Change in climatic patterns; development; loss of natural disturbance regime; habitat loss; water quality impacts.	Pre-dam
Freshwater invertebrates	Habitat availability	Change in hydrologic regime; loss of natural disturbance regime; habitat loss; water quality impacts.	Pre-dam

Table 3. Final MNRR NRCA framework. (continued)

Chemical and Physical Characteristics				
	Water Quality	**Turbidity**	**Dam operations limit peak flows, increase low flows, alter temporal flows (seasonality and duration); non-point source pollutants; Non-point source agricultural runoff; point source urban discharge; non-point source pollutants.**	**EPA and WRD standards; natural variability; "Natural" spatial and temporal patterns; predam and pre-river regulation conditions**
		Specific conductance		
		pH		
		Dissolved oxygen		
		Measures of velocity	**Dam operations limit peak flows, increase low flows, alter temporal flows (seasonality and duration)**	
		Water temperature		
		Nutrients	**Non Point Source Agricultural runoff**	
		Agricultural chemicals		
		Fecal coliform bacteria	**Point source urban discharge; non point source pollutants.**	
	Air Quality	Mercury	Atmospheric deposition from powerplant operations	EPA Air Quality Criterion; NPS Air Resources Division index values; "Natural" spatial/temporal patterns
		Nitrogen	Atmospheric deposition from agricultural operations	
		Ozone	Fossil fuel combustion	
		Particulate Matter	Powerplant emissions; dust from agricultural plowing	
	Climate	Phenologic relationships (Onset and duration of greeness)	Changing range for invasives and exotics, timing of biological events for plants and animals	Period of record.
		Precipitation pattern (change in frequency and amount)	Change in rainfall patterns (amounts and distributions)	
		Temperature (change in pattern and range)	Change in microclimate and habitat relationships	
Goods and Services				
Human Values				
	Soundscape	Ambient sound level	Development, trails, roads	Undeveloped park experience
		Distribution of non-natural sounds		
	Dark Night Skies	Schaff Scale Scores	Development and power production.	Pre-European settlement - absence of anthropogenic light
		Darkness - V Magnitude		
	Odorscape	Anthropogenic odors	Factory, development, feedlot	Natural ambient condition
	Viewshed	**Natural undeveloped viewsheds**	**Development, trails, roads, and power production.**	**Pre-European settlement, pre-dam**

3.2.2 Reporting Areas
Reporting zones were not used in this assessment.

3.2.3 General Approach and Methods
This study involved gathering and reviewing all existing literature and data relevant to each of the key resource components included in the framework. No new data were collected for this study, however, where appropriate, existing data were analyzed to provide summaries of condition for resources or to create new spatial representations. After all data and literature relevant to the measures of each component were reviewed and considered, a qualitative statement of overall current condition was created and compared this current condition to the reference condition when possible.

Individual Component Assessments

Data Mining
The data mining process (acquiring as much relevant data about key resources as possible) began at the first scoping meeting, at which time MNRR and NPS staff provided data and literature in multiple forms, including NPS reports and monitoring plans, reports from various state and federal agencies, published and unpublished research documents, Non-governmental organization reports, databases, tabular data, and charts. GIS data were provided by NGPN and by MNRR staff. Access was also granted to various NPS online data and literature sources, such as NatureBib and NPSpecies. Additional data and literature were also acquired through online bibliographic literature searches and inquiries on various state and federal government websites.

Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality regarding the resource components identified at the scoping meeting.

Data Development and Analysis
Data development and analysis was highly specific to each component in the framework and depended largely on the amount of information and data available on the topic and recommendations from MNRR staff about analysis. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Preparation and Review of Component Rough Draft Assessments (Phase I Documents)
The process of developing draft documents for each component began with a detailed phone or conference call with an individual or several individuals considered experts on the resource component(s) under examination. These conversations were a way for analysts to verify the most relevant data and literature sources that should be used and also to formulate ideas about current condition with respect to the experts' opinions. Information gained in these initial conversations was important for rough draft development. Rough drafts were developed using the data gathered through the data mining process and the insights provided by component experts. Documents were then forwarded to component experts for initial review and comments.

The preparation of rough draft assessments for each component was a highly cooperative process among SMU GSS analysts and MNRR and NGPN staff. Though SMU GSS analysts rely heavily on peer-reviewed literature and existing data in conducting the assessment, the expertise of NPS resource staff also plays a significant and invaluable role in providing insights into the appropriate direction for analysis and assessment of each component. This step is especially important when limited data or literature exist for a resource component.

Development and Review of Final Component Assessments (Phase II Documents)
Following review of the component rough drafts (Phase I documents), analysts used the feedback from resource experts to compile the final component assessments (Phase II documents). Consistent contact with experts was maintained throughout this process in order to adequately address questions and comments pertaining to rough draft reviews and to ensure accurate representation of MNRR and NGPN staff knowledge. Once Phase II documents were completed, they were sent back to expert reviewers for a second thorough review and to provide an opportunity to add more insights. Any comments or feedback received during this second review were incorporated into the assessment document. As a result of this process, and based on the recommendations and insights provided by MNRR resource staff and other experts, the final component assessments represent the most relevant and current data available and the sentiments of park resource staff and resource experts.

Format of Component Assessment Documents
All resource component assessments are presented in a standard format in the final report. The format and structure of resource component assessments is described below.

Description
This section describes the relevance of the resource component to the park and the context within which it occurs in the park setting. The importance of the resource component to the park and why it is included in this assessment are explained. For example, it may represent a unique feature of the park, may be a key process or resource in park ecology, or it may be a resource that is of high management priority in the park. Any interrelationships that occur among a given component and other resource components included in the broader assessment are also emphasized.

Measures
Resource component measures were defined in the scoping process and refined through extensive dialogue with resource experts. Those measures deemed most appropriate for assessing the current condition of a component are listed in this section, typically as bulleted items with a very brief description of metrics used in the assessment.

Reference Conditions/Values
This section explains the reference condition determined for each resource component as it is defined in the framework. Explanation is provided as to why specific reference conditions are appropriate or logical to use. Also included in this section is a discussion of any available data and literature that explain and elaborate on the designated reference conditions. If these conditions or values originated with the park experts or SMU GSS analysts, an explanation of how they were developed is provided.

Data and Methods
This section includes a discussion of the data sets used to evaluate the component and if or how these data sets were adjusted or processed as a lead-up to analysis. If adjustment or processing of data involved an extensive or highly technical process, these descriptions are included in an appendix or as a GIS metadata file. Also discussed is how the data were evaluated and analyzed to determine current condition (and trend when appropriate).

Current Condition and Trend
This section presents and discusses in-depth key findings regarding the current condition of the resource component and trends (when available). The information is presented primarily with text but is often accompanied by detailed maps or plates that display different analyses, as well as graphs, charts, and/or tables that summarize relevant data or show interesting relationships. All relevant data and information for a component is presented and interpreted in this section.

Threats and Stressor Factors
This section provides a summary of the threats and stressors that may impact the resource and influence to varying degrees the current condition of a resource component. Relevant stressors were described in the scoping process and are outlined in the NRCA framework. However, these are elaborated on in this section to create a summary of threats and stressors based on a combination of available data and literature, and discussions with experts and park natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Discussed specifically is how these data needs/gaps, if addressed, would provide further insight in determining the current condition of a given component in future assessments. In some cases, the data needs/gaps are significant enough to make it inappropriate or impossible to determine condition of the resource component. In these cases, stating the data needs/gaps is useful to natural resources staff who wish to prioritize monitoring or data gathering efforts.

Overall Condition
This section provides a qualitative summary statement of the current condition for the resource component. Condition is determined after thoughtful review of available literature, data, and any insights from park staff and experts, which are presented in the Current Condition and Trend section. The Overall Condition section summarizes the key findings and highlights the key elements used in determining and justifying the level of concern, if any, that analysts attribute to the condition of the resource component.

Initial designations of current condition for a component, made by the authors during component rough draft preparation, were subject to review from resource experts during the review process and amended when appropriate to provide a more accurate representation of park staff/experts' interpretation of condition. When applicable, condition designations were made with respect to the defined reference condition. At other times, when reference conditions were not available, the opinions of park staff and experts were relied on more heavily to determine condition.

Condition Graphic
This provides a graphical representation of the component's condition (and trend when appropriate). It is intended to give readers a more visual interpretation of the assessed condition. However, it does not replace the written statements of condition, which provide an in-depth discussion of and justification for the condition attributed by analysts to the resource component.

Figure 1 shows an example of the condition graphic as it is used to represent the assessed condition of a component. Colored circles indicate a component's condition expressed by level of concern. Red circles signify that a resource is of significant concern to park management. Yellow circles signify that a resource is of moderate concern to park management. Green circles indicate the condition of a component has been assessed as of low concern. Gray circles signify that there is currently insufficient data to make a statement about concern or condition of the component.

The arrows nested inside of the circles indicate the trend of the condition of a resource component. Arrows pointing up indicate the condition of the component is improving compared to reference condition. Arrows pointing to the right indicate a stable condition. Arrows pointing down indicate a decline in the condition of a component compared to reference condition. These are only used when it is appropriate to comment on the trend of condition of a component; a triple-pointed arrow indicates the trend of the component's condition is currently unknown.

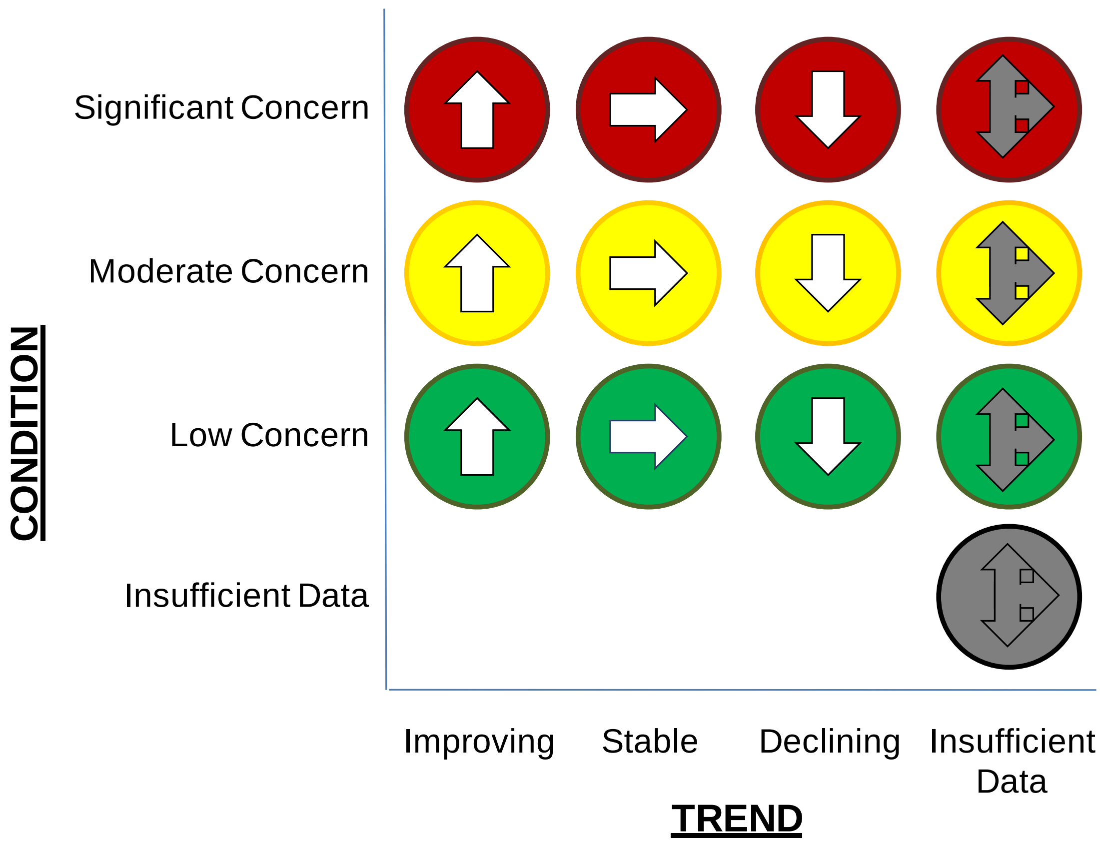

Figure 1. Graphical representation of current condition and trend of a component.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation) who had a primary role in providing expertise, insight, and interpretation to determine current condition (and trend when appropriate) for each resource component.

Literature Cited

This is a list of formal citations for literature or datasets used in the analysis and assessment of condition for the resource component.

3.3 Literature Cited

Gitzen, R. A., M. Wilson, J. Brumm, M. Bynum, J. Wrede, J. J. Millspaugh, and K. J. Paintner. 2010. Northern Great Plains Network Vital Signs monitoring plan. Natural Resource Report NPS/NGPN/NRR-2010/186. National Park Service, Fort Collins, Colorado.

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Chapter 4 Natural Resource Component Summaries

Disclaimer: Data and information presented in this report were compiled prior to the major flooding on the Missouri River in 2011; determination of resource condition did not take into account the effects of this flooding event.

This chapter presents the background, analysis, and condition summaries for the 18 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The order of component summaries roughly follows the project framework (Table 3); some components were combined (piping plover and least tern, and land cover and land use) and one component was moved to Chapter 5 (natural physical and biological interactions and processes).

1. Land Cover and Land Use

2. Erosional and Depositional Processes

3. Flow Regime

4. Aquatic and Terrestrial Habitats

5. Cottonwood

6. Pallid Sturgeon

7. Interior Least Tern and Piping Plover

8. Land Birds

9. Native Fish Populations

10. Northern Leopard Frog

11. Freshwater Invertebrates

12. Water Quality

13. Air Quality

14. Climate

15. Soundscape

16. Dark Night Skies

17. Odorscape

18. Viewshed

4.1 Land Cover and Land Use

Description

Land cover is the physical surface of the earth described using classes of vegetation and land use (e.g. agriculture, developed, transportation). Land cover is portrayed in maps created through field surveys and/or analyses of remotely sensed imagery (Comber et al. 2005). The Northern Great Plains Inventory and Monitoring Network (NGPN) recognizes land cover and land use (LCLU), as a Vital Sign because natural disturbances, stressors, and management cause large-scale changes to the general ecosystem composition of NPS units, altering the land cover of a park. In addition, the type, amount, and arrangement of vegetative structural types in park units partially determine the composition and abundance of vertebrate and invertebrate communities in those units (Vinton and Collins 1997). The protocol for monitoring this Vital Sign will be developed in the next one to five years.

In this assessment, multiple land cover classifications, scales, and data sources are utilized. Data in this assessment are reported within the park boundaries and at a regional scale. The area of analysis (AOA) as determined by NPScape (a 30-km buffer of the park boundaries) is used to report regional scale LCLU data from the National Land Cover Dataset (NLCD). Data from Dixon et al. (2010) also represent regional scale LCLU information, in relation to the park boundaries. The Missouri River segments in Dixon et al. (2010) associated with MNRR represent the historic floodplain (defined as bluff to bluff) surrounding the park boundaries.

Land ownership patterns are also important in understanding the context of land cover in and surrounding MNRR. That is, land ownership patterns can influence the land cover and typically drive the current stage of LCLU within the park boundaries. GIS data from MNRR displays the stewardship lands within and immediately surrounding the park boundaries. Generally, stewardship lands provide a context for protecting land from development.

LCLU within and surrounding the boundaries of MNRR are unique among other NGPN units, because MNRR is represented by dynamic aquatic and riparian ecosystems associated with the Missouri River and portions of its tributaries, Niobrara River and Verdigre Creek. Current LCLU composition is the result of numerous human-caused alterations to the river (upstream and downstream) and conversion of land surrounding the river for human use since the mid- to late-1800s. Bank stabilization, dike construction, and dredging started on the lower Missouri River in the late 1920s. Then, a six-dam system of flood control was constructed starting with Fort Peck Dam in the 1930s, followed by five additional dams under the 1944 Pick-Sloan Plan, with the last dam completed in 1963 (Weeks et al. 2005). The Fort Randall Dam was completed in 1954, upstream of the 39-mile district of MNRR, forming Lake Francis Case. The Gavins Point Dam was completed in 1957, upstream of the 59-mile district of MNRR, forming Lewis and Clark Lake.

The intent of the Pick-Sloan Plan was to ―secure the maximum benefits for flood control, irrigation, navigation, power, domestic, industrial and sanitary water supply, wildlife, and recreation” (Senate Document 247, quoted in Weeks et al. 2005). The results of the Pick-Sloan Plan represent ―the most important and lasting alteration of the Missouri River ecosystem” (Weeks et al. 2005). While the infrastructure and activities associated with the system created many positive effects on the social and economic conditions (e.g., electricity production, recreational use, irrigation for food production) along the Missouri River, there were also―devastating ecological costs associated with the development and operation of this system" (Weeks et al. 2005).

On a section of the Missouri River in North Dakota, Johnson (1992) found that floodplain forest area decreased by at least 56% from 1881 to 1978, primarily from clearing of forests to convert land for agricultural production. Similarly, in the historic floodplain surrounding MNRR the percentage of land classified as agriculture has increased dramatically since 1892, thereby decreasing the area of forests and shrub-lands (Dixon et al. 2010). Flood control efforts (including dam construction and operation) and the implementation of river channelization efforts (including bank stabilization features and woody debris removal) allowed for human development (agricultural, urban, and industrial) to encroach on 95% of the entire Missouri River floodplain (Weeks et al. 2005). These alterations to the river and surrounding land have led to dramatic changes in land cover and native plant community composition, reduced available supply of organic material by at least 65%, and interrupted vital life processes for nearly all the native resident and migratory fauna that depended on Missouri River corridor habitat (Hesse et al. 1988).

Several specific changes for flow regulation on the Missouri River affect riparian habitats within the boundaries of MNRR and the surrounding historic floodplain. Changes in the natural hydrograph (including lower river elevation and peak flows) affect the life cycles of plants, especially the cottonwood and willow communities. The elimination of flood pulses reduces scouring flows and the meandering rate of the river channel in the un-channelized reaches of the river. This reduction accelerates the conversion of barren sandbar habitat to permanently vegetated sandbars. Unnatural erosion has caused degradation in approximately the top half of the Fort Randall segment and over the entire section below Gavin's Point.

Measures

- Ownership pattern (protected land and its ownership, and generalized land ownership area)
- Land cover/use distribution (area of coarse classifications of LCLU)
- Dynamics (trends of land cover change)

Reference Conditions/Values

MNRR staff identify the reference condition as a time before non-native and invasive species establishment. The precise time that these species arrived in present-day MNRR is unknown, but was likely during European settlement after the Dakota Territory opened for settlement in 1859. Before major introductions (both intentional and accidental) of non-native flora and large-scale conversion of lands to agriculture, homesteads, and towns, the floodplain on the lower Missouri River was a mixture of grassland, deciduous forests, and wetlands, with approximately 76% of its vegetation being forest (Bragg and Tatschl 1977, as cited in Weeks et al. 2005). In addition, the entire Missouri River's 13.7 million ha (338.5 million acre) drainage basin was originally 87% prairie (Hesse and Schmulbach 1991 and USFWS 2003, as cited in Weeks et al. 2005).

A large portion of the area within the boundaries of MNRR is open water (Missouri River, Niobrara River, and Verdigre Creek). Much of the surrounding land area was once riparian in nature. Naiman et al. (1993) define a riparian ecosystem as the river or stream channel between the low and high water marks and the terrestrial landscape above the high-water mark, in which vegetation may be influenced by elevated water tables or extreme flooding events and by the ability of the soils to hold water. River channelization (including snag removal and construction of dikes, revetments, levees; and the construction and operation of the Missouri River main-stem dams) has had a myriad of effects on the river's physical, chemical, biological, and social attributes (Galat et al. 1996). After the construction of the dams, downstream lands were cleared for agricultural production. These lands, considered flood-free, were attractive to developers and helped fuel a continued demand for bank stabilization projects (Weeks et al. 2005).

Dixon et al. (2010) utilized Missouri River Commission maps created in 1892 and published in 1895 to classify major LCLU classes. The 1892 maps were digitized based upon vegetation type designations during the original mapping. The study area in Dixon et al. (2010) included several segments along the Missouri River (Plate 1). Figure 2 displays the segments of this dataset that relate to the 39-mile and 59-mile districts of MNRR. Plate 1 and Plate 2 display the broad land cover changes that have occurred along both districts of MNRR from 1892 to 2006 (Dixon et al. 2010). The pre-dam condition of LCLU identified by Dixon et al. (2010) was before significant human development and before large landscape-scale effects occurred from the alteration to keystone processes (e.g., wildfire, natural river erosional and depositional processes, and meandering rates in the Missouri River). Also, with the possible exception of white mulberry (*Morus alba*), the 1892 data represent a pre-non-native plant species LCLU (Dixon, pers. comm., 2010). Table 4 and Table 5 display the area and relative composition of land cover classes in the historic (1892) Missouri River floodplain associated with the 39-mile and 59-mile districts, respectively (Dixon et al. 2010).

Table 4. Area and percentage of major land cover types in the Missouri River's historic (1892) floodplain in the area of the 39-mile district of MNRR (results of conversion of 1892 Missouri River Commision Maps) (Segment 8 in Dixon et al. 2010).

Land Cover Description	Area		% Composition
	acres	ha	
Grassland	15,563	6,298	43.51
Deciduous forest	6,695	2,709	18.72
River channel - Missouri	6,479	2,622	18.11
Sandbar - Missouri	4,209	1,703	11.77
Bluffs	1,378	557	3.85
Shrubs	1,029	416	2.88
Cultivated	247	100	0.69
Urban	163	66	0.45
River channel - other	8	3	0.02
Totals:	35,769	14,475	100.00

Table 5. Area and percentage of major land cover types in the Missouri River's historic (1892) floodplain in the area of the 59-mile district of MNRR (results of conversion of 1892 Missouri River Commision Maps) (Segment 10 in Dixon et al. 2010).

Land Cover Description	Area		% Composition
	acres	ha	
Grassland	71,766	29,043	33.97
Cultivated	51,411	20,805	24.34
Deciduous forest	28,548	11,553	13.51
Unclassified	16,621	6,726	7.87
Sandbar – Missouri	13,005	5,263	6.16
Shrubs	12,108	4,900	5.73
River channel - Missouri	9,120	3,691	4.32
Bluffs	2,413	977	1.14
Farm woodlot	2,024	819	0.96
Marsh	1,452	587	0.69
Urban	1,053	426	0.50
River channel - other	862	349	0.41
Open woodland	569	230	0.27
Sandbar - other	130	53	0.06
Lake	109	44	0.05
Orchard	49	20	0.02
Totals:	211,239	85,485	100.00

See Plate 1 and Plate 2 for illustrations of relative land cover change from 1892 to 2006 for the 59-mile and 39-mile districts respectively.

Data and Methods

Dixon et al. (2010) examined current LCLU and historic LCLU for several segments (930 river miles) of the Missouri River including segments 10 and 8 associated with the 59-mile and 39-mile districts, respectively. The authors created 1892 LCLU data by digitizing 1892 vintage Missouri River Commission maps into GIS data. They also interpreted aerial photography from the 1950s, 1980s, and 2006/2008 to create LCLU data. The 1892 data were developed at a 1:63,000 map scale. Comparison of these data allows for an examination of LCLU change from 1892 to present (2006/2008). The authors note that land cover classes in the 1892 maps differ somewhat from land cover classes they used in the 2006 land cover. It is also important to note that the LCLU classes the authors use are more detailed than the Anderson Level I and II (Anderson et al. 1976) used in the NLCD data, and they are intended to focus on the cottonwood habitats within the historic Missouri River floodplain. In addition, the current (2006/2008) data were developed at a larger map scale (finer resolution, using heads-up digitizing) than the satellite derived LCLU classifications (using spectral raster classification) in the NLCD.

Current LCLU data (2006/2008) are summarized in this assessment from Dixon et al. (2010). These data were clipped to provide summaries within the MNRR boundaries and the original data by segment (8/9 and 10). These segments represent the historic floodplain of the Missouri River (bluff to bluff) surrounding MNRR. It is important to note that the study area segments do not match the boundaries of MNRR and do not cover the Niobrara River or Verdigre Creek sections of the 39-mile district (Figure 2). Dixon et al. (2010) noted that their study segment boundaries may differ slightly from other published definitions of these segments and that they based them on 1960s' river miles.

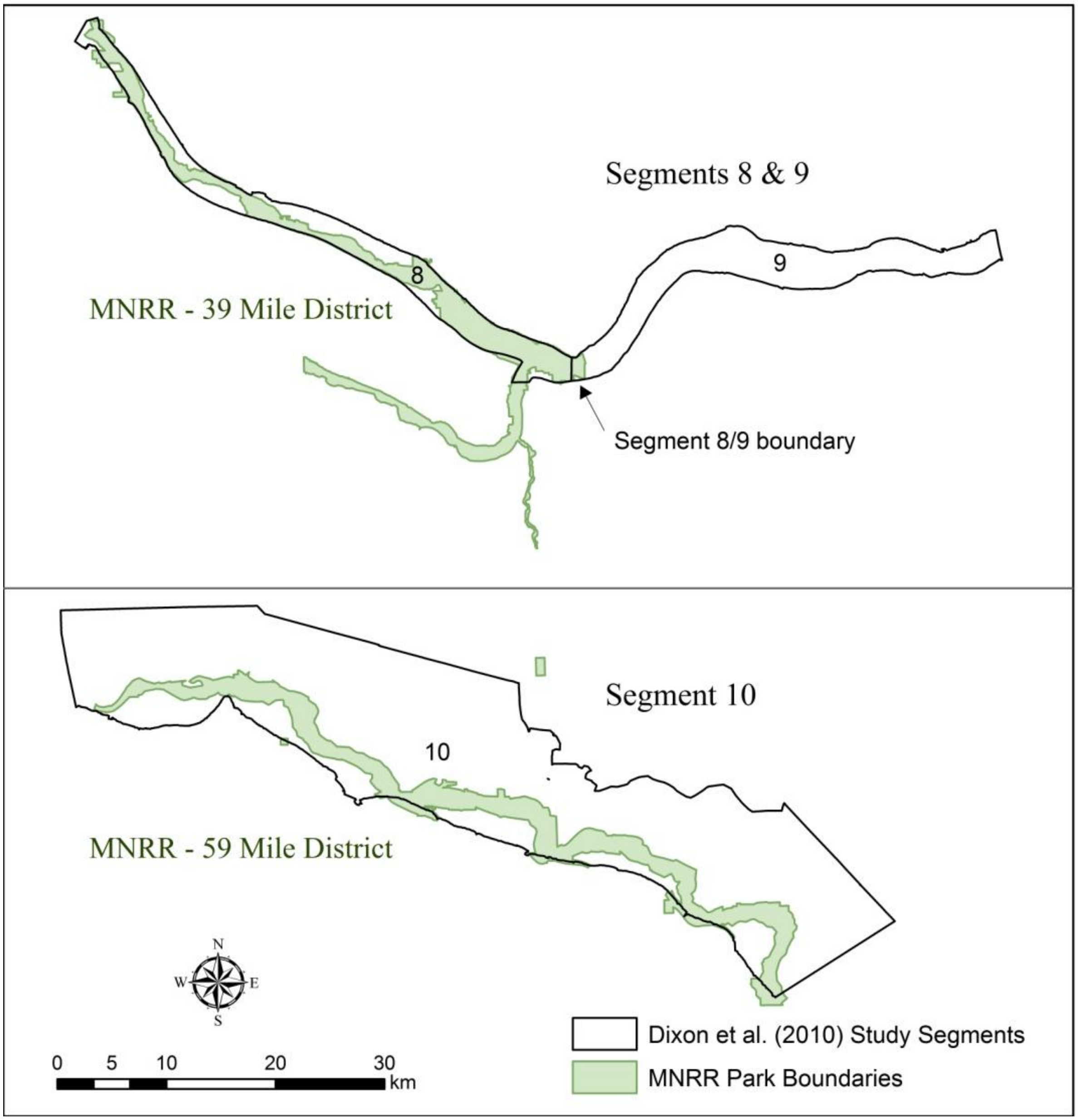


Figure 2. Relationship between MNRR boundaries by district and Dixon et al. (2010) segment boundaries.

The 2001 National Land Cover Dataset (NLCD) (Homer et al. 2004) provides LCLU data using a spatial resolution of 30 meter pixels. These data use a 21 class (Anderson Level II, Anderson et al. 1976) land cover classification using unsupervised clustering and GIS modeling. These data were spatially clipped to each of the park district boundaries and LCLU class area and composition are tabulated by each district. Recently 2006 NLCD data have been made available, however these data are considered provisional to date.

The 1992/2001 NLCD change product (Fry et al. 2009) provides a categorization of change between a reclassification of both 1992 and 2001 LCLU data. Fry et al. (2009) used a decision tree classifier at Anderson Level I (Anderson et. al. 1976), filtered intermediate results with confidence parameters, determined changed versus non-changed pixels, and finally, labeled the final change product using a ―from-to" change classification code. These data were spatially clipped to each of the park district boundaries and LCLU class area and composition are tabulated by each district. Another change product classifying the change between NLCD 2001 and 2006 has been made available, however these data are also considered provisional to date.

Additionally, information synthesized by Stevens et al. (2010) provides protected lands and ownership area summaries.

Current Condition and Trend

Land Ownership Patterns

Land ownership patterns are important because of the relationship between ownership type and the land use (i.e., the extent of land protected from development). Private land ownership may increase the potential for changes in LCLU (e.g., development, bank stabilization, and conversion of vegetated cover to agricultural uses). Stewardship lands in and around MNRR's boundaries provide a context for protecting land from development and conversion. These are federal or state tracts of land that are publicly owned or have conservation easements on them through federal programs. The easements are on privately owned property and there are assumptions made about state and federal lands being ―protected." Generally, the easements restrict the conversion of lands from their existing land use. Plate 4 and Plate 5 display the stewardship lands in or near the boundaries of the 59-mile and 39-mile districts, respectively. In addition to this map data, a recent vegetation inventory study plan for MNRR offers area estimates of protected land and its ownership within and adjacent to MNRR (Stevens et al. 2010, Table 6).

Table 6. Acreage of MNRR administrative area, protected lands within and adjacent to MNRR, and summary of protected lands ownership. Acreage totals include open water. GIS data provided by MNRR. This table is reproduced from Stevens et al. 2010, with the exception of the added % of total column.

Description	39-mile District (Acres)	59-mile District (Acres)	MNRR Totals (Acres)	% of total
MNRR Administrative Boundary total	33,324	35,687	69,011	--
Protected Area (all ownerships) within MNRR and in vicinity	27,670	9,482	37,152	--
Protected Area within Administrative Boundary	11,452	5,392	16,844	24.4***
Protected Area outside Administrative Boundary	16,218	4,090	20,308	--
Summary of "Protected" Lands within MNRR Boundary*				
National Park Service**		475	475	2.9
Nebraska Game and Parks Commission	1,971	1,648	3,619	22.0
South Dakota Game, Fish and Parks	1,734	1,146	2,880	17.5
US Army Corps of Engineers	5,904	490	6,394	38.9
US Department of Agriculture	18		18	0.1
US Fish and Wildlife Service	1,398		1,398	8.5
Yankton Sioux Tribe	24		24	0.1
USDA Natural Resources Conservation Service		162	162	1.0
Northern Prairies Land Trust		228	228	1.4
Cedar County, SD		15	15	0.1
City of Yankton, SD		64	64	0.4
SDGFP, Lewis and Clark NRD		1,164	1,164	7.1

*acreage figures for ownership categories are approximate and include surface water.

**includes water acreage. NPS land ownership is approximately 280 acres.

***24.4% of the total acreage within the MNRR boundaries is considered protected lands. All other percentages displayed are based on total acres of protected lands within the MNRR boundary.

The majority of land within the park boundaries is private property (76% of the total park area), and 24% is publicly owned (Stevens et al. 2010). The NPS owns approximately 300 acres (less than 1% of the total park boundary area), not counting surface water (NPS 2009b). The two areas include the Bow Creek Recreation Area and the Mulberry Bend Overlook. Since the majority of the land in MNRR is under private ownership, any proposed NPS management activities must be done in collaboration with private landowners or other organizations and in accordance with the Wild and Scenic Rivers Act and NPS policy.

Bow Creek Property

The Bow Creek Recreation Area is an NPS owned property; the northern tract was purchased in 2004 and the southern tract in 2008. The property is a Missouri River frontage tract located near Wynot, NE where Bow Creek enters the Missouri River (NPS 2009b). The property is a particular area of interest in terms of its relationship to land cover and native vegetation restoration efforts at MNRR. Because Bow Creek is under NPS ownership, land management activities are more readily implemented here than with non-NPS lands within MNRR boundaries. This property and the Mulberry Bend property represent areas in which the NPS can more actively manage the land compared with other lands not in NPS ownership within the park boundaries. In total, the Bow Creek property covers approximately 250 acres of dry land. This includes Upper Bow Creek (approximately 95 acres), which is primarily bluffland comprised of forest/savanna, grassland, and shrubland; and Lower Bow Creek which is primarily low land, comprised of a mix of cottonwood and other forest, grassland, and shrubland (approximately 125 acres). In Lower Bow Creek, there is also a 20-acre sandbar which is covered with a young cottonwood forest. A plan is in place to reseed ten acres of tame pasture in Lower Bow Creek to native prairie plants.

The overall NPS management strategy for this area is to restore native vegetation and landscapes through non-native and invasive plant removal, prescribed fire, and planting and seeding native plant species. Beginning in 2005 and continuing through 2009, MNRR natural resource staff, the Northern Great Plains Exotic Plant Management Team (NGP-EPMT), and the Minnesota Conservation Corps removed eastern red cedars (*Juniperus virginiana*) in the Upper and Lower Bow Creek areas. The historic land cover in the Upper Bow Creek area would likely have been a mix of bur oak (*Quercus macrocarpa*) savanna and prairie (Dixon, pers. comm., 2010). In addition to cedar removal, the Lower Bow Creek area, had approximately 12 ha (30 ac) of agricultural land reseeded to native grasses and forbes. Other recent activities include removal of Russian olive trees and continued treatment of invasive plant species (e.g., Canada, bull, and plumeless thistles, leafy spurge, purple loosestrife). MNRR's Fire Management Plan was approved in 2010 and staff conducted the first prescribed fire on 28.3 ha (70 ac) of the Bow Creek tract owned by the NPS.

Mulberry Bend Property

The MNRR Fire Management Plan (FMP) states the Mulberry Bend property, located along the Missouri River in Dixon County, NE, near the Vermillion-Newcastle Bridge, was acquired by the NPS in 2003 (NPS 2009a). Separating a low area (2 ha or 5 ac) to the west and a maintained scenic overlook area (11.3 ha or 28 ac) to the east, is Nebraska Hightway 15 (NPS 2009a). The overlook area contains a maintained landscape area (3.2 ha or 8 ac) and a larger mesic bur oak community area (8.1 ha or 20 ac). The primary NPS management activities at this property have included noxious weed treatments, thinning of eastern red cedars, and native plantings (NPS 2009b). According to the MNRR FMP, future management work, along with the use of prescribed fire, will include continuing mechanical treatments of eastern red cedar, and may include native plant resoration in the smooth brome pasture area.

LCLU Distribution

Regional - NLCD

The NPScape project clipped and reclassified 2001 NLCD LCLU data within a 30-kilometer buffer of MNRR boundaries, an area greater than 1.5 million hectares (3.7 million acres) (Plate 3, NPScape 2009). These data provide insight to the LCLU of the greater MNRR area. Within this area, cultivated agriculture and grassland/herbaceous were the primary LCLU types: 43.9% and 31.0% respectively. Pasture/hay (9.9%), developed open space (4.1%), and deciduous forest (4.1%) followed (Table 7, NPScape 2009).

Table 7. Land cover/use within a 30-km buffer of the MNRR boundaries. NLCD 2001 data processed by NPScape (2009).

Land Cover/Use Class Name	Area		% Composition
	ha	acres	
Cultivated Agriculture	672,737	1,662,363	43.85
Grassland/Herbaceous	475,673	1,175,410	31.00
Pasture/Hay	153,334	378,895	9.99
Developed Open Space	62,944	155,537	4.10
Deciduous Forest	62,514	154,474	4.07
Open Water	44,242	109,324	2.88
Emergent Herbaceous Wetlands	24,576	60,729	1.60
Woody Wetlands	11,941	29,506	0.78
Developed Low Intensity	10,260	25,352	0.67
Evergreen Forest	6,339	15,665	0.41
Scrub/Shrub	4,842	11,964	0.32
Developed Medium Intensity	2,752	6,799	0.18
Developed High Intensity	1,136	2,808	0.07
Barren Land	733	1,811	0.05
Mixed Forest	298	737	0.02
Totals:	1,534,321	3,791,374	

MNRR-wide – (USACE 2004)

According to USACE (2004), the MNRR park boundary includes 27,974 ha (69,124 acres) of land and water, 14,488 ha (35,800 acres) in the 59-mile district and 13,486 ha (33,324 acres) in the 39-mile district. Approximately 12,600 ha (31,000 acres) are non-vegetated aquatic habitats (e.g. main-channel river, backwater, and chutes) and the remainder is a mix of upland and wetland habitats (USACE 2004, Stevens et al. 2010). Wetlands make up a total of 15,064 ha (37,225 acres) of MNRR (Table 8, USACE 2004), the vast majority of which are non-vegetated aquatic habitats.

Table 8. Wetland and riparian acreages for Fort Randall (39-mile segment) and Gavins Point (59-mile segment) of MNRR, 1991 (USACE 2004). Open water habitats are not shown here. Percentages and hectares added to original table from USACE 2004.

Wetland/ Riparian Type	39-mile segment		Relative % comp. of district	59-mile segment		Relative % comp. of district	Total area		% Comp.
	acres	ha		acres	ha		acres	ha	
Emergent	1,682	681	19.5	2,461	996	20.3	4,143	1,677	20.0
Scrub Shrub	454	184	5.2	2,517	1,019	20.8	2,971	1,202	14.3
Forested	889	360	10.3	187	76	1.5	1,076	435	5.2
Exposed Shore	297	120	3.4	545	221	4.5	842	341	4.1
Riparian Forest	4,536	1,836	52.6	3,949	1,598	32.6	8,485	3,434	40.9
Riparian Shrub	196	79	2.3	874	354	7.2	1,070	433	5.2
Riparian Grass	564	228	6.5	1,595	646	13.2	2,159	874	10.4
Totals:	8,618	3,488		12,128	4,910		20,746	8,396	

59-mile District - Dixon et al.2010

The 59-mile district resembles the natural pre-dam river more than any other reach of the Missouri River (USACE 2004, as cited in Weeks et al. 2005). However, the historic floodplain was once much wider than it is today. Meander scars and their remnant lakes and marshes were more abundant in older topographic maps; later aerial photographs show that much of the evidence of this free-meandering river has been ―obliterated by agriculture" (USACE 2010). According to results of 2006/2008 aerial photo interpretation within the historic floodplain along the 59-mile district (segment 10 or bluff to bluff in Dixon et al. 2010), agricultural row crops are now the predominant LCLU class (76.9%), followed by Missouri River main channel (6.4%), forest (at least 15% cottonwood) (5.5%), town/city (4.4%), planted trees (farm woodlots, shelterbelts, orchards) (1.1%), upland forest (not in floodplain) (1.0%), and upland grassland or pasture (1.0%) (Table 9).

Table 9. Land cover classes, area, and composition in segment 10 (59-mile district area floodplain), 2006 and 2008. Data are the results of aerial photograph interpretation from Dixon et al. 2010.

Land Cover Class Type	Area		%
	ha	acres	Composition
Agricultural row crops	65,726	162,413	76.89
Missouri River main channel	5,487	13,558	6.42
Forest (*cottonwood at least 15%*)	4,707	11,631	5.51
Town/city (*e.g., Vermillion*)	3,749	9,264	4.39
Riparian low shrub with cottonwood (*successional sandbar sites, may include a mixture of low woody and herbaceous vegetation*)	120	2,519	1.19
Planted trees (*farm woodlots, shelterbelts, orchards*)	938	2,317	1.10
Upland forest (*not in floodplain*)	827	2,043	0.97
Upland grassland, pasture	803	1,985	0.94
In-channel sandbars (*Emergent Sandbar Habitat - ESH)*	382	943	0.45
Non-cottonwood (*cottonwood <15%*) floodplain forest	325	802	0.38
Riparian low herbaceous vegetation	246	607	0.29
Woodland (*cottonwood at least 15%*)	239	592	0.28
Oxbow lake/backwater	232	574	0.27
Cabin or managed cottonwood areas	166	409	0.19
Urban/recreational grasses (*developed right-of-ways, golf courses*)	160	395	0.19
Tributary river channel	150	372	0.18
Riparian low shrub w/o cottonwood	106	262	0.13
Farm ponds, other open water habitats	70	172	0.08
Emergent wetland	49	121	0.06
Unvegetated sandbar on Missouri	40	99	0.05
Farmstead and building complex (*excluding woodlots*)	31	76	0.04
Commercial/Industrial/Transportation (*roads, parking lots, boat landings*)	30	74	0.03
Barren	3	8	0.00
Totals:	85,486	211,236	100.00

Examination of Dixon et al. (2010) data within the boundaries of the 59-mile district naturally reveals a much different composition, as it is primarily a river and a floodplain area. As of 2006/2008, land cover within the 59-mile district boundaries was 42% Missouri River main channel, 23% forest (*at least 15% cottonwood*), 13% agricultural row crops, and 4% upland grassland or pasture (Table 10, Dixon et al. 2010). Note that the data do not cover the entire area of the 59-mile district; some small areas along the Nebraska shoreline were not part of the study area in Dixon et al. (2010) (Figure 2).

Table 10. Land cover classes, area, and composition within the 59-mile district boundary, 2006 and 2008 (Data from Dixon et al. 2010)[1].

Land Cover Class Type	Area*		% Composition
	ha	acres	
River main channel (*open water, sand, submersed aquatic vegetation*)	5,437	13,435	41.60
Forest (*cottonwood at least 15%*)	2,962	7,318	22.66
Agricultural row crops	1,684	4,162	12.89
Riparian low shrub with cottonwood (*successional sandbar sites, may include a mixture of low woody and herbaceous vegetation*)	962	2,377	7.36
Upland grassland, pasture	491	1,21414	3.76
In-channel sandbars (*Emergent Sandbar Habitat - ESH*)	382	943	2.92
Riparian low herbaceous vegetation	246	607	1.88
Non-cottonwood (*cottonwood <15%*) floodplain forest	201	497	1.54
Woodland (*cottonwood at least 15%)*	153	378	1.17
Upland forest (*not in floodplain*)	138	341	1.06
Cabin or managed cottonwood areas	103	255	0.79
Riparian low shrub w/o cottonwood	75	186	0.58
Oxbow lake/backwater – off channel or connected	46	114	0.35
Existing flow-through channels and backwaters	45	111	0.34
Cottonwood dominant riparian shrubland	41	102	0.32
Unvegetated sandbar	37	91	0.28
Town/city (*e.g., Vermillion*)	35	87	0.27
Urban/recreational grasses (*developed right-of-ways, golf courses*)	11	27	0.08
Tributary river channel	9	23	0.07
Planted trees (*farm woodlots, shelterbelts, orchards*)	6	14	0.04
Barren	3	8	0.03
Farmstead and building complex (*excluding woodlots*)	1	3	0.01
Commercial/Industrial/Transportation (*roads, parking lots, boat landings*)	1	2	0.00
Emergent wetland (*off river*)	1	1	0.00
Totals:	5,437	13,435	

[1] Data were clipped to 59-mile District boundary, however, some portions of the 59-mile district along the Nebraska shoreline were not mapped by Dixon et al. (2010) (see Figure 1).

39 Mile District – Dixon et al. 2010

Segment 8 (Fort Randall Dam to downstream of Niobrara delta) in Dixon et al. (2010) represents the historic Missouri River floodplain (approximately bluff to bluff) surrounding the 39-mile District of MNRR. This segment excludes Lewis and Clark Lake, which contains much more area classified as Missouri River channel (open water). However, this does not include Niobrara River and Verdigre Creek sections of the 39-mile district. Based on aerial photo interpretation using 2006 photography, this segment is primarily comprised of agricultural row crops (18.44%) and Missouri River main channel (17.15%), followed by a mix of forest (cottonwood at least 15%) (6.43%), riparian low herbaceous vegetation (4.25%), and upland grassland, pasture (3.83%), wet meadow/mesic grassland (2.39%), and riparian low shrub with cottonwood (1.82%) (Table 11, Dixon et al. 2010).

Table 11. Land cover in the Dixon et al. (2010) segment 8, subreaches 1, 2, and 3 (historic floodplain along the 39-mile district), 2006.

Land Cover/Use Class	Area* ha	Area* acres	% Composition
Agricultural row crops	4,322	10,680	29.85
Missouri River main channel	4,021	9,936	27.78
Forest (*cottonwood at least 15%*)	1,508	3,725	10.42
Riparian low herbaceous vegetation	996	2,461	6.89
Upland grassland, pasture	899	2,221	6.21
Wet meadow / mesic grassland	560	1,384	3.87
Riparian low shrub with cottonwood (*successional sandbar sites, may include a mixture of low woody and herbaceous vegetation*)	427	1,056	2.95
Emergent wetland	387	955	2.67
Woodland (*cottonwood at least 15%*)	343	846	2.37
Non-cottonwood (*cottonwood <15%*) floodplain forest	232	572	1.60
Cabin or managed cottonwood areas	131	325	0.90
Town/city (*e.g., Vermillion*)	110	271	0.76
Farm ponds, other open water habitats	99	245	0.68
Unvegetated sandbar on Missouri	67	166	0.46
Riparian low shrub w/o cottonwood	53	130	0.36
Commercial/Industrial/Transportation (*roads, parking lots, boat landings*)	46	114	0.32
Non-cottonwood (*cottonwood <15%*) woodland	43	107	0.30
Planted trees (*farm woodlots, shelterbelts, orchards*)	42	103	0.29
Non-cottonwood shrubland	39	97	0.27
Planted cottonwood trees	39	95	0.27
Tributary river channel	35	87	0.24
Oxbow lake/backwater	28	70	0.19
Shrubland (*with cottonwood*)	21	52	0.15
Farmstead and building complex (*excluding woodlots*)	15	37	0.10
Upland forest (*not in floodplain*)	10	23	0.07
Urban/recreational grasses (*developed right-of-ways, golf courses*)	4	11	0.03
Totals:	14,477	35,769	

*Area rounded to the nearest acre or hectare.

These data do not include Verdigre Creek and Niobrara River sections and do not cover some additional areas where the boundaries of MNRR extend beyond the historic river floodplain.

Examination of this data clipped to the boundaries of the 39-mile district reveals that the Missouri River main channel is the primary class (43.25%), followed by a mix of riparian low herbaceous vegetation (11.5%) forest (cottonwood at least 15%) (9.83%), upland grassland/pasture (6.14%), wet meadow/mesic grassland (5.86%) agricultural row crops (5.33%), riparian low shrub with cottonwood (4.53%), and emergent wetland (4.03%) (Table 12) (Dixon et al. 2010).

Table 12. Land cover/use in the 39-mile district, 2006. Dixon et al. (2010) GIS dataset was clipped to 39-mile district boundaries.

Land Cover/Use Class	Area		%
	ha	acres	Composition
Missouri River main channel	4,103	10,139	43.26
Riparian low herbaceous vegetation	1,094	2,704	11.54
Forest (*cottonwood at least 15%*)	932	2,304	9.83
Upland grassland, pasture	582	1,438	6.14
Wet meadow / mesic grassland	556	1,374	5.86
Agricultural row crops	502	1,242	5.30
Riparian low shrub with cottonwood (*successional sandbar sites, may include a mixture of low woody and herbaceous vegetation*)	450	1,132	4.75
Emergent wetland	382	943	4.02
Woodland (*cottonwood at least 15%*)	193	476	2.03
Non-cottonwood (*cottonwood <15%*) floodplain forest	126	310	1.32
Farm ponds, other open water habitats	110	273	1.16
Cabin or managed cottonwood areas	88	218	0.93
Unvegetated sandbar on Missouri	64	159	0.68
Riparian low shrub w/o cottonwood	80	197	0.84
Non-cottonwood (*cottonwood <15%*) woodland	43	107	0.46
Planted cottonwood trees	36	89	0.38
Tributary river channel	35	87	0.37
Town, city (*e.g., Vermillion*)	34	84	0.36
Oxbow lake/backwater	28	70	0.30
Commercial/Industrial/Transportation (*roads, parking lots, boat landings*)	17	42	0.18
Planted trees (farm woodlots, shelterbelts, orchards)	11	27	0.12
Upland forest (*not in floodplain*)	8	19	0.08
Farmstead and building complex (*excluding woodlots*)	6	16	0.07
Urban/recreational grasses (*developed right-of-ways, golf courses*)	4	11	0.05
Totals:	9,484	23,461	

These data do not include Verdigre Creek and Niobrara River sections and do not cover some additional areas where the boundaries of MNRR extend beyond the river floodplain.

LCLU Dynamics (change of land cover)

Regional – NLCD

A 30 km buffer of the park boundaries covers an area of over 1.5 million hectares (3.7 million acres). The 1992 to 2001 NLCD change product indicates that approximately 44,257 ha (109,362 acres) changed within a 30 km buffer of the park boundaries. The Anderson Level I classifications (a more generalized categorization than that of Level II) comprising the majority of the regional change were agriculture to grassland/shrub (22.0%), conversely grassland/shrub to agriculture (21.2%), followed by agriculture to open water (13.5%), agriculture to wetlands (11.3%), grassland/shrub to open water (8.0%), grassland/shrub to wetlands (4.5%), forest to grassland/shrub (3.9%), wetlands to grassland/shrub (2.7%), wetlands to open water (1.9%), wetlands to agriculture (1.9%), agriculture to urban (1.7%), grassland/shrub to forest. All other changes accounted for less than 1% of the total change area.

59-mile District - Dixon et al. 2010

Dixon et al. (2010) concluded that the land cover composition of the Missouri River floodplain changed dramatically from 1892 to 2006 in segment 10 (coinciding with the 59-mile district of MNRR). This composition change included large decreases in grassland and sandbar land cover classes and large increases in the cropland land cover class. There were also moderate decreases in forest and shrub land cover classes and increases in urban areas (Figure 3, Plate 1).

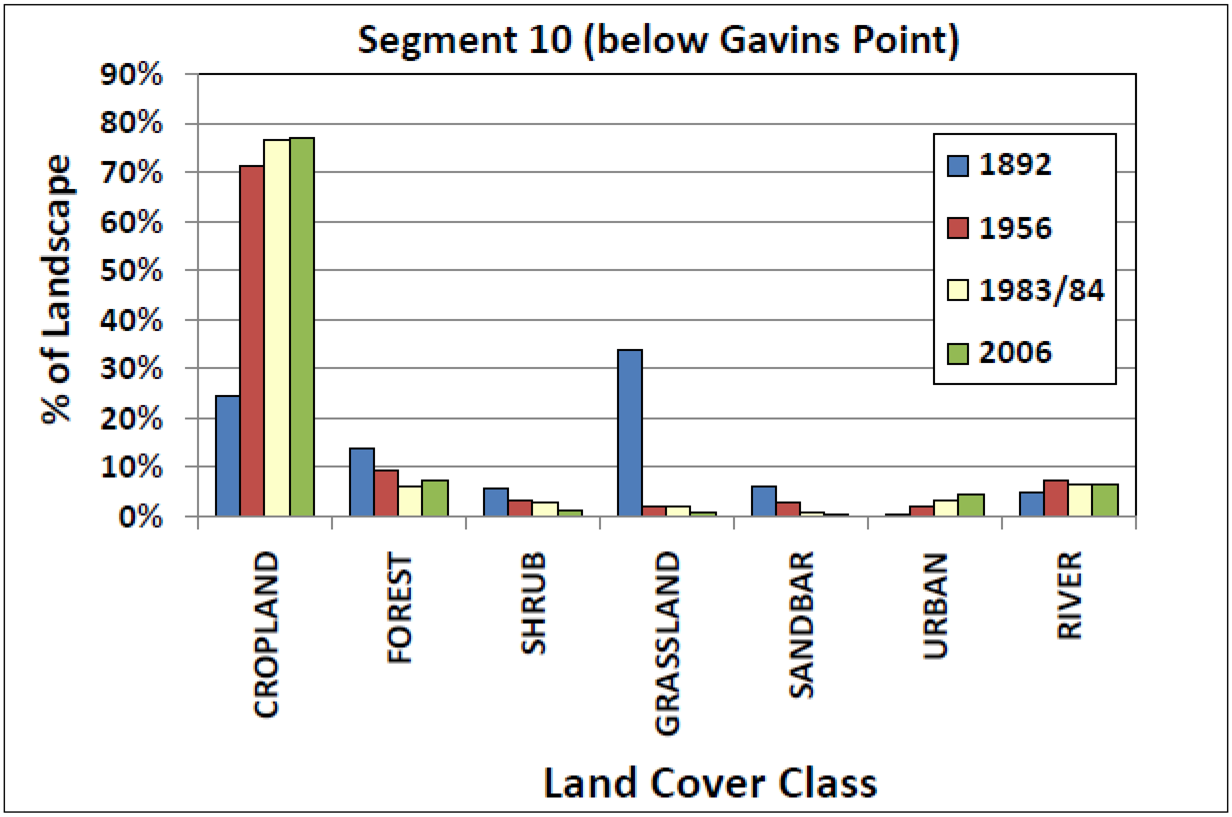


Figure 3. Historic changes in relative coverage of major land cover classes on segment 10 (flood plain surrounding the 59-mile district) (Dixon et al. 2010). Reproduced with permission by Mark Dixon.

59-mile District - NLCD

The NLCD categorized recent change land cover in a 1992 to 2001 change product (Fry et al. 2009). After clipping this data to the boundaries of the 59-mile district, 843 ha (2,082 acres) were classified as changed from one LCLU class to another. The majority of the change that occurred in the 59-mile District was categorized as agriculture to open water (56%), followed by open water to barren (25%) and open water to wetlands (12%). However, open water to agriculture accounted for approximately 3% of the change and open water to grassland/shrub approximately 2% of the detected change. Refer to Appendix A for a table displaying the area and the composition of each LCLU class.

39-mile District - Dixon et al. 2010
Historic changes of land cover in segment 8 (39-mile district's historic floodplain) from 1892 to 2006 were less dramatic than in segment 10 (59-mile district's historic floodplain), with only a 16% loss of forest. However, a high conversion rate of grassland to cropland was observed in the first half of the 20th century (about 96% of grasslands in the 39-mile District were lost over that duration) (Dixon et al. 2010). Dixon et al. (2010) also found that the amount of sandbar habitat declined precipitously, and now comprises less than 1% of the landscape. In addition, the relative percentage of area classified as river (open water) area increased, and cropland area dramatically increased from 1892 to the 1950s, then decreased from the 1950s to 2006 (Figure 4, Plate 2, Dixon et al. 2010).

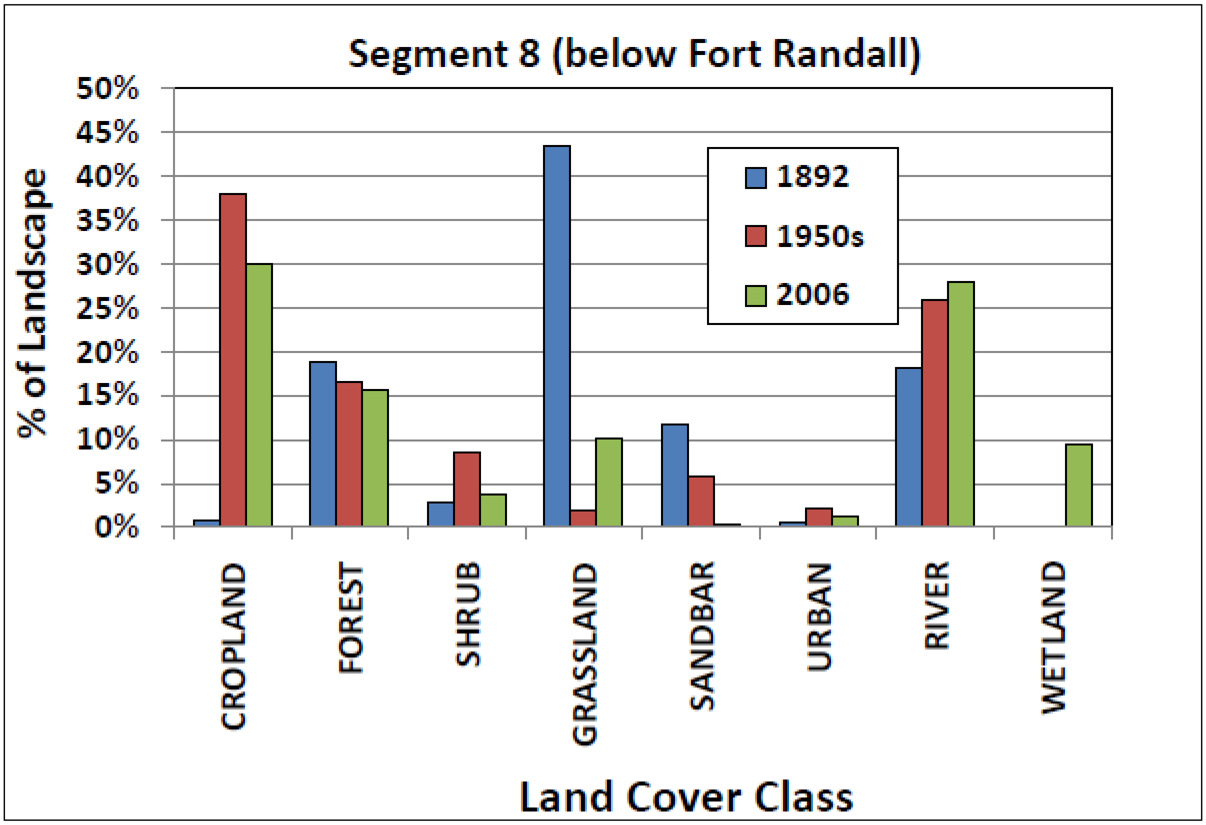


Figure 4. Historic changes in relative coverage of major land cover classes on segment 8 (Fort Randall Dam to downstream of Niobrara delta). Reproduced from Dixon et al. (2010).

39-mile District - NLCD
The NLCD 1992/2001 change dataset indicates a total area of 1,009 ha (2,494 acres) changed in 39-mile District boundaries (Plate 2). In the 39-mile district there were a larger number of change categories than in the 59-mile district. The primary categories were wetlands to open water (33%), agriculture to open water (20%), grassland/shrub to wetlands (17%), and agriculture to grassland/shrub (10%). Other categories of change include agriculture to wetlands (6%), open water to wetlands (5%), grassland/shrub to open water (4%), and open water to barren (2%). All other change categorizations accounted for one percent or less of the total change area; refer to Appendix A.

Threats and Stressor Factors

MNRR staff identify the following stressors to land cover: invasive and non-native vegetation, flow regulation, human development (residential and agricultural), and bank stabilization.

While invasive plants may not necessarily cause a shift in land cover such that it would justify a change of a designated land cover class, invasive and non-native plant species are important factors in landscape dynamics. Invasive plants displace native species, degrading the integrity and diversity of native plant communities. The primary non-native invasive plants of concern at MNRR include purple loosestrife (*Lythrum salicaria*), tamarisk (*Tamarix sp.*), leafy spurge (*Euphorbia esula*), Canada thistle (*Cirsium arvense*), plumeless thistle (*Carduus acanthoides*), bull thistle (*Cirsium vulgare*), musk thistle (*Carduus nutans*), Russian olive (*Elaeagnus angustifolia*), common reed (*Phragmites australis* subsp. *australis*), and spotted knapweed (*Centaurea maculosa*) (NPS 2005). All of these species (except for Russian olive) are considered noxious weeds by either Nebraska, South Dakota, or by both states.

Some plant species, though native, exhibit aggressive spread and increases in abundance which displace desirable native species. The plant's spread and success is often due to an alteration in a natural process such as loss of wildfire. Eastern red cedar provides an example of a native that has exhibited invasive spread in some of MNRR's landscape. This native tree has increased in abundance, expanded into prairies, filled in the gaps between trees in savannas, and replaced native understory vegetation in areas such as upland bur oak forests and woodlands. This is due in part to the absence of frequent, low-intensity fires. Also, eastern red cedar was promoted for conservation purposes outside their original habitat (Ganguli et al. 2008). Both South Dakota and Nebraska distributed thousands of red cedars for windbreaks, wildlife habitat, and Conservation Reserve Program plantings for 43 years in South Dakota and 76 years in Nebraska. Wildfires once controlled cedars by burning seedlings, and in larger trees the lower branches created ladder fuels which often allowed the entire tree to burn (Ganguli et al. 2008). In MNRR, cedars have also invaded cottonwood forests within the historic floodplain. Because of changes in the river flows through flow regulation by the system of dams, the water table in these forests is low enough for cedars to thrive, changing the species composition and stand structure.

Management of non-native invasive plants in MNRR is shared by many different partners, including five counties in South Dakota and four in Nebraska (NPS 2005). The South Dakota/Nebraska Purple Loosestrife Association has coordinated federal, state, tribal, and private landowners to treat purple loosestrife infestations. The Northeast Nebraska Weed Management Area includes all major landowner types in plant management and treatment (NPS 2005). Property owners conduct most of the exotic plant management and treatment on non-NPS lands, while the NPS manages the 250 acres it owns and participates with other partnerships (NPS 2005). Depending on the invasive plant species targeted for management in MNRR, one or many of a combination of treatments are employed (e.g., mechanical, biological, fire, and chemical). The Exotic Plant Management Team (EPMT) and MNRR staff began mapping invasive plant infestations using GPS units in 2004 (NPS 2005).

Flow regulation has created lasting effects on riparian and aquatic habitats in MNRR. Flow regulation causes interruption of several natural biological and physical processes and has direct and indirect effects on riparian vegetation. Most notably, the riparian ecosystem along the Missouri River has seen a reduction in the amount of sandbar habitat (Dixon et al. 2010), a reduction in the recruitment of cottonwoods (Johnson et al. 1976), a reduction in radial growth of most tree species (Johnson et al. 1976), and changes in species composition of riparian forests (Dixon et al. 2010), ultimately leading to ―dramatically altered future forest composition, structure, and productivity" (Johnson 1992). More detailed discussions of flow regulation effects are discussed in Chapter 4.2 and 4.3.

Each year, development converts riverfront land to recreational cabin developments, including the construction of both permanent and seasonal residences. Development in the 59-mile district exists on both the South Dakota and Nebraska shores, while in the 39-mile district most development occurs along the Nebraska shore (Weeks et al. 2005).

Bank stabilization can be considered a stressor to land cover because bank stabilization features are installed to protect developed lands and structures. Existing structures also allow for undeveloped land to be developed along the river. Areas with stabilized banks are attractive to developers and the expansion of existing features can create more opportunities for further development. They also contribute to reducing the meandering rate of the river and thereby alter land cover dynamics (e.g., the continuous change over time between open water, barren (sandbars), and vegetated sandbars and riparian areas). Bank stabilization is discussed in greater detail in the erosional and depositional processes component in Chapter 4.2.

Data Needs/Gaps

Current LCLU estimates in the Niobrara River and Verdigre Creek sections of 39-mile district in MNRR are only available on a coarse scale (30 meter cell resolution) offered by the NLCD (2001) data or by a Niobrara River watershed LCLU classification using Landsat Enhanced Thematic Mapper (ETM) satellite imagery. Despite being relatively coarse resolution, the NLCD data provides consistent and comparable data in their 1992/2001 NLCD change dataset. NLCD information was chosen for comparability across all portions of MNRR, as finer resolution data is not currently available. However, Stevens et al. (2010) created a vegetation inventory study plan for MNRR, which includes vegetation mapping within the park boundaries and possibly includes minor areas of interest outside boundaries and excludes minor areas not of interest within the boundaries. The authors suggest that, for example, in some cases the park boundaries do not include areas of high interest such as non-wooded wetlands, and include areas of relatively low natural value such as residential and agricultural areas. If the study goes forward, the authors of the study plan expect to map approximately 50 different vegetation types within MNRR, several of which may include semi-natural types where natural communities have been invaded by non-native plants but remain discernable. They also will map Level I and II land use types, based on the Anderson Land Use and Land Cover Classification system in Anderson et al. (1976). The results of this work will create a more detailed understanding of current land cover, and when comparing this to legacy datasets, additional land cover changes may be identified within park boundaries.

The 2006 NLCD and the 2001/2006 NLCD change products have recently become available but are considered provisional products to date. In the future, this will provide more up-to-date information regarding the status of LCLU in MNRR.

Overall Condition

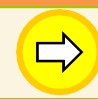
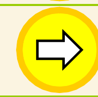
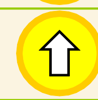
Measures	*Reference Condition*	*Condition*
Land cover/use distribution	Pre-exotics and invasives	
Ownership pattern	Pre-exotics and invasives	
Dynamics	Pre-exotics and invasives	

Figure 5. Land Cover and Land Use condition graphic.

Dixon et al. (2010) found the combined area of forests, woodlands, and shrublands in the historic Missouri River floodplain declined 47% from 1892 to 2006. Although both districts in MNRR represent unique stretches of the Missouri River, Dixon et al.(2010) data indicate similar changes in land cover from 1892 to 2006-2008 in the floodplain surrounding MNRR. The 59-mile district’s floodplain experienced significant declines in forest, grassland and sandbar habitats. Sandbar loss may be attributable to forest succession and to the lack of overbank flooding, channel meandering, and bed degradation, whereas the loss of forest and grassland was due primarily to large amounts of land being converted to agriculture from 1892 to 2006. The associated Missouri River flows for each of the aerial photographs are not discussed in Dixon et al. (2010), and, therefore, some of the composition of areas such as open water, sandbars, shrub, and forest lands could vary between photographs and years. However, the percent composition of land classified as agriculture increased from less than one percent of the floodplain in 1892 to more than 76 percent today. In addition, steady increases in the percent composition and total area of the ―urban” classification (e.g., towns such as Yankton, SD and Vermillion, SD) indicate this as another trend in the change of LCLU over this period of time.

In addition to direct conversion of land to agricultural production and other human uses (e.g. urban, industrial, and residential development), flow regulation by upstream dams has altered the flow and sediment regimes in both districts of MNRR. Bank stabilization features currently exist on more than one third of the linear miles of river bank within the boundaries of MNRR, contributing to the disruption of a naturally dynamic river and floodplain. These main factors have helped to alter the natural riparian vegetation succession and disturbance regimes and reduce the area of off-channel (backwater) habitats in MNRR. Dixon et al. (2010) noted significant recruitment of cottonwood and willow along the 59-mile district of MNRR since the closure of the Gavins Point Dam in 1956. Young cottonwood stands would likely be lumped in the Anderson Level 1 classification ―grassland/shrub” and as they mature the stands would be lumped into the ―forest” classification. The authors also note that the flood of 1952 resulted in considerable sediment transport and bar formation just prior to dam closure. Also a large flood in 1997 moved sediment and created sandbars. Since the Gavins Point Dam closure, these flood events have contributed to the changes of land cover along the Missouri River in the 59-mile district. In the 39-mile district, land cover has also been affected by the alteration of the river through dam installation and continued flow regulation. Aggradation has occurred in the lower part of the district where the Niobrara and other sources have contributed sediment inputs. These sediment inputs have formed a delta. In addition, the Missouri River, in approximately the upper one third of the 39-mile district, has experienced degradation. Yager (2010) found a 64.6% overall decrease in the area of off-channel habitats in 2008 compared with estimates from 1941 (pre-dam) in the 59-mile district. Aquatic habitats are not typically categorized in broad LCLU classifications other than broad open water classifications and therefore are addressed separately in the aquatic and terrestrial habitats section (Chapter 4.4).

The NLCD 1992/2001 change data indicate an expansion in the area of open water in both districts of MNRR. Some of this may be attributed to bed aggregation and subsequently rising water levels; however, the flow levels for the two satellite images may have been quite different. Therefore, the classified changes are not conclusive. Interestingly, a sizeable portion of the change detected in the 59-mile district was a conversion of open water to barren. This may be reflecting the creation of artificial sandbar habitat and the natural shifting of existing sandbars in the Missouri River. Very little change in areas classified as urban were indicated by the data in both districts.

Invasive and non-native plant species alter native plant community composition and structure and degrade their integrity and diversity (NPS 2010c). MNRR and the EPMT currently target about eight non-native species, several of which are also identified as state (Nebraska and/or South Dakota) noxious weeds. Exotic plant management has collected GPS locations of non-native invasive plants through inventory and control efforts, focusing primarily in the Bow Creek and Mulberry Bend properties, and on a large island referred to as Goat Island a few kilometers downstream from the Bow Creek property. Information regarding invasive species abundance and location are unavailable for other adjacent lands. Therefore, information on invasive plants and their effects on native plant community composition and structure across MNRR as a whole is lacking.

The two remnant free-flowing reaches (regulated by dam releases), the 39-mile and 59-mile districts, of the Missouri River in MNRR are bordered by homes, communities, tribal lands (Ponca, Santee Sioux, and Yankton Sioux), federal (e.g., Karl Mundt National Wildlife Refuge and Gavins Point and Fort Randall Projects), state, and community parklands, and recreational facilities (Weeks et al. 2005). The majority of lands within the park boundaries are privately owned. MNRR categorizes approximately one quarter of the land area within the park boundaries as ―protected lands.” In addition to providing protection from human development, protected lands offer a more immediate potential for restoration efforts. The Bow Creek property provides an opportunity for direct management efforts in restoring native plant communities and land cover of the property. Because the land is under NPS ownership it may require less time and effort devoted to coordination with various stakeholders as would non-NPS lands. Recent management efforts on this tract have reduced the abundance of eastern red cedars and a prescribed burn in 2009 has reintroduced fire to this landscape. However, this land represents less than half of one percent of the total area in MNRR. Therefore, broad and cooperative restoration efforts with multiple stakeholders, including private landowners, are important for ecologically positive landscape-scale changes.

The lasting effects of the Missouri River dams and their continued operation have created measureable, broad-scale changes, both direct and indirect, to LCLU across the historic floodplain of MNRR. Also, the conversion of land from native plant communities, generally grasslands, riparian shrublands and forests, upland forests, and herbaceous wetlands, to human uses such as agricultural production, industrial sites, urban areas, and cabins and other residential development, in the historic floodplain represent very significant changes. Together the dam effects and land conversion broadly represent a loss of floodplain habitat. In addition, with the urbanization and conversion of land has come the introduction and spread of invasive non-native and native plant species. The prevalence of bank stabilization features affect riparian habitat formation processes, promoting a further disconnect of the river to its floodplain and ultimately leading to broad-scale landscape changes measureable by LCLU mapping. Compared to the reference condition of what is known of LCLU (circa late 1800s), present day LCLU distribution in and surrounding MNRR represents a moderate concern (Figure 5). However, contemporary land conversion has decreased in scale and land cover change now appears to be driven primarily by changes in species composition due to altered river processes and non-native flora expansion. Overall, the condition of LCLU distribution is stable. Much of the land area within MNRR is in private ownership and therefore subject to potential development and land use alteration, this is a moderate concern for MNRR. However, trends in land conservation appear stable. Finally, land cover dynamics (i.e., natural factors andprocesses that drive river geopmorphology and vegetation succession) are disrupted due to the effects of flow regulation, channel armoring, bank stabilization, land use, and non-native invasive plant species expansion. Therefore natural land cover dynamics are a moderate concern for MNRR. In addition, negative effects of the distrupted processes appear to be continuing as older forests and trees die off and younger trees are not replacing them as quickly, species compositions are continually being altered, and the cumulative effects of aggredation and deposition within areas of the Missouri River and the delta of the Niobrara River continue to change in response to flow regulation and other man-made alterations to the area.

Sources of Expertise

Lisa Yager, MNRR biologist, NPS
Mark Dixon, Assistant Professor, Biology Dept., University of South Dakota.

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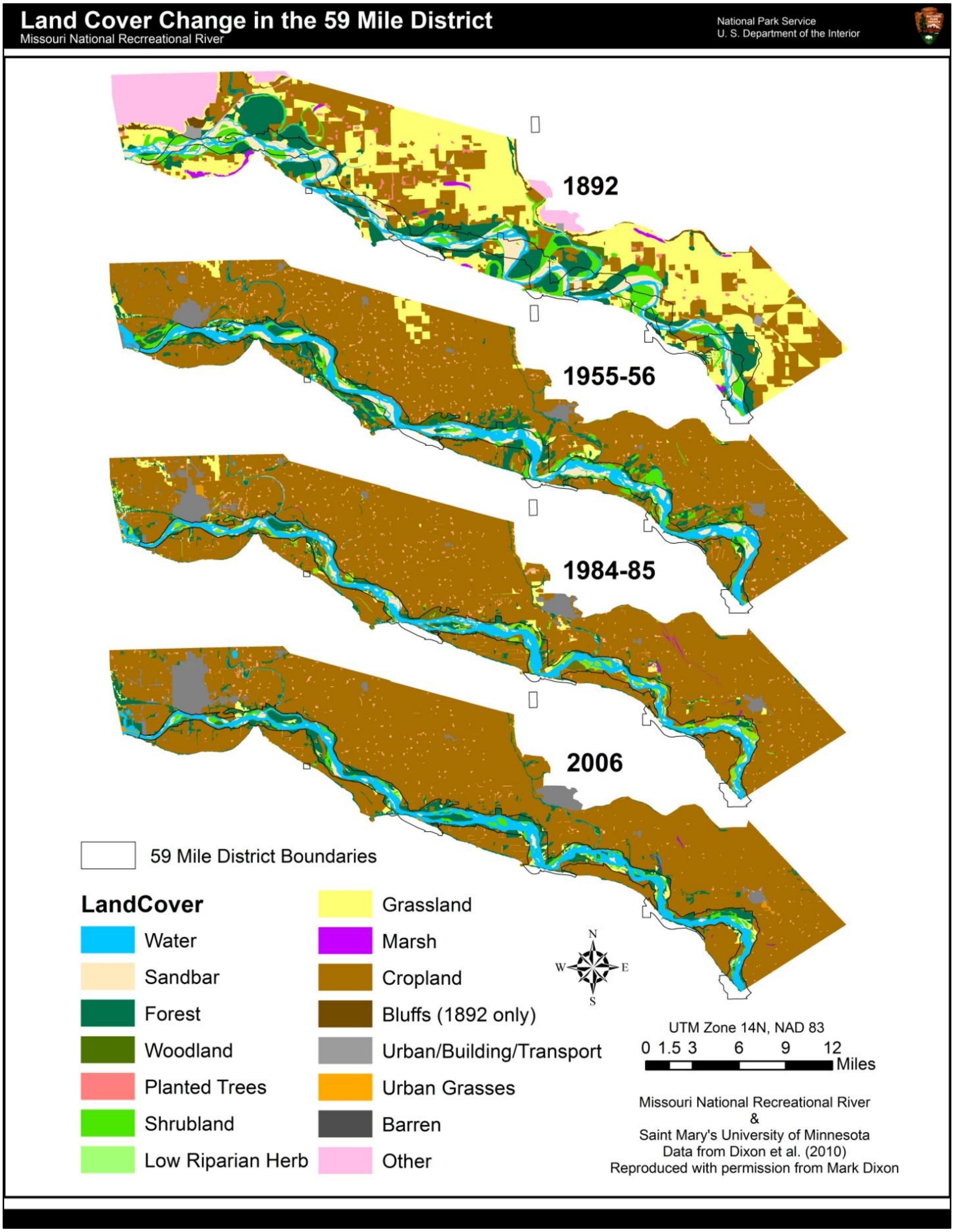


Plate 1. Land cover change associated with the 59-mile district of MNRR (segment 10 in Dixon et al. 2010), based on GIS analysis of 1892 Missouri River Commission maps and aerial photography from 1955-56, 1983-85, and 2006. Pink (other) in 1892 map indicates undefined land cover in 1892 Missouri River Commission maps (Dixon et al. 2010).

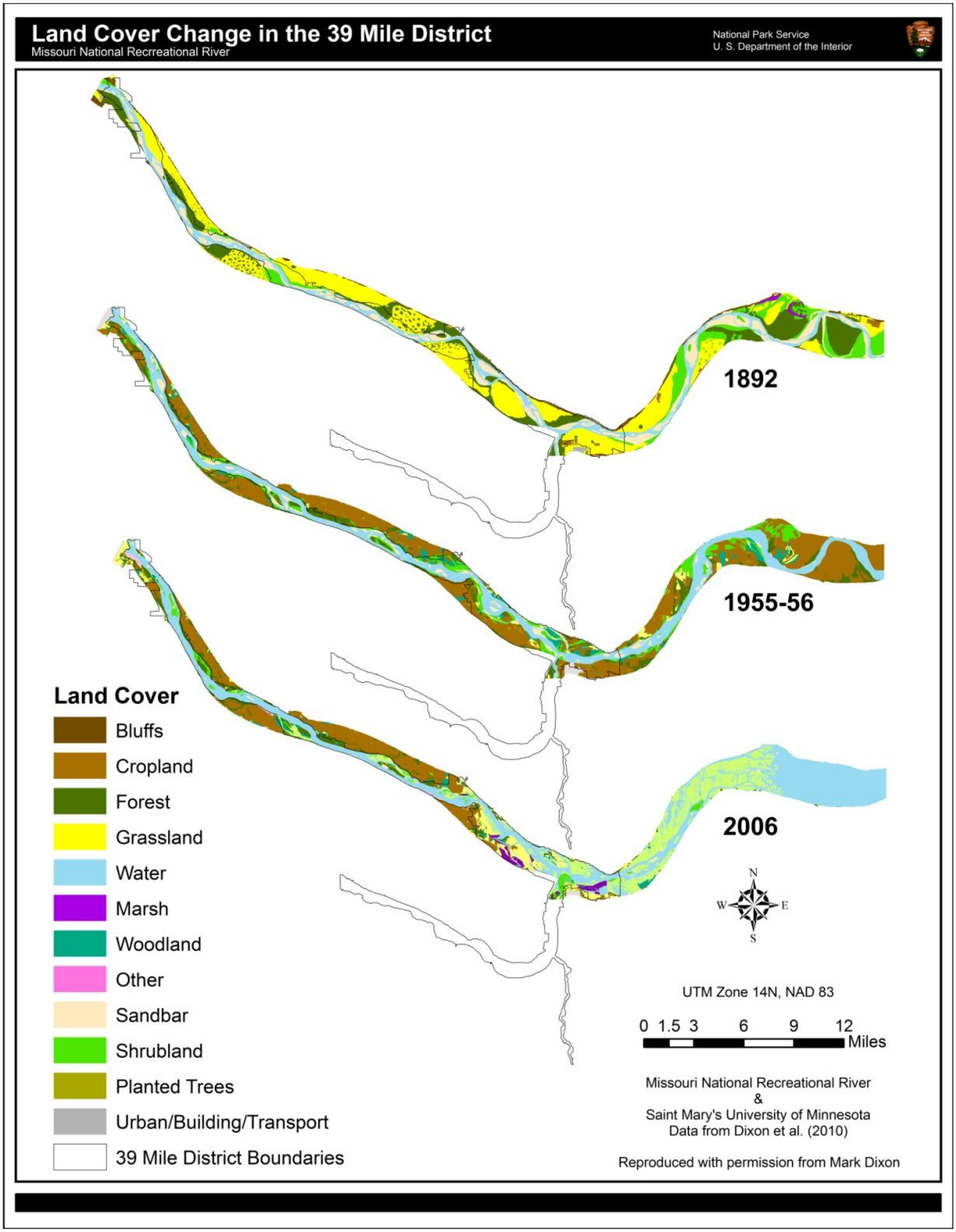


Plate 2. Land cover change associated with the 39-mile district of MNRR and Lewis and Clark Lake (segment 8-9), based on GIS analysis of 1892 Missouri River Commission maps and aerial photography from 1955-56, and 2006. Pink in 1892 map indicates undefined land cover in 1892 Missouri River Commission maps (Dixon et al. 2010).

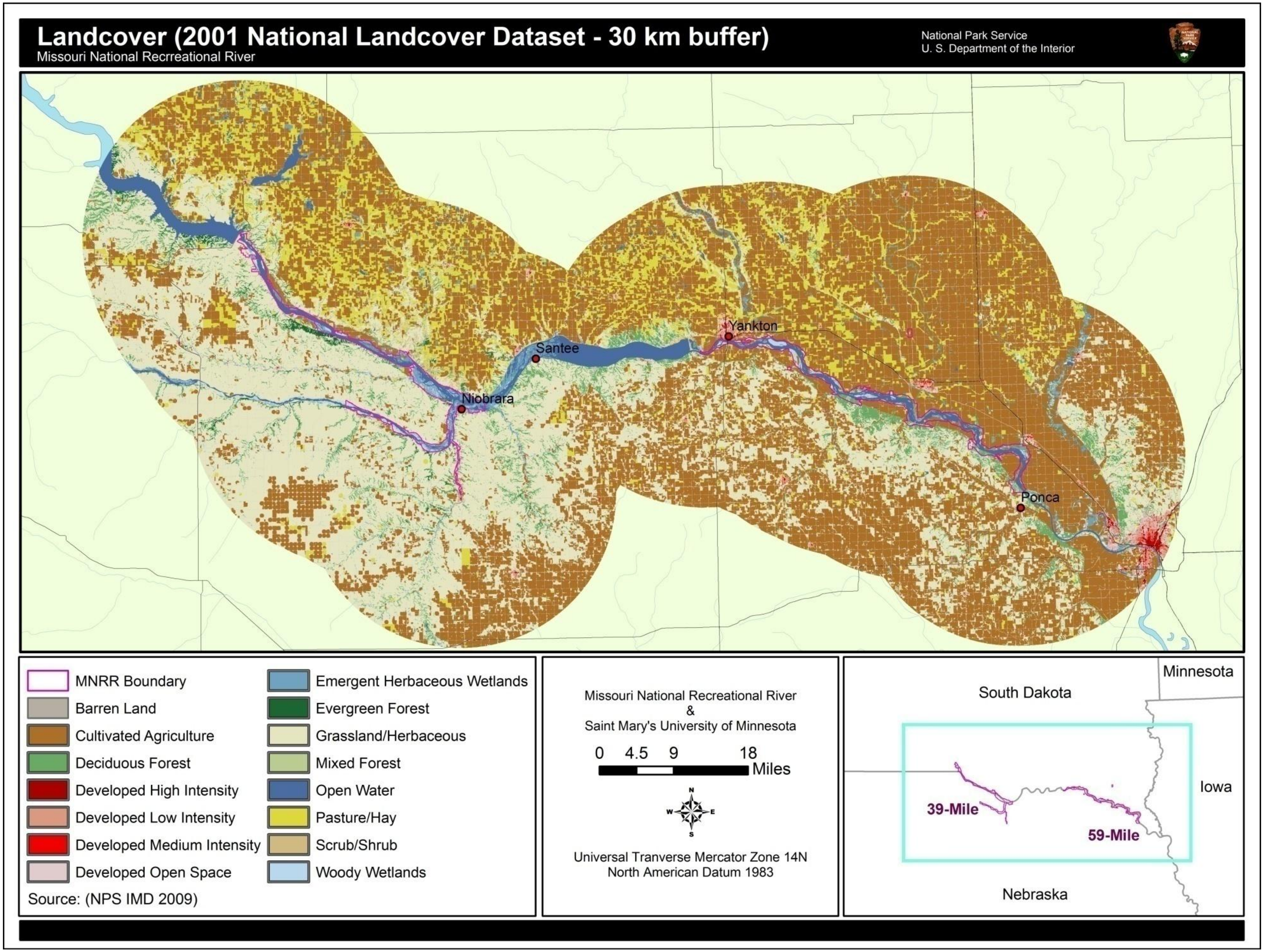


Plate 3. Land cover within a 30 km (18.6 mile) buffer of MNRR. (NPS IMD 2009).

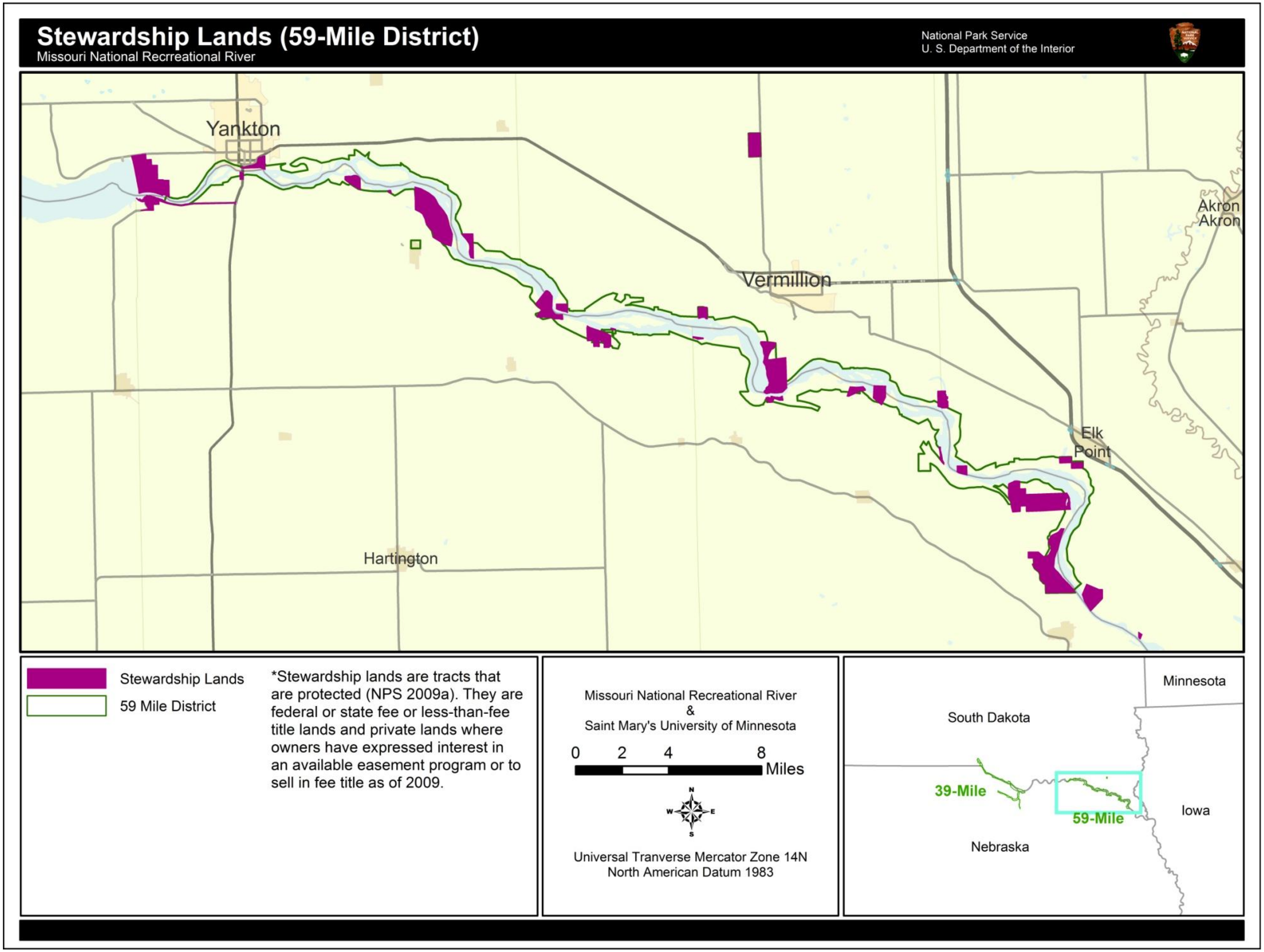


Plate 4. Stewardship lands in the 59-mile district of MNRR (NPS 2009a).

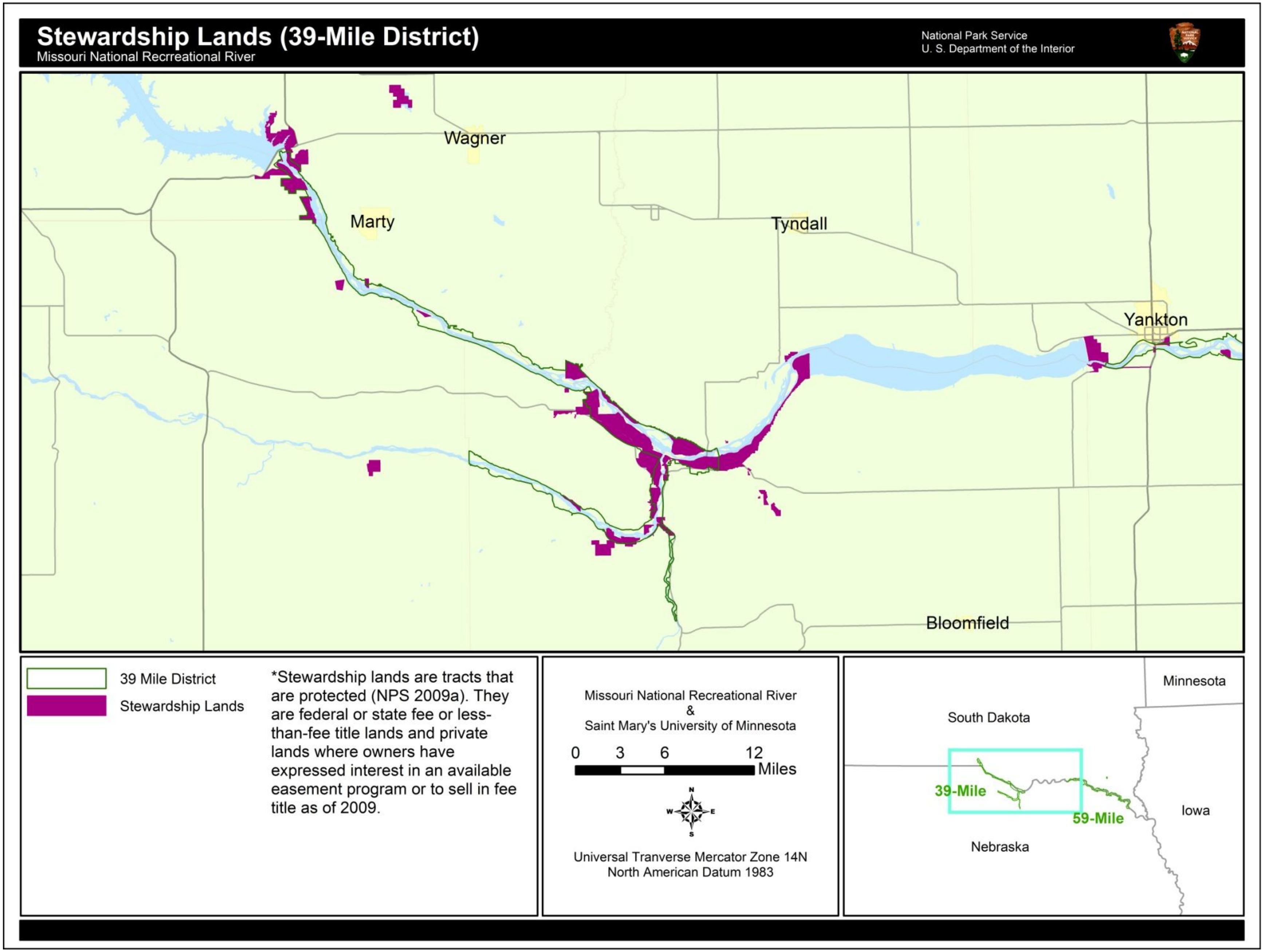


Plate 5. Stewardship lands in the 39-mile district of MNRR (NPS 2009a).

4.2 Erosional and Depositional Processes

Description

The Missouri River flows 3,346 km (2,135 mi) through seven states from Three Forks, Montana to St. Louis, Missouri. In addition, the Missouri River's watershed is larger than the Mississippi River watershed above its confluence. From the 1600s to the 1700s, the Missouri River facilitated trading and colonization. In the early to mid-1800s, steamboats on the river supported human migration and settlement. After the turn of the 20th century, navigation, irrigation, and hydroelectric power became the foundation of local river communities.

Major floods damaged homes, farmlands, and population centers in 1844, 1881, 1903, 1908, 1915, 1927, 1937, 1947, and 1952. These floods demonstrated the tremendous power of the river and led to recognition of how important flood control was to limit future destruction. As a result, seven dams were constructed to aid in flood control, navigation, hydroelectric power generation, and public water supply (Siouxland Interstate 1977, Jacobson et al. 2009). The seven reservoirs constructed between 1937 and 1963 on the mainstem of the Missouri River make up the largest reservoir system in North America.

The Missouri River is a complex ecosystem where fluvial geomorphic processes shape terrestrial and biotic ecological interactions (Petts and Gurnell 2005). The Missouri River has been modified by human activities for social, economic, and environmental concerns (NRC 2002,). Activities on the Missouri River related to dam construction, flood control, navigation, power generation, bank stabilization, and water supply have altered the river's fluvial dynamics and ecosystem (Stanford et al. 1996, Petts and Gurnell 2005). Activities began as early as 1824 when Congress appropriated funds to the USACE to remove large tree snags and other obstacles in the Missouri River channel (NRC 2002).

Flow regulation is perhaps the most pervasive change wrought by humans on rivers world-wide (Stanford et al. 1996); this is particularly true for the Missouri River. The Upper Missouri River (the portion of the river flowing through Montana, South Dakota, North Dakota, and Nebraska) has undergone flow regime changes since dam construction (Graf 2006, Jacobson and Galat 2008). Modifications to the flow regime have altered the erosional and depositional characteristics of the Missouri River (Petts and Gurnell 2005) and have impacted floodplains, chutes, islands, sandbars, and the main channel (Graf 2006).

Dams on the Missouri River affect downstream fluvial dynamics which alter overall stream ecology. Dam construction interrupts, alters, or eliminates river processes that help to determine the geomorphology and ecology of a river (Stanford et al. 1996, USGS 2000, Ward et al. 2001, Petts and Gurnell 2005, Graf 2006).

- Large dams can reduce peak flows, increase low flows, and alter the timing and duration of peak and low flows (Stanford et al. 1996, Graf 2006);
- Dams can isolate all, or a significant amount of the sediment load delivered from upstream sources (Petts and Gurnell 2005);
- Sediment trapping in reservoirs behind dams causes an imbalance between sediment transport capacity and sediment supply (Watson et al. 2002);

- Clear water releases from dams cause downstream channel degradation or incision (USGS 2000, Petts and Gurnell 2005) and channel armoring (Schumm 2005).

The historic pre-dam channel and floodplain of the Missouri River frequently exceeded 2,000 meters in width (in 1941, the widest portion of the 59-mile segment was 2,717 m), while the current channel/floodplain is much narrower (in 1999, the widest portion of the 59-mile segment was 1,686 m) (NRC 2002, Elliot and Jacobson 2006). Compared to historical conditions, the Missouri River is incised and dam releases no longer inundate the former floodplain (NRC 2002). Bank erosion, channel migration rates, the extent of vegetated islands, and the distribution of sandbars have all significantly changed in MNRR (NRC 2002, Elliot and Jacobson 2006).

Due to post-dam conditions, the Missouri River is evolving new channel morphology that will continue until the river achieves dynamic equilibrium (USACE 2008). Dynamic equilibrium can be thought of as a balance between sediment supply and sediment transporting capacity (Leopold et al. Schumm 1977, Simon and Rinaldi 2006). The morphologic adjustment of the Missouri River channel below dams includes

- Incision;
- Evolution of the incised channel through channel widening and establishment of a new floodplain within the widened channel;
- The former floodplain becoming a terrace (Schumm et al. 1984, Petts and Gurnell 2005, Simon and Rinaldi 2006, Figure 6):.

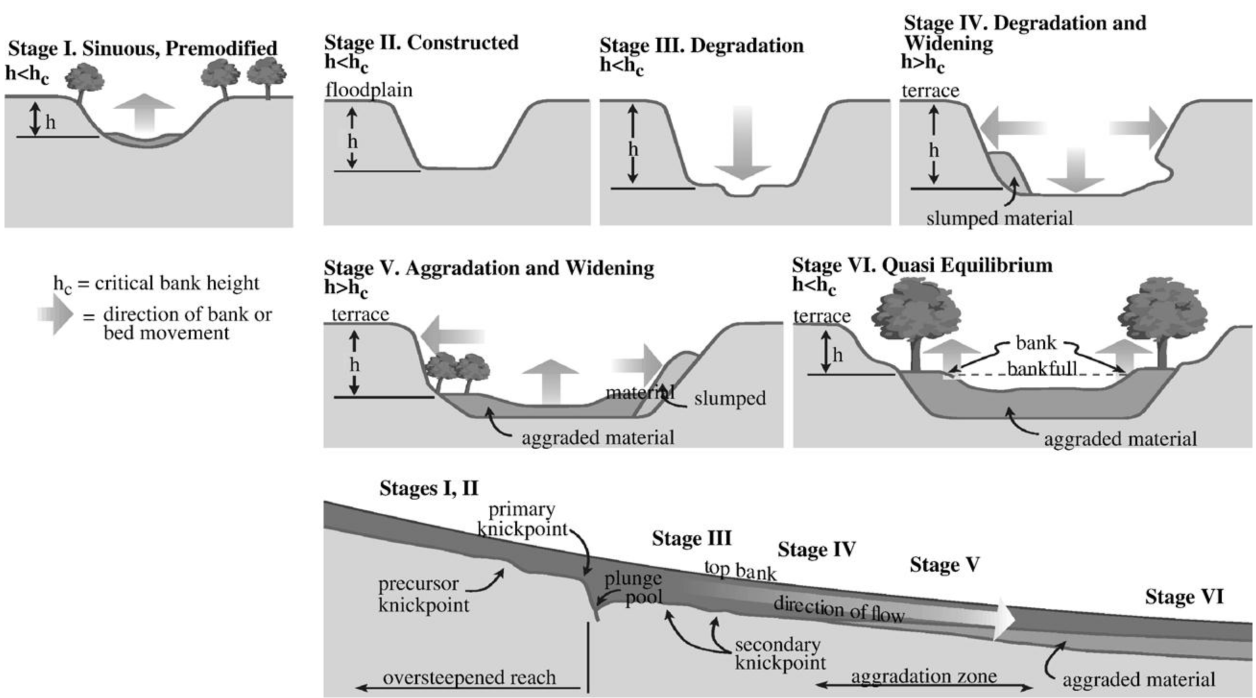


Figure 6. Incised channel evolution. Stages of channel evolution (Simon and Rinaldi 2006, modified from Simon and Hupp 1986).

Measures

- Channel elevation
- Sediment transport and deposition
- Bank erosion and channel migration
- Island and sandbar development
- Amount, areal extent, and mean particle size (D_{50}) of armored streambed

Reference Conditions/Values

The reference condition is defined as the conditions that existed prior to construction and closure of the Spencer Dam in 1927, the Fort Randall Dam in 1954, and the Gavins Point Dam in 1957.

Data and Methods

Most information regarding erosional and depositional processes was collected and analyzed by external agencies. Beidenharn et al. (2001), Elliot and Jacobson (2006), and USACE (1998, 2007, 2008, 2010) for example, were major sources of information for this document. These sources documented significant erosional and depositional change from the late 1800s to recent times.

Current Condition and Trend

Channel Elevation

The channel elevation reference condition, for both the Fort Randall and Gavins Point Dams, is the 1955 water surface elevation when the dam tailwater is at 10,000 cubic feet per second (cfs) (USACE 2007). For Fort Randall, reference condition is a water surface elevation of 377 m (1,236 ft). The Gavins Point Dam reference condition is a water surface elevation of 355 m (1,164 ft) (USACE 2007). Table 13 identifies the 10,000 cfs water surface elevation in 1955 and in 2006 for the Fort Randall and Gavins Point Dam tailwaters. Appendix B displays the trends in tailwater elevation overtime for the Fort Randall and Gavins Point reaches of the Missouri River.

Table 13. Fort Randall Dam and Gavins Point Dam tailwater surface elevation, 1955 and 2006 (USACE 2007)

Missouri River Location	1955 Water Surface Elevation at 10,000 cfs (in meters)	2006 Water Surface Elevation at 10,000 cfs (in meters)
Fort Randall Dam tailwater	377	375
Gavins Point Dam tailwater	355	351

In 2006, the water surface elevation (at 10,000 cfs) for the Fort Randall tailwater was 375 m (1,229 ft), 2.1 m (7.0 ft) below the 1955 reference condition (Table 13). The Gavins Point Dam tailwater (at 10,000 cfs) had a 2006 water surface elevation of 351 m (1,153 ft), 3.3 m (11 ft) below the 1955 reference condition (Table 13).

Channel elevation is influenced largely by streambed erosion and deposition rates. Streambed erosion and deposition rates for MNRR have been reported in Biedenharn et al. (2001) and

USACE (2008). These rates incorporated data from Pokrefke et al. (1998) and were estimated for geomorphic reaches based on measured cross-sectional and planform data (Biedenharn et al. 2001, USACE 2008). Table 14 displays the values reported in these documents by river mile (RM 1960) and geomorphic reach (GR). Both the Fort Randall and Gavins Point reaches have experienced more bed erosion than bed deposition from 1974-1985, which may potentially explain the decrease in surface elevation of the reaches since 1955.

Table 14. Streambed erosion and deposition rates below Fort Randall Dam and Gavins Point Dam.

Location	Biedenharn et al. 2001 (1975-1985)		USACE 2008 (1975-1995)*	
Fort Randall Reach	Bed Erosion (m^3/yr)	Bed Deposition (m^3/yr)	Bed Erosion (m^3/yr)	Bed Deposition (m^3/yr)
RM 879.3-873.9 (GR1)	-95,378		-173,552	
RM 873.9-867.5 (GR2)	-52,559	26,676	-111,446	
RM 867.5-861.7 (GR3)	-161,949	15,223		16,455
RM 861.7-854.5 (GR4)	-127,096	5,161		129,664
RM 854.5-851.0 (GR5)	0	1,185		79,005
RM 851.0-844.2 (GR6)	-138,901	134,812		84,186
	Biedenharn et al. 2001 (1974-1986)		**USACE 2008 (1974-1994)**	
Gavins Point Reach	Bed Erosion (m^3/yr)	Bed Deposition (m^3/yr)	Bed Erosion (m^3/yr)	Bed Deposition (m^3/yr)
RM 811-796 (GR1)	-343,540	10,835	-331,192	
RM 795-776.2 (GR2)	-569,242	95,341	-64,770	
RM 776.2-764.7 (GR3)	-361,611	54,843	-1,082,326	
RM 764.7-753 (GR4)	-589,490	105,843	-185,172	

*USACE 2008 uses net values.

Channel elevation is not degrading in all reaches of the river, however. From 1955-1985 in the Fort Randall reach (near the mouth of Ponca Creek), the Missouri River stream bed aggraded about 1 m (3.5 ft). Near the Niobrara River delta, the Missouri River aggraded about 1.2 m (4.0 ft) (USACE 1998). Total aggradation from 1955-1995 for the Missouri River streambed at Ponca Creek was 1.2 m (4.0 ft), and at the Niobrara River about 2.7 m (9 ft) (USACE 1998). Between 1955 and 1995, the maximum aggradation (5.5 m) occurred in the Lewis and Clark Lake Delta area, about 11-18 km (7-11 mi) below Springfield, SD between RM 825-821 (USACE 1998).

The upper portion of the Fort Randall reach (a 12.5 mile stretch extending from just below Fort Randall Dam to the vicinity of GR3) exhibits degradational tendencies (Biedenharn et al. 2001); the downstream portion of the reach transitions from dynamic equilibrium (at GR3) to slight aggradation (near the Lewis and Clark Lake delta area) (Biedenharn et al. 2001, USACE 2008). The entire Gavins Point reach is in a degradational trend and has not yet attained an equilibrium condition (Biedenharn et al. 2001).

The Fort Randall reach aggradation zone is receiving more sediment than is eroding from the upstream banks and bed, and tributary sources are likely supplying this sediment (USACE 2008). USACE (2008) suggests that the Fort Randall reach ―transition” zone (a region transitioning from degradation to aggradation) has moved from GR 4 to GR 3 (Dangberg et al. 1988, as cited by USACE 2008). The stream channel is degrading in the entire Gavins Point reach (Table 14).

<u>Bank Erosion</u>

Bank erosion is the scouring of material and the cutting of channel banks by flowing water or by mass failure. The USACE defines bank erosion as areal surface loss in acres of usable or productive land along the river banks. Annual areal rates of bank erosion have been reported for the Missouri River below the Fort Randall and Gavins Point Dams for both pre and post-dam periods (USACE 2006a, Elliot and Jacobson 2006, USACE 2010) (Table 15). Table 15 gives an approximation of reference condition (pre-dam) and current condition (post-dam).

Table 15. Areal extent per year of pre-dam and post-dam streambank erosion downstream of Fort Randall Dam and Gavins Point Dam.

Missouri River Location	**Elliot and Jacobson 2006**		**USACE 2006**		**USACE Draft Cottonwood Management Plan PEA 2010**	
	Pre-dam	Post-dam	Pre-dam	Post-dam	Pre-dam	Post-dam
Fort Randall Dam to Niobrara, NE	60 ha/yr	10 ha/yr	54 ha/yr	14 ha/yr	54 ha/yr	16 ha/yr
	148 ac/yr	25 ac/yr	135 ac/yr	35 ac/yr	135 ac/yr	40 ac/yr
	Pre-dam	Post-dam	Pre-dam	Post-dam	Pre-dam	Post-dam
Gavins Point Dam to Ponca, NE	80 ha/yr	50 ha/yr	81 ha/yr	54 ha/yr	81 ha/yr	64 ha/yr
	198 ac/yr	124 ac/yr	202 ac/yr	134 ac/yr	202 ac/yr	157 ac/yr

Comparison of pre-dam bank erosion rates to post-dam erosion rates is problematic because the regulated flow regime eliminates geomorphically effective floods that caused extensive bank erosion, channel migration, and erosion and creation of islands and sandbars; although record releases in 2011 may provide similar processes and results, they will not equal pre-dam channel migration or habitat turnover. Estimates of pre-dam bank erosion did not include deposition, which in an equilibrated system maintains, on average, a constant channel cross-section with deposition on one bank while the other bank erodes (Leopold et al. 1964).

Overall, rates of bank erosion were higher in the pre-dam era (Table 15). For the Fort Randall reach, the post-dam bank erosion rates were less than pre-dam rates by 70% (USACE 2010a), 83% (Elliot and Jacobson 2006), and 74% (USACE 2006a). For the Gavins Point reach, the post-dam bank erosion rates were less than pre-dam rates by 22% (USACE 2010a), 38% (Elliot and Jacobson 2006), and 35% (USACE 2006a).

Biedenharn et al. (2001) also calculated volumetric bank erosion rates based on interpretation of bank lines from aerial photography, estimated bank height from field reconnaissance, and available cross-sectional data from 1976-1998 (Table 16). Four reaches of the Missouri River were analyzed in this study, and with an average annual bank erosion of roughly 28,000m^3/yr/km, Gavins Point reach had the highest bank erosion rates per kilometer of any of the study sites (Table 16) (Biedenharn et al. 2001).

Table 16. Volumetric bank erosion rates by geomorphic reach for Ft. Randall and Gavins Point reaches (Biedenharn et al. 2001).

Gavins Point Reach Bank Erosion 1977-1998				
Segment or reach	**Total left bank erosion (m^3)**	**Total right bank erosion (m^3)**	**Annual volume (m^3)**	**Annual volume/km (m^3/yr/km)**
RM 811-796 (GR1)	2,925,063	5,145,819	366,858	15,200
RM 795-776.2 (GR2)	7,393,556	9,599,230	772,399	25,266
RM 776.2-764.7 (GR3)	5,706,287	11,028,291	760,663	42,978
RM 764.7-753 (GR4)	3,878,527	9,371,188	602,260	34,028
Total	19,903,433	35,144,528	2,502,180	27,770

Fort Randall Reach Bank Erosion 1976-1998				
Segment or reach	**Total left bank erosion (m^3)**	**Total right bank erosion (m^3**	**Annual volume (m^3)**	**Annual volume/km (m^3/yr/km)**
RM 879.3-873.9 (GR1)	1,528,102	814,002	106,459	11,027
RM 873.9-867.5 (GR2)	1,463,281	362,211	82,977	10,314
RM 867.5-861.7 (GR3)	1,655,688	2,517,367	189,684	23,578
RM 861.7-854.5 (GR4)	890,417	1,112,884	91,059	9,432
RM 854.5-851.0 (GR5)	436,569	561,724	45,377	14,101
RM 851.0-844.2 (GR6)	1,773,850	2,746,093	205,452	18,241
Total	7,747,908	8,114,281	721,009	14,455

Previous data presented in USACE (1998a) and available cross-sectional data from 1974-1995 was used in USACE (2008) to calculate volumetric bank erosion rates (Table 17). While this study aimed to capture the same measures as the Biedenharn (2001) study (i.e., volumetric bank erosion rates), the results presented are very different (Table 18).

Table 17. Volumetric bank erosion rates by geomorphic reach for Fort Randall and Gavins Point reaches (USACE 2008).

Gavins Point Reach Bank Erosion 1974-1994		
Segment or reach	**Total bank erosion (m^3)**	**Annual volume/km (m^3/yr/km)**
RM 811-796 (GR1)	-13,839,758	-57,486
RM 795-776.2 (GR2)	-20,197,905	-55,953
RM 776.2-764.7 (GR3)	-21,759,997	-132,600
RM 764.7-753 (GR4)	-20,355,545	-118,037
Total	-76,153,205	-364,076
Fort Randall Reach Bank Erosion 1975-1995		
Segment or reach	**Total bank erosion (m^3)**	**Annual volume/km (m^3/yr/km)**
RM 879.3-873.9 (GR1)	-1,539,369	-16,096
RM 873.9-867.5 (GR2)	-665,468	-6,132
RM 867.5-861.7 (GR3)	-1,659,784	-17,629
RM 861.7-854.5 (GR4)	2,060,422	17,629
RM 854.5-851.0 (GR5)	1,446,267	26,060
RM 851.0-844.2 (GR6)	1,113,841	9,964
Total	755,882	13,796

Table 18. Total volumetric bank erosion rates (volume per year per kilometer) for the Fort Randall and Gavins Point Reaches (Biedenharn et al. 2001, USACE 2008).

Study	**Dates for Study Data**	**Gavins Point Reach**		**Fort Randall Reach**	
		m^3	**m^3/yr/km**	**m^3**	**m^3/yr/km**
USACE 2010	1974-1995	-76,153,205	-364,076	755,882	13,796
Biedenharn et al. 2001	1976-1998	-2,502,180	-27,770	-721,009	-14,455

The USACE (2008) values presented in Table 18 include both deposition and erosion; the Biedenharn et al. (2001) values represent bank erosion only. In addition, Beidenharn et al. (2001) estimated bank heights and used available surveyed cross-sectional data, whereas USACE (2008) used only surveyed cross-sectional data in their calculations, extrapolating bank height through each reach. Because of varying definitions of bankline, differing methods of erosion detection and data collection, and differing periods of data collection, it is difficult to compare erosion rates directly (Elliot and Jacobson 2006).

Elliot and Jacobson (2006) calculated areal rate of bank erosion based on interpretation of bank lines from aerial photography and available cross-sectional data. Table 19 displays the post-dam, areal bank erosion rate from 1993-2004, as reported in Elliot and Jacobson (2006).

Table 19. Areal bank erosion rate for Fort Randall and Gavins Point reaches (Elliot and Jacobson 2006).

Total Erosion Area and Rate - Gavins Point Reach - 1993-2004				
	Total Erosion Area (ha)	**Total Erosion Area m/m[1]**	**Erosion Rate (ha/yr)**	**Erosion Rate (m/m/yr)**
Bank Erosion Rate	206	22.08	19	2.01
Mean Bank Erosion Rate			16	1.76
Total Erosion Area and Rate - Fort Randall Reach - 1993-2003				
	Total Erosion Area (ha)	**Total Erosion Area m/m[1]**	**Erosion Rate (ha/yr)**	**Erosion Rate (m/m/yr)**
Bank Erosion Rate	5.7	0.99	0.6	0.1
Mean Bank Erosion Rate			0.5	0.09

Gavins Point reach lateral bank erosion and approximate locations (River Mile in 1960) were estimated from Elliot and Jacobson (2006) which displays square meters of bank erosion per 200 meters of longitudinal channel centerline by river mile (RM 1960) (Figure 7).

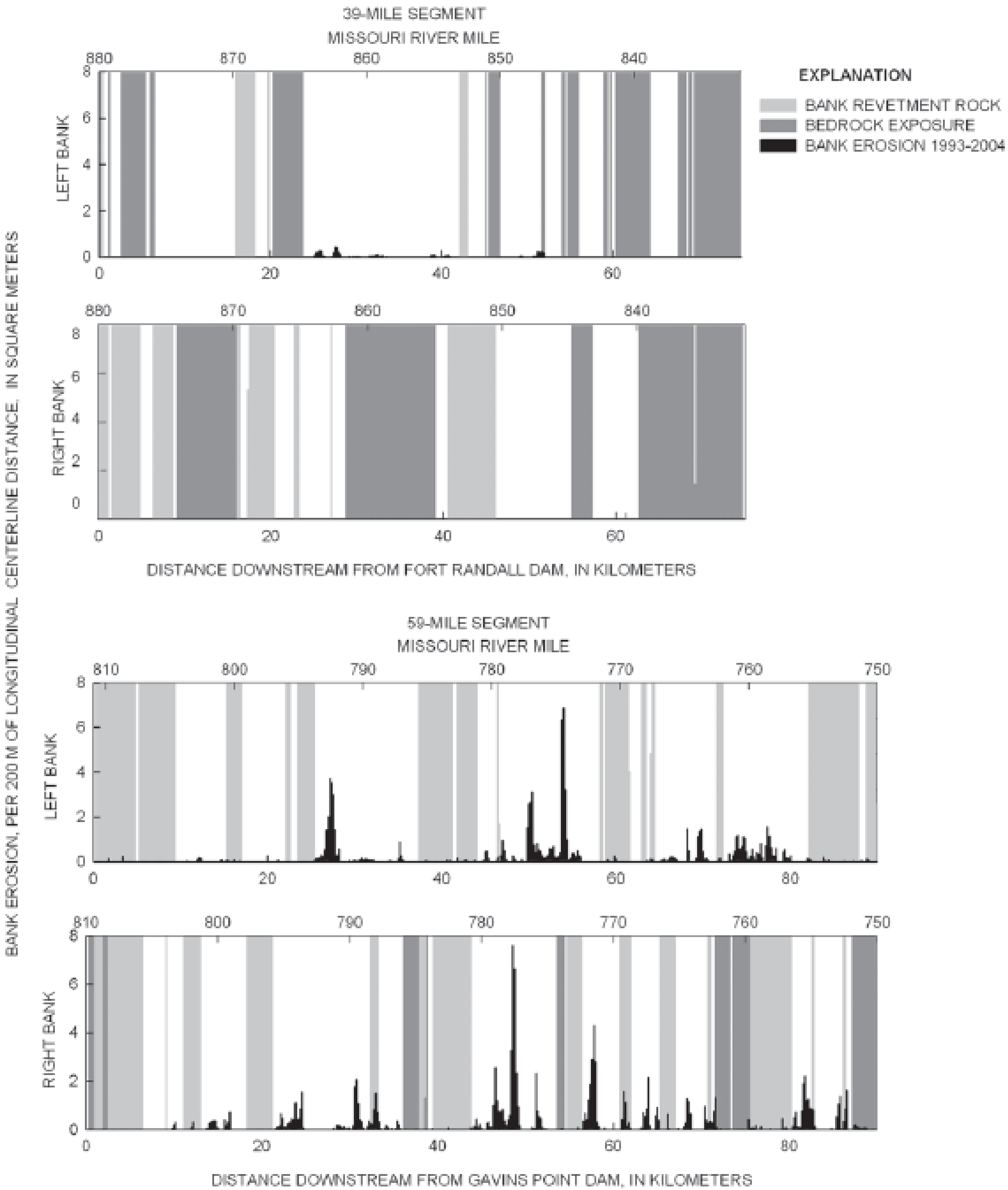


Figure 7. Erosion per 200 m of longitudinal channel by centerline for the 1993-2004 period in the 39-mile and 59-mile Missouri River segments. Bank revetment and banks within 50 m of bedrock exposures are also indicated. The left and right bank refer to the river left and river right banks when facing downstream. Reproduced from Elliot and Jacobson (2006).

Channel Migration

Channel migration is the movement of a stream channel across a floodplain or other surface (such as bedrock) through the processes of bank erosion, deposition, or avulsion (Dunne and Leopold 1978). A meandering stream will migrate from one side of a floodplain valley to the other (Schumm 1977). Historically, the Missouri River was described as a meandering river; from 1879 to 1930, over one-third of the river's floodplain was reworked along a 170 mile stretch from Glasgow, Missouri to St. Louis, Missouri (Schumm 1977).

Elliot and Jacobson (2006) found that the channel in the 39-mile reach occupied nearly the same location from 1894 to present, and that the stream channel in the 59-mile reach had a dynamic history of channel change. This is supported by the present-day landscape of channel migration scars, oxbow lakes, and abandoned chutes on the former floodplain (Elliot and Jacobson 2006). During lateral migration, stream channel width may remain fairly constant due to deposition on the point bar (Leopold et al. 1964). The pre-regulation main channel width was variable, ranging from 300 to 3,000 m during normal flow periods to 7,620 to 10,668 m wide (including the floodplain) during floods (Schneiders 1999, as cited by NRC 2002).

The pre-dam river was free to migrate across the entire valley. Elliot and Jacobson (2006) determined valley width from 1999 orthophotographs; the 39-mile free-flowing reach (above Lewis and Clark Lake delta) had a mean valley width of 2,377 m (7,798 ft), and the 59-mile mean valley width was 9,842 m (32,290 ft) (Figure 8, Figure 9). Table 20 displays mean and range of 1999 valley widths, and 1894 and 1999 channel widths (Elliot and Jacobson 2006). Valley width in 1999 is likely similar to pre-dam conditions (Macy, pers. comm., 2010).

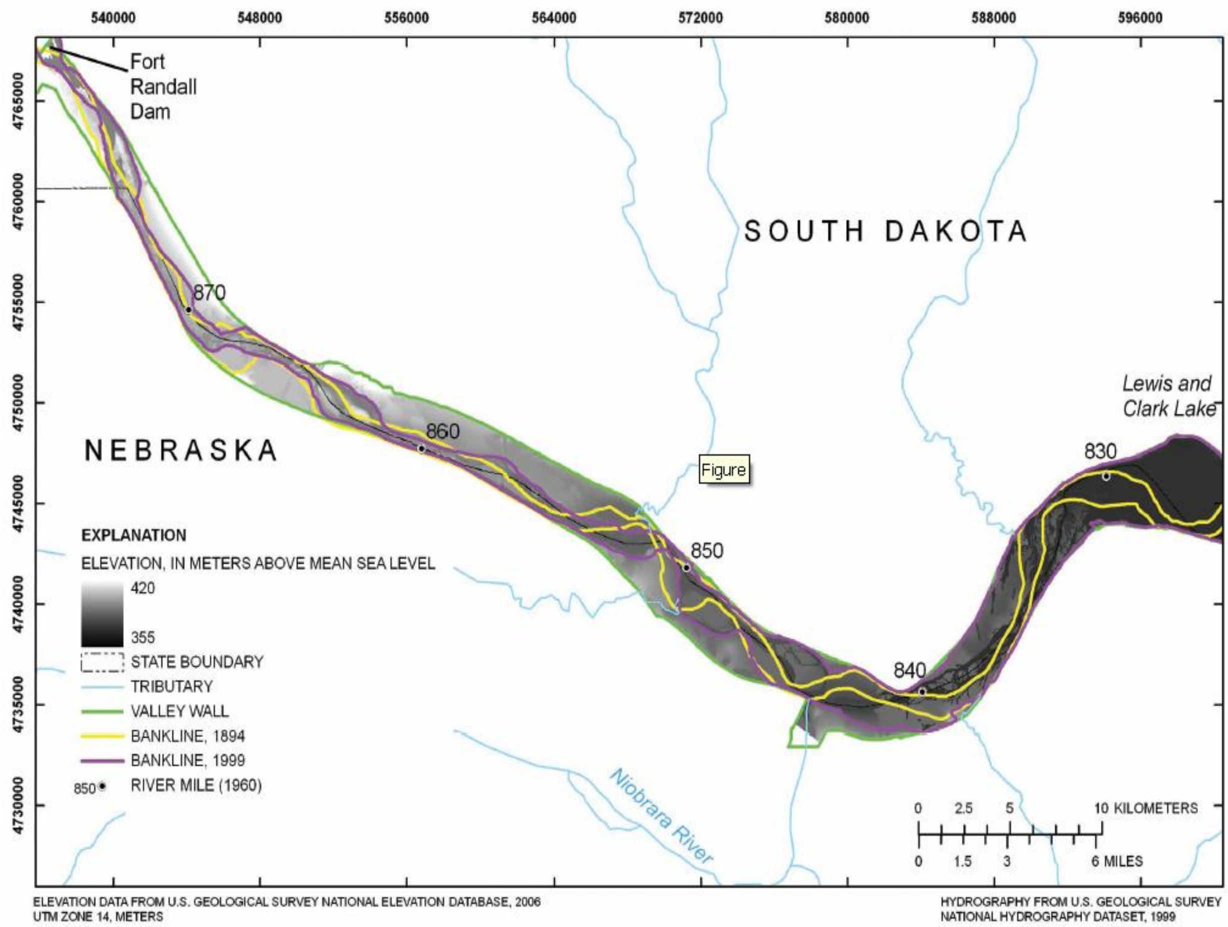


Figure 8. Historical channel positions and floodplain topography in the 39-mile segment of MNRR from 1894 to 1999 (Elliot and Jacobson 2006).

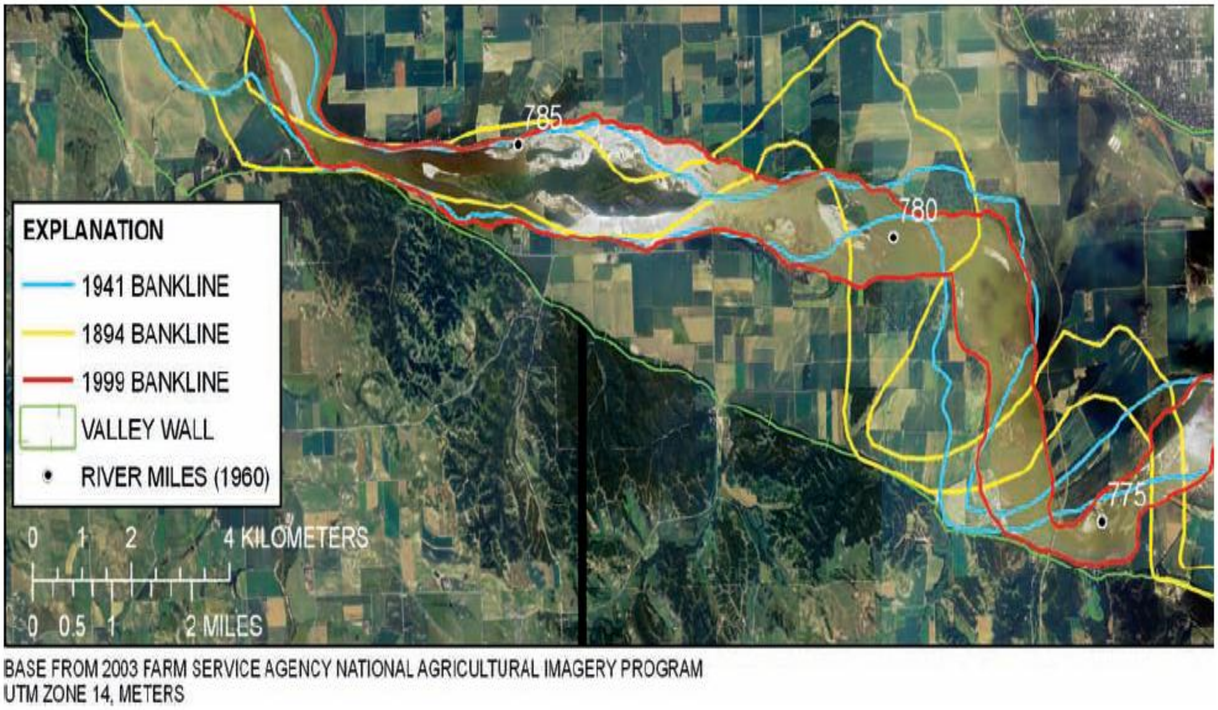


Figure 9. Historical channel positions on a portion of the 59-mile segment of MNRR from 1894 to 1999 (Elliot and Jacobson 2006).

Table 20. Mean and range of 1894 and 1999 channel widths and 1999 valley widths (Elliot and Jacobson 2006).

		Channel Width m(ft)		**Valley Width m(ft)**
Reach		**1894**	**1999**	**1999**
39-mile free-flowing	Mean	786 m (2,579 ft)	2,376 m (7,798 ft)	2,376 m (7,798 ft)
	Range	269-1950 m (883-6,398 ft)	1,467-3090 m (4,813-10,141 ft)	1,467-3090 m (4,813-10,141 ft)
59-mile	Mean	951 m (3,123 ft)	868 m (2,848 ft)	32,290
	Range	1,040-7,667	663-6,020	8,871-55,767

Sinuosity is defined as the deviation of a stream between two points from the shortest possible path, and it is most often expressed as the ratio of channel length to valley length (Rosgen 1996). A straight channel pattern has low sinuosity compared to a meandering channel which has higher sinuosity (Leopold et al. 1964). The sinuosity of the 39-mile free flowing reach (above Lewis and Clark Lake delta) in 1894 was 1.09, while the sinuosity of the 59-mile reach in 1894 was 1.20 (Table 21, Elliot and Jacobson 2006). The overall channel length of the Missouri River channel from Fort Randall Dam to RM 729 (near Sioux City, Iowa) was 256.9 km (159.6 mi).

Table 21. 1894 and 1999 39-mile and 59-mile reach sinuosity and channel length for the Fort Randall Dam to RM 729 segment (Elliot and Jacobson 2006).

Year	Sinuosity		Channel Length (km)
	39-mile free flowing reach	59-mile reach	Fort Randall to RM 729
1894	1.09	1.2	256.9 (159.6 mi)
1999	1.04	1.1	235.9 (146.6 mi)

The sinuosity of the 39-mile free-flowing reach (above Lewis and Clark Lake delta) in 1999 was 1.04, and the sinuosity of the 59-mile reach was 1.10. These values were lower than the 1894 sinuosity values by 0.05 and 0.1, respectively (Table 21). In the past 100 years, the overall channel length of the Missouri River channel from Fort Randall Dam to RM 729 has been reduced by 21 km (13 mi) from 257 km (159.6 mi) to 236 km (146.6 mi) (Table 21).

Elliot and Jacobson (2006) identified little change in channel position for the 39-mile reach from 1894 to 1999, while the 59-mile channel migration rates were higher in the pre-dam era than they are today.

Sediment Transport and Deposition

Sediment transport refers to the movement of solid, mineral, or organic material by flowing water from one location to another, either in suspension or as bed-load. Sediment may be deposited on the stream bed, stream banks, or on an accessible floodplain.

The actual sediment transported and deposited in the 59-mile and 39-mile reaches of MNRR prior to the closure of the Fort Randall and Gavins Point Dams is unknown. NRC (2002) identified that sediment transported past Omaha, Nebraska ranged from 39 million metric tons in 1931, to 228 million metric tons in 1944. Prior to closure of Gavins Point dam from 1940-1952, the average annual sediment load transported past Omaha was 148 million metric tons, and after 1954 the average annual sediment load was reduced to 29,487,600 metric tons (Slizeski et al. 1982, as cited by NRC 2002).

Biedenharn et al. (2001) determined a sediment budget for the 39- and 59-mile reaches of the Missouri River using bank and stream bed erosion and deposition rates. The sediment budget is based on a grain size that represents the lower size limit of material found in appreciable quantities in the bed and habitat bars (Biedenharn et al. 2001). The sediment budget for the 39-mile Fort Randall reach uses a grain size >0.16 mm, and in the 59-mile Gavins Point reach a grain size of >0.20 mm was used. Table 22 displays bank and bed deposition, as well as a sediment transport budget for the geomorphic reaches (GR) of the 39- and 59-mile portions of MNRR (Biedenharn et al. 2001).

Table 22. Bank and bed deposition and sediment transport budget (Biedenharn et al. 2001).

Gavins Point 59-mile Reach	Deposition (1974-1986) (m^3/yr)		Net Sediment Transport from Erosion & Deposition (m^3/yr)	Upstream Sediment Supply (m^3/yr)	Sediment Transport Budget (m^3/yr)
	Bank	**Bed**			
RM 811-796 (GR1)	61,978	10,835	-463,017	-463,017	-463,017
RM 796-776.2 (GR2)	95,554	95,341	-734,619	-1,197,636	-1,197,636
RM 776-764.7 (GR3)	61,200	54,843	-884,753	-2,082,388	-2,082,388
RM 764.7-753.9 (GR4)	164,340	105,843	-730,458		-2,812,846
Total	383,072	266,863	-2,812,846		

Fort Randall 39-mile Reach	Deposition (1975-1985) (m^3/yr)		Net Sediment Transport from Erosion & Deposition (m^3/yr)	Upstream Sediment Supply (m^3/yr)	Sediment Transport Budget (m^3/yr)
	Bank	**Bed**			
RM 879-873(GR1)	53		-107,043	-107,043	-107,043
RM 872-867 (GR2)	51,940	26,676	16,923	-90,120	-90,120
RM 866-861 (GR3)	2,229	15,223	-165,375	-255,495	-255,495
RM 860-854 (GR4)	5,161	22,130	-125,318	-380,813	-380,813
RM 853-851 (GR5)	5,947	1,185	-5,582	-386,395	-386,395
RM 850-843 (GR6)	69,616	134,812	16,186		-370,210
Total	134,946	200,026	-370,210		

(GR = geomorphic reach)

The sediment budget for the Gavins Point reach revealed that the reach as a whole was in a degradational trend; an equilibrium condition had not yet been obtained for this reach of the Missouri River (Biedenharn et al. 2001). Both the Gavins Point and Fort Randall reaches had deposition on the stream banks and bed for the time-period studied by Biedenharn et al. (2001). At the same time, the erosion of the river bank and bed was greater than the rate of deposition, except in the Fort Randall 39-mile GR2 and GR6 (Table 22). USACE (2008) documented bed erosion and deposition from 1975-1995 (Table 14), with net deposition in GR 3-6. In both studies, the stream bed in the Gavins Point 59-mile reach continued to experience net erosion for the time periods investigated.

Island and Sandbar Development

Riverine islands are defined as discrete areas of woody riparian vegetation within river corridors. Sandbars are discrete areas composed primarily of sand within river corridors having only sparse plant cover, or are devoid of higher vegetation.

Island formation requires (1) a natural flood regime, (2) a sediment source, (3) an unconstrained channel, and (4) a source of large woody debris (Ward et al. 2001, Ward et al. 2002,). Acording to Osterkamp (1998), ―Islands [sand bars] form by long-term aggradational and sorting processes of coarse bed sediment or by redistribution of sand and gravel in streams with large bedload fluxes". Montgomery et al. (2003) states, ―Wood can force the formation of bars…and consequent sediment deposition."

Sandbars form through depositional processes on the stream bed. Leopold et al. (1964) describe the importance of changes in bed configuration as a relationship of the changing form to flow resistance and sediment transport. In natural channels the change of bed configuration has a large effect on flow resistance (Leopold et al. 1964). Sediment caliber or grain size may help govern the nature, action, and form of the features built on the bed, which exert the greatest influence on flow resistance. On the whole, the downstream reduction in flow resistance, resulting from decrease in particle size, is partly compensated by other forms of flow resistance, particularly that offered by bars and channel bends (Leopold et al. 1964). The change of bed is a mechanism or process by which the interactions of hydraulic variables (width, depth, velocity, etc.) can readjust to promote and maintain a kind of equilibrium or steady-state condition in the open system represented by the water and sediment in the adjustable channel (Leopold et al. 1964).

The number and area of bare sand bars is related to stage (discharge level) with greater amounts of bare sand bars exposed in the river corridor when the stage is low. High flow events are capable of creating new sand bars and scouring vegetation from existing low-lying bars (Elliot and Jacobson 2006).

A natural sediment source is necessary for sandbar/island formation (Ward et al. 2001). Prior to closure of Gavins Point Dam (1940-1952), the average annual sediment load transported past Omaha, Nebraska was 148 million metric tons. After 1954, the average annual sediment load was reduced to 29 million (Slizeski et al. 1982, as cited by NRC 2002). Sandbar creation is also dependent upon a source of large, woody debris (Ward et al. 2001). Using 1999 orthophotographs, Elliot and Jacobson (2006) identified an average of 38.1 pieces of large woody debris in the 39-mile reach and 96.2 pieces per kilometer in the 59-mile reach.

Elliot and Jacobson (2006) determined the number and area of vegetated bars (islands) and bare sandbars prior to dam construction on the Gavins Point 59-mile reach of the Missouri River from 1941 orthophotographs. The number and area of islands and sandbars were not determined for the Fort Randall 39-mile reach before dam construction. Table 23 displays the discharge (when the aerial photographs were taken) and the number and area of islands and sandbars by date for both reaches of the MNRR (Elliot and Jacobson 2006). The values obtained in 1941 represent the reference condition for island and sandbar condition, although pre-European settlement island and sandbar conditions may have been different than what was found in 1941 (Macy, pers. comm., 2010)

Table 23. Sandbar analysis for the Fort Randall and Gavins Point reaches of the Missouri River (Elliot and Jacobson 2006).

Year	Discharge (m^3/sec)	Number of Bars	Bars/km	Total Bar Area (ha)	Mean Bar Area (ha)
Gavins Point 59-mile Reach					
Vegetated Bars (Islands)					
1941	795	46	0.5	4534	99
1998	735	45	0.5	1209	27
2004	750	145	1.7	1921	13
Bare Sand Bars					
1941	795	312	3.6	1804	6
1998	735	312	3.6	2022	6
2004	750	634	7.2	492	1
Fort Randall 39-mile Free-Flowing Reach					
Vegetated Bars (Islands)					
1999	680	322	5.6	1749	5.4
2004	735	164	2.9	1902	12
Bare Sand Bars					
1999	680	82	1.4	302	3.7
2004	735	85	1.5	351	4
Fort Randall 39-mile Delta Reach					
Vegetated Bars (Islands)					
1999	680	703	26.9	4414	6.3
2004	735	465	17.6	4177	9
Bare Sand Bars					
1999	680	111	4.2	232	2.1
2004	735	77	2.9	237	3

Elliot and Jacobson (2006) digitized islands and sandbars for the Fort Randall reach from 1999 and 2004 orthophotographs and for the Gavins Point reach from 1941, 1996, 1997, 1998, 1999, 2003, and 2004 orthophotographs. Table 23 displays only three years of data for the Gavins Point reach: 1941 (before dam construction), 1998 (second highest mean sandbar area), and 2004 (most recent sandbar analysis).

In addition to the Elliot and Jacobson (2006) values in Table 23, Biedenharn et al. (2001) documented islands and sandbars during their geomorphological assessment. Table 24 displays the discharge (when the aerial photographs were taken), reach average area per kilometer, range of aerial values, and total area of vegetated bars and sandbars (Biedenharn et al. 2001). Biedenharn et al. (2001) divided the Fort Randall reach into eight segments (seven segments of 8.0 km in length, and one segment 3.2 km in length) for a total length of 59.2 km. Biedenharn et al. (2001) divided the Gavins Point Reach into six segments (four segments 16.1 km in length, one segment 24.1 km in length, and one segment 8.0 km in length) for a total length of 96.5 km. The range values in Table 24 includes the eight segments in the Fort Randall reach and the six segments in the Gavins Point reach.

Table 24. Bar analysis for Fort Randall and Gavins Point reaches of the Missouri River (Biedenharn et al. 2001).

Gavins Point 59-mile Reach Island and Sandbar Density and Area						
	Islands (vegetated bars)			**Sandbars (bare)**		
Year	1976	1994	1998	1976	1994	1998
Discharge (m^3/sec)	906	866	1826-1843	906	866	1826-1843
Reach Average (ha/km)	25.8	24.4	27.2	16.5	11.5	30.7
Range (ha/km)	3-61	4-59	0-53	7-32	0-54	8-51
Total Area (ha)	2490	2355	2625	1592	1110	2963
Fort Randall 39-mile Reach Island and Sandbar Density and Area						
	Islands (vegetated bars)			**Sandbars (bare)**		
Year	1976	1994	1998	1976	1994	1998
Discharge (m^3/sec)	1076	835	801-818	1076	835	801-818
Reach Average (ha/km)	52.6	40.6	34.6	30	3.5	8
Range (ha/km)	0-166	0-95	0-97	0-82	0-10	2-12
Total Area (ha)	3114	2404	2048	1776	207	474

Dam operations limit high discharge events, affecting natural island and bare sand bar formation and preventing scouring of vegetation from vegetated bars. Dam operations that sustain elevated flows for navigation prevent exposure of bare sand bars related to low-stage conditions that occurred prior to flow regulation (Macy, pers. comm., 2010).

<u>Amount and Areal Extent of Armored Streambeds</u>

Armored streambeds consist of a gravel armor layer (gravel that results from stream flow winnowing fine sediment) with the residual gravel covering the stream bed. Channels downstream of dams may have a gravel-armored stream bed caused by reservoir sediment-trapping resulting in excess transport capacity.

There is no anecdotal information or data that would provide the pre-dam gravel armoring condition. There may have been gravel armoring in the Missouri River caused by large wood accumulations that would block sediment transport and create excess transport capacity downstream (Macy, pers. comm., 2010).

Fort Randall Reach

Elliot and Jacobson (2006) found that bed material has coarsened in the first 16 km below the Fort Randall Dam. For the channel below Fort Randall Dam, Schumm (2005) states, “A very small amount of gravel in the alluvium had been concentrated on the bed during degradation.” Additionally, Schumm (2005) states, “Immediately below the dam the D_{90} increased from 0.35 mm to 10 mm,” but the time-period of this particle size distribution adjustment was not identified in the study. Biedenharn et al. (2001) reported a range of bed material from approximately 0.14 mm to 10 mm and a D_{50} of 0.90 mm.

Gavins Point Reach

Bed sediment size has changed from medium sand (0.2-0.6 mm) to fine and medium gravel (2-20 mm) in the first 4.8 km downstream of the Gavins Point Dam (Elliot and Jacobson 2006). These bed material changes are not evident at RM 795, which is 25.7 km downstream of the Gavins Point Dam (Elliot and Jacobson 2006).

Threats and Stressor Factors

Bank Stabilization

Bank stabilization is the process of placing material on streambanks to prevent channel bank erosion. There is no estimate for reference condition (pre-dam) bank stabilization on the 39- or 59-mile reaches, but there were likely local efforts to prevent erosion of private land through placement of auto bodies, rock, broken concrete, etc. on stream banks (Macy, pers. comm., 2010).

Bank stabilization using hard structures like rip-rap prevents bank erosion and channel migration. The existing level of bank stabilization limits the ability of the channel to adjust and attain dynamic equilibrium. Bank erosion and channel migration, although part of a naturally dynamic ecosystem, are currently subject to social and economic constraints; there is increased demand for bank stabilization for protection of infrastructure (bridges, roads, residential, and recreational property) and agricultural land (Macy, pers. comm., 2010).

Likewise, sediment transport and deposition are also affected by bank stabilization. Biedenharn et al. (2001) suggested that bank stabilization increases erosion of the stream bed, bars, islands, and unprotected banks. Bank stabilization may also reduce the supply of bed material and bar-sized material needed for sandbar creation. However, bank stabilization affects only sediment supply and does not directly affect sediment transport, since sediment transport is dependent on discharge, sediment caliber, and gradient (Schumm 1977).

Bank stabilization may also negatively affect sediment deposition. Stabilization reduces material supplied through bank erosion and creates a deficit that must be made up through increased levels of bed, bar, island, or unprotected bank erosion (Biedenharn et al. 2001). Bank stabilization requests continue to be received from landowners, and stabilization activities may continue to affect depositional features within the Missouri River channel (Macy, pers. comm., 2010).

Managers at MNRR believe that island and sandbar development are affected by bank stabilization activities. For the 59-mile reach, MNRR staff used GIS to designate the linear amount of bank stabilization through 2004. Left and right banks are located by looking downstream. MNRR estimates of bank stabilization included all hard materials on the bankline or windrowed above. Total linear left bank stabilization is approximately 40,339 meters (132,347 ft) or 40% of the total digitized left bank. Total linear right bank stabilization is approximately 35,008 meters (114,859 ft) or 33% of the total digitized right bank. Biedenharn et al. (2001) found that eroded bank contribution to bed and bar material ranges from 15%-45%.

Estimated bank stabilization for the Fort Randall reach is around 12.4% (ranging from 0-33% by GR), and 33-40% for the Gavins Point reach. Additional bank stabilization could potentially reduce the banks' estimated contribution to the river's stream bed and bar material. Biedenharn et al. (2001) identified that in the Fort Randall reach, 10-20% bank stabilization may have reduced bank contributions by 1-2%. In the Gavins Point reach, 30-40% bank stabilization may have reduced bank contributions from 7-10% (Biedenharn et al. 2001). This material has to be made up by scouring the bed, bars, and/or remaining unprotected banks in the reach. Tailwater elevation continues to decline below Fort Randall and Gavins Point Dams (USACE 2010).

Additionally, as bank stabilization causes additional bed degradation, the areal extent of bed armoring will increase. Bank stabilization material is typically of a size that is not readily eroded or transported. The particle size of the armored bed is not expected to substantially change, because the size of gravel present in the alluvium determines what remains after winnowing of fine materials. However, there are no substantial gravel contributions from tributaries immediately downstream of the dams (Macy, pers. comm., 2010).

Flow Regulation

Flow regulation can have substantial effects on island and sand bar formation, maintenance, and destruction. Higher peak discharges may create and maintain greater amounts of bare sand bars and vegetated islands (see Table 23). The Missouri River's historic hydrograph typically had two peak flow periods – one from early March to mid-April, and the second from early June to mid-July. The post-dam peak discharge typically occurs from mid-August to December and is more than an order of magnitude lower. The post-dam peak discharge cannot create, maintain, or destroy as much island or sand bar area and density as existed pre-dam.

High peak discharges were responsible for a disturbance regime that recruited large wood to the stream channel (Benda et al. 2003). Transported driftwood and large amounts of sediment can induce surface aggradation and form islands and sand bars (Gurnell and Petts 2006, Montgomery et al. 2003, Piegay 2003). Without this source of driftwood and sediment, flow regulation dramatically alters the natural sandbar and island formation regime. Because the processes that once formed sand bars and islands have been modified by flow regulation, the USACE currently uses mechanical methods for bare sand bar creation. While high peak discharge once scoured vegetation from existing sand bars, now it is common for USACE to remove vegetation through herbicide application or mechanical practices (Macy, pers. comm., 2010).

Lowered intensity, frequency, and duration of disturbance events are primarily responsible for the declining trend in island and sandbar formation. Island and sandbar formation and maintenance are expected to remain at lower levels than pre-dam conditions until the incised river evolutionary sequence reaches dynamic equilibrium; even then, sandbars and islands will likely be at reduced levels because of peak flows below pre-dam conditions (Macy, pers. comm., 2010).

Restoration of a more naturalized flow regime could promote island and bare sandbar creation (and destruction), but it would likely be necessary to augment the available sediment load downstream of existing dams through practices such as shallow water habitat construction in the floodplain, bank stabilization removal, reduced sand dredging, bypassing sediment around dams, or even dam removal (NRC 2010).

Flow regulation, as a departure from historic levels, is believed to affect sediment transport and deposition in the Missouri River. The pre-dam Missouri River channel was in dynamic equilibrium between discharge and sediment transport and deposition. The current channel is adjusting to the managed releases from dams, and reservoir storage of sediment in transport from upstream sources has led to bed degradation below the dams. Sediment transport and deposition rates are unlikely to equal historic conditions because of the interrupted sediment supply and managed releases different from a natural flow regime (Macy, pers. comm., 2010). A naturalized flow regime would restore or move towards historic rates of sediment transport and deposition. However, large sediment-free releases from dams would cause increased bed, bar, island, and bank erosion to meet the transport capacity of that release. Sediment augmentation could meet the transport capacity of large releases. The current operations of dams for the assigned purposes of flood control, hydropower, water supply, irrigation, navigation, recreation, water quality, and fish and wildlife are under study, but any changes to dam management are likely years away (Macy, pers. comm., 2010).

High releases from Gavins Point Dam occurred from 1995-1997 (approximately 50.000-70,000 cfs) to evacuate flood-reserve zones within the reservoirs. These high releases created bare sandbar area greater than what existed in 1941 pre-dam conditions (Elliot and Jacobson 2006). These releases transported and deposited sediment more like that of the natural sediment regime, although the peak discharge, duration, and seasonality of the high releases were different from what would occur in the natural flow regime.

USACE investigated initiating spring pulse events for the benefit of the endangered pallid sturgeon (*Scaphirhynchus albus*) population in the Missouri River (USACE 2006b). A spring pulse could also benefit sediment transport and deposition for sandbar accretion. The spring pulses would occur in March (maximum 35,000 cfs) and May (restricted to downstream flow limits at Omaha, Nebraska; Nebraska City, Nebraska; and Kansas City, Missouri:41,000 cfs, 47,000 cfs, and 71,000 cfs, respectively).

Flow regulation has also resulted in sediment being trapped in reservoirs, and clear water releases from dams are responsible for increased levels of channel degradation. The rate of channel incision below Fort Randall and Gavins Point Dams has diminished over time, but there was increased incision during and following the high flow period from 1995-1997 (USACE 2010). Tailwater elevation continues to decline below Fort Randall and Gavins Point Dams (USACE 2010) and will continue until dynamic equilibrium is reached between the current flow regime and available sediment supply.

Flow regulation and the reduction of peak flows have modified the spatial and temporal scale of bank erosion and channel migration in the Missouri River. Bank erosion and channel migration rates are low compared to historical conditions (Schumm 1977, Elliot and Jacobson 2006). Low frequency, high energy floods were responsible for an active disturbance regime that eroded large areas of the riparian zone (Gurnell and Petts 2006). The flood control mechanisms for the Missouri River dams' operations and flow regulation are expected to continue at their current levels. Bank erosion and channel migration rates are not expected to substantially change under the current flow regulation scenario. Historical rates of bank erosion and channel migration are not likely to return to the Missouri River and its valley under the current management strategy (Macy, pers. comm., 2010).

Finally, flow regulation is believed to impact the amount and areal extent of armored streambeds. Since degradation of stream channels below dams is a function of the sediment-free releases from dams, present day flow regulation and dam operation should have minimal effect on the areal extent and particle size of the armored streambed. If a more naturalized flow regime is instituted without sediment augmentation, there could be an increase in areal extent of armoring but little change in the particle size of the armored bed. If releases are high enough to breach the armor layer, there will be higher rates of incision below the dam and perhaps increased areal extent of armoring (Macy, pers. comm., 2010).

Reduction of Large Woody Debris

Historic levels of large woody debris in the Missouri River channel compared to what is currently present have not been documented. Moody et al. (2003) included an 1833 painting by Karl Bodmer showing the Missouri River channel laden with snags and large wood. It is believed that the historic channel contained thousands of snags.

The reduction of large wood in the Missouri River compared to historic conditions is the result of ―snagging" operations, riparian/floodplain clearing, and the lowered intensity, frequency, and duration of disturbance events. The reduction of large wood increased transport capacity (Montgomery et al. 2003) and may have contributed to early channel incision.

Large wood can initiate bar and island formation. The lack of large wood in the system today compared to historical conditions, results in fewer and slower-developing riparian woodland patches and islands (Gurnell and Petts 2006). With the reduction of large wood in the channel, the natural process of creating islands and sandbars has been modified and affects current channel dynamics.Reduction of large woody debris increases transport capacity, which increases sediment transport rates (Montgomery et al. 2003). Large wood can initiate deposition and island and bar formation, so the reduction in large wood can reduce deposition capacity within the stream channel.

In addition, woody debris can create significant hydraulic roughness, which influences flow velocity, discharge, and shear stress (Montgomery et al. 2006). Large wood in stream channels can also form organic dams that block sediment transport and store large amounts of sediment, causing local aggradation (Montgomery et al. 2003, Gurnell and Petts 2006). Removal of large-scale logjams caused channel incision of 1-5 m in the Red River in Louisiana (Veatch 1906, as cited by Montgomery et al. 2003).

Finally, woody debris influences channel width by either armoring the channel banks or by locally directing flow into the banks causing localized erosion and channel widening (Montgomery et al. 2003). A supply of large wood to the channel can dramatically influence lateral channel migration and may be responsible for avulsion into side channels and even chute formation (Montgomery et al. 2003). The role of large wood in the channel dynamics of the Missouri River has decreased since historic time, and its diminished influence in today's river is expected to continue because of the reduction in riparian forests, bank stabilization, and altered disturbance regime (Macy, pers. comm., 2010). Current removal of large wood from the channel is not believed to be substantial, and if it occurs at all it is likely to occur near boat ramps or in front of recreational property (Macy, pers. comm., 2010). The recruitment of large wood to the river will remain low because of the reduction in riparian forests and a reduction in the intensity, frequency and duration of disturbance events (Macy, pers. comm., 2010).

Data Needs/Gaps

There are few studies that document the pre-dam conditions in the MNRR reaches of the Missouri River; the USACE (2010) and Biedenharn et al. (2001) studies do not address pre-dam historical data (e.g., 1894 channel maps). Many of the data sets for the park are not current into the new millennium. The data used for USACE bank and bed analyses are only current through 1994-1995 (cross-sections) and 1997-1998 (aerial photographs). Biedenharn et al. (2001) bank and bed analyses are current through 1998 (cross-sections) and 1997-1998 (aerial photographs). The sediment budget (bank and bed erosion and deposition) is not current, although the tailwater stage trends were updated through 2009 (USACE 2010).

Overall Condition

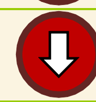
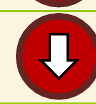
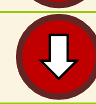
Measures	*Reference Condition*	*Condition*
Island and sandbar development and maintenance processes	Pre-dam	
Sediment transport and deposition	Pre-dam	
Bank erosion and channel meander	Pre-dam	
Channel elevation	Pre-dam	
Amount and areal extent of armoured streambed	Pre-dam	

Figure 10. Erosional and Depostional Processes condition graphic.

Pre-dam conditions supported a system in dynamic equilibrium. After the dams were installed, the Missouri River channel went through a period of rapid adjustment to the altered sediment and flow regimes. Today, the river is not responding as aggressively as it did from 1955 to 1985, but is still adjusting to the altered sediment and flow regimes (Appendix B). Until the incised river completes the evolutionary sequence of degradation, widening, and aggradation of a new floodplain within the incised widened channel, the bed and banks of the river will continue to adjust. This evolutionary sequence has been impacted by the altered sediment and flow regimes. The altered sediment regime may facilitate the evolutionary sequence, but the altered flow regime may retard attainment of the evolutionary sequence end point.

Island and Sandbar Development

The formation of islands and sandbars has been affected by the altered sediment and flow regimes and by the reduction of large woody debris in the channel (Elliot and Jacobson 2006, Biedenharn et al. 2001). The areal extent of bare sandbar exposure is affected by the ―navigation support" mandate for dam operation. Island and sandbar formation and maintenance have been reduced by the lowered intensity, frequency, and duration of disturbance events. As island and sandbar formation and maintenance are expected to remain at lower levels than pre-dam conditions until the incised river evolutionary sequence reaches dynamic equilibrium, this measure is of significant concern in MNRR and has a declining trend (Figure 10). Even if equilibrium is reached, it will likely be at reduced levels because of peak flows below pre-dam conditions.

Sediment Transport and Deposition
Sediment transport and deposition will only attain dynamic equilibrium once the evolutionary sequence is complete. However, sediment transport rates have changed as peak discharges in the post-dam era have been lower (lower stream power leads to reduced transport capacity). Sediment deposition rates have dropped primarily because of the altered sediment supply, reduction of large woody debris in the channel, and the lower peak discharges in the post-dam era (Biedenharn et al. 2001). It is because of these factors that sediment transport and deposition in MNRR are of high concern and have a declining trend at this time.

Channel Elevation
Channel elevation in MNRR is of high concern and has a declining trend. Rates of bed erosion in the Gavins Point reach were lower in 1980-2009 compared to 1955-1980. Similarly, the Fort Randall reach experienced lower bed erosion rates from 1985-2009 compared to 1955-1985 (Appendix B). Bed erosion rates increased slightly following the 1995-1997 high flow period. Bed degradation will continue especially in the dam tailwater areas as dams continue to release sediment-free water. Until dynamic equilibrium is attained, bed degradation is likely to continue (bank stabilization further complicates this issue).

Aggradation has occurred in the delta area of Lewis and Clark Lake: 2.74 m at the Niobrara River mouth, and 1.21 m at the mouth of Ponca Creek (USACE 1998). Aggradation in this region will continue because the sediment supply exceeds the sediment transport capacity (Macy, pers. comm., 2010). An aggradation zone continues to move up-channel as sediment is deposited in the delta area, and aggradation will continue until the reservoir fills.

Bank Erosion and Migration
Compared to pre-dam erosion rates, bank erosion in MNRR is of high concern with a declining trend. Rates of bank erosion were higher in the pre-dam era (Table 22). For the Fort Randall reach, the ranges of post-dam bank erosion rates were 70% less (USACE 2010a), 83% less (Elliot and Jacobson 2006) and 74% less (USACE 2006a) than pre-dam rates. For the Gavins Point reach, the ranges of post-dam bank erosion rates were 22% less (USACE 2010a), 38% less (Elliot and Jacobson 2006) and 35% less (USACE 2006a) than pre-dam rates.

MNRR channel migration also has a declining trend and is of high concern. The construction of the dams on the Missouri River has dramatically affected the stream's ability to meander. Post-dam channel migration is substantially less than pre-dam conditions (see 1941 and 1999 bank lines in Figure 9). Bank erosion and channel migration have been reduced because of bank stabilization and the lowered intensity, frequency, and duration of disturbance events associated with the flood control mandate for construction and operation of the Missouri River dams (Macy, pers. comm., 2010). Bank erosion is likely to continue at current rates because of sediment-free dam releases. Channel migration is also likely to be insubstantial because of societal constraints (i.e., landowners and farmers not wanting their land to erode) (Macy, pers. comm., 2010).

Amount and Areal Extent of Armoured Streambeds
The amount and areal extent of armored streambeds are of high concern in MNRR. These are not expected to substantially change under the current dam management regime, however, changes may occur to the areal extent of armored streambed with increased bank stabilization or breaching of the armor layer.

Sources of Expertise
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4.3 Flow Regime

Description

Flow regime is a major driver of the ecological characteristics in MNRR. When the Missouri River dams became operational in the mid-twentieth century, flow regimes changed drastically, altering the natural resources in present-day MNRR. Five federally protected species in MNRR (piping plover (*Charadrius melodus*), least tern (*Sternula antillarum*), pallid sturgeon (*Scaphirhynchus albus*), scaleshell mussel (*Leptodea leptodon*), and Higgins eye pearly mussel (*Lampsilis higginsii*)) have specific habitat requirements that relate directly to the flow regime of the Missouri River. In addition, the change in Missouri River flow regime following dam closure has compromised available habitat for other natural resources in the park: cottonwood (*Populus deltoides*) forests, native fishes, breeding birds, and northern leopard frogs (*Rana pipiens*). Several characteristics define MNRR's flow regime:

- Magnitude: the amount of stream flow moving through a geographic location at a particular time - usually measured as a volume per unit of time, for example, cubic feet per second (cfs).
- Timing: the occurrence of flows of a given magnitude within the annual hydrologic cycle.
- Frequency: the probability that flows of a certain amount will occur.
- Duration: the period of time associated with a specific flow condition.
- Rate of change: how quickly flows change from one magnitude to another.

Measures

- Frequency of flood pulses (magnitude and rate of change).
- Frequency, timing, and duration of discharge.

Reference Conditions

Magnitude

Figure 11 and Figure 12 display annual peak flow for the Missouri River at Yankton, SD, and Fort Randall Dam. Table 25 displays pre-dam peak flow values for selected years at Yankton. The Yankton historic pre-dam (1931-1953) average annual peak flow magnitude is 149,374 cfs, ranging from 46,500 cfs (1931) to 480,000 cfs (1952) (Figure 11). The Fort Randall historic pre-dam (1948-1953) average annual peak flow magnitude is 204,000 cfs, ranging from 103,000 cfs (1948) to 447,000 (1952) (Figure 12). The short period of record for the Fort Randall peak flow data likely skews results higher compared to the Yankton data, and the Yankton value is probably a more realistic long-term average estimate for both of the MNRR reaches.

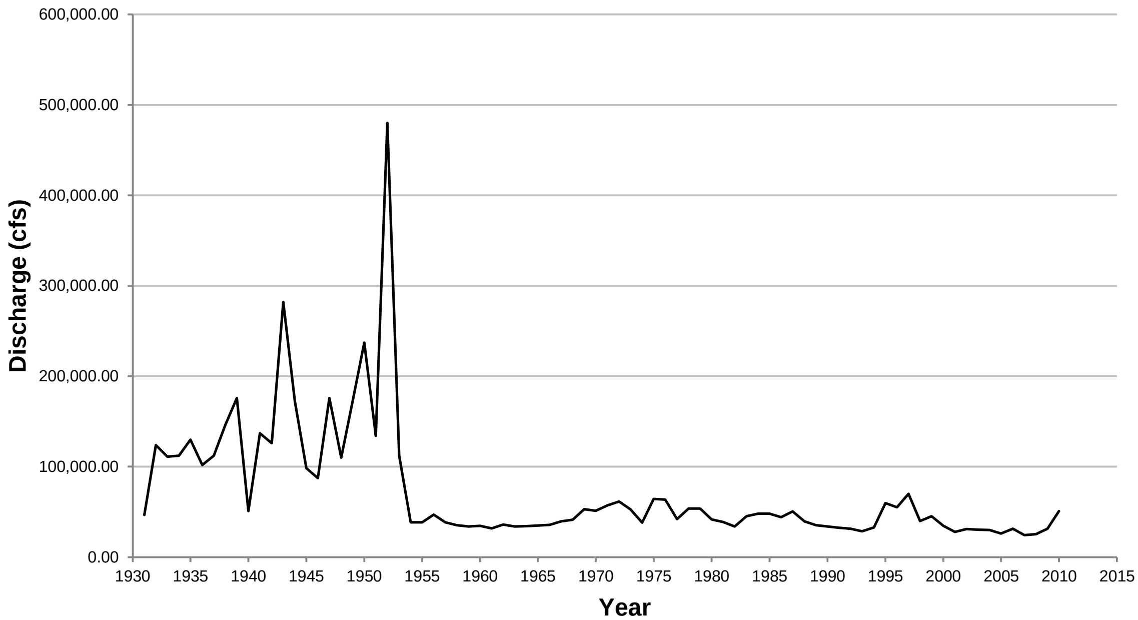


Figure 11. Annual peak flow for the Missouri River at Yankton 1931-2008 (1931-1995 USGS gage station data; 1996-2008 releases from Gavins Point Dam).

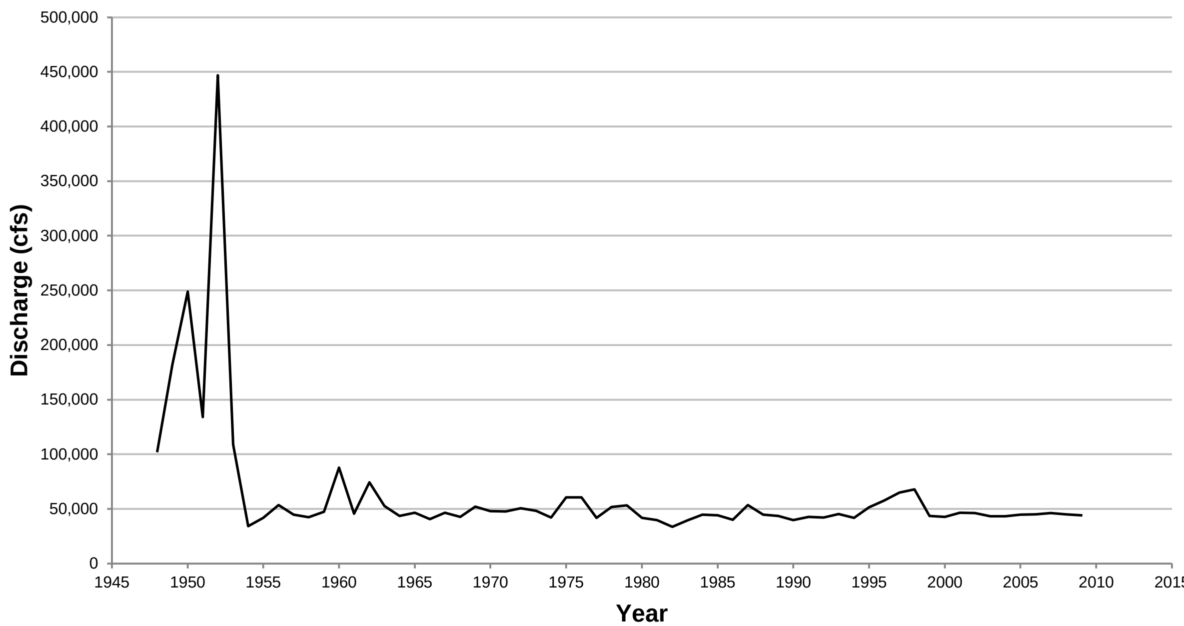


Figure 12. Annual peak flow for the Missouri River at Fort Randall 1948-2009 (1948-1986 from USGS website: 1987-2009 from Ft. Randall hourly releases USACE).

Table 25. Peak discharge (cubic feet per second) at Yankton, SD, for selected years (data compiled by John Macy, MNRR Hydrologist).

Year	1932	1935	1940	1945	1950	1953
Peak Discharge (cfs)	124,000	130,000	50,800	98,300	237,000	112,000

Timing

Figure 13 through Figure 18 display the daily mean discharge for selected years prior to dam closure at Yankton, SD. Historic (pre-dam) flood pulses occurred at various times during the year with base flows beginning in late summer or early fall and continuing through late winter – early spring (Figure 13 through Figure 18). The historic peak discharge on the Missouri River in the MNRR was typically bi-modal, with peaks occurring between April and July (Figure 19). Figure 19 (Jacobson and Galat 2008) shows the duration hydrograph at Sioux City, IA, for pre and post-dam 25–75% flow.

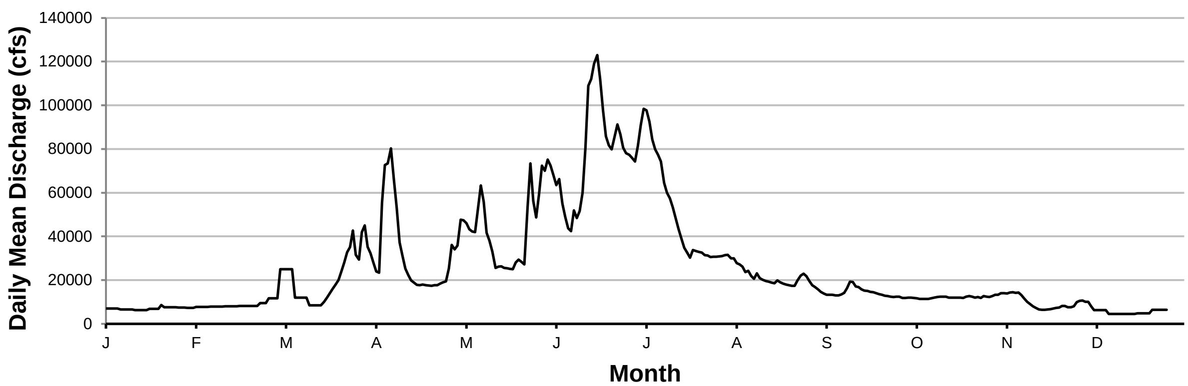


Figure 13. 1932 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

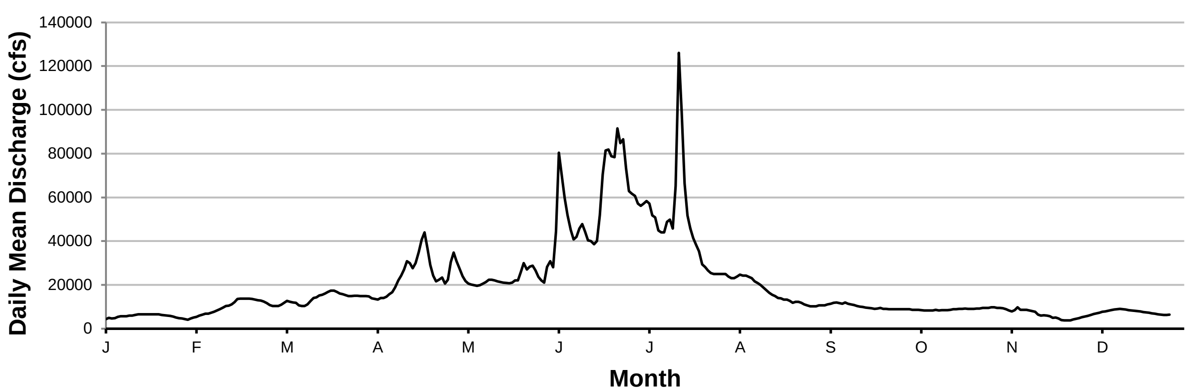


Figure 14. 1935 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

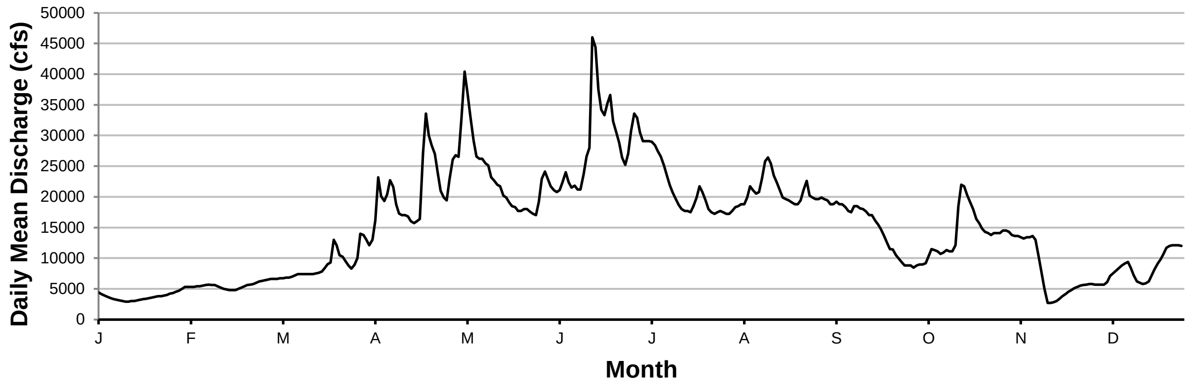


Figure 15. 1940 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

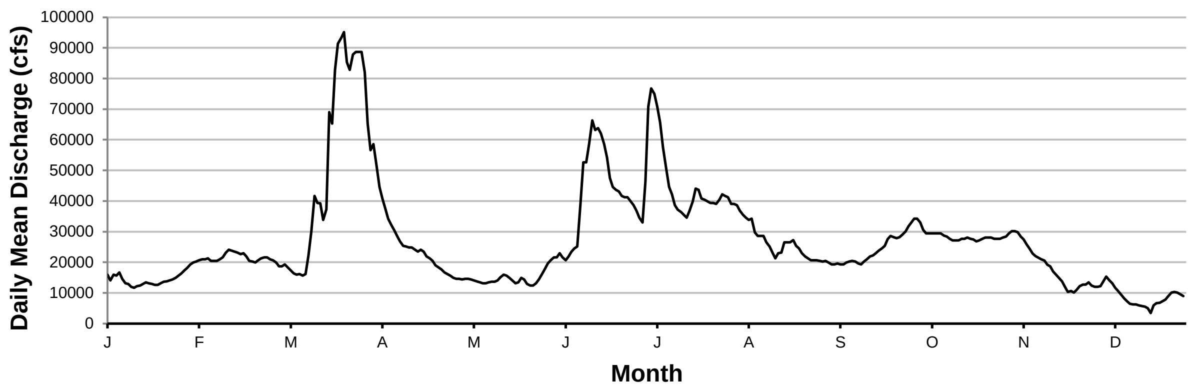


Figure 16. 1945 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

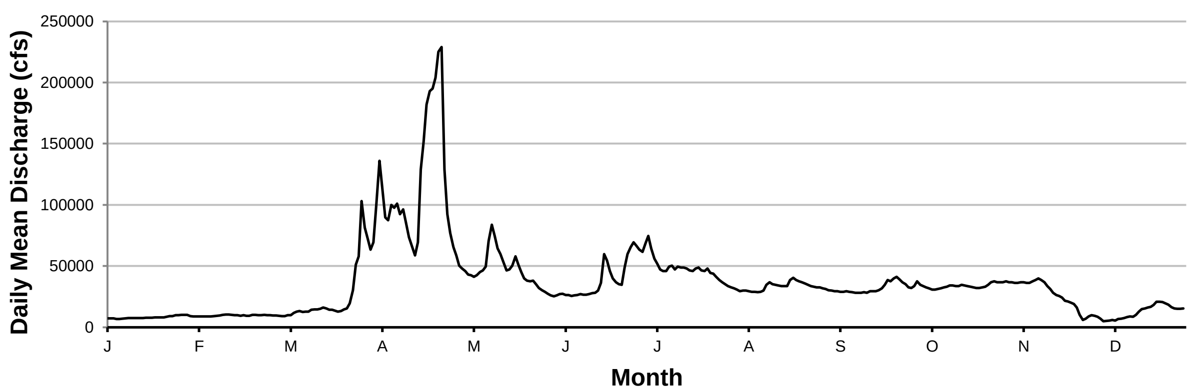


Figure 17. 1950 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

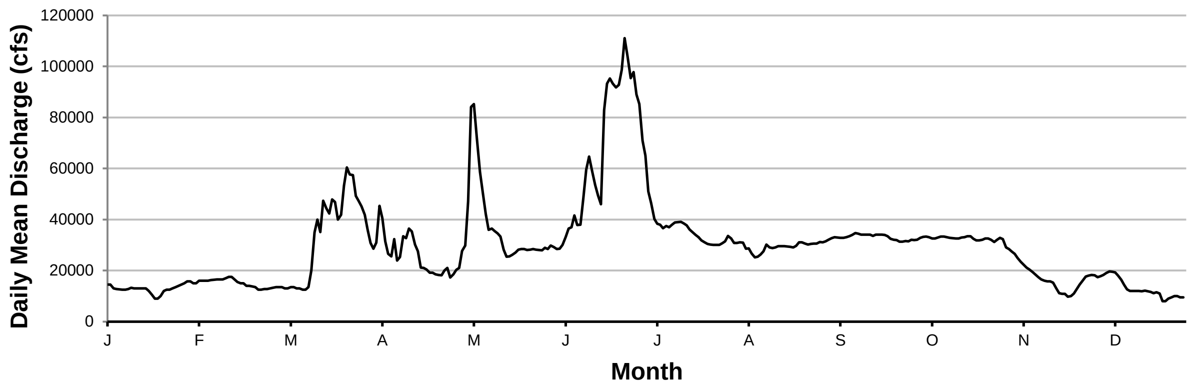


Figure 18. 1953 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist)

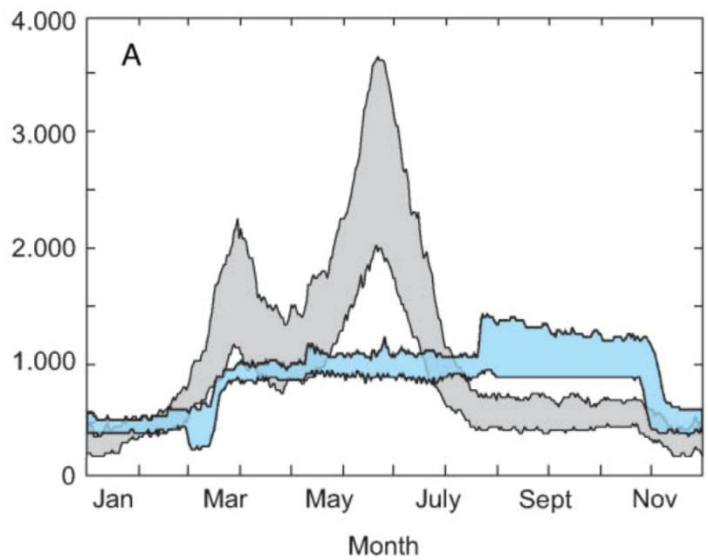


Figure 19. Annual hydrograph, pre-dam (gray) and post-dam (blue), at Sioux City, Iowa, with discharge in thousand cubic meters per second (from Jacobson and Galat 2008).

<u>Frequency</u>

Frequency is the probability that a particular flow magnitude will occur. The exceedance probability of certain discharge values is calculated by the formula: P = 100(m/ (n+1)),where P = exceedance probability; m = the rank of a value (ranking from highest to lowest of all daily mean flows for the period of record; and n = total number of records (Oosterbaan 1994). The exceedance probability is the probability of an equal or greater discharge occurring in any given year. Table 26 displays the pre-dam exceedance probability for various discharge levels for the period of record at Yankton, SD (1931-1953).

Table 26. Exceedance probability for pre-dam selected discharges on the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

Discharge (cfs)	10,000	20,000	30,000	40,000	50,000	60,000	70,000	80,000
Exceedance Probability	0.79	0.51	0.29	0.16	0.10	0.07	0.05	0.04

Duration and Rate of Change

The duration and rate of change for flood pulses in the pre-dam era occurred over relatively short time frames (Figure 13 to Figure 18). Rate of change refers to how quickly flows change from one magnitude to another. Table 27 displays the rate of change for discharge from relatively steady state conditions to peak flow discharge and return to initial discharge (or to discharge at the beginning of another climb to peak) for selected years at Yankton, SD (USGS gage station data). Table 3 also displays the increase in discharge from the steady state condition to the peak discharge. The years displayed in Table 27 are from USGS gage data at Yankton, SD, and they should be representative of pre-dam conditions.

Table 27. Yankton, SD, selected year peak flow rise and fall dates, time to peak, number of days in rise and fall cycle, and increase in discharge to peak (data compiled by John Macy, MNRR Hydrologist).

Year	Peak	Rise & Fall Dates* (month/day)	Time to Peak (days)	Days of Rise and Fall (return to approx. initial discharge or begin new rise)	Increase in Discharge (from initial discharge to peak discharge)
1932	1st	4/4-4/14	5	11	56,900 cfs
	2nd	6/9-7/16	10	38	80,700 cfs
	2nd (intermediate peaks)	6/23-6/25	3	9	11,400 cfs
		7/1-7/16	4	16	24,100 cfs
1935	1st	5/31-6/10	6	11	59,400 cfs
	2nd	6/18-7/10	8	23	46,400 cfs
	3rd	7/11-7/21	6	11	82,000 cfs
1940	1st	4/6-4/27	5	12	14,300 cfs
	2nd	4/28-5/13	6	16	17,500 cfs
	3rd	6/11-6/26	5	16	24,800 cfs
1945	1st	3/9-4/16	14	39	79,000 cfs
	2nd	6/5-7/1	12	27	43,100 cfs
	3rd	7/1-7/16	4	16	43,800 cfs
1950	1st	3/21-3/31	8	11	89,700 cfs
	2nd	3/31-4/14	4	15	72,500 cfs
	3rd	4/15-4/29	10	15	170,020 cfs
1953	1st	3/10-4/1	14	23	46,900 cfs
	2nd	4/27-5/16	9	20	68,000 cfs
	3rd	6/10-7/6	16	27	73,000 cfs

*the dates used are from beginning of rise from relative steady state to a return to that steady state (nearly the same discharge) or to the beginning of the next rise toward peak

Table 28 displays the low flow periods for selected years at Yankton, SD, including dates, beginning and ending mean daily discharge, average discharge and number of days of the low flow period. The values were derived from USGS discharge records used to construct yearly hydrographs indicating when discharge was nearly flat on the graphed data. Values derived from the annual hydrograph might vary slightly depending on individual interpretation and should be considered an approximation of the low flow period.

Table 28. Low flow periods, discharge and number of days at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

Year	Date	Discharge (cfs)	Discharge (avg. cfs)	# of days	Year	Date	Discharge(cfs)	Discharge (avg. cfs)	# of days
1931	9/2	10100	8800	193	1942	12/1	13700	7681	88
1932	3/12	8500			1943	2/24	10200		
1932	9/5	13200	13200	189	1943	12/17	11500	13751	86
1933	3/12	10500			1944	3/11	11500		
1933	9/26	14000	10598	153	1944	12/4	12400	16644	96
1934	2/28	4500			1945	3/9	16200		
1934	7/31	11300	8862	247	1945	11/21	12000	9617	87
1935	4/1	14700			1946	2/15	8900		
1935	8/19	14000	8217	198	1946	11/28	11000	10673	103
1936	3/3	8600			1947	3/10	16200		
1936	8/8	12300	8827	210	1947	11/24	14600	12467	108
1937	3/5	8500			1948	3/10	14600		
1937	8/12	15000	8443	217	1948	12/10	10000	11201	80
1938	3/16	12800			1949	2/27	14500		
1938	10/23	13600	12099	144	1949	11/20	17200	10373	122
1939	3/15	13500			1950	3/20	14200		
1939	8/15	14000	8912	213	1950	11/26	16000	14437	116
1940	3/14	7500			1951	3/21	15000		
1940	10/24	14800	8466	159	1952	11/27	12000	12179	100
1941	3/31	13000			1953	3/6	13000		
					1953	11/18	13000	11997	78
					1954	2/3	10600		

Data and Methods

Analysis used USGS discharge records for Fort Randall Dam and the gage station at Yankton, SD, and USACE release data for Fort Randall and Gavins Point dams. The analysis compares flow regime conditions for the pre- and post-dam timeframes.

The analysis of discharge/release data includes maximum flow; timing of flow; days of rise to peak; days of rise to peak and fall to steady state condition or the beginning of a new rise; peak discharge; change in discharge from relatively steady state condition to peak flow; low flow period; low flow average discharge; and exceedance probability for selected discharges.

The low flow period was generally the ―flat-lining" of the annual hydrograph and did not include the rise-to-peak or peak-to-fall time periods. Some interpretation of the data is needed because of the highly variable flow conditions and multiple rises within the hydrographs or data.

Peer-reviewed literature was also integrated into analysis.

Current Condition and Trend

Magnitude

Figure 11 and Figure 12 display the peak flows for both pre and post-dam timeframes. Figures 18 through 25 display the hydrographs of mean daily discharge for selected years at Yankton, SD following dam closure. The magnitude of peak flow is substantially reduced in the post-dam era. Table 29 displays peak flow magnitude for selected years for the post-dam timeframe.

Table 29. Peak flow for selected years for the post-dam timeframe (1954-2010) at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

Year	1954	1965	1975	1986	1995	2005	2010
Peak Discharge (cfs)	38,600	35,000	64,300	50,500	59,600	26,000	50,900

Timing

Post-dam hydrographs (Figure 20 through Figure 27) illustrate the timing of releases from Gavins Point Dam, with higher flows occurring in the late summer and fall and the length of time of these higher flows. Figure 19 contrasts pre- and post-dam flow magnitude and timing for the Missouri River at Sioux City, Iowa.

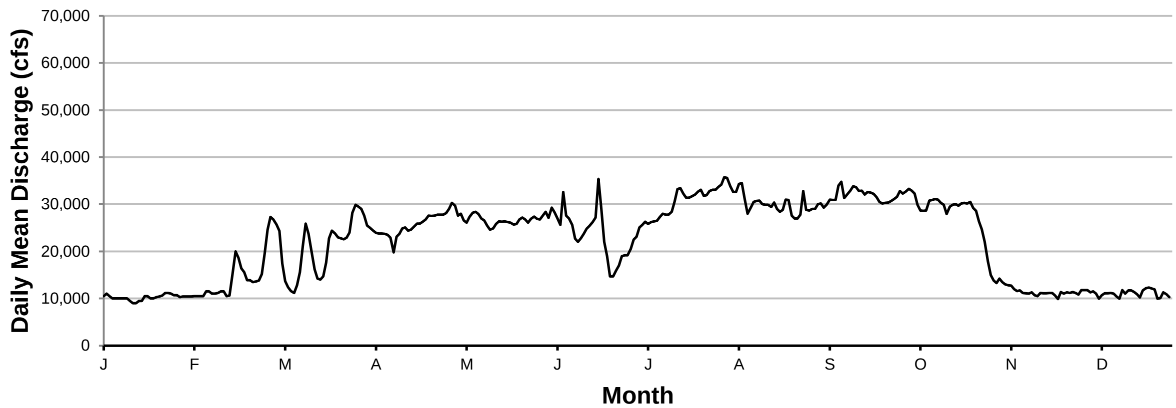


Figure 20. 1954 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

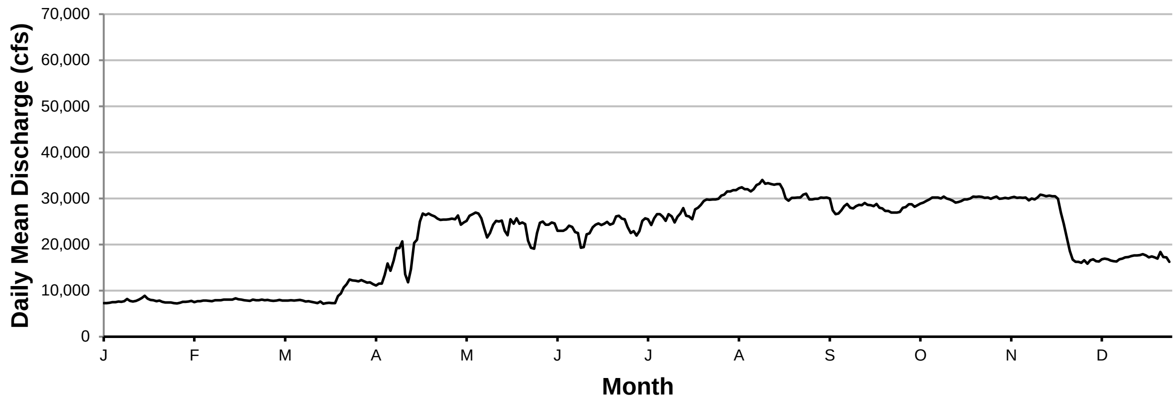


Figure 21. 1965 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

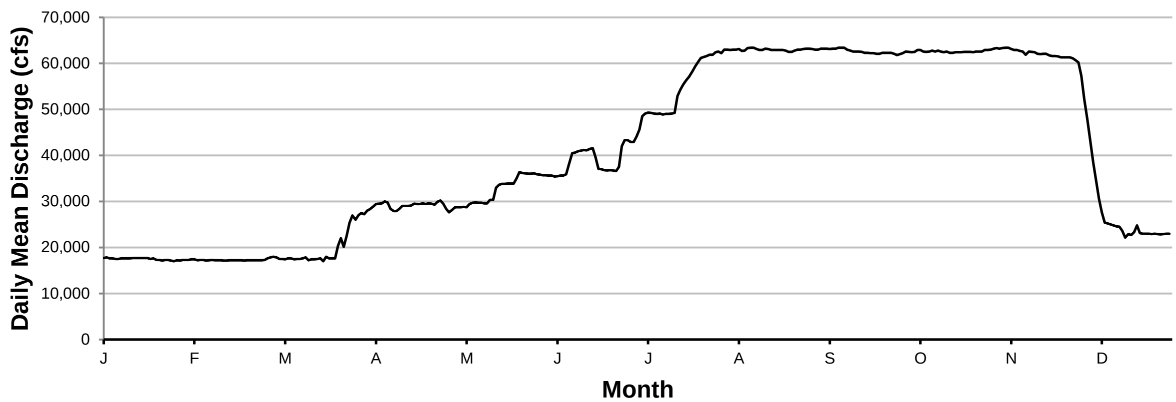


Figure 22. 1975 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

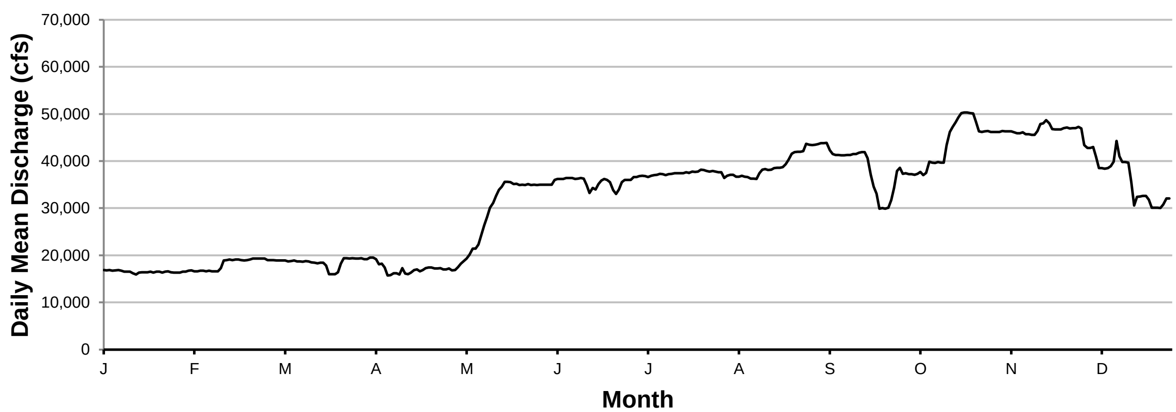


Figure 23. 1986 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

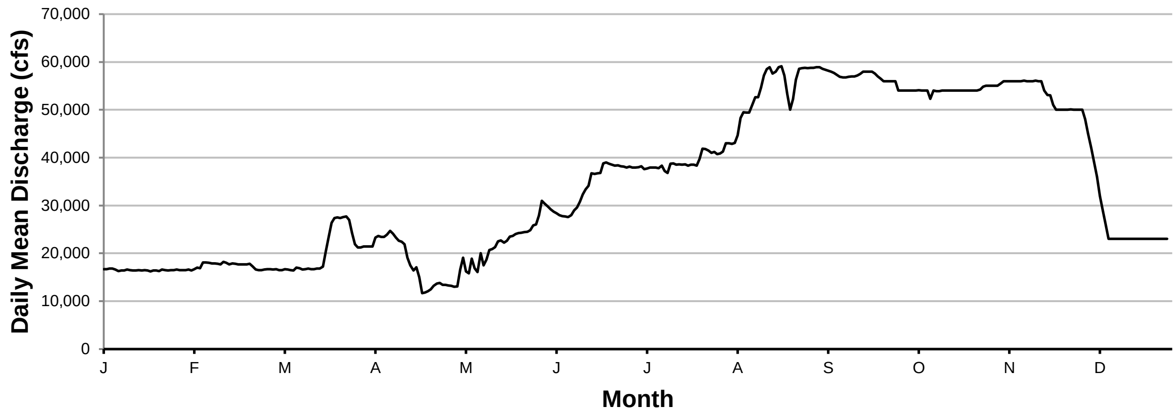


Figure 24. 1995 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

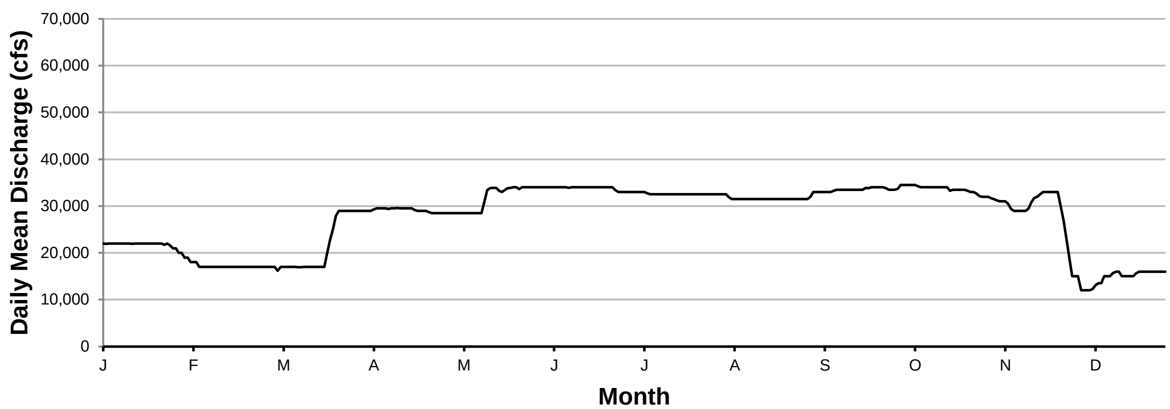


Figure 25. 2000 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

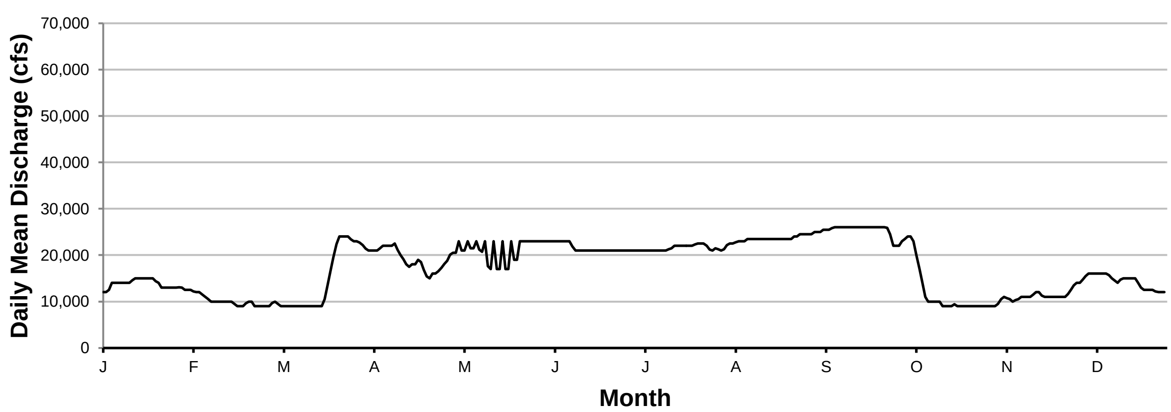


Figure 26. 2005 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

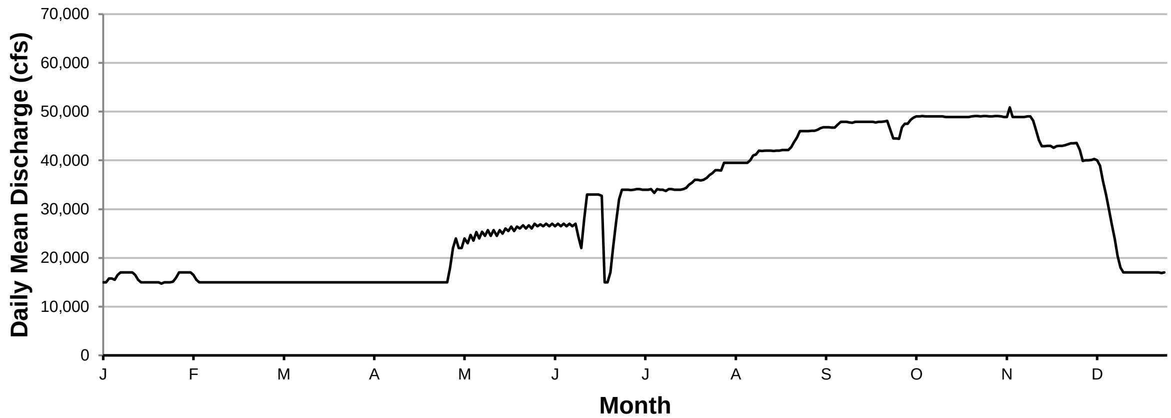


Figure 27. 2010 daily mean discharge for the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

Frequency

Table 30 displays the exceedance probability (the probability of an equal or greater discharge occurring in any given year) for Yankton, SD, in the post-dam timeframe (1954-2010). Although the exceedance probability analysis indicates low to no probability of discharges above 70,000 cfs (70,100 cfs is the highest discharge in the post-dam era), if runoff and storage capacity of the reservoirs in the Missouri River system experienced greater in-flows than in the past, there may be larger discharges released from Gavins Point Dam.

Table 30. Exceedance probability for post-dam selected discharges on the Missouri River at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

Discharge (cfs)	**10,000**	**20,000**	**30,000**	**40,000**	**50,000**	**60,000**	**70,000**	**80,000**
Exceedance Probability	0.91	0.66	0.24	0.10	0.04	0.01	0.0002	0.0

Duration and Rate of Change

Table 31 displays post-dam selected year peak flow rise and fall dates, time to peak, number of days in the rise and fall cycle, and the increase in discharge magnitude from beginning of rise to the peak flow.

Table 32 displays post-dam low flow periods for selected years at Yankton, SD, including dates, beginning and ending mean daily discharge, average discharge, and number of days of the low flow period. The values were derived from USGS discharge records used to construct yearly hydrographs indicating when discharge was nearly flat on the graphed data. Values derived from the annual hydrograph might vary slightly depending on individual interpretation and should be considered an approximation of the low flow period.

Table 31. Missouri River at Yankton, SD: selected year peak flow rise and fall dates, time to peak, number of days in rise and fall cycle, and increase in discharge to peak (data compiled by John Macy, MNRR Hydrologist).

Year	Peak	Rise and Fall Dates* (month/day)	Time to Peak (days)	Days of Rise and Fall (return to approx. initial discharge or begin new rise)	Increase in Discharge (from initial discharge to peak discharge)
1955	1st 2nd	3/8-3/20 3/25-11/6	5 153	13 226	16,000 cfs 25,900 cfs
1960	1st 2nd	3/27-4/13 4/17-11/11	3 129	18 218	24,500 cfs 21,200 cfs
1965	1st 2nd	3/24-4/15 4/15-12/1	21 122	23 232	10,000 cfs 19,000 cfs
1970		3/8-12/12	161	280	28,500 cfs
1975		3/21-12/16	187*	271	45,800 cfs
1980		3/17-12/18	242	278	23,500 cfs
1985	1st 2nd	3/28-4/23 4/27-12/8	25 217	27 224	10,500 cfs 19,900 cfs
1990		3/23-10/31	178	223	23,960 cfs
1995	1st 2nd	3/16-3/29 5/2-9/29	10 112	14 192	10,900 cfs 46,500 cfs
1997		1/1-12/15	319	348	48,900 cfs
2000		3/15-12/2	171	263	17,000 cfs
2005		3/17-10/6	169	214	17,000 cfs
2010		4/29-12/17	194	233	35,900 cfs

*Some years have the same peak discharge multiple times – typically used the middle date in calculation.

Table 32. Low flow periods, discharge and number of days at Yankton, SD (data compiled by John Macy, MNRR Hydrologist).

Year	Date	Discharge (cfs)	Discharge (avg. cfs)	#days	Year	Date	Discharge (cfs)	Discharge (avg. cfs)	#days
1954 1955	10/31 3/8	15000 9000	10268	129	1984 1985	12/20 3/26	21600 19800	20650	97
1955 1956	11/6 3/4	12100 9820	9324	120	1985 1986	12/8 5/1	17400 16900	17537	145
1959 1960	11/8 3/25	9400 8560	9080	138	1989 1990	11/4 3/23	10500 9440	11753	140
1960 1961	11/20 3/20	9850 9520	8607	121	1990 1991	10/31 3/23	9320 7080	10964	144
1964 1965	11/29 3/17	8650 7110	8164	113	1994 1995	11/28 5/2	17100 13100	16938	107
1965 1966	11/28 3/1	16700 14700	16599	94	1995 1996	12/11 2/5	23000 20000	21509	58
1969 1970	12/8 3/5	18200 16800	16498	88	1999 2000	12/10 3/17	22900 17000	19535	99
1970 1971	12/9 3/14	17500 17700	16785	96	2000 2001	11/29 3/14	15000 12600	13845	106
1974 1975	11/28 3/18	18100 14000	17452	111	2004 2005	10/11 3/17	12000 9000	11111	158
1975 1976	12/15 1/15	23600 20000	21621	32	2005 2006	10/10 2/3	11000 11000	11663	117
1979 1980	12/19 3/14	22000 15000	17845	87	2008 2009	12/29 3/11	12000 9100	11460	73
1980 1981	12/1 3/13	17800 14800	15119	103	2009 2010	12/25 4/29	15000 15000	15288	126

Threats and Stressors

Dam Operations

Reduced magnitude – Limited peak flows: Post-dam releases for the reach below Fort Randall and Gavins Point Dams are generally substantially lower than pre-dam peak flow values (Figure 11, Figure 12). The average annual maximum discharge for the pre-dam timeframe is 149,347 cfs and for the post-dam timeframe it is 41,105 cfs. Table 33 displays the peak flow values for the reach below Gavins Point Dam at Yankton, SD, and releases from the dam.

Table 33. Peak flow values for Yankton, SD (includes releases from Gavins Point Dam).

Date	Discharge (cfs)	Date	Discharge (cfs)	Date	Discharge(cfs)
6/15/1931	46500	10/7/1957	35300	10/25/1984	48000
6/18/1932	124000	8/28/1959	33900	8/26/1986	44100
5/29/1933	111000	3/29/1960	34700	10/21/1986	50500
3/3/1934	112000	7/6/1961	31800	8/31/1988	39700
7/16/1935	130000	7/4/1962	35900	11/2/1988	35400
6/22/1936	102000	7/25/1963	33800	9/18/1990	33800
3/24/1937	112000	8/6/1964	34400	9/3/1991	32400
4/1/1938	146000	8/14/1965	35000	10/1/1991	31300
4/1/1939	176000	7/21/1966	35800	10/9/1992	28500
6/15/1940	50800	8/23/1967	39600	9/4/1994	32800
6/14/1941	137000	7/16/1968	41200	8/21/1995	59600
5/15/1942	126000	8/30/1969	53100	11/1/1996	55000
4/8/1943	282000	10/1/1969	51200	10/1/1997	70100
4/9/1944	172700	6/17/1971	57200	11/1/1998	40100
3/22/1945	98300	8/17/1972	61400	8/1/1999	45200
6/22/1946	87300	10/1/1972	52600	9/1/2000	34500
4/3/1947	176000	7/24/1974	38000	9/1/2001	28000
3/26/1948	110000	9/11/1975	64300	8/1/2002	31000
4/7/1949	173000	11/5/1975	63700	9/1/2003	30500
4/24/1950	237000	12/2/1976	42000	5/1/2004	30000
4/7/1951	134000	8/8/1978	53900	9/1/2005	26000
4/13/1952	480000	10/12/1978	53700	8/1/2006	31500
6/25/1953	112000	11/30/1979	41600	7/1/2007	24500
6/7/1954	38600	11/12/1980	38700	8/1/2008	25500
8/25/1955	38500	9/28/1982	33800	9/27/2009	31500
8/24/1956	47000	12/1/1982	45100	11/8/2010	50900
10/2/1956	38600	7/28/1984	48200		

Increased low flows: Table 28 and Table 32 display the low flow period, average discharge values and length of time with low flows for pre and post-dam flows at Yankton, SD, respectively. The pre-dam 1932-1954 timeframe had a low flow discharge average of 10,472 cfs over an average 154-day period. The post-dam period of 1955-2010 had a low flow discharge average of 14,567 cfs over an average 108-day period. Pre-dam low flows ranged from approximately 8,217-16,644 cfs, and in the post-dam period the range was approximately 8,607-21,621 cfs. Galat and Lipkin (2000) identified the percent increase in median monthly discharges as: 62% in August; 88% in September; 157% in October; 143% in November; 128% in January; and 97% in February.

Galat and Lipkin (2000) analyzed 1929-1948 discharge records as the pre-dam (―pre-flow regulation") period. It is possible that low flow discharge in MNRR reaches prior to 1955 may have been influenced by upstream dam operations and construction; The Fort Peck Dam closed on June 24, 1937, followed by Fort Randall Dam closure on July 20, 1952, and the Garrison

Dam closure on April 15, 1953. Additional dam closures include the Gavins Point Dam on July 31, 1955, the Oahe Dam on August 3 1958, and the Big Bend Dam on July 24, 1963.

Altered Temporal Flow Conditions – Seasonality

Peak Flow: Figure 19 gives the best visual representation of the changed seasonal flow patterns, but individual yearly hydrographs (Figure 13 through Figure 18; Figure 20 through Figure 27) also portray the shift that dam operations cause to flow patterns. The peak flows in pre-dam conditions were bi-modal or had numerous peaks and generally occurred between March and July; Galat and Lipkin (2000) describe mean monthly discharge peaks occurring in April and June for the Yankton gage station. The peak discharge period in the post-dam era generally begins its rise between March and April (Table 31) but often persists into October through December with most peaks in July-December (Table 33).

Low Flow: As with peak flows, Figure 13 through Figure 18 and Figure 20 through Figure 27 display the pre-and post-dam hydrographs and the shift that has occurred with dam operations, respectively. Pre-dam conditions had longer low flow periods that usually began towards the end of summer (Table 28); Galat and Lipkin (2000) identify “an extended period of low flow from August through February.” Post-dam low flows typically start in late fall (Table 32).

Altered Temporal Flow Conditions – Duration

Peak Flow: For the pre-dam condition, the time-to-peak and days of rise and fall are of short duration, ranging from 3-16 days and 9-39 days, respectively (Table 27). For the post-dam era, the time-to-peak and days of rise and fall have greater duration, ranging from 3-319 days and 13-348 days, respectively (Table 31). The average pre-dam rise-to-peak is about eight days while the post-dam rise-to-peak averages about 135 days. The average pre-dam rise and fall is about 19 days while the average post-dam rise and fall is about 183 days.

Low Flow: The pre-dam low flow period averages about 142 days while the post-dam low flow period averages about 108 days. The low flow period prior to dam construction was about 32% longer.

Altered Temporal Flow Conditions – “Power Peaking”

Releases from Fort Randall Dam are sometimes minimized to provide power-generating capacity when needed on a daily basis, meaning there are low releases during the day and higher releases during evening hours. Daily minimum releases may be small (and anecdotally, reduced to zero release).

Change in Climatic Pattern

Changes in the climatic pattern of precipitation amounts, temperature, wind speed, and direction are all factors that can influence the flow regime of the Missouri River. Operation of the dams on the Missouri River will respond to these conditions to maximize the benefits of the authorized purposes (flood control, navigation, hydropower, irrigation, fish and wildlife, recreation, water quality, and water supply). During periods with greater precipitation than normal, higher releases from dams will accommodate this condition. During drought periods, dams will have lower releases to meet the authorized purposes.

Data Needs/Gaps

Minimum daily releases at Fort Randall Dam are not currently used in the flow regime analysis because the data are not readily available, but have been requested from USACE. Minimum daily releases at Fort Randall Dam need to be compared to pre-dam mean daily discharge to document stream flow in the reach downstream of the dam.

Overall Condition

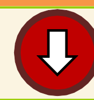
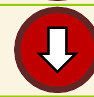
Measures	*Reference Condition*	*Condition*
Frequency of flood pulses (hydrograph)	Pre-dam	
Frequency, timing, and duration of discharge	Pre-dam	

Figure 28. Flow Regime condition graphic.

The flow regime for the Missouri River reaches managed by the NPS has been substantially modified by dam operations, compared to a ―natural” or pre-dam condition. Because of the many changes to flow regime and the continuing influence of dams, the condition of this component is of significant concern with a declining trend (Figure 28).

Flow regime is a major driver of the ecological characteristics in MNRR. When the Missouri River dams became operational in the mid-twentieth century, flow regimes changed drastically, altering the natural resources in present-day MNRR. Five federally protected species in MNRR, the piping plover (*Charadrius melodus*), least tern (*Sternula antillarum*), pallid sturgeon (*Scaphirhynchus albus*), scaleshell mussel (*Leptodea leptodon*), and Higgins eye pearly mussel (*Lampsilis higginsii*) have specific habitat requirements that relate directly to the flow regime of the Missouri River (USFWS 2009, USFWS 2004, Hesse and Schmulback 1991). In addition, the change in Missouri River flow regime following dam closure has compromised available habitat for other natural resources in the park: cottonwood (*Populus deltoides*) forests, native fishes, breeding birds, and northern leopard frogs (*Rana papiens*) (Johnson et al. 1976, Miller et al. 1995, USFWS 2000, NRC 2002, Smith and Keinath 2004).

Peak Flows

- Post-dam average peak flow is about 27% of the pre-dam average.
- The highest post-dam peak flow is about 15% of the highest pre-dam peak flow.
- For the post-dam era, 17 out of 57 years (30%) had a peak flow that exceeded the lowest pre-dam peak flow.
- Pre-dam peak flows were typically bi-modal, occurred from March to July, and were of short duration; post-dam peak flows typically are plateau-like, occur from July to December and occur over longer time periods
- Duration of post-dam peak flows is longer than pre-dam conditions.

Low Flows

- Average post-dam low flows are about 34% higher than average pre-dam low flows.

- The duration of the post-dam low flow period averages 24% less than the pre-dam low flow period.
- Post dam low flows typically occur from late October through March, while pre-dam low flows began in late summer to early fall, lasting until the spring rise. However, there appears to be a shift in pre-dam conditions towards later fall once the Fort Peck Dam had storage available for regulating flow in 1940.

Galat and Lipkin (2000) found that the Missouri River reach below the Gavins Point Dam has an extreme degree of hydrologic alteration compared to pre-dam conditions, based on 32 hydrologic variables. Galat and Lipkin (2000) state that low-flow pulse duration (pulses relative to a low discharge threshold that was set at the 25th-percentile daily discharge for the month with the lowest pre-regulation monthly median discharge.) increased by over 75% below Gavins Point Dam and that annual peak daily discharge is occuring much later in the post-dam era.

Sources of Expertise

John Macy, MNRR Hydrologist analyzed the stream flow records.

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4.4 Aquatic and Terrestrial Habitats

Description

Prior to the 1950s, the Missouri River was a meandering river with islands, sandbars, log jams, chutes, backwaters, and large sediment loads. The natural processes of the river supported a lotic ecosystem created and maintained by flood pulses that continuously reshaped the channel and floodplain through bank erosion and deposition (Weeks et al. 2005). Aquatic and terrestrial habitats of the Missouri River include the river channel, floodplain, sandbars, vegetated islands, aquatic-terrestrial transition zone (littoral zone), stream beds, large wood (in-channel, riparian forest), tributary confluences, backwaters, chutes, wetlands, pools, oxbow lakes, hyporheic zones, streambanks, and terraces. Dams constructed on the Missouri River in the 1950s altered natural processes and the extent and complexity of aquatic and terrestrial habitats of the lotic ecosystem. The natural aquatic and terrestrial habitats of the river are affected by significantly altered flood pulses, straightened stream meanders, reduced sediment loads, reduced riparian vegetation, and smaller variations in water temperature (NRC 2002). Studies conducted by the NPS, USACE, and USFWS have shown various factors impacting aquatic and terrestrial habitats including climate change, exotic and invasive species, human development, loss of natural disturbance regime, river bank stabilization, and dam operations limiting flow. The altered natural processes pose significant risks to federally listed species such as the pallid sturgeon, piping plover, and interior least tern, which depend on aquatic and terrestrial habitats for reproductive success. It is important to monitor and understand the changes of the Missouri River to better understand how aquatic and terrestrial habitats are affected by these changes.

Measures

- Distribution and abundance of diverse native plant communities
- Amount of vegetation in diverse seral stages
- Amount of vegetated island and sandbar habitat
- Wetland distribution, type, and location
- Depth and substrate diversity
- Amount of chutes, backwaters, and shallow-water habitat
- Presence of exotic and invasive species

Reference Conditions/Values

The reference condition for aquatic and terrestrial habitats is the time prior to construction and closure of the Fort Randall and Gavins Point Dams (1954 and 1957, respectively).

<u>Distribution and Abundance of Diverse Native Plant Communities</u>

Prior to dam closure, the Missouri River floodplain (covering 338.5 million acres of Missouri River Basin and tributary valleys) was a mixture of deciduous forests (76%) and wetlands (10%) (Bragg and Tatschl 1977, as cited in Weeks et al. 2005). The other 14% was not indicated in their research but can be assumed to have been a mixture of shrubland and grassland.

Fort Randall 39-mile reach

Table 34 displays a generalized depiction of historic composition (approximately 67% grassland, 29% deciduous forest, and 4% shrub) associated with the floodplain of the 39-mile district of MNRR (Dixon et al. 2010).

Table 34. Area and percentage of plant communities in the Missouri River's historic floodplain (bluff to bluff) in the MNRR 39-mile reach from Fort Randall Dam to Niobrara River (Dixon et al. 2010).

Composition	Area		% Composition
	acres	ha	
Grassland	15,563	6,298	66.84
Deciduous forest	6,695	2,709	28.75
Shrubs	1,029	416	4.41
Totals:	35,769	9,423	100.00

Gavins Point 59-mile reach

Table 35 displays the area and relative composition of plant communities in the historic floodplain (from bluff to bluff) associated with the 59-mile reach (Dixon et al. 2010). The historic floodplain in the 59-mile reach included approximately 63% grassland, 25% deciduous forest, and 11% shrubs. The remaining 1% was a mix of marsh, open woodland, and orchard.

Table 35. Area and percentage of plant communities in the Missouri River's historic floodplain (bluff to bluff) in the area of the 59-mile reach of MNRR (Dixon et al. 2010).

Composition	Area		% Composition
	acres	ha	
Grassland	71,766	29,043	62.68
Deciduous forest	28,548	11,553	24.93
Shrubs	12,108	4,900	10.58
Marsh	1,452	587	1.27
Open woodland	569	230	0.50
Orchard	49	20	0.04
Totals:	114,492	46,333	100.00

Amount of Vegetation in Diverse Seral Stages

A reference condition for the amount of vegetation in diverse seral stages has not been documented for MNRR.

Amount of Island and Sandbar Habitat

Elliot and Jacobson (2006) report the Gavins Point 59-mile reach had approximately 46 island bars (4,534 ha) and 312 sandbars (1,804 ha) in 1941. Dixon et al. (2010) reported the pre-dam sandbar area from Fort Randall Dam to Niobrara River was approximately 1,703 hectares (4,209 acres). A reference condition for the Niobrara River to Lewis and Clark delta reach was not reported.

Wetland Distribution, Type, and Location
Historical wetland distribution, type, and location is not documented for the pre-dam MNRR. However, Dixon et al. (2010) showed an increase in wetland area, due to the Fort Randall Dam and Lewis and Clark Reservoir delta area. Dixon et al. (2010) indicated no wetland increases in the Gavins Point reach.

Depth and Substrate Diversity
A reference condition for depth and substrate diversity has not been documented for the MNRR.

Amount of Chutes, Backwater, and Shallow-Water Habitat (SWH)
Elliot and Jacobson (2006) identified 13 chutes in the 59-mile reach of MNRR from 1941 pre-dam photographs. Figure 29 illustrates a 1941 chute located at RM 804. They report chutes at this time ranged in length from 0.57 km to 13.50 km, with an average length of 3.67 km (2.28 mi) and average width of 55 meters.

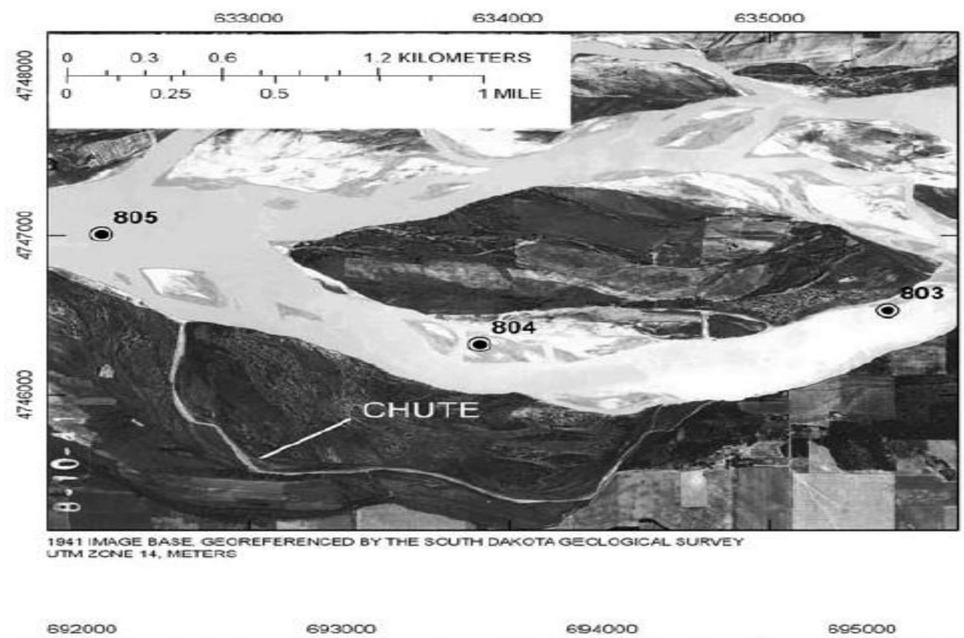


Figure 29. Side-channel chute from RM 805-803 in 1941 on the 59-mile reach of MNRR (Elliot and Jacobson 2006).

Presence of Exotic and Invasive Species
A reference condition for presence of exotic and invasive species has not been documented for the MNRR.

Data and Methods
Literature provided by MNRR, USGS, and USACE were the primary sources of information for this document. In addition, resource guidance was provided by John Macy, MNRR Hydrologist; Gia Wagner, MNRR Chief of Resource Management; Lisa Yager, MNRR Biologist; Aaron DeLonay, USGS Ecologist; Stephen Wilson, NGPN Data Manager; and Duane Chapman, USGS Fisheries Biologist. For each measure, the primary sources of information are as follows:

- Distribution and abundance of diverse native plant communities: Stukel (2002), NPScape (2009), Dixon et al. (2010), Stevens et al. (2010).
- Amount of vegetation in diverse seral stages: Dixon et al. (2010).
- Amount of vegetated island and sandbar habitat: Elliot and Jacobson (2006), Dixon et al. (2010), USACE (2005a, 2010a), Duberstein and Downs (2008), USFWS (2003).
- Wetland distribution, type, and location: USACE (2004), Weeks et al. (2005), Dixon et al. (2010).
- Depth and substrate diversity: DeLonay et al. (2009), Reuter et al. (2009), Jacobson and Galat (2008), USACE (2010b), Elliot et al. (2004).
- Amount of chutes, backwaters, and shallow-water habitat: Tracy-Smith (2006), Elliot and Jacobson (2006), USACE (2008), Shields et al. (2000), Yager (2010), Hesse (1987), Jacobson et al. (2004).
- Presence of exotic and invasive species: Weeks et al. (2005), USFWS (2003), CERC (2003), Kottas and Stubbendieck (2005).

Current Condition and Trend

Distribution and Abundance of Diverse Native Plant Communities

In 2001, an eight county plant inventory project was conducted by the Fort Randall Resource Conservation Development District and the South Dakota Division of Resource Conservation and Forestry. The counties surveyed included Bon Homme, Brule, Buffalo, Charles Mix, Yankton, Gregory, Lyman, and Tripp counties. A total of 94,583 trees and shrubs were inventoried and the results showed that the naturally occurring forest within the entire study area was comprised of 75% hardwoods (Stukel 2002). Stukel (2002) found that the most common trees with a diameter at breast height (DBH) of 20 cm or greater (in all counties of the study area) were oak , ash (21%), eastern red cedar (17%), elm (15%), box elder (*Acer negundo*) (5%), hackberry (*Celtis* spp.) (4%), cottonwood (4%), or other (1%). Cottonwood regeneration was lowest and eastern red cedar regeneration was highest in the areas inventoried (Stukel 2002). Bon Homme and Yankton Counties (which border MNRR) had similar results, with oak, elm, and easter red cedar as the highest percent composition (Stukel 2002). Table 36 and Figure 30 summarize the total number of trees, along with percent composition of trees in Bon Homme and Yankton Counties, which border MNRR.

Table 36. Tree composition in Bon Homme and Yankton Counties, SD (Stukel 2002).

	Bon Homme		**Yankton**	
Species	Total	% Composition	Total	% Composition
Oak	420	27.15%	212	20.60%
Cedar	385	24.89%	185	17.98%
Elm	356	23.01%	236	22.93%
Cottonwood	100	6.46%	95	9.23%
Hackberry	90	5.82%	62	6.03%
Ash	78	5.04%	137	13.31%
Boxelder	47	3.04%	9	0.87%
Honeylocust	28	1.81%	33	3.21%
Basswood	20	1.29%	5	0.49%
Mulberry	16	1.03%	7	0.68%
Willow	6	0.39%	2	0.19%
Black Walnut	1	0.06%	1	0.10%
Ponderosa Pine	0	0.00%	4	0.39%
Silver Maple	0	0.00%	41	3.98%
Total:	1,547	100.00	1,029	100.00

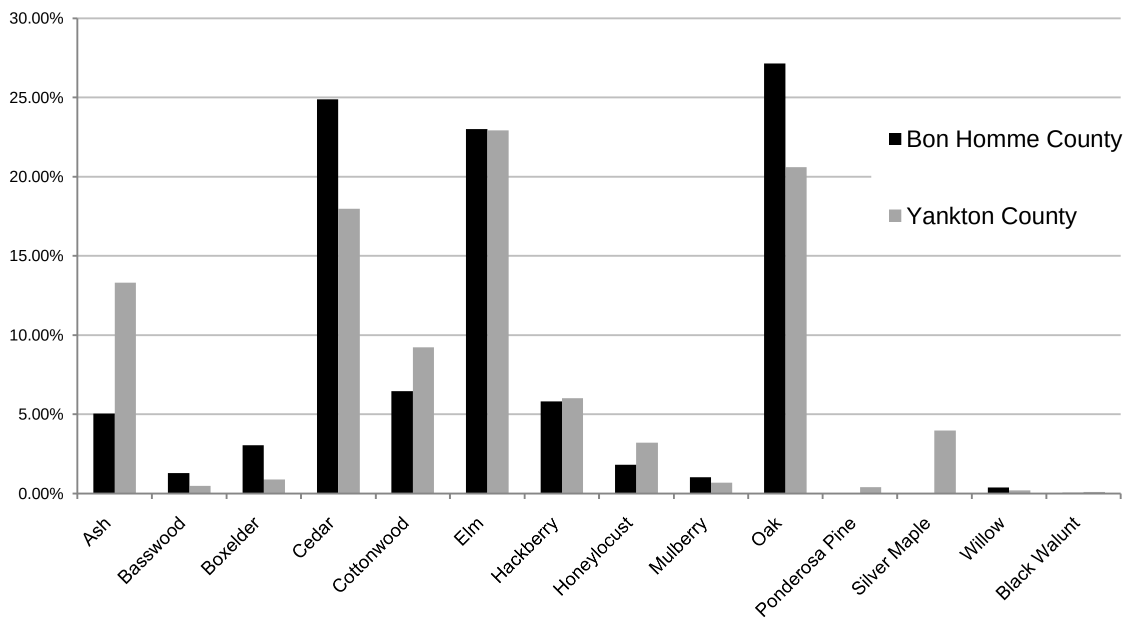


Figure 30. Tree composition in Bon Homme and Yankton Counties, SD (Stukel 2002).

The NPScape (2009) project examined 2001 National Land Cover Data (NLCD) on 1.5 million hectares within a 30-kilometer buffer of MNRR boundaries. This identified general land cover classes of the greater MNRR area. The primary land cover type within this buffer (including within the park boundaries) was cultivated agriculture (43.85%). The other predominant land cover types included grassland/herbaceous, pasture/hay, developed open space, deciduous forest, open water, and emergent herbaceous wetlands (Table 37, NPScape 2009).

Table 37. Land cover classes within a 30-km buffer of the MNRR park boundaries (NLCD 2001 data reported by NPScape 2009).

Land Cover/Use Class Name	Area		% Composition
	ha	acres	
Cultivated Agriculture	672,737	1,662,363	43.85
Grassland/Herbaceous	475,673	1,175,410	31.00
Pasture/Hay	153,334	378,895	9.99
Developed Open Space	62,944	155,537	4.10
Deciduous Forest	62,514	154,474	4.07
Open Water	44,242	109,324	2.88
Emergent Herbaceous Wetlands	24,576	60,729	1.60
Woody Wetlands	11,941	29,506	0.78
Developed Low Intensity	10,260	25,352	0.67
Evergreen Forest	6,339	15,665	0.41
Scrub/Shrub	4,842	11,964	0.32
Developed Medium Intensity	2,752	6,799	0.18
Developed High Intensity	1,136	2,808	0.07
Barren Land	733	1,811	0.05
Mixed Forest	298	737	0.02
Totals:	1,534,321	3,791,374	100

Dixon et al. (2010) examined change in forest area from 1892 through 2006 within several segments of the Missouri River (Figure 31). The 39-mile reach from Fort Randall Dam to the Niobrara River and from the Niobrara River to the Lewis and Clark Lake showed an approximate decrease in forest area by 18% and 95%, respectively. The large decrease in forest area in the Fort Randall reach was due to the Niobrara River confluence and Lewis and Clark Reservoir. Almost all of this area was converted from forest, shrubland, grassland, and cropland to reservoir (75%) and wetland (25%). The 59-mile reach saw a decrease of approximately 45%.

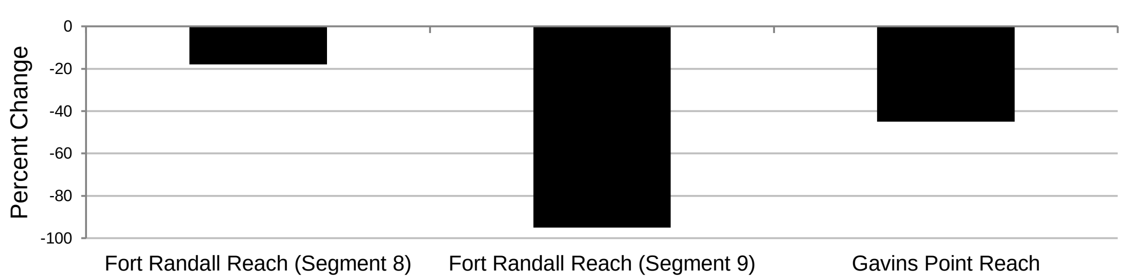


Figure 31. Percent change in total forest area per study segment from 1892 through 2006. Total forest area includes both cottonwood and non-cottonwood types (from Dixon et al. 2010).

Fort Randall 39-mile reach

Dixon et al. (2010) determined from 2006 aerial photography for the Fort Randall to Niobrara River reach of the Missouri River that the floodplain was 33.3% forested stands including at least 15% cottonwood. Other land cover types in this reach included riparian low herbaceous vegetation (17.94%), upland grassland (16.19%), wet meadow/mesic grassland (10.09%), riparian low shrub (7.7%), emergent wetland (6.96%), non-cottonwood (< 15%) floodplain forest (4.17%) followed by a mix of woodland, shrubland, and upland forest (3.6%) (Dixon et al. 2010). Table 38 displays the land cover type from Dixon et al. (2010) analysis of 2006 aerial photography. Table 38 does not include Verdigre Creek or Niobrara River sections and only covers floodplain areas of MNRR.

Table 38. Area and percent composition of land cover types in the 39-mile reach (Fort Randall Dam to Niobrara River mouth), 2006 (Dixon et al. 2010).

Land cover in the 39-mile reach	**Area**		**% Composition**
	ha	**acres**	
Forest (*cottonwood at least 15%*)	1,851	4,568	33.29
Riparian low herbaceous vegetation	996	2,461	17.94
Upland grassland, pasture	899	2,221	16.19
Wet meadow / mesic grassland	560	1,384	10.09
Riparian low shrub with cottonwood	427	1,056	7.70
Emergent wetland	387	955	6.96
Non-cottonwood (*cottonwood <15%*) floodplain forest	232	572	4.17
Riparian low shrub w/o cottonwood	53	130	0.95
Non-cottonwood (*cottonwood <15%*) woodland	43	107	0.78
Non-cottonwood shrubland	39	97	0.71
Planted cottonwood trees	39	95	0.69
Shrubland (*with cottonwood*)	21	52	0.38
Upland forest (*not in floodplain*)	10	23	0.17
Totals:	5,557	13,721	100

Figure 32 illustrates changes in the Fort Randall reach (from Fort Randall Dam to Niobrara River mouth) from 1890 to 2006. The greatest change occurred from 1892-1950s with expansion of agriculture (Dixon et al. 2010). Additional increases in river and wetland areas occurred from the 1950s to 2006 as a result of reservoir development (Dixon et al. 2010). Forest cover increased from 1983 to 2006, due to conversion of shrubland (saplings and pole stands) to forest through growth and maturation (Dixon et al. 2010).

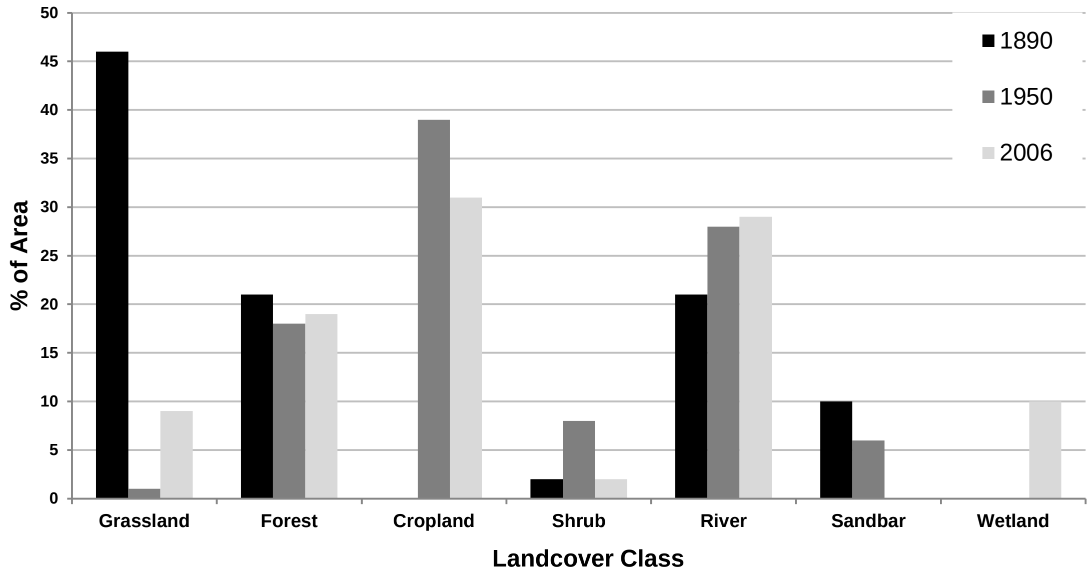


Figure 32. Fort Randall reach (from Fort Randall Dam to Niobrara River) land cover changes 1890 to 2006 (Dixon et al. 2010). Note: graphs were recreated without urban data.

The Fort Randall reach from the Niobrara River into the Lewis and Clark delta area have also seen increased river and wetland areas by 75% and 25%, respectively (Figure 33).

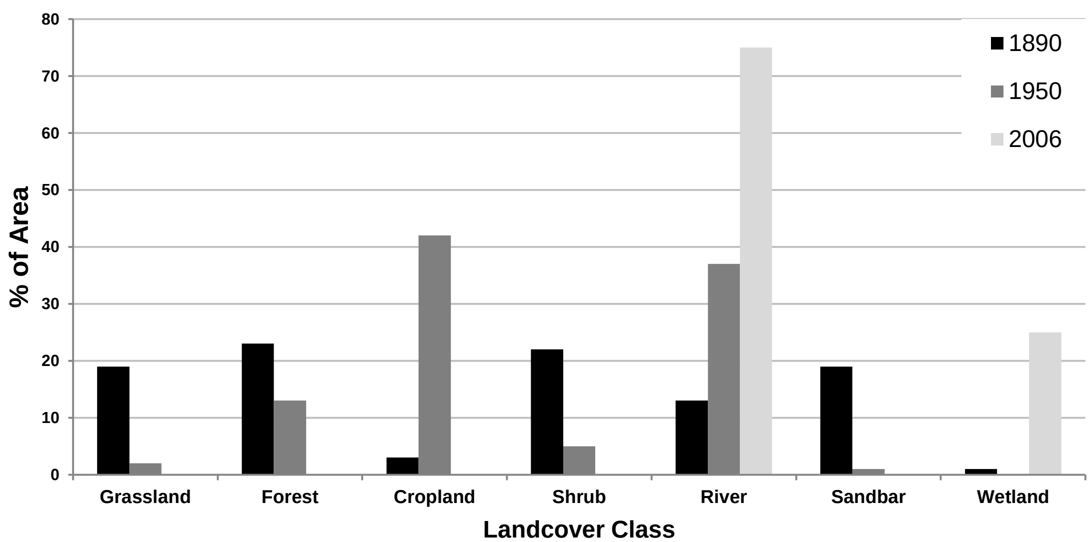


Figure 33. Fort Randall reach (from Niobrara River to Lewis and Clark Lake) land cover changes 1890 to 2006 (Dixon et al. 2010). Note: graphs were recreated without urban data.

Gavins Point Dam 59-mile district

Dixon et al. (2010) found land cover in the 59-mile reach composed of forest (56.9%), upland forest (9.99%), upland grassland (9.71%), riparian low shrub with cottonwood (7.69%), shrubland (4.64%), non-cottonwood floodplain forest (3.92%), and a combination of other riparian, woodland, and shrubland (7.2%). Table 39 displays the land cover type from Dixon et al.'s (2010) analysis of 2006 aerial photography.

Table 39. Land cover type in the floodplain (bluff to bluff) of the 59-mile reach, 2006 (Dixon et al. 2010).

Land cover in the 59-mile reach	**Area**		**% Composition**
	ha	**acres**	
Forest (*cottonwood at least 15%*)	4,707	11,631	56.90
Upland forest (*not in floodplain*)	827	2,043	9.99
Upland grassland, pasture	803	1,985	9.71
Riparian low shrub with cottonwood	636	1,571	7.69
Shrubland (with cottonwood)	384	948	4.64
Non-cottonwood (*cottonwood <15%*) floodplain forest	325	802	3.92
Riparian low herbaceous vegetation	246	607	2.97
Woodland (*cottonwood at least 15%*)	239	592	2.90
Riparian low shrub w/o cottonwood	74	182	0.89
Non-cottonwood shrubland	32	80	0.39
Totals:	8,273	20,441	100

A four-year quantitative inventory vegetation project is underway within MNRR (Stevens et al. 2010). Preliminary data suggests that approximately 12,600 ha (31,100 acres) or 45% of MNRR is non-vegetated aquatic habitat (Stevens et al. 2010). The other 55%, which is considered vegetated habitat, will be included in their study (114 species of vegetation in MNRR with 34 known species and 80 potentially occurring). Table 40 displays known and potential vegetation types (including wetland) in MNRR (using the Steinauer and Folsmeier [2003] classification) (Stevens et al. 2010).

Table 40. Preliminary list of vegetation types of MNRR (reproduced from Stevens et al. 2010).

Steinauer and Rolfsmeier (2003) Name	Occurence in MNRR (k= known, p = potential)	Wetland (w)
American Lotus Aquatic Wetland	p	w
Buckbrush Shrubland	p	w
Buffaloberry Shrubland	k	w
Bur Oak - Basswood - Ironwood Forest	k	
Cattail Shallow Marsh	k	w
Chokecherry - Plum Shrub Thicket	p	
Cottonwood -Diamond Willow Woodland	k	w
Cottonwood-Peachleaf Willow Riparian Woodland	k	w
Dry-Mesic Bur Oak Forest and Woodland	k	
Eastern Bulrush Deep Marsh	k	w
Eastern Cordgrass Wet Prairie	k	w
Eastern Cottonwood- Dogwood Riparian Woodland	k	w
Eastern Pondweed Aquatic Wetland	k	w
Eastern Riparian Forest	k	w
Eastern Sand Prairie and Sandhills Dry Valley Prairie	k	
Eastern Sandstone Bluff	k	
Eastern Sedge Wet Meadow	k	w
Freshwater Seep	k	w
Green ash - Elm - Hackberry Canyon Bottom Woodland	p	
Northern Chalk Bluff and Cliff	k	
Lowland Tallgrass Prairie	k	
Missouri River Floodplain Terrace Grassland	k	
Missouri River Valley Dune Grassland	k	
Northern Cordgrass Wet Prairie	p	w
Northern Loess/Shale Bluff Prairie	k	
Reed Marsh	k	w
Riparian Dogwood-False Indigobush Shrubland	k	w
Sandbar/Mudflat	k	w
Sandbar Willow Shrubland	k	w
Sandbar Willow Shrubland and Perennial Sandbar	k	w
Sandhills Dune Prairie	p	
Threadleaf Sedge Western Mixedgrass Prairie	p	
Upland Tallgrass Prairie	k	
Water-lily Aquatic wetland	p	w

The Gavins Point reach is one of the most natural and least altered segments in the Lower Missouri River because it is located below the furthest downstream dam and is unchannelized (Dixon et al. 2010). This reach has physical characteristics of pre-dam conditions (Schneiders 1999), but has experienced large changes in plant communities since 1890 (Figure 34). Dixon et al. (2010) reported large decreases in plant communities (grassland, forest, and shrubland) and large increases in cropland, with most of the large changes occurring between 1892 and 1956. Overall, MNRR saw a decline in forest, shrubland, and grassland habitats in both the 39-mile and 59-mile reaches, but an increase in wetland habitat in the Niobrara River to Lewis and Clark Lake delta area (Dixon et al. 2010).

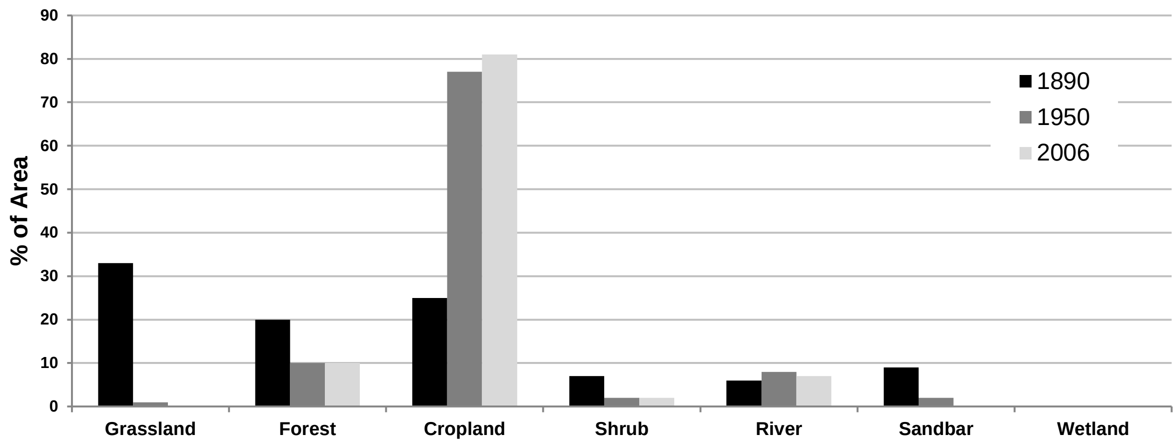


Figure 34. Gavins Point reach land cover changes from 1890 to 2006 (Dixon et al. 2010). Note: graphs were recreated without urban data.

Amount of Vegetation in Diverse Seral Stages

The amount of vegetation in diverse seral stages has only been documented for cottonwoods. Seral stages of cottonwoods could be comparable to the ―intermediate" stand age (25-50 years old) classification in Dixon et al. (2010). In the 39-mile reach, 22% of the cottonwood stands were of intermediate age and in the 59-mile reach, 33% of cottonwood stands were of intermediate age (Dixon et al. 2010). Refer to the cottonwood assessment (Section 4.5 of this document) for further information on cottonwood stand age.

Amount of Islands and Sandbar Habitat

Fort Randall 39-mile reach

Elliot and Jacobson (2006) mapped over 1,700 bars based on 1999 orthoimagery from Fort Randall Dam to Sioux City, Iowa. Table 41 shows islands and sandbars for the Fort Randall 39-mile reach divided into two reaches: free-flowing reach and Lewis and Clark delta reach. Upstream of the Niobrara River confluence is the free-flowing reach and downstream of the confluence is the delta reach. In 1999, there were 322 islands in the free-flowing reach compared to 703 in the delta reach. There were 5.6 islands/km in the free-flowing reach and 26.6 islands/km in the delta reach. On average, there were 1.4 sandbars/km in the free-flowing reach and 4.2 sandbars/km in the delta reach. Elliot and Jacobson (2006) note that in the delta reach, sandbars were smaller and were only present in the former Missouri River thalweg.

Table 41. Fort Randall 39-mile reach 1999 island and sandbar statistics (Elliot and Jacobson 2006).

Reach	Number	Bars / km	Total bar area (ha)	Bar area / km (ha)	Mean bar area (ha)
Islands					
39-mile free flowing reach	322	5.6	1,749	31	5.4
39-mile delta reach	703	26.6	4,414	167	6.3
Total:	1,025	-	163	198	12
Sandbars					
39-mile free flowing reach	82	1.4	302	5.0b	3.7
39-mile delta reach	111	4.2	232	9.0	2.1
Totals:	193	-	534	14.0	5.8

Gavins Point 59-mile reach

Elliot and Jacobson (2006) examined the prevalence of sandbars in the 59-mile reach of MNRR from seven different years of orthoimagery: 1941, 1996-1999, and 2003-2004. There were fewer vegetated bars in 1941 compared to 1996-1999 and 2003-2004, but vegetated bar area was larger in 1941 (Elliot and Jacobson 2006). ―This difference results from the prevalence of long, off-channel chutes in the pre-dam river" (Elliot and Jacobson 2006, Figure 35).

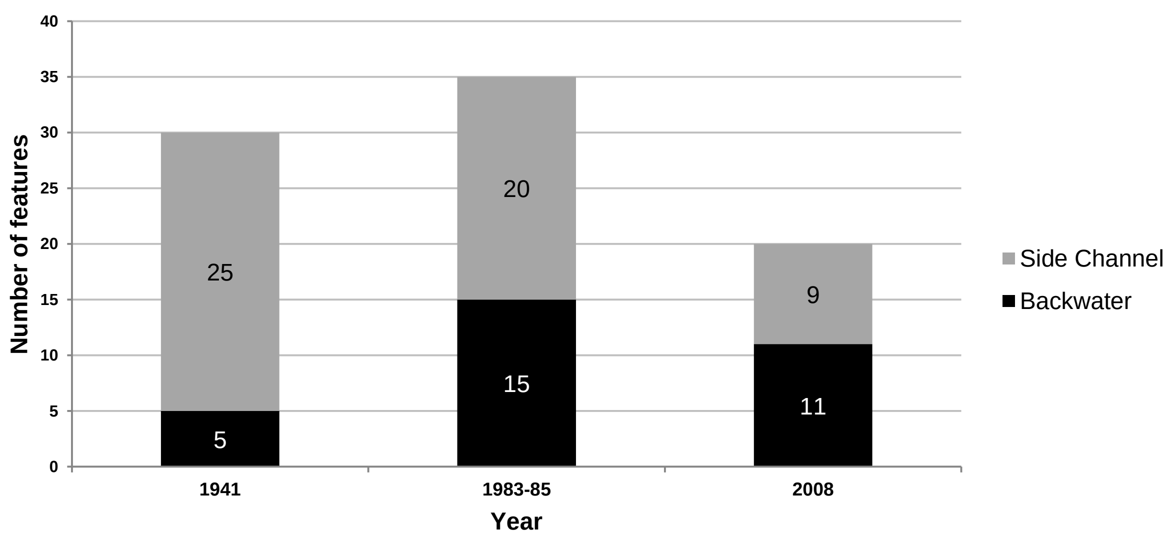


Figure 35. The number of off-channel features identified by image year within MNRR (reproduced from Yager 2010).

The number of sandbars in the 59-mile reach has remained fairly stable (up to 2006) (Elliot and Jacobson 2006). In 2003 and 2004, there were 6.2 and 7.2 bars/km, respectively (Elliot and Jacobson 2006). These data are similar to the number of sandbars in 1996: 6.5 bars/km. During high flows in 1997, most of the sandbars were submerged, which is reflected by the lower 3.5 bars/km value (Elliot and Jacobson 2006). From 1997-1999, there were fewer sandbars per kilometer (3.5, 3.6 and 3.0 respectively) compared to all other post-dam sandbar data available in this study. During 1998, even though the number of sandbars per km were comparatively low for the post-dam period, the total area of sandbars and the mean bar area were the highest for that period (Elliot and Jacobson 2006, Table 42).

Table 42. Multi-year bar analysis in the 59-mile reach of MNRR (reproduced from Elliot and Jacobson 2006).

Year	Discharge (m/s)	Total number	Number per km	Total area (ha)	Mean bar area (ha)
			Islands		
1941	795	46	0.5	4,534	99
1996	1,104	118	1.3	1,486	13
1997	1,826	589	6.7	1,212	2
1998	736	45	0.5	1,209	27
1999	1,025	90	1.0	1,420	16
2003	800	93	1.1	1,793	19
2004	747	145	1.7	1,921	13
			Sandbars		
1941	795	312	3.6	1,804	6
1996	1,105	568	6.5	840	1
1997	1,825	309	3.5	108	0.4
1998	735	312	3.6	2,022	6
1999	1,025	262	3.0	532	2
2003	800	540	6.2	858	2
2004	750	634	7.2	492	1

Data from Elliot and Jacobson (2006) show that from 1941 to 2004 island bar area decreased 58% and sandbar area decreased 73%. Dixon et al. (2010) report sandbars within the MNRR Gavins Point Dam to Ponca, NE reach declined 48% between 1892 and 1956.

Creating and Maintaining Sandbar Habitat

USACE uses various methods to create sandbar habitat, including: placement of dredged material, low flow releases, mowing, and herbicide spraying of encroaching vegetation. USACE (2005a) describes a vegetation removal project that included 76 island bars on approximately 505 ha (1,248 ac) located along three reaches of the Missouri River: (1)275 ha (681 ac) downstream from Gavins Point Dam located between River Mile (RM) 756 and 805; (2) 76 ha (190 ac) between Fort Randall Dam and Lewis and Clark Lake located between RM 832 and 870; and (3) 152 ha (377 ac) below Garrison Dam in North Dakota located between RM 1284 and 1330. In 2004, 58 ha (145 ac) in the Gavins Point reach were sprayed, and additional islands were identified and sprayed in 2005 and 2006 (Table 43).

Table 43. Vegetation management on island bars within Gavins Point reach, 2004–2007 (Duberstein and Downs 2008).

River Mile	Herbicide	Mowed	Comment
756.6	2004	2005 and 2006	Lower portion
756.8	2005	2006	Upper portion
757.2	2005	2006	
759.2	2005	Spring 2006	Nesting not in treated area
759.5	2005	Not Mowed	
768.0	2005	Not Mowed	
773.0	2005	2007	
777.7	2004 and 2005	2007	
778.5	2005	Not Mowed	
778.7	2005	2007	Now eroded away
781.5	2004	2005	
782.5	2005	2007	Nesting not in treated area
783.0	2005	2007	
784.5	2005	2007	
785.2	2005	2007	
786.0	2005	2007	
788.5	Not Sprayed	Not Mowed	
789.5	2005	2007	
790.0	2005	2007	
790.9	2005	2007	
793.3	2005	Not Mowed	
793.5	2005	2007	
794.0	2005	2007	
795.3	2005	2007	
796.0	2005	Not Mowed	
796.5	2005	2007	
797.0	2005	2007	
799.0	2005	2007	
801.1	2005	2006	Partially sprayed/mowed

Emergent sandbar habitat (ESH) is used for nesting and rearing by the endangered piping plover and nterior least tern (USFWS 2003). These birds nest on sandbars in the Missouri River and along reservoir shorelines (USACE 2010a). ESH is most effective for these species when there is no vegetation present and there is sufficient elevation to avoid flooding during spring-pulse flows, navigation flows, or storm runoff. The results of a study performed by Duberstein and Downs (2008) indicated that least terns and piping plovers have successfully reproduced on the USACE constructed ESH at or above the levels stipulated in the BiOp. Within the Gavins Point reach, both terns and plovers use sand bars that are exposed during low flow releases or through vegetation removal by herbicide spraying or mowing (Duberstein and Downs 2008). Piping plover and least tern are covered in more detail in Chapter 4.7 of this document.

Wetland Distribution, Type, and Location

According to USACE (2004), in 1991, the 39-mile reach was approximately 48% water, 33% riparian vegetation, and 19% wetland (Table 44). This 1991 data was mapped by USACE using the Cowardin et al. (1979) wetland classification; this is the same classification used in USFWS National Wetland Inventory (NWI) data. Riparian forest, composed of cottonwood, green ash (*Fraxinus pennsylvanica*), Russian olive (*Elaeagnus angustifolia*), slippery elm (*Ulmus rubra*), and box elder were the dominant vegetation in the 39-mile reach. Wetlands in the 39-mile reach include 56% emergent, 30% forested mixture, and 14% other wetland types. The emergent wetlands supported a mix of reed canary grass (*Phalaris arundinacea*) and common reed (*Phragmites australis*). The forested wetlands were characterized by a mix of peachleaf willow (*Salix amygdaloides*) and cottonwood with some sandbar willow (*Salix exigua*) as well. Expansive areas of cattail (*Typha* spp.) mixed with softstem bulrush (*Scirpus validus*) comprised old channels and backwaters (USACE 2004).

Table 44. Amount of wetland and riparian areas for Fort Randall (39-mile reach) and Gavins Point (59-mile reach) of MNRR, 1991 (USACE 2004, Weeks et al. 2005).

Wetland/Riparian Type	39-mile reach (ha)	59-mile reach (ha)
Emergent	680	995
Scrub Shrub	183	1,018
Forested	359	75
Exposed Shore	120	220
Riparian Forest	1,835	1,598
Riparian Shrub	79	353
Riparian Grass	228	645
Total:	3,487	4,908

In 2005, the 59-mile reach consisted of approximately 58% water, 23% riparian vegetation, and 19% wetland (Weeks et al. 2005). Agricultural clearing has severely reduced the riparian vegetation along the 59-mile reach. The riparian vegetation was dominated by over 50% cottonwood forest with lower densities of green ash, slippery elm, red cedar, Russian olive, mulberry (*Morus* spp.), and box elder (Weeks et al. 2005). The sparse herbaceous layer beneath mature cottonwood consisted mostly of scouring rush (*Equisetum variegatum*), Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), and switchgrass (*Panicum virgatum*) (Weeks et al. 2005). Kentucky bluegrass, smooth brome, and other invasive grasses and weeds dominate riparian grasslands (Weeks et al. 2005). Wetlands in the 59-mile reach were 49% scrub-shrub and 48% emergent (Weeks et al. 2005). Scrub-shrub wetlands typically occur as dense stands of young sandbar willow, and less frequently as inundated sandbars comprised of peachleaf willow and cottonwood (Weeks et al. 2005). Most emergent wetlands consisted of reed canary grass or a mix of hydric and mesic species. Cattails occurred in old channels, backwaters, and near islands (Weeks et al. 2005).

Wetlands increased from 10-25% in the Fort Randall reach, predominantly related to the Niobrara River confluence and the Lewis and Clark Lake delta (Dixon et al. 2010).

Depth and Substrate Diversity

Few benthic studies have been conducted within MNRR, but recent sturgeon habitat assessments and mussel surveys illustrate the importance of depth and substrate diversity. Sturgeon habitat assessments show depth, water velocity, and substrate as the three main physical habitat preferences for benthic organisms (Elliot et al. 2004, DeLonay et al. 2009, Reuter et al. 2009). Optimal sturgeon habitat is generally found in minimally engineered and unchannelized river reaches (Reuter et al. 2009). A minimally engineered river segment is shallow, wide, with relatively low mean velocity (Reuter et al. 2009). An example of a minimally engineered river segment is the Missouri River from Gavins Point Dam to Ponca State Park. In addition, Elliot et al. (2004) found pallid sturgeon to prefer deeper areas, ranging from 3.5-6.5 meters. In a bathymetric study performed on an 11 mile section of the 59-mile segment (from RM 798-787), Christensen (2010) found depths to range from 0.5-7.3 meters, with the majority of depths in the 0.5-2.75 meter range. Christensen (2010) also found depths of 3.5-6.5 meters (which pallid sturgeon prefer), but they were less common than shallower areas.

In addition to depth, hard substrate (such as rock, rubble, or gravel) is vital to the success of all benthic organisms including mussels and gravid sturgeon (Jacobson and Galat 2008). Pallid sturgeon deposit sinking eggs that adhere to hard substrates (Jacobson and Galat 2008) and mussel beds are generally formed on stable rock, pebble, or sand substrate (Ecological Specialists 2005). In addition, Elliot et al. (2004) found pallid sturgeon avoid areas with mud and submerged vegetation. In general, the Fort Randall and Gavins Point Dams act as catchments, blocking a large amount of substrate from moving downstream (USACE 2010b). However, the areas below the dams are armored with gravel, providing habitat for many benthic organisms (Macy, pers. comm., 2010). Missouri River tributaries provide some natural substrate deposition, but they do not replace the natural load from the main stem of the Missouri River (DeLonay, pers. comm., 2011). See Erosion and Depositional Processes (Section 4.2 of this document) for more on the areal extent of armoring.

Amount of Chutes, Backwater, and Shallow-Water Habitat

Since damming and channelization, the Missouri River has lost nearly all of its natural chutes and backwaters (Hesse 1987). Yager (2010) found that from 1941 to 2008, the total and mean areas of off-channel features (i.e., backwaters and chutes < 100 m wide) declined by 70% and 55%, respectively. In addition, clear water that is released from the dams has directly caused channel bed degradation. This degradation has resulted in incised channels, a lowered floodplain, and subsequent drained backwaters (Hesse 1987, USACE 2008).

USACE (2008) illustrates the amounts of chutes and backwaters for the Fort Randall reach by geomorphic reach (GR) as classified by Biedenharn et al. (2001) (Table 45). The overall total SWH area in 1977 was 18% backwater and 82% chutes within the Fort Randall reach.

Table 45. Chute and backwater habitat from 1977 aerial photographs and 1960 river mile for the Fort Randall reach (USACE 2008).

Geomorphic Reach	1960 RM	Backwater Habitat (acres)	Chute Habitat (acres)	Total Backwater/Chute Habitat (acres)	Backwater (%)	Chute (%)
GR 1	879.3-874.8	8.3	26.9	35.3	24	76
GR 2	872.0-868.0	4.6	76.9	81.5	6	94
GR 3	867.0-862.6	32.9	127.5	160.4	21	79
GR 4	861.5-854.7	28.5	123.1	151.6	19	81
GR 5	853.1	41.5	68.1	109.5	38	62
GR 6	850.8-844.2	25.4	226.4	251.8	10	90
Totals:		141.2	648.9	790.1	18%	82%

The number and area of natural backwaters and chutes have changed over time (Table 46, Figure 36). Yager (2010) reports the overall number of off-channel features (chutes and backwaters as indicated by imagery) increased slightly from 1941 (30 features) to 1985 (35 features) and declined by 2008 (20 features). Total area of chutes and backwaters has decreased 70% from 1941 to 2008 and total area of side channels has decreased 77% over the same period (Yager 2010). These decreases are largely due to flow regulation, which has caused channel bed degradation and disconnection of the natural floodplain (Yager 2010). The disconnection from the historic floodplain causes off-channel features to convert to backwaters, which eventually dry up without periodic high flows (Yager 2010).

Table 46. Historical changes of off-channel features in MNRR (Yager 2010).

Image Year	Feature Type	Total Number	Total Length (m)	Mean Length (m)	Total Area (ha)	Mean Area (ha)
2008	Restored backwater	4	4,723	1181	21.157	5.289
	Backwater	11	6,874	625	31.039	2.822
	Side channel	9	12,567	1396	80.043	8.894
	All natural features	20	19,441	972	111.083	5.554
1983-1985	Backwater	15	9,823	655	26.961	1.797
	Side channel	20	29,390	1470	135.875	6.794
	All natural features	35	39,213	1120	162.837	4.652
1941	Backwater	5	3,692	738	22.164	4.433
	Side channel	25	60,033	2401	350.455	14.018
	All natural features	30	63,725	2124	372.619	12.421

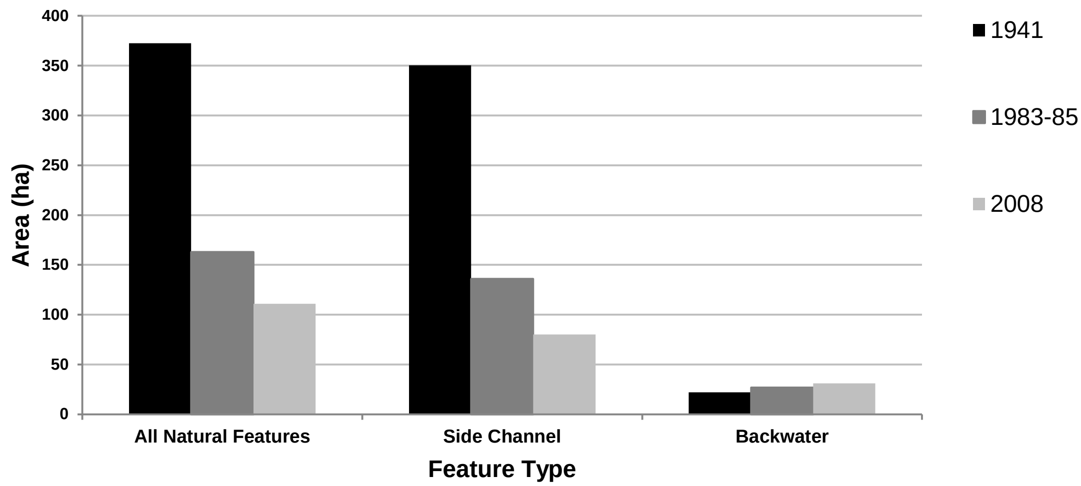


Figure 36. Total off-channel habitat area, including side channels and backwaters (1941 to 2008) (Yager 2010).

Great changes in areas of natural backwaters and side channels have occurred over time (Figure 35), with a progressive decline in the number of side channel habitats and a shift in the ratio of side channels to backwaters (Yager 2010). In 1941, 83% (25 of 30) of the identified off-channel features were side channels (Yager 2010). By 1983-85, the number of side channels declined (from 25 to 20) and the number of backwaters increased (from 5 to 15) (Yager 2010). “Cumulative changes from 1941-2008 show a sharp decline in the total number of side channels (from 20 to 9), and a significant shift in the relative proportions of side channels to backwaters (chi2=8.104, df=1, p=0.004)” (Yager 2010).

Tracy-Smith (2006) describes SWH as a component of channel-margin and sandbar aquatic-terrestrial transitional zones (ATTZ). The ATTZs of river-floodplain systems are ecologically significant because they provide heterogeneous habitat conditions across space and time (Tracy-Smith 2006). However, the pre-dam floodplain is now disconnected because of channel incision, and the floodplain/islands/bars forming within the incised channel are subject to inundation under some flow conditions (Macy, pers. comm., 2010).

In 2004, USACE began constructing new chutes and backwaters to increase the amount of SWH. In addition, backwater areas were created by the Nebraska Department of Roads due to bridge construction (S. Wilson, pers. comm., 2010). The newly constructed backwaters include Gunderson backwater (RM 777; 11 acres) and Ponca backwater (RM 754) (SDGFP 2010). SDGFP (2010) did not indicate acreages for the Green Island/Yankton backwater or Ponca backwater. Both the Gunderson and Ponca backwaters were built in relation to nearby ESH projects (Yager, pers. comm., 2011).

Jacobson et al. (2004) studied four side-channel chutes (Cranberry Bend, Lisbon Bottom, Hamburg Bend, and North Overton Bottoms) on the lower channelized Missouri River (downstream from Gavins Point reach), with each of the chutes showing evidence of erosion and deposition. The Cranberry Bend side-channel chute has existed for over 40 years and continues to maintain natural form and process. Extreme flood events from 1993-1996 created the Lisbon side-channel chute and this chute has evolved with minimal engineering. The Hamburg chute, constructed in 1996, shows evidence of lateral movement and construction of a floodplain. The North Overton Bottoms chute is the newest chute and appears to be extremely stable despite two floods that included an accumulation of large woody-debris jams (Jacobson et al. 2004).

<u>Presence of Exotic and Invasive Species</u>

Asian Carp

Asian carp found in the Lower Missouri River (LMOR) and Mississippi River systems include bighead carp (*Hypophthalmichthys nobilis)*, silver carp (*H. molitrix*), and grass carp (*Ctenopharyngodon idella*). Bighead and silver carp exist within the 59-mile reach and are estimated to be the most abundant large fish (>2.25 kg) in the LMOR, with populations in the thousands (Chapman, pers. comm., 2011). Asian carp spawn in the 59-mile reach and in its tributaries, such as the James River (Chapman, pers. comm., 2011) In 2004, only six grass carp were identified in the 59-mile reach (Weeks et al. 2005), with very few observations since 2004 (Chapman, pers. comm., 2011). It should be noted that some of these nonnative fishes are important recreational species. However, these nonnative recreational species can still alter the native fish community.

Gavins Point Dam has prevented the spread of these exotic invasive species into upper reaches of the Missouri River (Chapman, pers. comm., 2011; USFWS 2003). Asian carp are incapable of traveling upstream over large dams and thus have not yet been found in large reservoirs on the Missouri River (Chapman, pers. comm., 2011).

Asian carp are a risk to the productivity of the Missouri River's food web because of their population size and their plankton and detritus feeding ability (USFWS 2003; Weeks et al. 2005). Bighead and silver carp are highly invasive species and feed on zooplankton and phytoplankton. Grass carp consume vast quantities of large aquatic plants and were brought to North America for biological control of pond weeds (Weeks et al. 2005). Bighead and silver carp compete with native filter feeding fish and most fish in the early stages that feed on zooplankton (CERC 2003). Silver carp also pose a health hazard risk as this species is known for jumping many feet in the air and sometimes striking boat passengers (Chapman, pers. comm., 2011).

Zebra Mussel

The zebra mussel (*Dreissena polymorpha)* is an exotic invertebrate species from Europe that was first discovered in North America in 1988 and in the Missouri River basin in 1999 (Weeks et al. 2005). This species spread from the Great Lakes basin through the Illinois and Hudson Rivers to the Mississippi River by 1992. Zebra mussels are known for their ability to accumulate on wetted surfaces, sometimes referred to as biofouling. Zebra mussels can disperse in the water column in their larval stage or in their adult stage by attaching to boat hulls, engines, aquatic macrophytes, or other surfaces. Like the Asian carp, zebra mussels feed on zooplankton and phytoplankton and compete with other filter feeding organisms (CERC 2003). Zebra mussels also impact native mussels by interfering with feeding, growth, locomotion, respiration, and reproduction (Weeks et al. 2005). The potential introduction of zebra mussels poses a significant risk to native mussels, as well as the entire ecosystem. To date, no zebra mussels have colonized MNRR (Yager, pers.

comm., 2011). Zebra mussel veligers (larvae) were independently confirmed in 2003; however, despite increased sampling efforts, neither veligers nor adults have been detected since (Yager, pers. comm., 2011).

Terrestrial Invasive Species
To establish baseline plant species data in 2004, Kottas and Stubbendieck (2005) performed a preliminary qualitative assessment of four parks within MNRR: Karl Mundt National Wildlife Refuge, Niobrara State Park, Frost Game Production Area, and Bow Creek Bottomland. Invasive species were included as part of their study. Kottas and Stubbendieck (2005) indicated competitive expansion of eastern red cedar at all the park locations within MNRR, particularly at Niobrara State Park and Frost Game Production Area. The following invasive species were identified in MNRR: Canada thistle, leafy spurge, and purple loosestrife. According to Kottas and Stubbendieck (2005), these species have the potential to overtake much of the area if left unchecked. GPS locations of these noxious weeds and species of concern are provided in Kottas and Stubbendieck (2005).

Threats and Stressor Factors

Bank Stabilization
Most streambank stabilization efforts are intended to protect infrastructure and other important investments by using riprap, gabions, or concrete linings. Fischenich (2003) divides riprap stabilization into four basic categories: (1) Armor techniques that include stone placement along the bank face preventing erosion from the river current; (2) Flow deflection structures that extend outward forcing higher velocity flows away from the bank; (3) Slope stabilization measures that include large stone placement at the toe of the bank slope preventing translational or rotational failures; and (4) Energy reduction measures include a wide array of techniques for reducing the energy gradient of the river.

Bank stabilization affects riparian areas by increasing water velocity and inhibiting vegetation re-establishment. Additionally, bank stabilization impacts channel width, natural bank substrate, channel bank sediment exchanges, and access to side channels, which are necessary to sustain a range of aquatic habitats (Florsheim et al. 2008). Bank stabilization features in MNRR currently exist on approximately 33-40% of the 59-mile reach and 12.4% of the 39-mile reach (NPS 2007).

Florsheim et al. (2008) discusses the geomorphic bank erosion process and document the cumulative effect of river bank stabilization on riparian function and habitat for riparian species. Florsheim et al. (2008) also identifies and summarizes the main geomorphic and ecological effects of channel bank infrastructure, the potential habitat or ecosystem services lost, and examples of organisms affected (Table 47).

Table 47. Effects of channel bank infrastructure to control bank erosion (Florsheim et al. 2008).

Geomorphic and Ecological Attribute	Influenced Habitat or Ecosystem	Examples of Organisms Affected
A) Loss of sediment source:		
Supply	Downstream sandbars as resting habitat for migrating birds	Whooping Crane (*Grus americana*)
Grain size	Coarse-grained substrate for attachment and interstitial space for hiding from predators	Macroinvertebrates (e.g., mayflies [Ephemeroptera], caddisflies [Trichoptera], and stoneflies [Plecoptera])
B) Loss of geomorphic process:		
Migration	Newly scoured or deposited surfaces	Riparian trees (e.g., cottonwood , willow, alder [*Alnus*])
Widening	Adjustment necessary for incised channel to evolve toward equilibrium with floodplain at elevation to support riparian plants	Riparian trees (see above)
C) Loss of bank structure:		
Unconsolidated sediment	Vertical banks for wildlife burrowing and nesting	Bank Swallow (*Riparia riparia*)
	Retention of nutrients and filter of pollutants	Macroinvetebrates (see above)
Natural biotic and abiotic components of land-water margin	Shoreline microhabitat: soft sediment or burrows, emergent vegetation to cling to; underwater plants, snags, roots protruding from bank	Shore-dwelling insects (e.g., *Neocurtilla*); Macroinvertebrates (see above)
Roughness and irregularity of land water margin	Variation in near-bank flow velocity, refugia during storm flows	Overwintering fish, macroinvetebrates (see above)
Undercut banks	Protection from predators	California shrimp (*Syncaris pacifica*), juvenile fish (e.g., Coho salmon [*Oncorhynchus kisutch*])

Table 47. Effects of channel bank infrastructure to control bank erosion (Florsheim et al. 2008). (continued)

Geomorphic and Ecological Attribute	Influenced Habitat or Ecosystem	Examples of organisms affected
D) Loss of riparian forest:		
Stream-side riparian ecosystem willow and cottonwood forests	Complex riparian vegetation, areas for wildlife: bird breeding, nesting, and safety from predators; probing for insects under tree bark; migration corridor, and/or dispersal route; and plants structure for vines	Birds (e.g., willow flycatcher [*Empidonax traillii extimus*], Gila woodpecker [*Melanerpes uropygialis*], western yellow-billed cuckoo [*Coccyzus americanus occidentalis*]), reptiles (e.g., riparian lizard [*Scelopo rus occidentalis*]), semiaquatic mammals (e.g., river otter [*Lontra canadensis*]), macroinvertebratres, climbing vines (e.g., river-bank grape [*Vitis riparia*])
Overhanging branches, leaves	Shade, organic material, fish food	Fish, macroinvetebrates (nymph and adult stages)
Large woody debris	Reduction in pool complexity and depth, loss of attachment sites	Fish, macroinvertebrates (see above)

Florsheim et al. (2008) suggests the placement of each new structure may shift bank erosion to a new location, causing a continuous cycle that requires new bank stabilization controls downstream. Florsheim et al. (2008) also discussed four alternative solutions to address bank erosion issues: (1) Dynamic-process conservation areas, which define zones with sufficient area to accommodate bank erosion along with other dynamic processes such as flooding; (2) Erosion easements, which would be placed on private or public riparian land to allow bank erosion processes to operate; (3) Elimination of direct stressors caused by human activities or land use such as placing fences on shore lines to keep cattle from damaging stream banks; and (4) Nonstructural approaches that would include planting native vegetation instead of structures containing hard rocks, concrete, or construction material.

There are requests for new stabilization projects and these requests will likely continue into the future (Macy, pers. comm., 2011).

Dam Operations – Flow Regulation

Peak Flows: Current dam operations have reduced peak flows compared to historical conditions (see Flow Regime, section 4.3 of this document). Reduced peak flows limit fluvial disturbance intensity, frequency, and duration (Opperman et al. 2010) that provide environmental heterogeneity and high levels of ecosystem biodiversity and production (Stanford et al. 1996).

Gavins Point Dam releases during the high runoff period during 1995-1997 created substantial amounts of bare sandbar habitat in 1998, equaling the amount of sandbars per kilometer and exceeding the total sandbar area found in 1941 pre-dam orthophotography (Elliot and Jacobson

2006). Aside from the 1995-1997 period, typical peak flow dam releases do not sustain pre-dam sand bar habitat (Elliot and Jacobson 2006).

Peak flows no longer inundate the floodplain, nor recharge oxbows lakes, wetlands, ephemeral ponds, backwaters and chutes compared to the historical extent, both as a result of channel incision (see Erosional and Depositional Processes, section 4.2 of this document) and lowered peak flow discharge (see Flow Regime, section 4.3 of this document). Peak flows are capable of pulsing nutrient-rich waters laterally into backwaters and onto floodplains (Stanford et al. 1996). Lowered peak flows have likely affected nutrient cycling through backwater and floodplain habitats (Macy, pers. comm., 2011).

Peak flow reductions are one cause of lower bank erosion rates (see Erosional and Depositional Processes, section 4.2 of this document) compared to historical rates. Large floods are capable of eroding extensive sections of floodplain and stream banks and delivering large volumes of wood to the stream channel (Benda et al. 2003). Although Elliot and Jacobson (2006) determined that large woody debris was common in the MNRR reaches, Moody et al. (2003) report that Lewis and Clark likely encountered a river ―crowded with snags".

Current dam operations meet the assigned purpose (see Pick-Sloan Flood Control Act 1944) of flood control through reservoir storage and managed releases from dams on the Missouri River. The managed releases from Fort Randall and Gavins Point Dams will continue to limit peak flows to prevent downstream flooding. The reduced peak flows and lower levels of fluvial disturbance will continue under the current management scenario; aquatic and terrestrial habitats within the river corridor will be shrunken, simplified versions of their former condition in the unregulated Missouri River (Graf 2006). Managed releases at the upper level of post-dam flows, such as those occurring from 1995-1997, have the ability to create aquatic and terrestrial habitat within the regulated river.

Low Flows: The Flow Regime Section (4.3 of this document) discusses changes in low flow discharge, timing and duration for the post-dam period compared to the pre-dam period. The post-dam period has higher low flows, shorter duration and the timing has changed from late summer through March to late fall through March.

Higher low flow levels reduce aquatic habitat (sandbars and ATTZ) because of increased stage within the river channel. The effects of higher low flows are described by Galat and Lipkin (2000): they indicate that for the lower Missouri River (including the MNRR 59-mile reach), sand islands and shallow in-channel habitats used by riverine fishes for spawning and nursery are flooded or reduced in area during their reproductive season and these circumstances may also affect birds and turtles; they identify that protracted summer-fall high flows prevent germination of early-successional tree species and moist-soil annual vegetation; and they attribute the decline in the Missouri River's native fluvial fishes to the protracted summer-fall high flows and in-channel habitat loss.

Current dam operations meet the assigned purpose (see Pick-Sloan Flood Control Act 1944) of navigation through reservoir storage and managed releases from dams on the Missouri River. The releases from dams needed to sustain downstream navigation will continue under the current management scenario with higher minimum flows that affect sandbar exposure and shallow water habitat.

Temporal Flow Conditions

The Flow Regime Section (4.3 of this document) discusses changes in the duration and timing of both peak flows and low flows. The effects of the protracted summer-fall high flows (compared to pre-dam conditions) are addressed above. The effects of post-dam peak flow duration and timing on aquatic and terrestrial habitat may not be significant compared to the loss of geomorphologically-effective flood events.

Human Development

Human development includes activities that modify vegetation and land cover within the river corridor. The former floodplain of the Missouri River has towns, farms, roads, and cropland. Human development includes: dam construction that created reservoirs, modified stream flow affecting channel morphology and floodplain connectivity; a reduction in riparian forests; and conversion of forest, grass/shrublands to cropland. Most human development activities affecting aquatic and terrestrial habitat are either residual from pre-dam conditions (settlements, land cover conversion) or modifications since dam construction such as residential recreational developments, bank stabilization, aquifer mining and some land cover conversions. The areal extent of most natural pre-dam aquatic and terrestrial habitats has decreased, although some may have increased (such as stream bank area) due to the incising channel.

Loss of Natural Disturbance Regime

As discussed above, geomorphologically-effective floods do not occur under current operations at Fort Randall and Gavins Point Dams. Humans have modified the intensity and frequency of disturbance events by dam construction and operation, resulting in suppression or permanent loss of environmental heterogeneity and biodiversity and reducing the productivity of biotic resources (Stanford et al. 1996). This is not to say that dynamic channel processes no longer occur; currently in the MNRR, stream banks erode, large wood is delivered to the stream channel, sandbars and islands are created and eroded, and humans are creating backwater, sand bar, and shallow water aquatic habitat. The spatial and temporal level of fluvial disturbance is reduced by flow regulation and the regulated river is a ―shrunken, simplified version of [the] former unregulated river" (Graf 2006).

Climatic Patterns and temporal flow conditions (seasonality and duration)

According to Thorpe et al. (2006), climatic conditions control hydrogeomorphic patch characteristics by influencing runoff (including water, sediment, organic matter, and nutrients), riparian/floodplain vegetation, and aquatic vegetation. Some areas that may be affected by climate conditions are areas with constricted, braided or anabranch channels, extensive slackwater areas, and broad floodplains (Thorp et al. 2006).

Releases from dams are based on reservoir inflow which is driven by climate. High inflows can fill drought reduced reservoirs or fill reservoirs to flood pool levels. Releases from dams are lower during times of drought and higher when reservoirs are full (Macy, pers. comm., 2011).

The effect of climate patterns and temporal flow conditions on aquatic and terrestrial habitats has not yet been studied within MNRR.

Data Needs/Gaps

- Additional vegetation monitoring is needed. To resolve this, NGPN and MNRR are establishing long-term vegetation monitoring plans.
- There are no studies regarding climate patterns and temporal variations effects on aquatic and terrestrial habitats in the MNRR area.
- Other than Dixon et al. 2010 (for cottonwoods), there are no studies specifically examining the diversity of vegetation seral stages within MNRR.

Overall Condition

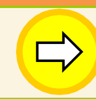
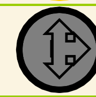
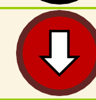
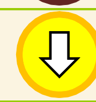
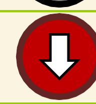
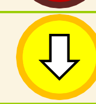
Measures	*Reference Condition*	*Condition*
Distribution and abundance of diverse native plant communities	Pre-dam	
Amount of vegetation in diverse seral stages	Pre-dam	
Amount of vegetated island and sandbar habitat	Pre-dam	
Wetland distribution, type, and location	Pre-dam	
Depth and substrate diversity	Pre-dam	
Amount of chutes, backwater, and shallow-water habitat	Pre-dam	
Presence of exotics and invasives	Pre-exotics and invasive	

Figure 37. Aquatic and Terrestrial Habitats condition graphic.

Broad changes have occurred in plant communities (forest, woodland, shrubland, low riparian herb, grassland, marsh, cropland, and urban grasses) from 1892 to 2006 for the 39-mile and 59-mile reaches of MNRR. The combination of conversion to cropland, flow regulation, and bank stabilization have impacted natural riparian vegetation succession and reduced aquatic habitats including off-channel (backwater) habitats of MNRR (Yager 2010).

Distribution and Abundance of Diverse Native Plant Communities
The condition of distribution and abundance of diverse native plant communities is of moderate concern, largely due to the significant decrease in forested area (Figure 37). The forested area in the Fort Randall to Niobrara River reach declined by 18% (Dixon et al. 2010). The forested area below the Niobrara River declined by 95% due to aggradation of sediment and the Lewis and Clark Reservoir (Dixon et al. 2010). The 45% decline in forested area in the Gavins Point reach was due to conversion of native species to agricultural cropland from 1892 to 2006 (Dixon et al.

2010). Agriculture increased from less than one percent of the floodplain in 1892 to more than 76 % today (Dixon et al. 2010).

Amount of Vegetation in Diverse Seral Stages
The amount of vegetation in diverse seral stages within MNRR has only been documented for cottonwoods. The condition of this measure cannot be determined at this time.

Amount of Island and Sandbar Habitat
Island and sandbar habitat is of significant concern, due to the decrease in extent of this habitat in MNRR. Sandbar habitat declined by over 50% in MNRR from the 1890s to the 1950s (Figure 31, Figure 33). Dixon et al. (2010) data suggests that almost all natural sandbars in the Fort Randall Dam to Lewis and Clark delta reach have been depleted. Elliot and Jacobson (2006) point out that, in the delta reach, sandbars are smaller than in the free-flowing reach and are only present in the former Missouri River thalweg.

Elliot and Jacobson (2006) determined that in the 59-mile district island bars decreased by 58% and sandbars by 73% from 1941 to 2004. The total number of islands (Table 42) increased from 46 islands (pre-dam, 1941) to 145 islands (post-dam, 2006). However, total bar area decreased from 1,804 (pre-dam, 1941) to 492 (post-dam, 2006) (58% decrease), which indicates islands are much smaller today than prior to dam construction.

Wetland Distribution, Type, and Location
The current wetland distribution, type, and location are of moderate concern. Dixon et al. (2010) report wetlands increasing 10-25% in the Fort Randall to Niobrara River reach, primarily in relation to the developing delta near the mouth of the Niobrara River. However, the water table has lowered as a result of channel incision and agricultural practices such as installing drain tile to facilitate crop production by draining wetlands (Macy, pers. comm., 2011).

Depth and Substrate Diversity
Overall condition for this measure is unknown. Recent sturgeon habitat assessments illustrate the importance of depth and substrate diversity. Pallid sturgeon deposit sinking eggs that adhere to hard substrates (Jacobson and Galat 2008) and mussels rely on stable rock, pebble, and sand substrate to establish mussel beds; however, flow regulation blocks much of the substrate from moving downstream. Jacobson and Galat (2008) hypothesize that spring-pulse flows could increase available hard substrate and ultimately increase pallid sturgeon reproductive success. Currently, tributaries such as the James River provide an important substrate load to the main channel of the Missouri River (DeLonay, pers. comm., 2011).

Amount of Chutes, Backwater, and Shallow-Water Habitat
The condition for this measure is of significant concern. From 1941 to 2008, total area of off-channel features has decreased by 70%, total area of side channels has decreased by 77%, and total area of natural backwaters has increased by 41% (Table 46, Figure 36) (Yager 2010). However, the backwaters have only increased as a result of changed geomorphology and flow regime of the Missouri River (Yager, pers. comm., 2011). In addition, backwaters are being drained due to surrounding land use and to a lowered water table due to channel incision (Yager 2010). Subsequently, the amount of chutes, SWH, and backwaters is of significant concern. In 2004, USACE began constructing new chutes and backwaters to increase the amount of SWH.

The newly constructed backwaters include Green Island/Yankton backwater (RM 806), Gunderson backwater (RM 777, 11 acres) and Ponca backwater (RM 754). Both the Gunderson and Ponca backwaters were built in relation to nearby ESH projects (SDGFP 2010; Yager, pers. comm., 2011).

Presence of Exotic and Invasive Species

The presence of exotic and invasive species is of moderate concern. Recent studies on the LMOR indicate that populations and number of invasive species are increasing. In the 59-mile reach, various species of Asian carp are present with population estimates of silver and big head carp in the thousands (USFWS 2003; Weeks et al. 2005; Chapman, pers. comm., 2011). However, no zebra mussels have colonized MNRR (Yager, pers. comm., 2011). Along the river, invasive plants (e.g., eastern red cedar, Canada thistle, leafy spurge, etc.) are altering isolated areas. Kottas and Stubbendieck (2005) indicate that, if left unchecked, invasive terrestrial plants could take control of many areas in MNRR. Currently, MNRR and other stakeholders are examining 198 plots to determine vegetation composition (Stevens et al. 2010).

Sources of Expertise

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4.5 Cottonwood

Description

Historically, cottonwood forests were abundant within the floodplain of the Missouri River (Bragg and Tatschl 1977, Johnson 1992, Dixon et al. 2010). During the 1950s and 1960s, flow regulation by Missouri River dams changed the flow regime and subsequently affected cottonwood regeneration, along with broad landscape-scale configuration of vegetation and biodiversity (Johnson et al. 1976, Rood and Mahoney 1990, Johnson 1992, and Miller et al. 1995, NRC 2002). This flow regulation reduced floods that once maintained the ecological health of the cottonwood forests on the Missouri River (Johnson 1992, NRC 2002, Dixon et al. 2010), and led to long-term changes. Flow regulation reduces peaks in Missouri River discharge, preventing high enough flow to allow lateral meandering of the channel needed to create recruitment sites for pioneer forest communities dominated by cottonwoods and willows (Weeks et al. 2005). The impoundment of the Missouri has caused sediments carried by the Niobrara River and other tributaries such as Verdigre Creek to aggragate, forming a delta and increasing groundwater elevations which may reduce cottonwood survival and future recruitment in the area around the Niobrara/Missouri River confluence (Weeks et al. 2005). The Missouri River flow alterations continue to present implications for the trajectories of change in floodplain forest structure, composition, and related biological diversity in the future (Scott et al. 2010).

While cottonwood forests persist within MNRR, natural regeneration has largely ceased in the Missouri River floodplain since the construction of the Missouri River Mainstem Reservoir System and Bank Stabilization and Navigation Project (MRRP 2010). In addition, existing cottonwood and willow stands are changing in to later successional species compositions, including green ash, American elm (*Ulmus americana*), and box elder (Johnson 1992) (Photo 2). The lack of cottonwood regeneration, a reduction in the area of forests (e.g., total forest area in the 1890s was reduced by approximately 50% in the 59-mile district by 2006), potential reductions in cottonwood vigor, and increased mortality in mature forests are important concerns for the future of cottonwood in MNRR and throughout the Missouri River.

Photo 2. Young trees along the Missouri River bank (GeoSpatial Services, 2009).

A diversity of plant and wildlife species depend on cottonwood stands for habitat (Dixon et al. 2010, Benson 2011). The protected bald eagle specifically depends on large, mature cottonwood trees for nesting and roosting (USACE 2010). Fallen cottonwood trees in the river and backwaters create habitat for a variety of fish and macroinvertebrates (USACE 2010,. In addition, a diversity of plants occur along the Missouri

River; Dixon et al. (2010) documented more than 530 plant species in a study of cottonwood and non-cottonwood floodplain forests and shrublands covering a total of 1,496 km (930 mi) of the Missouri River. The authors examined 54 stands (41 cottonwood) in segment 8 (along the 39-mile district's Missouri River floodplain) and 59 stands (41 cottonwood) in segment 10 (along the 59-mile district's Missouri River floodplain). Examining both cottonwood and non-cottonwood woody riparian sites, the authors found 177 species in segment 8 and 208 species in segment 10, for a total of 248 species across both segments.

Measures

- Cottonwood habitat extent (total area and area by river mile (RM) of cottonwood patch types).
- Cottonwood age (stand age composition across the landscape provides a measure of regeneration).

Reference Conditions/Values

Cottonwood conditions as they were before the construction of Gavins Point and Fort Randall Dams act as the reference for this assessment. Changes in relative proportions of the landscape occupied by riparian forests and current stand ages help create a picture of historic cottonwood conditions along the Missouri River. Johnson (1992) calculated the relative proportions of overall forest types (not cottonwood exclusively) by age categories in a study of the Missouri River on the Garrison Reach in North Dakota (Table 48). Johnson (1992) created a model that simulated pre-dam and post-dam alluvium and its relationship to past, present, and future proportions of forest types on the Missouri River floodplain; notice the proportions of the various stand ages (e.g., equilibrium, transitional, pioneer-old, pioneer-young) (Figure 38). Johnson (1992) suggests that a mix of young, transitional, and equilibrium forest stands, driven by the natural processes of river flooding and channel migration creates the highest biodiversity in the riparian ecosystem.

Table 48. Changes in the area of forest types on the Missouri River (Garrison reach) floodplain since settlement. Numbers are proportions of total forest area (Johnson 1992).

		Percentage of Coverage	
Category	**Time Period**	**Pre-settlement**	**Post Settlement (1979)**
Pioneer Forest (young)	<40 years of age	47	6
Pioneer Forest (old)	40-80 years of age	25	23
Transitional Forest	80-150 years of age	21	48
Equilibrium Forest	>150 years of age	7	23

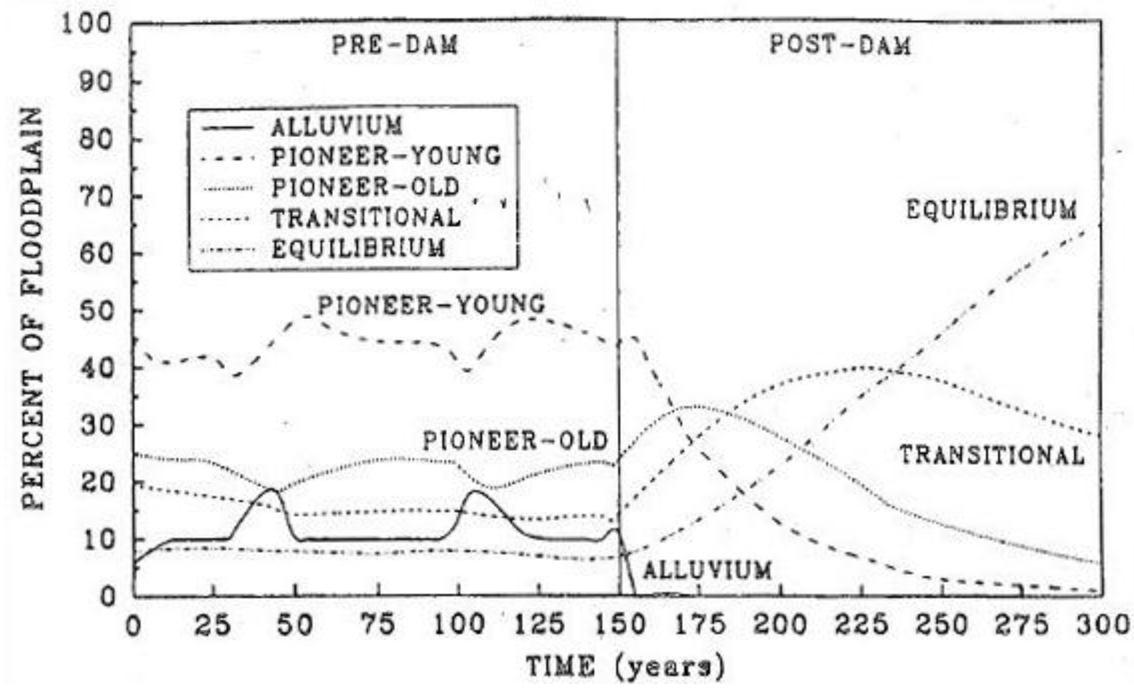


Figure 38. Simulated forest type proportions for the Missouri River floodplain during pre-settlement (pre-dam) and after closure of Garrison Dam (post-dam). Erosional/deposition (i.e., meandering) rates were changed in the model at time = 150 years (ca. 1953). Reproduced from Johnson (1992).

Flow alteration on the Missouri River and a decline in the meandering rate reduced the amount of new alluvium produced for cottonwood and willow regeneration and increased the succession ages of established forest due to an extension of their life-spans (Johnson 1992). Likewise, peak flows (flooding) once drove channel migration, eroding banks, and vegetation on the outer bends of the river, which provided a sediment source for the deposition of new alluvium on point bars (sandbars on the inside of downstream bends). Now the lack of lateral channel migration and deposition of sediment on point bars reduces the opportunity for cottonwood regeneration. In addition, the timing of the peak flows plays a role in successful establishment of cottonwood seedlings; the trees release their seeds during an approximately four to six week period (Mahoney and Rood 1993); then wind and water dispersal usually follows the declining side of seasonal peak flow events, when more alluvium is exposed (USACE 2010). Johnson (1992) presents a schematic for the successional pattern of cottonwood and willow habitat, identifying that new alluvium is critical to the regeneration of cottonwood/willow habitat (Figure 39).

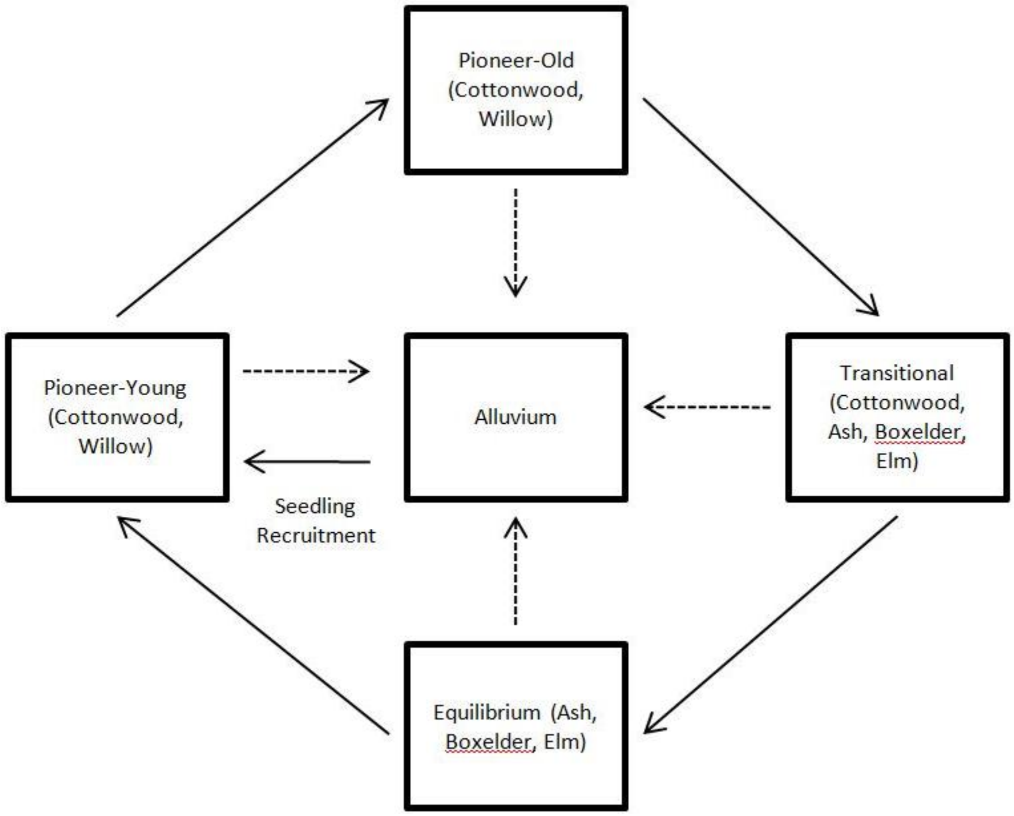


Figure 39. Schematic of the vegetation simulation model. Dashed arrows represent erosion losses to the alluvium compartment and solid arrows represent succession pathways among forest types. Reproduced from Johnson (1992).

Mahoney and Rood (1998) developed the –recruitment box” model that illustrates the relationship between river stage patterns and cottonwood seedling establishment, describing sediment bar elevation and timing of river stage patterns that allow for cottonwood seedlings to last through at least one season. Dixon and Turner (2006) modified the recruitment box concept to develop a model that projected first year seedling establishment for several different riparian tree species along the Wisconsin River (Figure 40). Information about the important variables (in smaller text on the right side of the diagram) is to be used to model cottonwood succession as a part of the USACE Cottonwood Recovery Plan (USACE 2010). To date, there has not been any formal work to parameterize a recruitment box model for the Missouri River nor has data been collected for this. This type of information may help determine potential parameters in an effort to naturalize the flow regime on the Missouri River.

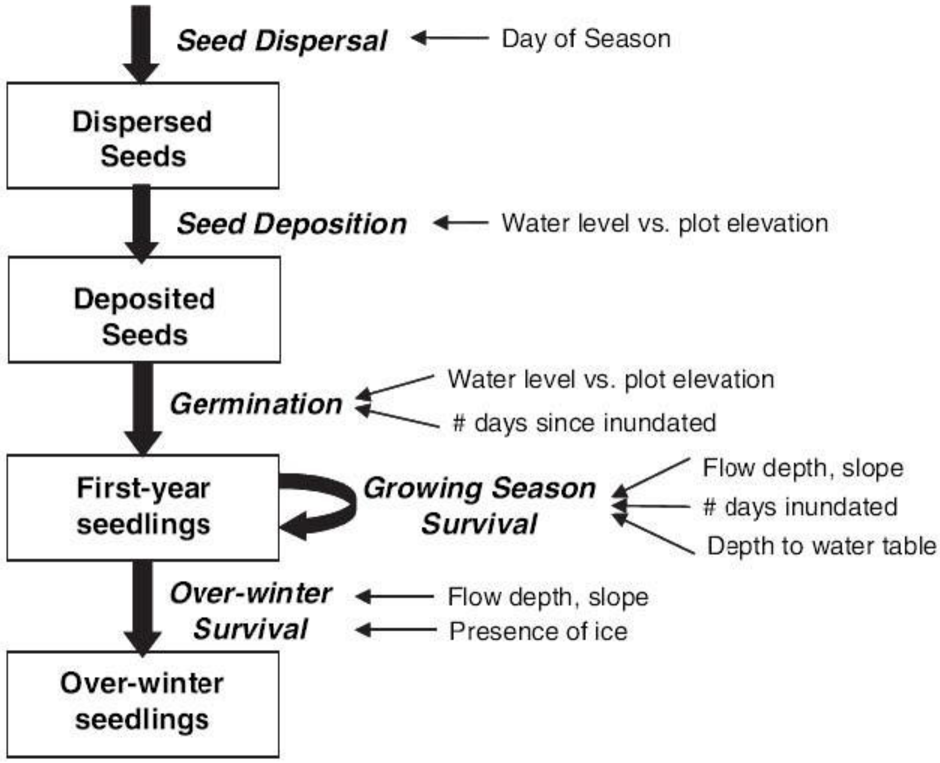


Figure 40. Modified recruitment box model structure and important variables (e.g., day of season, water level vs. plot elevation, etc.). From Dixon and Turner (2006).

Data and Methods

Dixon et al. (2010) conducted a study examining the current (2006) and historic (1892 and mid-1950s) extent, current age distribution, and plant species composition of plains cottonwood and non-cottonwood riparian stands along the Missouri River. This study provides evidence of the observations made by Johnson (1992) on a different segment of the Missouri River and information for both reference and current conditions in this assessment. Dixon et al. (2010) interpreted and digitized land cover from 1892 Missouri River Commission maps published in 1895, 1950s geo-rectified aerial photography, and 2006 NAIP orthophotography for multiple Missouri River segments covering a total of 930 river miles. The authors also mapped stand age classes (old growth >114 years, mature 50 to 114 years, transitional 25 to 50 years, poles 10 to 25 years, and saplings <10 years) of the riparian shrublands, woodlands, and forests (both cottonwood and non-cottonwood). Note the age classes did not map precisely onto the split between shrubs and trees; some pole-aged stands may have been classified as forest and some as shrubs. Also, the stand ages used from Dixon et al.(2010) do not match the successional stages identified in Figure 39. However, M. Dixon (pers. comm., 2010) estimates the age ranges of each successional stage in Johnson (1992) and characterizes the probable relationship to stand ages mapped in Dixon et al. (2010) (Table 49). See Appendix C for descriptions of land cover classifications used in the Dixon et al. (2010) study for each of the major categories (e.g., shrublands, woodlands, and forests).

Table 49. Johnson (1992) successional stages compared to cottonwood age classes mapped in Dixon et al. (2010). The age ranges for Johnson (1992) and the relationship to the age classes mapped are estimates proposed by M. Dixon (pers. comm., 2011).

Johnson (1992) Successional Stages	Age Ranges	Dixon et al. (2010) Stand Age Classes	Age Ranges
Pioneer Young	1-40 yrs	All of the Sapling Cottonwood	<10 yrs
		All of the Pole Cottonwood	10-25 yrs
		Most of the Intermediate Cottonwood	25-50 yrs
Pioneer Old	40-80 yrs	Some of the Intermediate Cottonwood	25-50 yrs
		Most of the Mature Cottonwood	50-114 yrs
Transitional	80-120 yrs	Some of the Mature Cottonwood	50-115 yrs
		All of the“Old Growth Cottonwood	>114 yrs
Equilibrium	Older (e.g., pre-dam non-cottonwood	Not a match to cottonwood stands	

When describing the overall condition of cottonwoods in the Missouri River floodplain, segments 8 and 10 examined by USACE (2010) and Dixon et al. (2010) are used here as they relate to the 39-mile district and 59-mile districts, respectively. Data were queried from a geodatabase accompanying Dixon et al. (2010), providing data for tables, figures, and plates (maps). Generally the boundaries of the segments follow the historic floodplain of the Missouri River, although some relatively small upland (non-historic floodplain) areas were added to segment 10 in Dixon et al. (2010). Conversely, in a few areas the study boundaries do not extend as far out as what may be considered the outside boundary of the historic floodplain; study extents were limited by the extent of the 1890s Missouri River Commission maps. Dixon et al. (2010) data do not cover the Niobrara River and Verdigre Creek areas of the 39-mile district, and there are some areas of the 59-mile district (e.g., Bow Creek area) outside of the USACE and Dixon et al. (2010) study areas (Figure 41). However, these segments characterize the general pattern and conditions in the surrounding historic Missouri River floodplains of both MNRR districts. Only data within the boundaries of MNRR were used to report cottonwood habitat specific to each district (39-mile and 59-mile) within MNRR; otherwise it is noted that the original data (i.e., segment 8 or 10) from Dixon et al. (2010) were used.

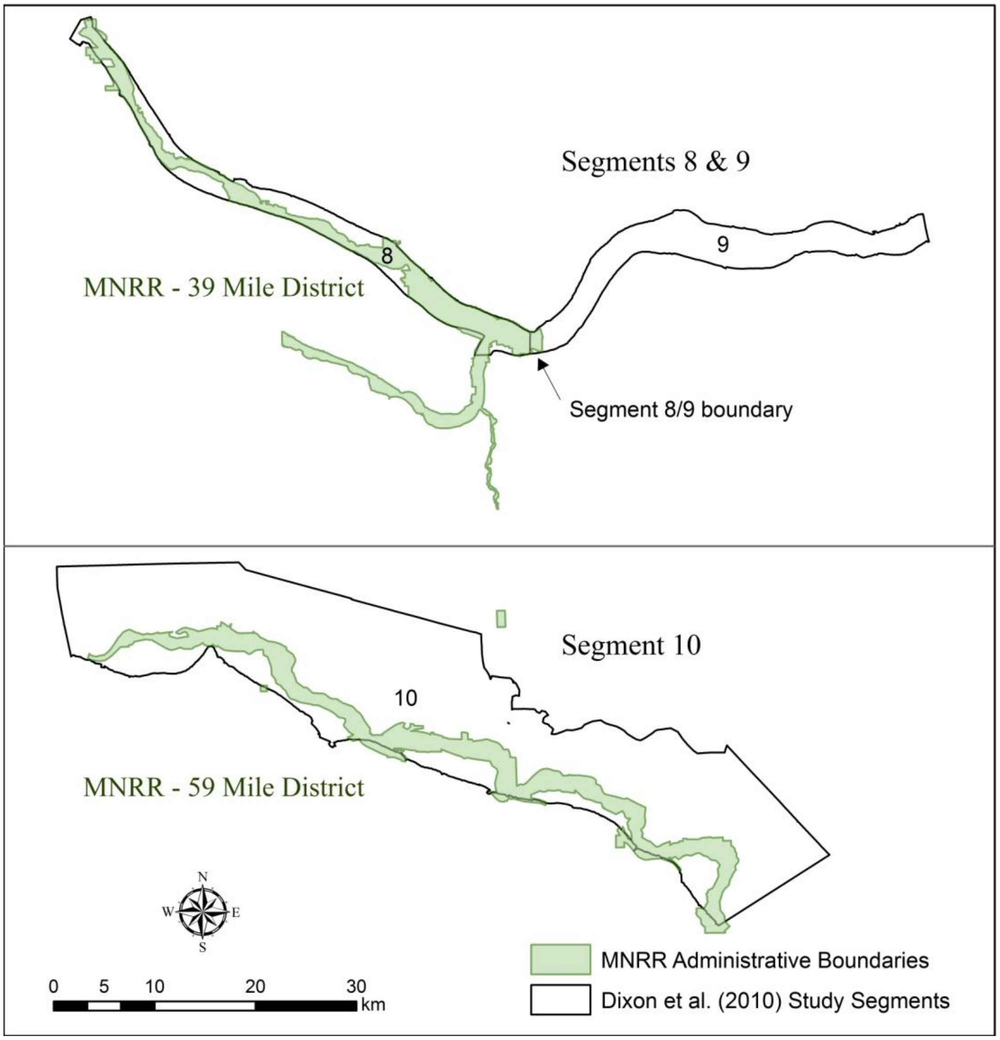


Figure 41. Relationship between the MNRR administrative boundaries and study area boundaries (segments) in Dixon et al. (2010).

In order to characterize stand structure and species composition, Dixon et al. (2010) determined stand ages by viewing historic maps and aerial photography and then by sampling stands within each age class. The authors sampled a total of 59 stands in segment 10 (along the 59-mile district's Missouri River historic floodplain or Gavins Point Dam to Ponca, Nebraska). This included several stand age categories, sampling the following number of stands in each stand age category: 23 stands of >25 yr. old cottonwood, 11 stands of sapling and pole (< 25 yrs. old) cottonwood, seven stands of disturbed cottonwood (five >25 yrs old and two pole and sampling age), 13 stands >25 yr. old non-cottonwood, and five stands of sapling and pole (<25 yrs. old) non-cottonwood. ―Disturbed cottonwood" stands are those with an anthropogenically altered understory or overstory, as from heavy grazing, selective clearing, or mowing. In segment 8 (along the 39-mile district's Missouri River historic floodplain or Fort Randall Dam to Springfield, SD) Dixon et al. (2010) sampled 54 total stands (21 stands >25 yr. old cottonwood, 12 stands of sapling and pole cottonwood, four stands of disturbed cottonwood, seven stands of >25 yr. old non-cottonwood, six stands of sapling and pole non-cottonwood, and four stands of planted cottonwood).

Current Condition and Trend

Cottonwood Habitat Extent

Across all eight study segments in Dixon et al. (2010), there are approximately 75,632 ha (186,890 acres) of cottonwood patch types (forests, woodlands, and shrublands). Segment 8 in Dixon et al. (2010) (the historic Missouri River floodplain along the 39-mile district of MNRR) contains about 4% of the total cottonwood patch types in the entire study area. Segment 10 (along the 59-mile district of MNRR) contains approximately 9% of the entire study area's remaining cottonwood patch types.

39-mile district

Forested areas changed less from 1892 to present in segment 8 (along the Missouri River section of the 39-mile district) compared with the 59-mile district, with a 16% decline of relative forest area. This may have been due, in part, to the floodplain being more constrained by the bluffs than in segment 10 and therefore less susceptible to human land conversion, especially conversion to agriculture. Since 1892, the total grassland area declined by 96% while total area of cropland increased. Relative to other major land cover classes, grassland decreased approximately 34% and cropland increased 30% from 1892 to 2006. Figure 42 displays overall relative changes in percent cover of major land cover classes from 1892, 1950s, 2006/2008 (Dixon et al. 2010).

Beyond conversion of lands to cropland, other factors affecting the changes in vegetation from 1892 to 2006 are the aggradation and degradation that has occurred since the installation of the Gavins Point and Fort Randall Dams. The first one-third of the upstream river in segment 8 has degraded and the lower half of segment 8 and the delta area of segment 9 have significantly aggraded. Aggraded areas exhibit higher surface water elevations, flooding of some vegetated areas, and increasing ground water elevations. An example of this occurs at the confluence of the Niobrara and Missouri Rivers; Dixon et al. (2010) notes that because of rising water levels, the town of Niobrara was relocated to higher ground. Notice the increase in the relative area of the river (water) in the study area in Figure 42. Degraded sections can allow for disconnect from the riparian areas (floodplain) and the river. This allows areas that were shrubs to succeed to forests and, depending on their position in the floodplain, transition eventually to equilibrium forests.

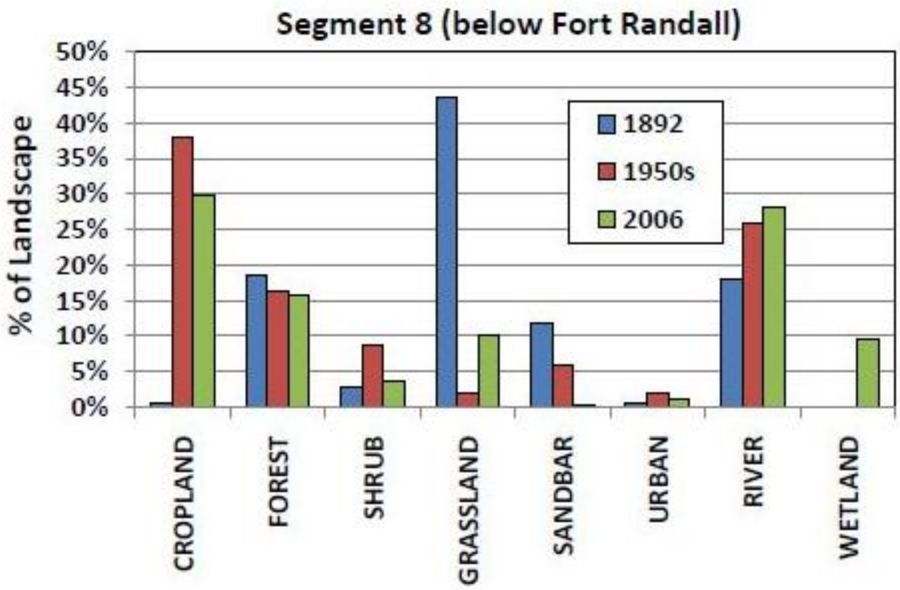


Figure 42. Historic changes in the relative coverage of major land cover classes on segment 8 (Fort Randall Dam to downstream of Niobrara delta, 39-mile district's historic Missouri River floodplain) (reproduced from Dixon et al. 2010).

The current (2006) extent of cottonwood riparian habitats in segment 8 of Dixon et al. (2010) is approximately 2,430 ha (6,002 acres) or 17% of the total area examined in that segment. This corresponds to 38.7 ha of cottonwood habitat per river-km (159.9 acres per RM).

59-mile district

Vegetation composition in the 59-mile district has changed significantly since 1892. This is illustrated by major changes in land cover from 1892, 1956, 1982/83, and 2006 as depicted in Figure 43 (Dixon et al. 2010). In the historic floodplain surrounding the 59-mile district, land conversion from forest to agriculture was the primary cause for a nearly 50% decrease in the total area of forest since 1892 (Dixon et al. 2010). In addition to forest loss, the area of sandbar and shrubland decreased during this time. As of 2006, grassland and sandbars represent a very small portion of the landscape. The limited sandbar area reduced the amount of potential area suitable for cottonwood seedling establishment. However, potentially more limiting to cottonwood establishment is the lack of overbank flows and the reduction in the amount of river meandering (S. Wilson, pers. comm., 2011). Although, from 1983 to 2006, the combined area of woody vegetation (forest and shrubland) remained nearly unchanged (forest area actually increased slightly as shrubland in the 1980s matured to forest, hence the area of shrubland declined slightly), the present-day forest occupies a substantially smaller area and is considerably more fragmented than during pre-dam times (Dixon et al. 2010).

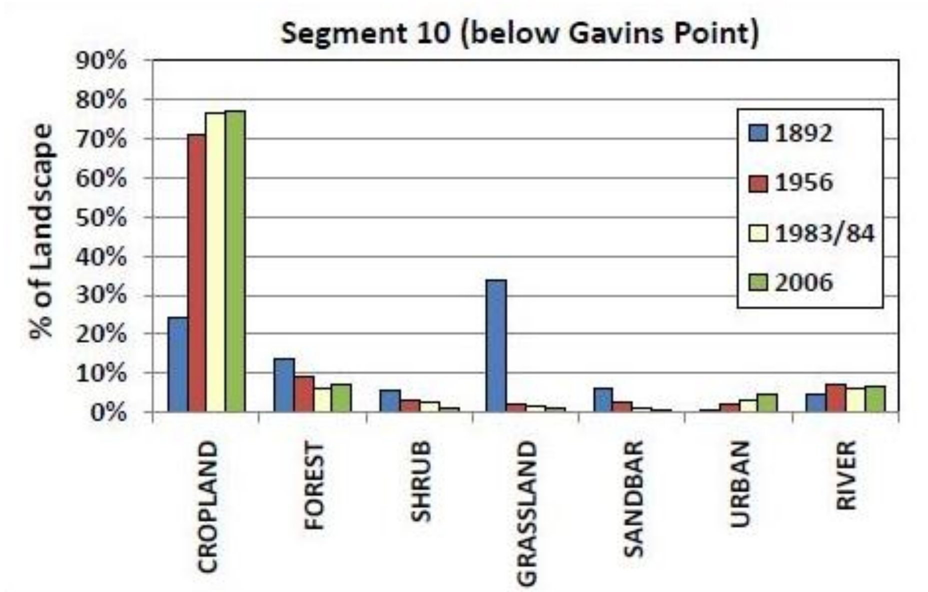


Figure 43. Historic changes in relative coverage of major land cover classes on segment 10 (Gavins Point Dam to Ponca, NE, the 59-mile district's historic Missouri River floodplain) (reproduced from Dixon et al. 2010).

The current (2008) extent of cottonwood riparian habitats in segment 10 (the 59-mile district's historic Missouri River floodplain) totals 6,131 ha (15,144 acres) and represents nearly 8% of the total area (land and water) in segment 10 (Dixon et al. 2010). This equates to approximately 65.5 ha of cottonwood habitat per river-km (260.7 acres per RM).

A comparison across all segments in the Dixon et al. (2010) study area indicates that segment 10 has a relatively high mean cottonwood area per km made up of a relatively balanced contribution from each major age class, despite the drastic losses in cottonwood coverage. Segment 8 has lost a smaller portion of its cottonwood forest; however, segment 8 has less cottonwood and is made up of fewer stands under 25 years of age (Figure 44). As mentioned earlier, segment 8 is surrounded by a narrower valley and a more constrained floodplain; therefore, it contains less suitable cottonwood habitat than segment 10.

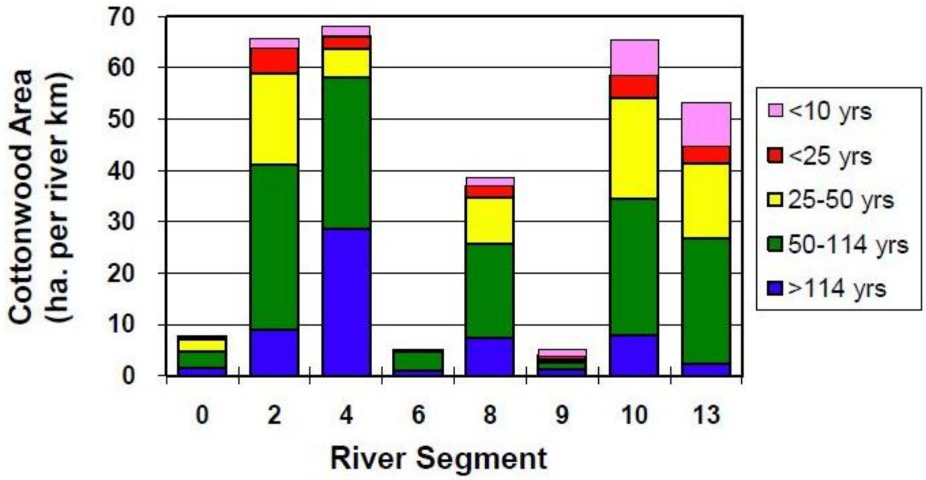


Figure 44. Mean cottonwood area (ha) per river kilometer, by age class, on each study segment. Lowest areas per river kilometer were on two segments containing reservoirs (segments 6 and 9) and the relatively free-flowing, but geologically-constrained, Wild and Scenic (segment 0) in Montana (reproduced from Dixon et al. 2010).

Cottonwood Age

A forest overstory study in a North Dakota Missouri River segment (segment 4 in USACE 2010), concluded that a natural (non-flow regulated or channelized) river meandering pattern helps control the vertical and horizontal distribution of vegetation communities on the floodplain, and that the rate of such meandering is a major factor determining the proportion of the floodplain area in pioneer, transitional, and terminal forest types (Johnson et al. 1976). Scott et al. (1996) found that in addition to channel meandering, fluvial geomorphic processes such as channel narrowing and flood deposition create suitable sites for cottonwood establishment. However, the channel narrowing that occurs after dam closure eventually stops and subsequent recruitment of riparian forests are confined mainly to areas along the channel margins (Johnson 1998). Some net channel narrowing has occurred on both segments 8 and 10, and much of this is represented by 25-50 year old cottonwood stands that may be the result of this channel narrowing after the dams were constructed (Dixon, pers. comm., 2011). Dixon (pers. comm., 2011) also suggests that both segments may be nearing a stage in which subsequent recruitment will be limited to the relatively narrow margins of the river channel.

39-mile district

The Missouri River floodplain along the 39-mile district is constrained by a relatively narrow valley and, therefore, it contains less cottonwood shrublands and forests per river-km than some of the other segments examined by Dixon et al. (2010). Most of the forest area, approximately 67% of the study area, including non-cottonwood areas, established prior to dam closure approximately 50 years ago. Most of this area (47%) is in the mature age class (50-114 years old). The 25-50 year stand age class comprises 23% and the <25 year age class (sapling and pole) together comprise 10% of the forest in segment 8 (along 39-mile district's Missouri River floodplain). Maps displaying the current (2006) distribution and extent of cottonwood shrubland and forests by stand age in the historic floodplain of the Missouri River (determined by Dixon et al. 2010, segments 8 and 9) are available in Plate 6, Plate 7, and Plate 8. The 39-mile district is split into 3 maps with some geographical overlap in order to provide reference between maps.

Examination of cottonwood habitats in the historic floodplain (segment 8) and those only within the administrative boundaries of MNRR reveal slightly different proportions of stand age classes (Figure 45). The land cover classes chosen for summary in Figure 45 include the following from Dixon et al. (2010) cottonwood dominant riparian shrubland, forest (cottonwood at least 15%), riparian low shrub with cottonwood, woodland (cottonwood at least 15%), and cabin or managed cottonwood areas.

59-mile District

The 59-mile district's historic floodplain is very wide, in some places over 16 km (9 mi). It is important to note that the data presented in Dixon et al. (2010) does not extend to the full valley width in this widest part of the historic river valley, as the 1890s maps did not cover this area. The floodplain examined by the authors contains a total of 6,562 ha (16,214 acres) of riparian shrubland, woodland, and forest vegetation types (including both cottonwood and non-cottonwood habitats). The greatest percentage (40%) of the floodplain is comprised of mature forests (50 to 114 years old), followed by young or intermediate stands (29%; 25 – 50 years old), and old growth (~14%; >114 years old). Pole (10 to 25 years old) and sapling (>10 years old) comprise 7% and 10% respectively (Dixon et al. 2010). The existing forests in segment 10 are still dominated by cottonwood, but also contain a significant component of native green ash , native American elm, native but often considered invasive Eastern red cedar, non-native Russian olive, and non-native white mulberry.

Cottonwood-dominated patch types, which made up over 90% of the area of woody riparian vegetation, are also primarily composed of mature (50 to 114 years old) and old growth (>114 years old) stands with approximately 30% of the cottonwood forest made up of intermediate-aged stands. Only 11% and 7% of the total area of existing cottonwood stands are in the sapling and pole size, respectively (Figure 45). Proportions of stand ages by area remain similar when examining the study area within the administrative boundaries of the 59-mile district (Figure 45). However, slightly higher percentages of sapling, pole, and intermediate aged cottonwood stands are present when examining the forests only within the administrative boundaries (clipped from the original segment 10 data in Dixon et al. (2010)). The 59-mile district is split into three maps in Plate 9, Plate 10, and Plate 11 to display the current (2006) distribution and extent of cottonwood shrubland and forests by stand age in the historic floodplain of the Missouri River (determined by Dixon et al. 2010, segment 10) in and surrounding the 59-mile district of MNRR. Note that some geographical overlap across sequential maps was used intentionally in order to provide reference between maps.

Dixon et al. (2010) suggest that the reason for a large percentage of cottonwood forest in the intermediate age class (trees established after the closing of the Gavins Point Dam), may be due in part to a flood in 1952 (peak of 480,000 cfs at Yankton, SD) which created significant sediment and bar formations just before dam closure. After the dam closure, channel degradation may have increased favorable sites for cottonwood recruitment and the lower peak flows would have protected young stands from peak flows and ice scour. Dixon (pers. comm., 2011) notes that cottonwood regeneration was fairly extensive post-dam (like several other segments) for the first couple of decades after dam closure, but apparently has experienced lower recruitment rates in the 25 years since then; the saplings and poles occupy a smaller area than the 25-50 year age class. Also noted as an important consideration in comparing the proportions of stand area established in the pre- and post-dam time periods, considerable loss of older forest due to land use conversion occurred after 1892 and 1955/56 (Dixon et al. 2010). If the area of older forest was included, then the area of forest <50 years old would represent a much smaller percentage of total forest area.

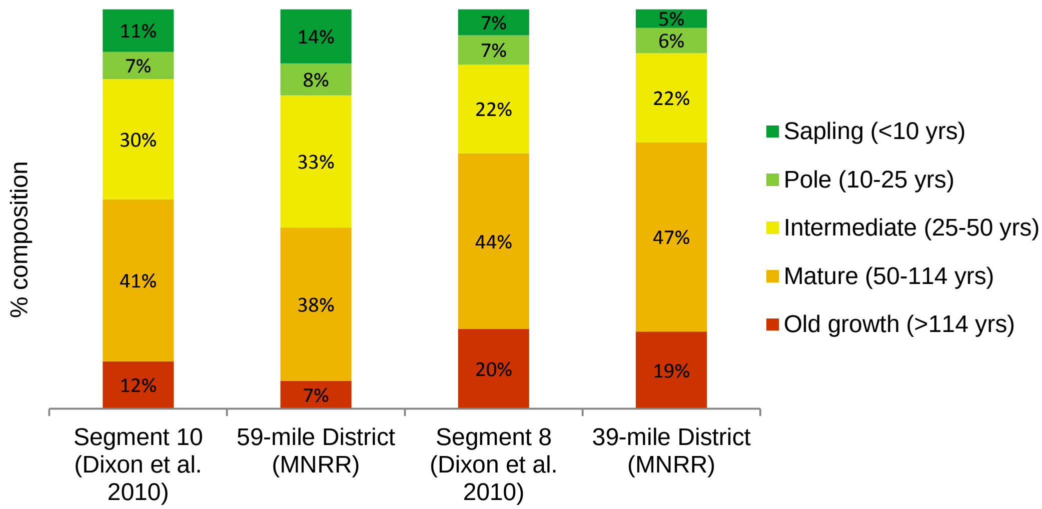


Figure 45. Percent composition of cottonwood stand ages by MNRR district, both the Dixon et al. (2010) segments and the MNRR districts. The segments represent original data from Dixon et al. (2010) and each MNRR district represents data clipped to the MNRR park boundaries; segment 10 data were clipped to the 59-mile district boundaries and segment 8 and a small portion of segment 9 data were clipped to the 39-mile district boundaries. Data shown here include the following land cover classes identified in Dixon et al. (2010): Cottonwood dominant riparian shrubland, Forest (cottonwood at least 15%), Riparian low shrub with cottonwood, Shrubland with cottonwood, Woodland (cottonwood at least 15%), and Cabin areas or managed cottonwood areas.

Threats and Stressor Factors

The following are stressors that may influence vegetation and landscape patterns in the Missouri River floodplain, each followed by a brief discussion of their context in MNRR.

Forest clearing for agricultural cropland and urban or exurban expansion

Clearing of land for various human uses has resulted in dramatic reductions in the area of forest. Dixon et al. (2010) found a 42% decline in forest and a 59% decline in shrubland area, together representing a 47% decrease in natural woody vegetation across their Missouri River study areas. Segment 10 experienced nearly a 50% decline in the total area of forest, with the vast majority of forest loss from the mid-1950s to 2006 through conversion to agriculture. Primary gains in forest area were through shrublands succeeding to forests (Figure 46;Dixon et al. 2010). However, the majority of the total loss and proportional loss of forest was greater from the 1890s to the 1950s than the 1950s to present. Although development (i.e., urban and exurban expansion) along the river, especially in the 59-mile district has reduced cottonwood habitat along the Missouri River banks, losses of cottonwood habitat from development was much lower than the losses to agricultural conversion. Most land within the administrative boundaries and surrounding MNRR is privately owned, and the most common land use is agricultural row crop production. Refer to Plate 1 andPlate 2 in the land cover section (Chapter 4.1) of this document for illustrations of land cover change in segment 10 (59-mile district’s Missouri River historic floodplain) and segment 8/9 (39-mile district's Missouri River historic floodplain), respectively, from GIS data developed by Dixon et al. (2010).

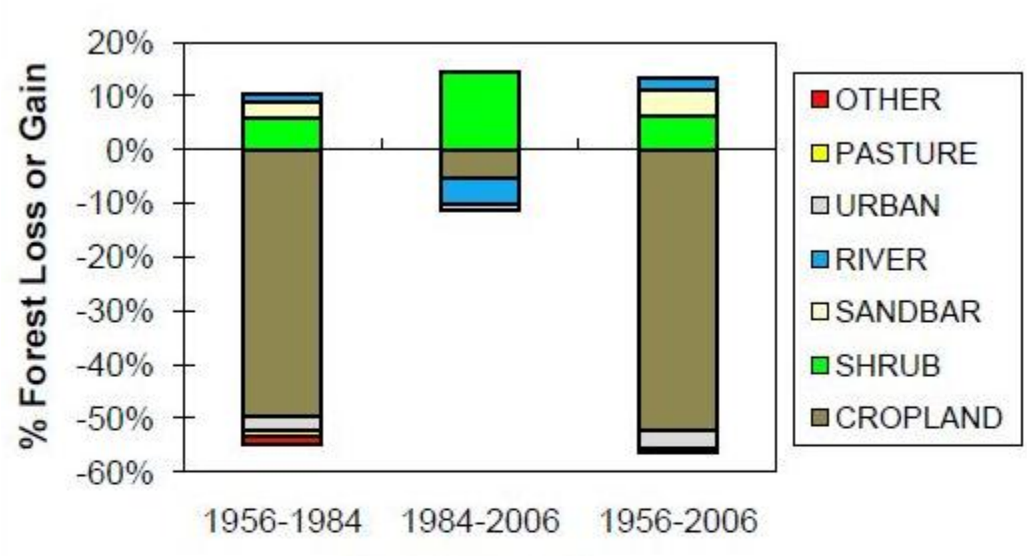


Figure 46. Net land cover conversions to or from forest in segment 10 (59-mile district of MNRR) from 1956 to 1984 and 1984 to 2006. Dominant mode of forest loss was conversion to agricultural cropland, while dominant mode of forest gain was via maturation of shrubs or saplings to forest (reproduced from Dixon et al. 2010).

Land management (e.g., grazing, vegetation management)

NLCD LCLU data offer a coarse categorization of land use (Andersen Level II categorization) within and surrounding the park. According to NLCD 2001 data used by NPScape in an approximately 30 km buffer of the park (the area of analysis used in the NPScape data), of the total area, cultivated agriculture comprises 43.8 %, pasture/hay 10.0%, and developed land (open space, low, medium, and high intensity) 5%. Within the boundaries of the 59-mile district, the composition of LCLU classifications is primarily open water (44.4%), but the major land uses are cultivated crops (15.4%), developed open space (1.7%), and pasture/hay (1.0%). Less than one percent of the area is classified as developed (low, medium, or high intensity). Within the boundaries of the 39-mile district, the majority of the area is open water (45.9%), but land use classes are lower in percent of total area. Cultivated acriculture comprises 1.6%, developed open space 1.4%, developed low intensity 0.4%, and pasture/hay 0.4%. It is important to note the majority of the land in the analysis area and within the 59-mile boundaries of the NPScape data are private lands. See the Land cover/Land use section of this document for a map displaying LCLU in and around MNRR (Chapter 4.1).

Dixon et al. (2010) identifies grazing and various vegetation management practices as stressors that may influence vegetation and landscape patterns. Livestock grazing has been ongoing in the area since the late 1800s. It is unclear how much grazing occurs within the MNRR boundaries. In a study of a Montana Missouri River reach, Scott et al. (2003) found that areas subject to long-term grazing were correlated with low vegetation structural complexity and lower bird diversity and abundance. Other land management actions (e.g., haying or set aside land for hunting and wildlife viewing) specifically in and along the MNRR boundaries may affect cottonwood habitats. However, the extent of differing land management and associated effects can be considered a data gap in this assessment.

Channel incision and cessation of overbank flooding below dams
A lowering of streambed elevation (measured via changes in water surface elevation) causes an increase in the level of the floodplain relative to the river. This has led to floodplain forests being abandoned or isolated from the river's historic floodplain, thereby further reducing the potential for overbank flooding (Dixon et al. 2010). From 1956 to 2001, segment 10 (59-mile district) experienced an average decrease in bed elevation and water surface of 2 meters (West Consultants, Inc. 2002), with the greatest channel degradation occurring immediately below the Gavins Point Dam. Currently, the total degradation (elevation loss) below the dam is estimated to be 3.5 m (12 feet) (Jacobson et al. 2009). Channel degradation also occurred in the upstream portions of the 39-mile district (RM 860-841) (Dixon et al. 2010). As a result, riparian forests in these areas may be taking on more upland characteristics (e.g., less water availability because of lower water table depths resulting in fewer wetland species and greater red cedar in the understory).

Disruption of sediment supply and transport, with resultant declines in formation of alluvial surfaces needed for cottonwood recruitment
Johnson's (1992) successional model (Figure 39) identifies the relationship of new alluvium to cottonwood/willow successional pathways. Sediment supply and transport has been disrupted by the dams and bank stabilization features on the Missouri River. For more information regarding sediment supply and transport, refer to the erosional and depositional section of this document (Chapter 4.2). This has resulted in a decline in the formation of new alluvial surfaces suitable for cottonwood seedling germination. Most cottonwood establishment occurs in bare, moist sites protected from intense physical disturbance (USACE 2010). Therefore, in the absence of new alluvium (bare, moist sites) cottonwood recruitment is dramatically reduced.

Cottonwoods in MNRR could also be stressed by possible alterations in available nutrients. Johnson et al. (1976) noted decreases in the diameter growth of several major tree species on the Missouri River in North Dakota. Because of reductions in soil moisture, the authors hypothesized that nutrient enrichment was also reduced with the cessation of periodic flooding. These are two important aspects that have likely changed because of alterations in the flow regime in both districts of MNRR. However, no specific data and information were available.

Aggradation with resultant water table rise adjacent to river-reservoir delta areas
The impoundment of the Missouri River behind Gavins Point Dam causes the sediments carried by the Niobrara River and other tributaries such as Verdigre Creek to aggrade, forming a delta just downstream of the 39-mile district. This aggradation and subsequent increases in groundwater elevations may be related to the loss of cottonwood trees in the area (Weeks et al. 2005). Dixon (pers. comm., 2011) suggests that cottonwoods do not do well with soil that is saturated to the surface and notes there are many dead cottonwoods in this area as portions of the land are transitioning to marsh due to rising water levels.

Non-native plant species and invasive plant species (both native and non-native)
A portion of the Dixon et al.(2010) study involved on-the-ground, plot-based vegetation sampling. Ground level sampling in both segments revealed lower overall percentage of non-

native plant species and generally higher species richness in the herbaceous-layer, shrub layer, and tree layers in cottonwood stands compared with most other segments in the study. Both segments (8 and 10) associated with MNRR districts showed significantly lower mean percentages of non-native plant species when examining all vegetation layers (herbaceous, shrub, and tree) than all other river segments except segment 13. However, the mean percent of non-native tree species in cottonwood stands were higher in segments 8 and 10 compared with all other segments except for the highly modified segment 6 (Oahe Dam to Big Bend Dam). Dixon et al. (2010) also note that the relative importance value (the sum of the relative frequency of stems, relative density, and relative basal area by stand) of later successional (or equilibrium) species increased with the stand age (Figure 47). One of the species showing increasing importance values with increasing stand age was non-native, invasive buckthorn. In the 39-mile district, Russian olive trees (also an invasive non-native) were common in young stands and green ash and red cedar in stands older than 25 years (Dixon et al. 2010).

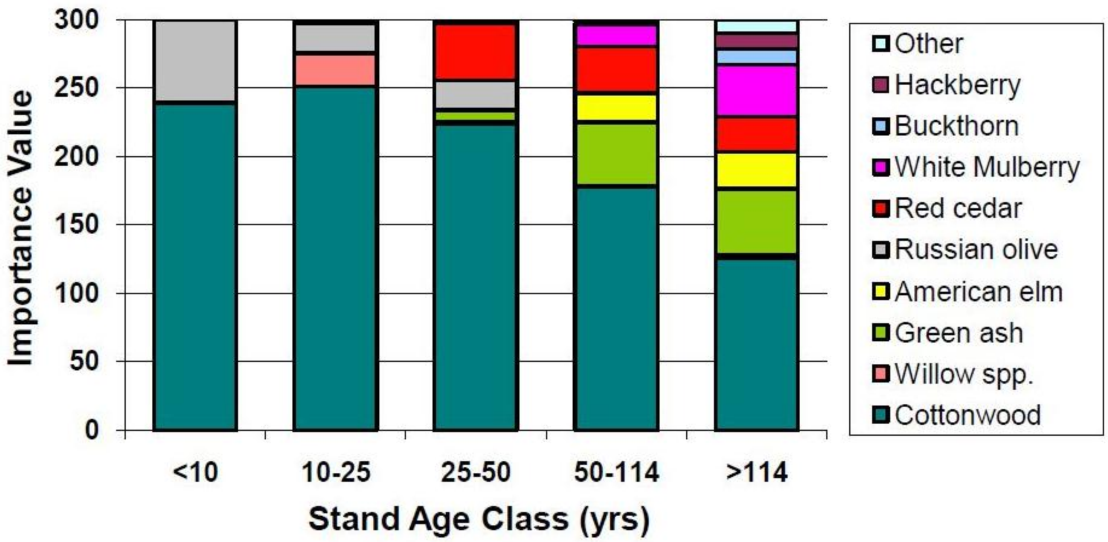


Figure 47. Relative importance value (sum of relative frequency, density, and basal area of each species by stand) of different tree species by cottonwood forest age class in segment 10 (reproduced from Dixon et al. 2010).

Specifically in the 39-mile district, Dixon et al. (2010) note that Russian olive trees have colonized micro sites in the flooded area near the delta above Lewis and Clark Lake. They also state that the overall proportion of non-native trees was high based on composition (the average percentage of tree species that were non-native in each stand), commonly reporting Russian olive, white mulberry and common buckthorn (*Rhamnus cathartica*). Similarly, within the riparian forests in the 59-mile district (segment 10 in Dixon et al. 2010), non-native trees and shrubs were common including common buckthorn, Russian olive, and white mulberry (USACE 2010). Dixon (pers. comm., 2011) suggests that non-native species are common within stands of the 39-mile district, but native tree species are still dominant.

Eastern red cedar, a native tree species considered invasive in MNRR, is more abundant in the 39-mile and 59-mile districts of the Missouri River compared with other river segments in Dixon et al. (2010). Dixon and Johnson (2008) hypothesize that along with Russian olive, white mulberry, and common buckthorn, eastern red cedar trees colonize primarily through bird dispersal, unlike most of the native floodplain trees whose seeds are dispersed by wind and water. Therefore, Dixon and Johnson (2008) suggest that with an increasingly fragmented and human-dominated landscape and the elimination of overbank flooding, the recruitment of wind, and especially water dispersed trees and shrubs may be reduced in favor of bird dispersed trees and shrubs. The competition from non-natives may further reduce the availability of suitable cottonwood establishment sites.

Data Needs/Gaps

Information regarding cottonwood stand health, including measures such as growth rates, decay, and tree condition ratings, may provide a more complete picture of the overall condition of existing cottonwood habitats in MNRR. No information is currently available describing the extent, regeneration status, or overall condition of cottonwood habitats along the Niobrara River and Verdigre Creek areas within the 39-mile district.

Dixon et al. (2010) suggest that future research should model the rates of cottonwood forest loss and determine conditions for successful cottonwood recruitment and if future management activities designed to improve cottonwood regeneration should include planting cottonwoods. Research should evaluate how planted stands compare to natural stands in their diversity, structure, and ecological function.

Johnson et al. (1976) noted decreases in the diameter growth of several major tree species on the Missouri River in North Dakota. Because of reductions in soil moisture, the authors hypothesized that nutrient enrichment was also reduced with the cessation of periodic flooding. These are two important aspects that have likely changed because of alterations in the flow regime in both districts of MNRR. Nutrient enrichment and soil moisture of cottonwood habitats are not characterized in the literature for MNRR and data collected in the future may inform the proposed Cottonwood Recovery Plan efforts.

Land management is considered a stressor to cottonwood habitat in this assessment. Land management in and around MNRR is only categorized by NLCD as broad land use classes such as cultivated agriculture, pasture/hay and four levels of developed lands (developed open space and low, medium, and high intensity developed). These data can indicate broad shifts in land use with repeat products over time, but do not capture variations in, for example, the intensity of use and associated ecological effects nor the various land management practices within each broad land use category. Higher resolution maps of land use and examinations of the effects of associated practices on cottonwood habitats and cottonwood regeneration within MNRR could provide additional understanding of cottonwoods' status.

Overall Condition

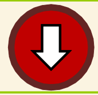
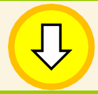
Measures	Reference Condition	Condition
Cottonwood Age	Pre-dam	
Cottonwood Habitat Extent	Predam	

Figure 48. Cottonwood condition graphic.

Dixon et al. (2010) conclude that regeneration is not matching the pace of the losses in cottonwoods in the Missouri River floodplain because of land conversion and succession with current river management regimes. Cottonwood forest regeneration is restricted to narrow shorelines or the upstream side of river deltas (Weeks et al. 2005, Dixon et. al. 2010). A lack of sandbar formation and reduced rates of channel migration, because of the loss of periodic flooding and the effects of bank stabilization, is limiting cottonwood seedling establishment. A loss of approximately 18% of riparian forest in the 39-mile district's historic floodplain and a 45% decrease in the 59-mile district's historic floodplain riparian forests occurred from 1892 to present in MNRR. While cottonwood forests remain in MNRR and some of the surrounding Missouri River floodplain, the lack of cottonwood regeneration is a significant concern because of its implication for the future trajectory of cottonwood ecosystems. Dixon et al. (2010) expect declines in landscape diversity (e.g., declines in the mix of types and age classes of riparian forest) and reduction in the total forest area, both of which may lead to declines in floodplain biodiversity. ―Under continued chronically poor conditions for recruitment and only limited channel migration and bar formation, cottonwood forests in the long-term may be restricted to the immediate margins of the river channel and will gradually senesce and disappear farther away from the channel" (Dixon et al. 2010). Therefore, cottonwood age (i.e., cottonwood regeneration) is a significant concern in MNRR and conditions are likely to continue to degrade (Figure 48).

Because the current extent of cottonwood habitat is reduced from pre-dam conditions, and the future implications of cottonwood habitat due to poor recruitment in recent years, cottonwood habitat can be viewed as a moderate concern in MNRR. The existing cottonwood forests in MNRR largely represent a ―legacy of past recruitment success"; Dixon et al. (2010) suggest that without the dynamic river processes originally forming and maintaining cottonwood habitat, reversing the trend of cottonwood forests will require ―innovative thinking and action" to restore or replicate natural processes. Therefore, the trend of condition is likely to decline. The USACE created a draft cottonwood management plan for six priority segments of the Missouri River including segments 8 and 10 associated with the 39-mile district and 59-mile district of MNRR respectively. The primary goals were to 1) develop a management plan that will allow for natural regeneration, periodic seed germination, and seedling establishment at a sufficient rate such that regeneration is maintaining pace with or exceeding mortality, and 2) evaluate the condition of existing cottonwood communities within each segment and develop a suite of ecological strategies for conserving them through preservation, compensatory mitigation, recovery, and restoration activities that will maintain pace or exceed mortality (USACE 2010).

Sources of Expertise

Mark Dixon, Assistant Professor, Biology Dept., University of South Dakota
Lisa Yager, MNRR Biologist

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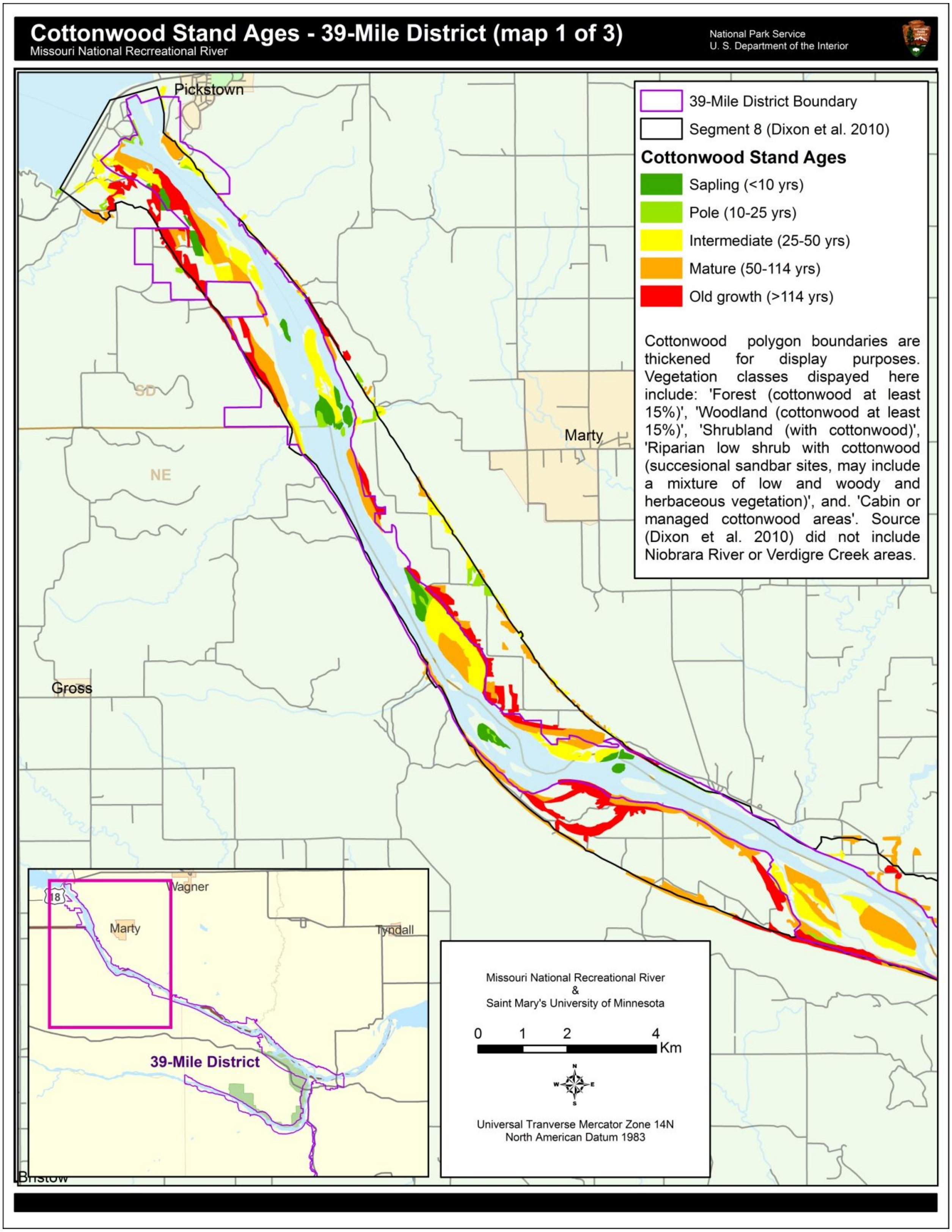

Plate 6. Cottonwood stand ages (2006) in the 39-mile district of MNRR, Map 1 of 3 (Dixon et al. 2010).

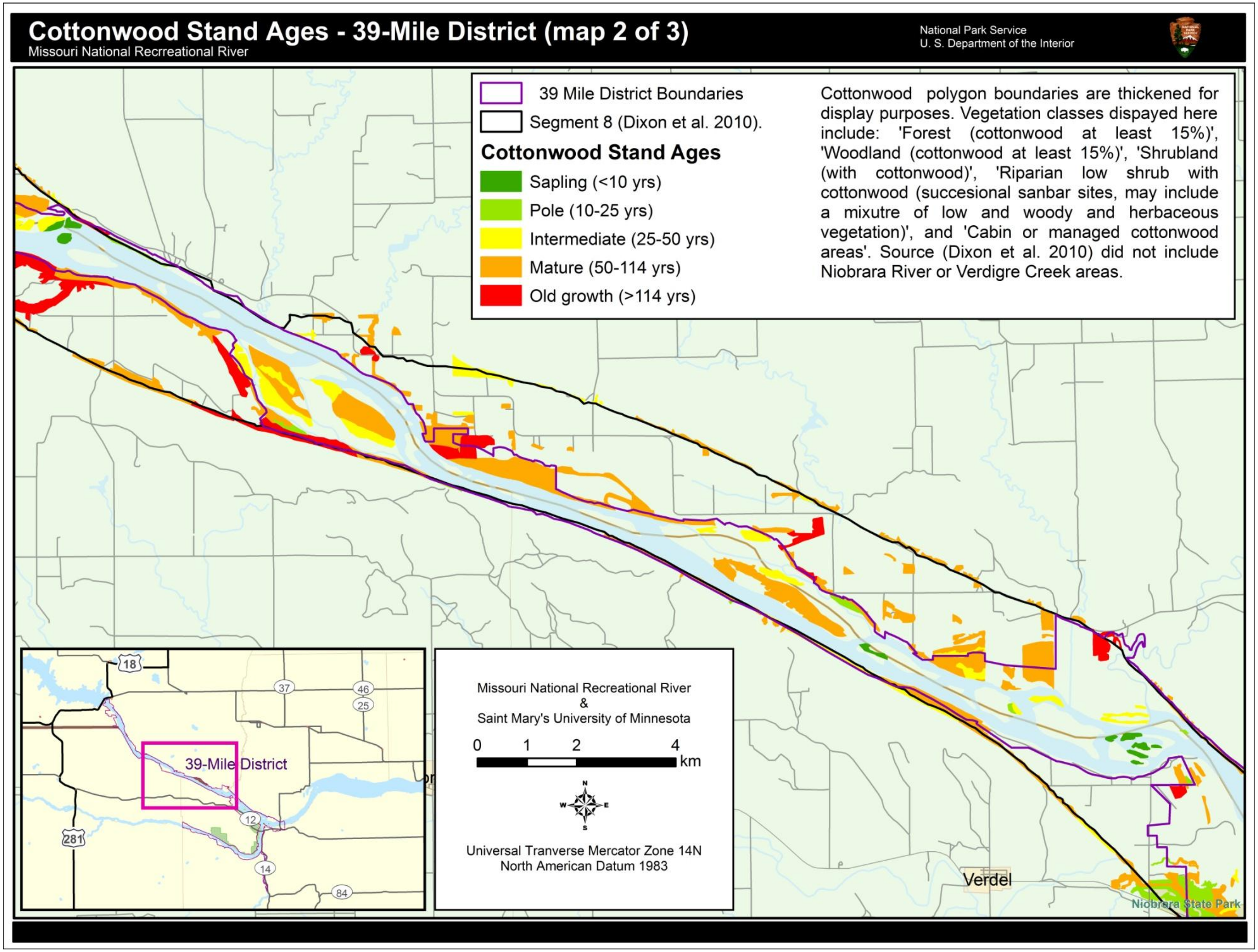

Plate 7. Cottonwood stand ages (2006) of the 39-mile district of MNRR, Map 2 of 3 (Dixon et al. 2010).

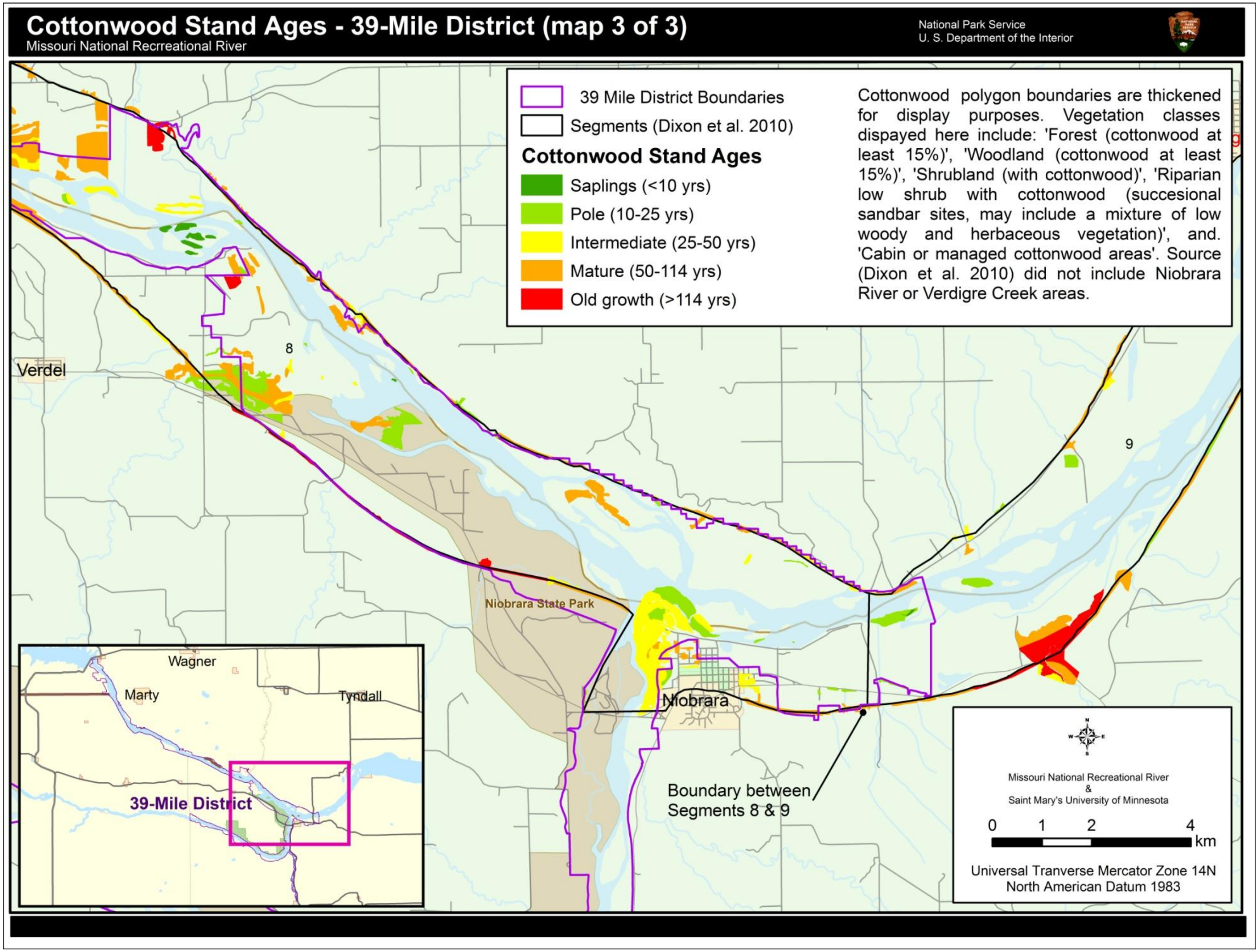

Plate 8. Cottonwood stand ages (2006) in the 39-mile district of MNRR, Map 3 of 3 (Dixon et al. 2010).

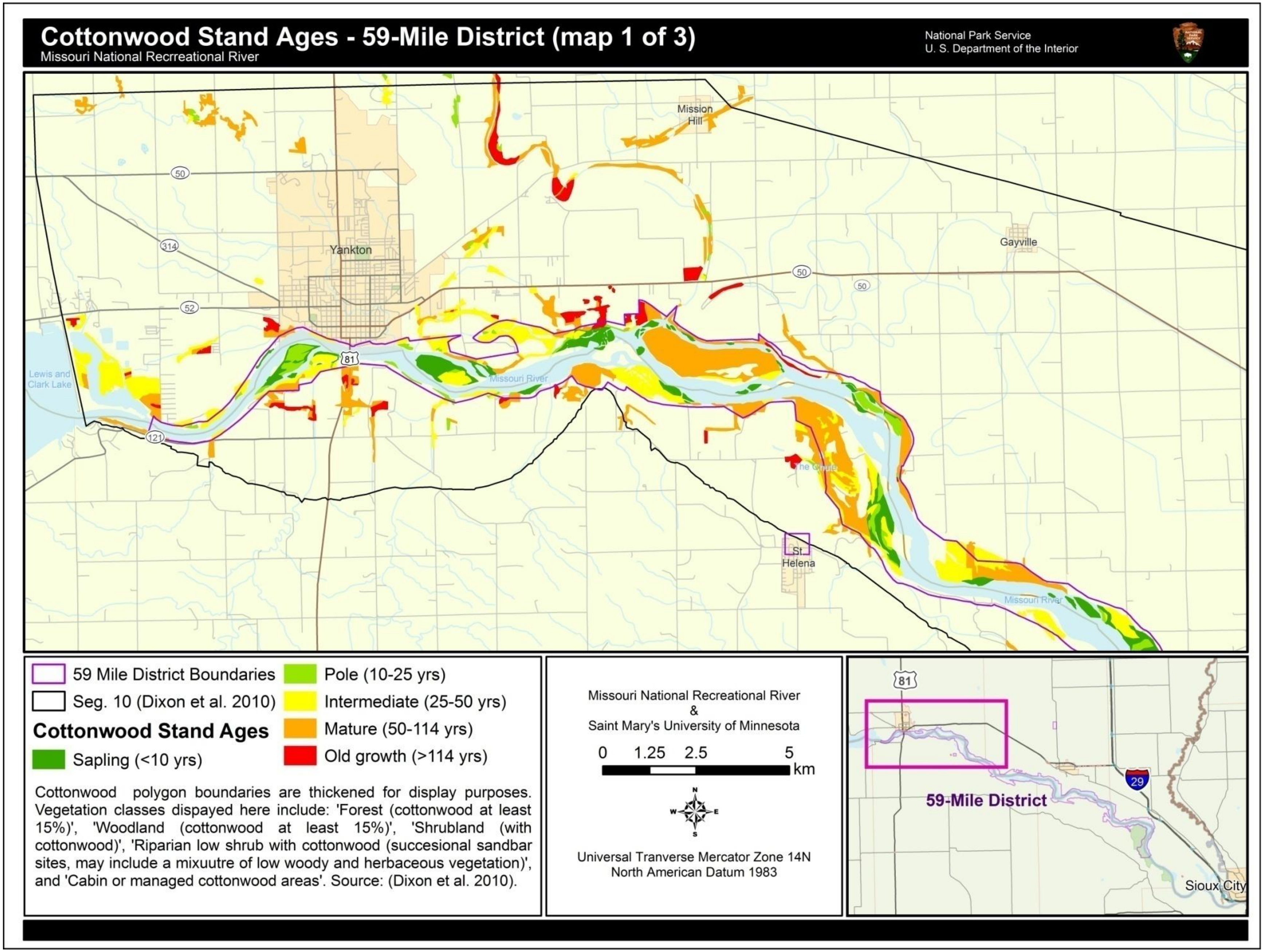

Plate 9. Cottonwood stand ages (2006) in the 59-mile district of MNRR, Map 1 of 3 (Dixon et al. 2010)

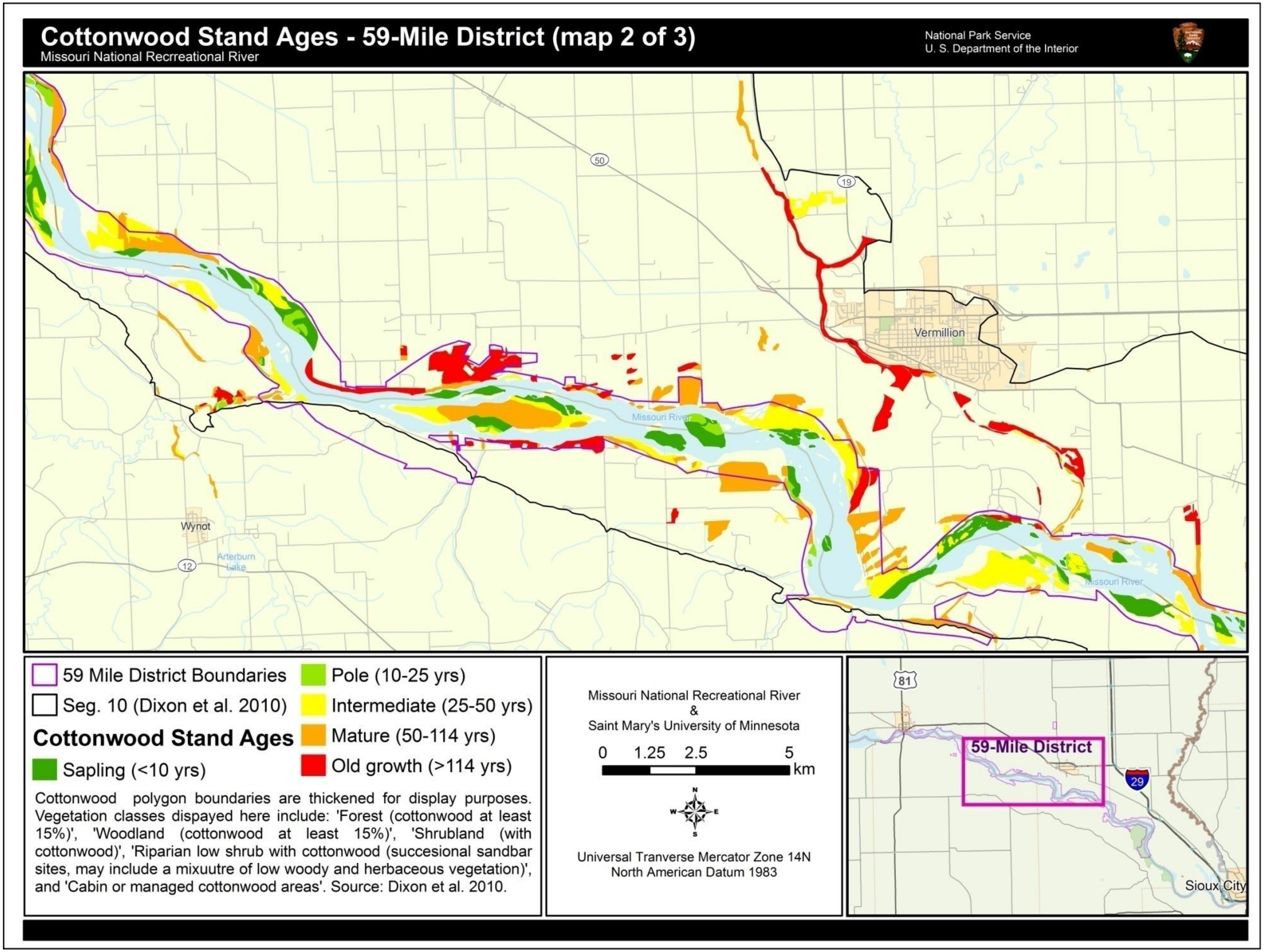

Plate 10. Cottonwood stand ages (2006) in the 59-mile district of MNRR, Map 2 of 3 (Dixon et al. 2010).

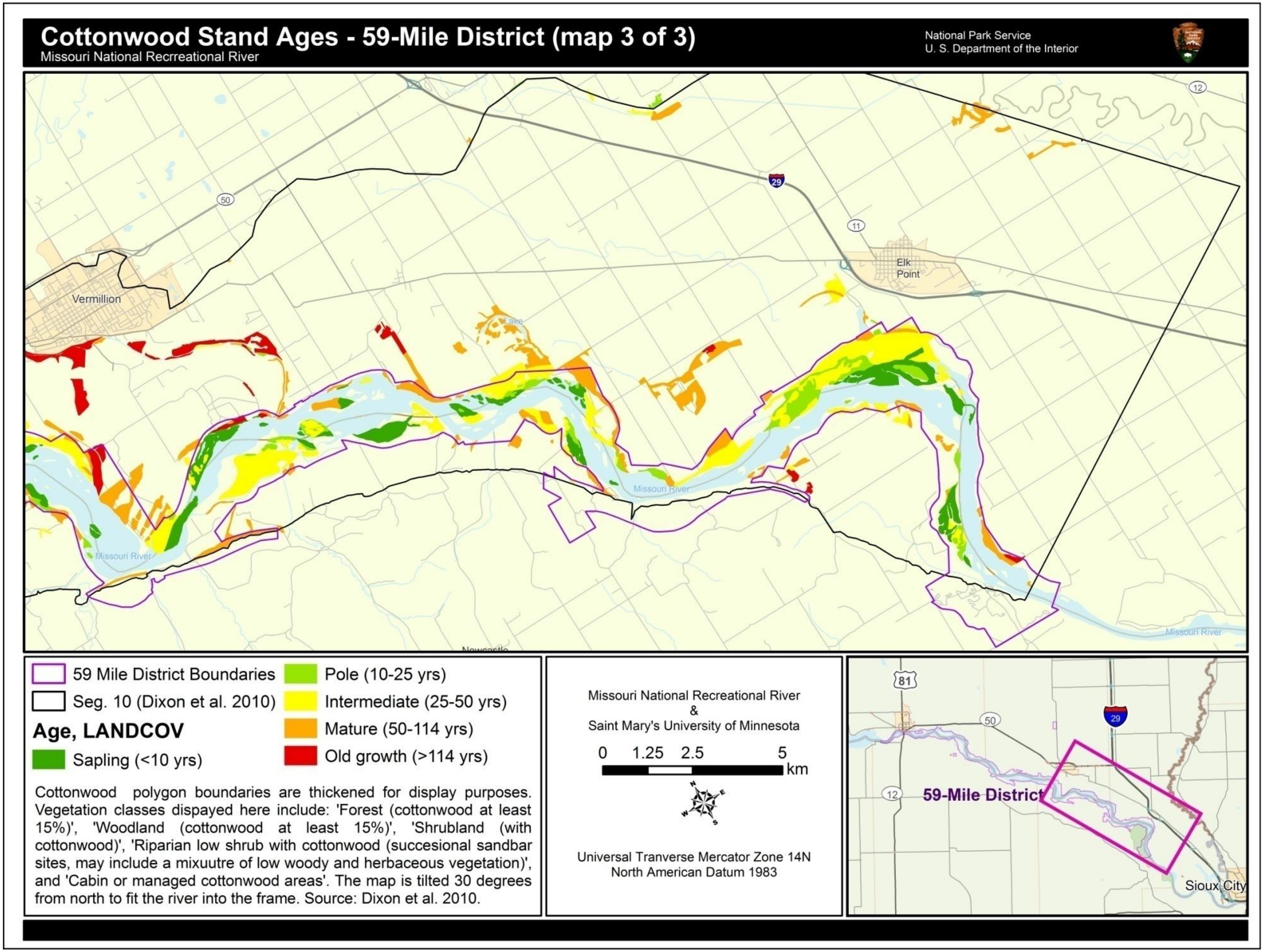

Plate 11. Cottonwood stand ages (2006) in the 59-mile district of MNRR, Map 3 of 3 (Dixon et al. 2010).

4.6 Pallid Sturgeon

Description

The pallid sturgeon (*Scaphirhynchus albus*) is a large-river fish that is native to the Missouri River. According to catch records, pallid sturgeon were considered to be somewhat common in the 1950s and 1960s, with an average of 50 observations per year (NRCS Montana 2005). Today, wild pallid sturgeon are rare in the Missouri River, primarily due to effects of dam construction and channelization (Weeks et al. 2005). Impoundment has eliminated upstream migratory movement, obstructed normal flow patterns, reduced sediment loads, lowered turbidity, and altered water temperature (Hesse and Schmulback 1991). These changes have extensively reduced available spawning habitat for pallid sturgeon and ultimately compromised their reproductive success. In 1990, USFWS listed the pallid sturgeon as federally endangered under the Endangered Species Act of 1973 (USFWS 1990). The closely related shovelnose sturgeon (*S. platorynchus*) is listed as threatened under the similarity of appearance provisions of the Endangered Species Act because it is difficult to differentiate between the two species. This ruling is intended to avoid accidental harvesting of pallid sturgeon (USFWS 2010). Because of the endangered status of the pallid sturgeon and the changes the river has endured as a result of impoundment, it is important to understand habitat diversity and productivity in MNRR to aid population recovery efforts.

Photo 3. Steve Krentz and Rich Holcom capture a pallid sturgeon in the Missouri River in North Dakota. Photo taken April 1992 (Courtesy USFWS).

Measures

- Habitat diversity
- Productivity

Reference Conditions/Values

The reference condition for pallid sturgeon is the status of the population in MNRR prior to dam construction. Prior to impoundment, the Missouri River was a meandering river with high sediment load, frequent overbank flooding, and two major spring pulses that were triggered by local and mountain snowmelt, ice melt, and rainfall (Weeks et al. 2005). In addition, the pre-dam average annual suspended sediment load near Yankton, SD, was 125 million metric tons (Galat et al. 1996). More recently, the average annual suspended sediment load near Yankton has decreased to 12-38 million metric tons (Galat et al. 1996). In addition to the loss of sediment, approximately 36% of historic pallid sturgeon habitat within the Missouri River has been lost due to dam construction, leaving the remaining 64% channelized or with unnatural flow (Kallerneyn 1983, Dryor and Sandvol 1993). The massive loss of habitat, along with the extensive changes in existing habitat, has significant negative implications on pallid sturgeon population and spawning capabilities.

Proper water velocity, turbidity, and temperature, along with a sufficient food source, are essential in providing a diverse and productive habitat for pallid sturgeon. Typically, an ideal pallid sturgeon habitat is a long and free-flowing river with swift and turbid water, coarse sand substrate, and small invertebrates and native chubs for feeding (DeLonay, pers. comm., 2011). Pallid sturgeon are typically found in water between 0-30° C, which is the temperature range of the entire Missouri River (Dryor and Sandvol 1993).

Data and Methods

Due to the limited number of pallid sturgeon available for research, some of the spawning habitat research conducted used shovelnose sturgeon as a substitute, due to their morphological, physiological, and genetic similarities to pallid sturgeon (DeLonay et al. 2009). Though shovelnose sturgeon have been used to examine pallid sturgeon habitat use, they do not act as a perfect surrogate because of some major differences which have allowed them to be more successful in terms of population numbers. Shovelnose sturgeon are more flexible in their feeding and spawning behaviors (having the ability to spawn over a longer time period), while pallid sturgeon typically spawn during a shorter time period between the end of April and beginning of May (DeLonay, pers. comm., 2011). Shovelnose sturgeon can spawn in tributaries, such as the Big Sioux River, while it is believed that pallid sturgeon will only spawn in main channels (DeLonay, pers. comm., 2011). Other key differences in shovelnose sturgeon include shorter drift distances of larvae, more frequent reproduction, and less dependence on piscivory (feeding exclusively on fish) in their adult lives (Braaten et al. 2008; DeLonay et al. 2009).

Literature provided by MNRR and through literature searches (Dryer and Sandvol 1993, Berry and Young 2004, Weeks et al. 2005, Laustrup et al. 2007, DeLonay et al. 2009, Reuter et al. 2009, Shuman et al. 2010, Stukel et al. 2009) were the main sources of information for this assessment. Personal communications with Aaron DeLonay from the USGS Columbia Environmental Research Center, Dane Shuman from USFWS, and Sam Stukel from SDGFP were also major sources of information.

Current Condition and Trend

<u>Habitat Diversity and Productivity</u>
Pallid sturgeon habitat selection is difficult to describe due to their complex life cycle and small population, but basic macro and microhabitat descriptions exist. Ideal pallid sturgeon habitats have high seasonal discharge events that produce fast moving water and deep channels (Peters and Parham 2008). The presence of coarse sand substrate appears to be important for spawning (Peters and Parham 2008; DeLonay, pers. comm., 2011) and in addition, pallid sturgeon generally prefer areas with high turbidity, as their retinas are adapted to turbid environments (Sillman et al. 2005, as cited in Peters and Parham 2008). This adaptation is likely a defense of juvenile pallid sturgeon to sight-feeding predaceous fish.

Precise spawning requirements are unknown, but upstream migration of pallid and shovelnose sturgeon have been documented through telemetry movement and behavior data (DeLonay et al. 2009). For pallid sturgeon, this migration is performed by gravid (pregnant) females, which only spawn once every three to ten years (Keenlyne and Jenkins 1993; Mayden and Kuhadja 1997, as cited in Reuter et al. 2009), due to the multiple breeding seasons required for gonadal development (DeLonay et al. 2009). The distance fertile pallid sturgeon migrate can be anywhere from tens to thousands of kilometers (Delonay et al. 2009). However, the construction of six major dams on the Missouri River (two of which are immediately adjacent to the park boundaries of MNRR) do not allow for upstream migration of fish (DeLonay, pers. comm., 2011). This prevents pallid sturgeon within MNRR and the entire Missouri River ecosystem from migrating upstream to find suitable habitat for spawning. Corridors for upstream migration will likely never be opened due to the risk of spreading invasive Asian carp species to the upper reaches of the Missouri River (Klumb 2007).

Larval drift dynamics are crucial in understanding distribution of pallid sturgeon in the Missouri River. Typically, pallid sturgeon larvae drift for seven to thirteen days; these larvae can drift a total distance of 245-530 kilometers over that time (Braaten et al. 2008). It is important that the water is turbid, because larvae are fairly easy to see in the water, so drifting into clear water could result in a poor chance of survival (DeLonay, pers. comm., 2011). In 2004, USFWS released various ages of pallid sturgeon fry into the Missouri River in Montana, and in 2005, recaptured four yearlings that were originally released around 11 to 17 days of age. These findings suggest that some recruitment can be successful if the fry survive past the first 11 days and that unsuccessful recruitment could be due to fatalities prior to the first 11 days (USFWS 2007).

Due to the uncertainties of spawning requirements and the complexities of pallid sturgeon reproductive biology, an extensive hatchery program augments the population in the Lower Missouri River. Between 1994-2007, over 79,000 hatchery-reared pallid sturgeon were stocked in the Lower Missouri River (from Gavins Point Dam to the confluence of the Missouri and Mississippi Rivers), with over 10,000 pallid sturgeon stocked in the 59-mile segment of MNRR (Utrup et al. 2008). Between 1999-2008, researchers successfully captured 825 pallid sturgeon in the Lower Missouri River, with 595 of hatchery origin, 56 of wild origin, and 174 of unknown origin (undergoing genetic testing) (Utrup et al. 2008). Of the fish recaptured within the 59-mile segment, none were confirmed to be of wild origin (Utrup et al. 2008). However, trends suggest that pallid sturgeon are dispersing from their stocking site largely because the Lower Missouri

River has no dams, so they are free to move upstream or downstream (Utrup et al. 2008). In the 59-mile segment (near Mulberry Bend, NE) pallid sturgeon traveled a mean distance of 202 km (126 mi) downstream, while in Boonville, MO, pallid sturgeon traveled a mean distance of 138 km (86 mi) upstream (Utrup et al. 2008). In summary, the upstream pallid sturgeon are moving downstream and the downstream pallid sturgeon are moving upstream (Utrup et al. 2008).

Surveys indicate most pallid sturgeon originated from hatcheries. Therefore, the number of wild versus hatchery-reared pallid sturgeon should be monitored. This is important because a population consisting of mostly hatchery-reared fish implies that neither wild nor hatchery reared fish are sufficiently reproducing on their own to maintain a viable population (DeLonay, pers. comm., 2011). However, in 2007, two female pallid sturgeon were documented spawning in the 59-mile segment (USGS 2007). In addition, spawning pallid sturgeon were documented in 2008, 2009, and 2010, with at least one pallid sturgeon spawning twice (DeLonay, pers. comm., 2011). In total, 10-12 female pallid sturgeon have been documented spawning in the 59-mile segment, with half of hatchery origin and half of wild origin (DeLonay, pers. comm., 2011). Accordingly, a possible explanation for the lack of spawning (until 2007) is that many hatchery-reared fish have not yet reached sexual maturity (Stukel, pers. comm., 2011). Hatchery-reared pallid sturgeon (spawned in 1992 at Blind Pony State Fish Hatchery in Missouri) were first stocked in 1995, and female pallid sturgeon typically take at least ten years before they can reproduce (Keenlyne 1993). According to Stukel (pers. comm., 2011), fisheries biologist with the SDGFP, the upcoming years should be telling in determining if pallid sturgeon will continue to naturally reproduce in the Lower Missouri River.

The stocking summaries for the 59-mile segment and the 39-mile segment are found in Table 50 and Table 51 respectively. In 2004, researchers released 13,765 fingerlings and yearlings in the 59-mile segment, marking the largest release to date (Stukel et al. 2009). For the 39-mile segment, 2008 was the largest hatchery releases, with 4,579 fingerlings and yearlings (Shuman et al. 2010). Table 52 and Table 53 summarize mean length (mm), weight (g), relative condition factor (Kn), and growth rates for hatchery reared pallid sturgeon caught in MNRR during 2009.

Table 50. Juvenile and adult pallid sturgeon stocking summary, segment 7 (59-mile segment). Directly reproduced from Stukel et al. 2009.

Year	Stocking Site	Number Stocked	Year Class	Stock Date	Age at Stocking
1997	Platte River	402	1997	10/15/1997	Fingerling
1998	Two Rivers Rec. Area	84	1992	4/17/1998	6 yr Old
1999	Two Rivers Rec. Area	15	1992	5/17/1999	7 yr Old
2004	Leavenworth	38	2003	7/8/2004	Yearling
2004	Leavenworth	787	2003	7/8/2004	Yearling
2004	Leavenworth	944	2003	7/30/2004	Yearling
2004	Leavenworth	9170	2004	9/10/2004	Fingerling
2004	Leavenworth	2864	2004	10/8/2004	Fingerling
2006	Rulo	626	2005	5/5/2006	Yearling
2006	Parksville	427	2005	8/31/2006	Yearling
2008	Platte River Confluence	310	2007	5/7/2008	Yearling

Table 51. Juvenile and adult pallid sturgeon stocking summary, segments 5 and 6 (39-mile segment). Directly reproduced from Shuman et al. 2010.

Year	Stocking Site	Number Stocked	Year Class	Stock Date	Age at Stocking
2000	Verdel Boat Ramp	416	1997	6/6/2000	Age 3
2000	Verdel Boat Ramp	98	1998	9/20/2000	Age 2
2000	Verdel Boat Ramp	4	Adults[a]	7/6/2000	Unknown - Adult
2000	Verdel Boat Ramp	3	Adults[a]	9/20/2000	Unknown - Adult
2000	Running Water	2	Adults[a]	7/6/2000	Unknown - Adult
2002	Verdel Boat Ramp	558	2001	4/21/2002	Age 1
2002	Sunshine Bottom	181	1999	4/27/2002	Age 3
2003	Standing Bear Bridge	300	2002	7/26/2003	Age 1
2003	Sunshine Bottom	301	2002	7/26/2003	Age 1
2004	Sunshine Bottom	244	2003	10/7/2004	Age 1
2004	Standing Bear Bridge	271	2003	10/7/2004	Age 1
2005	Running Water	868	2004	8/30/2005	Age 1
2006	Standing Bear Bridge	1,005	2005	8/25/2006	Age 1
2006	Sand Creek	3	Adults[a]	12/8/2006	Unknown - Adult
2007	Standing Bear Bridge	600	2006	5/9/2007	Age 1
2008	Standing Bear Bridge	600	2007	4/17/2008	Age 1
2008	Sunshine Bottom	569	2007	5/8/2008	Age 1
2008	Standing Bear Bridge	3,410	2008	9/14/2008	Age 0
2009	Standing Bear Bridge	340	2008	4/13/2009	Age 1
2009	Verdel Boat Ramp	297	2008	5/28/2009	Age 1

[a.] Translocated fish from Lake Sharpe, South Dakota

Table 52. Mean length (mm), weight (g), relative condition factor (Kn), and growth rates for hatchery reared pallid sturgeon caught in segment 7 (59-mile segment) during 2009. Directly reproduced from Stukel et al. 2009.

Year Class	N	Stock Data			Recapture Data			Growth Data	
		Length (mm)	Weight (g)	Kn	Length (mm)	Weight (g)	Kn	Length (mm/d)	Weight (g/d)
2001	13	190			593	802.5	0.83	0.187	
		12			67	294.7	0.032	0.03	
2002	6	291	85.5	1.29	587	767.3	0.839	0.159	0.309
		18	29	0.138	88	321.3	0.027	0.031	0.341
2004	1				400	174	0.765		
2005	7	319	158.3	1.406	399	195.4	0.866	0.103	0.069
		54	80.9	0.088	26	33	0.08	0.017	0.027
2006	8				393	171.3	0.773		
					29	41.7	0.056		
2007	7	280	81.7	1.111	338	108.6	0.848	0.413	0.199
		66	56.3	0.159	28	22.7	0.153	0.165	0.023

Table 53. Mean fork length (mm), weight (g), relative condition factor (Kn), and growth rates for hatchery reared pallid sturgeon caught in segments 5 and 6 (39-mile reach), 2009. Directly reproduced from Shuman et al. 2010.

Year Class	N	Stock Data			Recapture Data			Growth Data	
		Length (mm)	Weight (g)	Kn	Length (mm)	Weight (g)	Kn	Length (mm/d)	Weight (g/d)
1997	16	541	684.9	1.203	804	1901	0.902	0.086	0.405
		18	107.3	0.129	33	239.2	0.022	0.012	0.084
1998	3	460	309.3	0.915	540	515	0.932	0.026	0.065
		37	150.7	0.179	30	50	0.077	0.001	0.03
1999	4	426	258.3	0.98	653	933.3	0.888	0.09	0.267
		41	101	0.127	44	228.6	0.07	0.015	0.059
2001	22	203			603	773.3	0.936	0.155	
		11			28	108.2	0.025	0.017	
2002	20	252	62.2	1.361	592	700.3	0.919	0.166	0.311
		10	7.7	0.053	23	89.3	0.029	0.011	0.042
2003	18	322	126.6	1.232	521	443.1	0.896	0.124	0.198
		12	14.9	0.033	16	39.6	0.022	0.014	0.029
2004	30	296	106.8	1.409	485	372.3	0.938	0.136	0.188
		10	7.1	0.075	14	36.9	0.027	0.013	0.025
2005	22	315	132.8	1.358	457	305.4	0.947	0.143	0.175
		14	22.1	0.08	16	31.8	0.031	0.02	0.034
2006	8	189	26.7	1.54	454	297.1	0.933	0.334	0.339
		5	2.7	0.29	23	54.6	0.067	0.024	0.061
2007	5	231	40	1.075	402	199	0.949	0.465	0.441
		25	22.3	0.311	14	22.7	0.025	0.148	0.167
2008	3	263	55	1.059	299	87.3	1.058	0.473	0.193
		22	14	0.021	42	41.3	0.122	0.176	0.54

Wanner et al. (2007a) looked at stomach contents of juvenile pallid sturgeon, using a non-lethal gastric lavage, a procedure in which water is used to flush food items from the stomach. In 2003 and 2004 (and depending on the time of the year), different prey species were identified with different percent composition in pallid sturgeon stomachs. In general, aquatic insects and fishes were important food sources for pallid sturgeon downstream of Fort Randall Dam (Wanner et al. 2007a). Overall, in 2003 and 2004, Chironomidae (a family of midges) were the most abundant prey species for pallid sturgeon, in terms of total number of species (Wanner et al. 2007a). When considering composition by dry weight, fishes, followed by Chironomidae, comprised most prey species in 2003 and Ephemeroptera (an order of mayfly) comprised most of the diet in 2004 (Wanner et al. 2007a). The findings in Wanner et al. (2007a) differed from previous research performed by Gerrity et al. (2006) which looked at juvenile pallid sturgeon above Fort Peck Reservoir in the upper reaches of the Missouri River. Gerrity et al. (2006) found sicklefin chub (*Macrhybopsis meeki*) and sturgeon chub (*M. gelida*) made up approximately 90% of pallid sturgeon diet. Neither the sicklefin chub nor the sturgeon chub have been captured in the Fort Randall reach since 2003 and are thought to be extirpated or in extremely low abundance in this area (Shuman et al. 2008). Their absence could be due to an altered hydrograph, low sediment loads in the Fort Randall reach (Wanner et al. 2007a), or the increase of stocked sportfish, such as walleye (*Sander vitreus*), smallmouth bass (*Micropterus dolomieu*), and white bass (*Morone chrysops*) (Shuman, pers. comm., 2011). Fishes that were observed by Wanner et al. (2007a) and likely consumed by pallid sturgeonincluded Johnny darter (*Etheostoma nigrum*), channel catfish (*Ictalurus punctatus*), silver chub (*Macryhbopsis storeriana*), and emerald shiner (*Notropis atherinoides*). The findings based on stomach content analysis do not indicate food preferences but rather food use bypallid sturgeon; in the 39-mile reach of MNRR, pallid sturgeon are demonstrating an opportunistic feeding strategy foraging on what is available to them (Shuman, pers. comm., 2011).

It should be noted that sicklefin and sturgeon chub are listed by South Dakota as threatened, and sturgeon chub are listed by Nebraska as endangered (SDGFP 2010, NGPC 2011). Both sicklefin and sturgeon chub are candidates to be federally listed as endangered (USFWS 2001). Other potential pallid sturgeon prey species that have reduced or declining populations in MNRR include flathead chub (*Platygobio placitus*), silver chub, speckled chub (*Macryhbopsis aestivalis*), plains minnow (*Hybognathus placitus*), and western silvery minnow (*Hybognathus argyritus*) (Berry and Young 2004).

59-Mile Segment Habitat Condition

Laustrup et al. (2007) looked at potential spawning habitat for pallid sturgeon in the Lower Missouri River (from Gavins Point Dam to the Mississippi River), and determined (similarly to DeLonay et al. 2009) that sturgeon prefer coarse gravel, cobble, or boulder substrate where water velocity is swift. The Gavins Point reach had the highest concentration of natural particulate deposits in the Lower Missouri River (Laustrup et al. 2007). Assuming prime pallid sturgeon spawning habitat includes coarse substrate, the findings in Laustrup et al. (2007) indicate the Gavins Point reach contains some of the best available spawning habitat for pallid sturgeon in the entire Lower Missouri River. According to Stukel (pers. comm., 2011), the Gavins Point Dam scours the sand out, leaving gravel and rocks, which are thought to be pallid sturgeon spawning habitat (see the Erosion and Depositional Processes assessment, Chapter 4.2 of this document, for more information). Areas of the river upstream from Yankton, SD (such as the Fort Randall Reach) may have once provided suitable habitat for spawning, due to gravel-cobble deposits of glacial origin, but the construction of the Gavins Point and Fort Randall Dam likely changed this (DeLonay et al. 2009). Figure 49 displays the distribution of pallid sturgeon captures during 2009 in the 59-mile segment by river mile (Stukel et al. 2009).

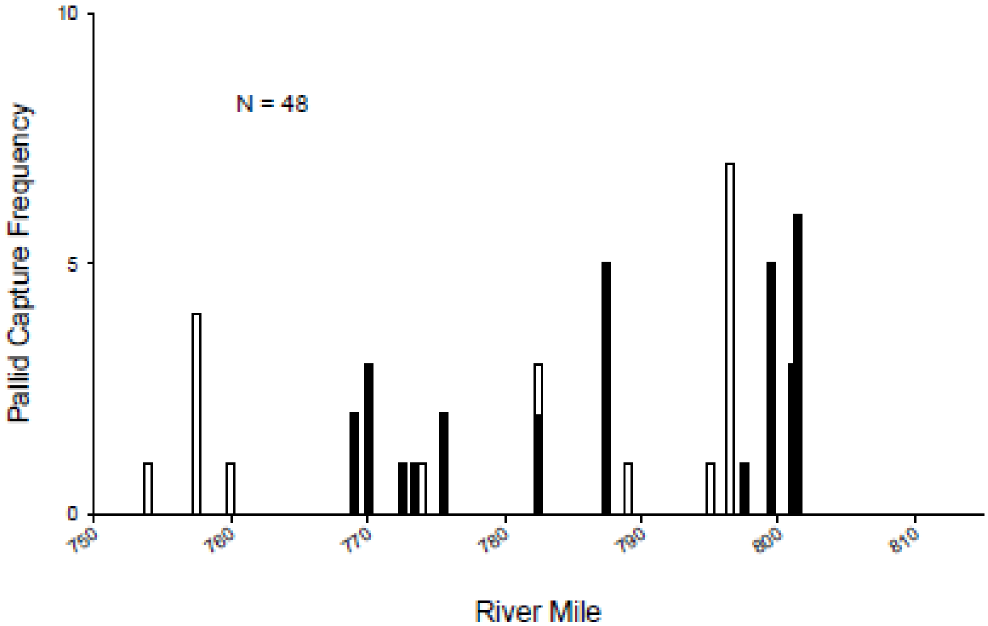

Figure 49. Distribution of pallid sturgeon captures by river mile for Segment 7 (59-mile segment) of the Missouri River during 2009. Black bars represent pallid sturgeon captures during the sturgeon season (fall-spring) and white bars during the fish community season (summer). Figure includes all pallid sturgeon captures including non-random and wild samples. Directly reproduced from Stukel et al. 2009.

Though research is not conclusive, adult pallid sturgeon are thought to prefer water that is deep, relatively fast, and has turbulent flow (DeLonay et al. 2009). Reuter et al. (2009) performed a study to examine fluvial habitat availability and use by adult sturgeon in the Lower Missouri River. In this study, they relocated 166 sturgeons (151 shovelnose and 15 pallid) to examine where the sturgeon settled. Reuter et al. (2009) found relatively consistent patterns of sturgeon settling in areas with high depth slope, high velocity gradient, and a low Froude number (a dimensionless number relating velocity to depth). Analyses of hydroacoustic maps performed by DeLonay et al. (2009) confirmed the findings of Reuter et al. (2009) that sturgeon select velocities of 0.5-0.8 m/s in minimally engineered sections (such as Gavins Point reach). In addition, DeLonay et al. (2009) found that sturgeon avoid flat areas of channels, preferred bottom slopes of 2-20 degrees, and selected areas with a relatively high velocity gradient of 0.6-3.0 percent per meter.

Pallid sturgeon rely on coarse gravel, cobble, and boulder substrate for spawning habitat, but the dams that exist act as catchments for much of the substrate that would naturally come down the Missouri River (USACE 2010). As the water approaches each reservoir, water velocity slows and the heavier substrate falls to the bottom of the river, taking longer to move through the reservoir. Despite the dams blocking the natural sediment load, the James River and the Vermillion River (two tributaries in the 59-mile segment) still bring in some natural sediment loads and are crucial to providing the Gavins Point Reach with sediment and coarse substrate (DeLonay, pers. comm., 2011). Stukel et al. (2009) found 48% of pallid sturgeon in the 59-mile segment located within 8 km (5.0 mi) of the confluence with the James River. Stukel et al. (2009) noted that these were also the trends in 2007 and 2008 (with 66% and 65% within 8 km respectively). Stukel et al. (2009) concluded this stretch of river is the most reliable place to find pallid sturgeon due to the warmer and more turbid water coming from the tributary. Though these two tributaries do not replace the sediment load once present on the pre-dam Missouri River, it is still important to monitor the tributaries' flow and their sediment loads to ensure they continue to provide the Gavins Point reach with the substrate that is needed for sturgeon spawning (DeLonay, pers. comm., 2011).

Stukel et al. (2009) documented the location of pallid sturgeon captures (based on habitat type) on the 59-mile segment in 2009, using three sampling methods: 1-inch trammel nets, gill nets, and otter trawls (Table 54). Overall, 46 fish were captured in 2009, with 43 being of hatchery origin (Stukel et al. 2009). Braided channels, inside bends, outside bends, and large connected secondary channels appeared to be the most common macrohabitats for pallid sturgeon during the sturgeon season (fall through spring), while only braided channels and outside bends were the most common locations for pallid sturgeon in the summer months (Stukel et al. 2009). In addition to the preferred broad macrohabitat locations of pallid sturgeon, Stukel et al. (2009) documented environmental characteristics (depth, bottom velocity, temperature, turbidity) of their macro and micro habitats (Table 55). Overall trends show sturgeon selecting bottom velocities from 0.25-0.99 m/s, turbidity from 11-197 Nephelometric Turbidity Units (NTU), depth from 1.2-5.2 m, and temperatures from 3.1-26.1° C (Stukel et al. 2009).

Table 54. Total number of pallid sturgeon captured for each gear type during each season and the proportion caught within each macrohabitat type in segment 7 (59-mile segment) of the Missouri River, 2009. The percent of total effort for each gear type in each habitat is presented on the second line of each gear type. Habitat definitions and codes are presented in Appendix D. Directly reproduced from Stukel et al. 2009.

		Macrohabitat													
Gear	N	BRAD	CHXO	CONF	DEND	DRNG	ISB	OSB	SCCL	SCCS	SCN	TRIB	TRML	TRMS	WILD
		Sturgeon Season (Fall through Spring)													
1 inch Trammel Net	6	17	17	17	0	0	0	0	50	0	0	0	0	0	0
		59	7	4	0	0	14	13	4	0	0	0	0	0	0
Gill Net	2	0	0	0	0	0	50	0	50	0	0	0	0	0	0
		43	9	3	0	0	25	16	3	0	0	0	2	0	0
Otter Trawl	2	50	0	0	0	0	0	50	0	0	0	0	0	0	0
		53	10	3	0	0	13	16	5	0	0	0	0	0	0
Total	10	222	43	27	0	0	102	95	112	0	0	0	2	0	0
		Fish Community Season (Summer)													
1-inch Trammel Net	9	44	11	22	0	0	0	22	0	0	0	0	0	0	0
		41	12	3	0	0	19	21	3	0	0	0	0	0	0
Gill Net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		26	0	2	0	0	13	4	19	26	6	0	4	0	0
Otter Trawl	4	75	0	0	0	0	0	25	0	0	0	0	0	0	0
		38	12	3	0	0	23	21	3	0	0	0	0	0	0
Total	13	224	35	30	0	0	55	93	25	26	6	0	4	0	0

Table 55. Pallid sturgeon summaries for all gear types relative to habitat type and environmental variables on the 59-mile segment, 2009. Means (minimum and maximum) are presented. Habitat definitions and codes are presented in Appendix D. Directly reproduced from Stukel et al. 2009.

Habitat		**Depth (m)**		**Bottom Velocity (m/s)**		**Temperature (C°)**		**Turbidity**		**Total Catch**
Macro-	Micro-	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	
BRAD	BARS	0.4(0.2-0.6)		0.14(0.00-0.38)		23.0(19.9-25.6)		38(10-69)		
	CHNB	2.3(1.2-7.6)	2.1(1.2-5.2)	0.63(0.00-1.03)	0.58(0.00-0.76)	17.4(1.4-25.7)	19.1(3.8-24.8)	42(9-130)	48(26-89)	15
	DTWT									
	ITIP									
	POOL	1.9(1.2-5.0)	1.7(1.4-2.0)	0.34(0.02-0.73)	0.39(0.35-0.43)	8.9(1.5-18.2)	10.2(10.2-10.2)	66(11-140)	65(64-65)	2
	TLWG									
CHXO	BARS									
	CHNB	2.4(1.2-4.8)	2.2(1.8-2.7)	0.69(0.26-1.11)	0.37(0.30-0.43)	16.9(1.9-25.6)	14.3(3.1-22.9)	37(10-119)	37(11-62)	3
	DTWT									
	ITIP									
	POOL									
	TLWG									
CONF	BARS	0.3(0.3-0.3)		0.11(0.11-0.11)		25.4(25.3-25.5)		350(350-350)		
	CHNB	2.8(1.2-8.7)	2.3(1.8-2.8)	0.60(0.35-1.05)	0.51(0.44-0.62)	18.9(2.2-27.0)	23.2(19.5-26.1)	94(16-197)	160(74-197)	9
	DTWT									
	ITIP									
	POOL									
	TLWG									
DRNG	BARS									
	CHNB									
	DTWT									
	ITIP									
	POOL									
	TLWG									
ISB	BARS	0.4(0.3-0.6)		0.08(0.00-0.18)		21.7(20.8-23.5)		46(12.131)		
	CHNB	2.0(1.1-6.6)	2.2(2.2-2.2)	0.62(0.09-1.07)	0.53(0.53-0.53)	16.3(1.4-26.1)	9.7(9.7-9.7)	31(7-98)	26(26-26)	1

Table 55. Pallid sturgeon capture summaries for all gear types relative to habitat type and environmental variables on the 59-mile segment during 2009. Means (minimum and maximum) are presented. Habitat definitions and codes are presented in Appendix D. Directly reproduced from Stukel et al. 2009. (continued)

Habitat		**Depth (m)**		**Bottom Velocity (m/s)**		**Temperature (C°)**		**Turbidity**		**Total Catch**
Macro	Micro	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	
ISB	DTWT									
	ITIP									
	POOL	1.7(1.2-2.5)	1.3(1.3-1.3)	0.34(0.03-0.78)	0.78(0.78-0.78)	9.0(1.3-19.7)	12.0(12.0-12.0)	33(11-87)	22(22-22)	1
	TLWG									
OSB	BARS	0.4(0.3-0.6)		0.05(0.01-0.09)		23.6(21.7-25.5)		31(15-47)		
	CHNB	3.3(1.2-8.4)	2.7(1.3-4.4)	0.63(0.13-0.99)	0.70(0.43-0.99)	16.8(1.2-26.1)	14.9(3.1-23.5)	30(7-100)	38(17-87)	10
	DTWT									
	ITIP									
	POOL	3.2(1.4-6.0)	1.4(1.4-1.4)	0.12(0.00-0.24)		7.0(2.0-17.8)	5.7(5.7-5.7)	41(17-80)	27(27-27)	1
	TLWG									
SCCL	BARS	0.4(0.3-0.6)		0.09(0.00-0.22)		23.1(20.8-25.4)		27(9-54)		
	CHNB	1.9(1.2-4.0)	2.1(1.3-4.0)	0.58(0.00-1.09)	0.34(0.25-042)	17.4(4.1-24.5)	13.7(6.6-16.1)	42(6-110)	92(45-110)	6
	DTWT									
	ITIP									
	POOL									
	TLWG									
SCCS	BARS	0.4(0.3-0.6)		0.13(0.00-0.22)		23.6(20.1-25.7)		38(10.-79)		
	CHNB									
	DTWT									
	ITIP									
	POOL									
	TLWG									
SCN	BARS									
	CHNB									
	DTWT									
	ITIP									

Table 55. Pallid sturgeon capture summaries for all gear types relative to habitat type and environmental variables on the 59-mile segment during 2009. Means (minimum and maximum) are presented. Habitat definitions and codes are presented in Appendix D. Directly reproduced from Stukel et al. 2009. (continued)

Habitat		**Depth (m)**		**Bottom Velocity (m/s)**		**Temperature (C°)**		**Turbidity**		**Total**
Micro	Macro	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	
SCN	POOL									
	NULL	0.6(0.5-0.6)		0.00(0.00-0.01)		21.6(21.1-22.2)		15(11-18)		
TRIB	BARS									
	CHNB									
	DTWT									
	ITIP									
	POOL									
	TLWG									
TRML	BARS	0.4(0.3-0.5)		0.01(0.00-0.02)		24.0(22.9-24.9)		261(69-452)		
	CHNB	2.3(1.8-3.8)		0.03(0.00-0.06)		14.4(5.4-26.9)		72(71-73)		
	DTWT									
	ITIP									
	POOL									
	TLWG									
WILD	BARS									
	CHNB									
	DTWT	4.4(2.7-5.7)		0.59(0.50-0.68)		21.4(21.4-21.5)		11(10-11)		
	ITIP									
	POOL									
	TLWG									

39-Mile Segment Habitat Condition

Wanner et al. (2007b) performed a study similar to Reuter et al. (2009), focusing on habitat and movement patterns of pallid sturgeon in the 39-mile segment. Using ultrasonic telemetry devices, Wanner et al. (2007b) found that pallid sturgeon were located in main channel habitats at relative depths ranging from 79 to 100% of the maximum channel depth. Jordan et al. (2006) found juvenile pallid sturgeon at depths greater than 80% of the maximum depth. These movement patterns were found throughout all seasons of the year. All of the pallid sturgeons studied in Wanner et al. (2007b) were found in these habitats, except for one fish on one occasion, which was found in a deep, secondary channel near the headwaters of Lewis and Clark Lake. Wanner et al. (2007b) recorded no pallid sturgeon in the following habitat types: tailrace, island tips, backwaters, reservoirs, or tributaries.

Shuman et al. (2010) studied the pallid sturgeon population in the 39-mile segment of MNRR, using three sampling methods: 1-inch trammels, gill nets, and otter trawls. Shuman et al. (2010) found a total of 177 pallid sturgeon in the 39-mile segment, with 94% of hatchery origin. Braided channels proved to be the dominant macrohabitat for pallid sturgeon, with a total of 119 sturgeon. Table 56 summarizes the number of pallid sturgeon found in different macrohabitats per sampling method and season. In addition, Table 57 summarizes specific environmental characteristics of macrohabitats where Shuman et al. (2010) captured pallid sturgeon.

Table 56. Total number of pallid sturgeon captured for each gear type during each season and the proportion caught within each macrohabitat type in the 39-mile segment of the Missouri River, 2009. The percent of total effort for each gear type in each habitat is presented on the second line of each gear type. Habitat definitions and codes are presented in Appendix D. Directly reproduced from Shuman et al. 2010.

Gear	N	Macrohabitat											
		BRAD	CHXO	CONF	DEND	DRNG	ISB	OSB	SCCL	SCCS	SCN	TRIB	TRML
Sturgeon Season (Fall through Spring)													
1-inch Trammel Net	9	67	22	0	0	0	0	11	0	0	0	0	0
		43	11	3	0	0	13	10	19	0	0	0	0
Gill Net	44	73	9	0	0	0	0	5	14	0	0	0	0
		46	15	0	0	0	14	16	11	0	0	0	0
Otter Trawl	6	17	0	50	0	0	17	17	0	0	0	0	0
		44	14	4	0	0	14	11	13	0	0	0	0
Total	59	157	71	57	0	0	58	70	57	0	0	0	0
Fish Community Season (Summer)													
1-inch Trammel Net	12	67	8	0	0	0	8	0	17	0	0	0	0
		41	13	4	0	0	11	12	18	0	0	0	0
Gill Net	0	0	0	0	0	0	0	0	0	0	0	0	0
		40	16	6	0	0	12	16	10	0	0	0	0
Otter Trawl	8	88	0	0	0	0	13	0	0	0	0	0	0
		40	14	6	0	0	14	16	10	0	0	0	0
Total	20	276	51	16	0	0	58	44	55	0	0	0	0

Table 57. Pallid sturgeon capture summaries for all gear typess relative to habitat type and environmental variables on the 39-mile segment of the Missouri River, 2009. Means (minimum and maximum) are presented. Habitat definitions and codes are presented in Appendix D. Directly reproduced from Shuman et al. 2010.

Habitat		Depth (m)		Bottom Velocity (m/s)		Temperature (C°)		Turbidity		Total Catch
Macro-	Micro-	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	
BRAD	BARS	0.4 (0.2-0.6)		0.08 (0.00-0.14)		22.0 (20.9-23.0)		19 (10-36)		
	CHNB	3.4 (1.2-9.1)	4.1 (1.2-9.1)	0.43 (0.03-0.91)	0.40 (0.04-0.79)	14.5 (8.2-24.0)	13.3 (8.2-22.6)	40 (12-139)	51 (16-139)	119
CHXO	BARS	0.4 (0.2-0.6)		0.07 (0.04-0.14)		21.8 (19.7-24.0)		14 (4-26		
	CHNB	3.1 (1.2-7.0)	2.6 (1.3-4.2)	0.36 (0.01-0.78)	0.30 (0.19-0.38)	12.3 (3.2-23.5)	8.5 (3.7-16.5)	8 (4-28)	9 (5-21)	18
CONF	BARS	0.5 (0.3-0.8)		0.01 (0.01-0.01)		20.3 (20.3-20.3)		17 (17-17)		
	CHNB	4.7 (1.3-8.9)	6.2 (6.2-6.2)	0.60 (0.38-0.82)	0.38 (0.38-0.38)	17.6 (13.0-24.0)	14.5 (14.3-14.7)	16 (13-19)	17 (17-17)	5
ISB	BARS	0.4 (0.3-0.7)		0.04 (0.01-0.09)		22.5 (20.3-25.2)		16 (6-30)		
	CHNB	3.1 (1.2-8.3)	3.6 (2.1-5.8)	0.35 (0.04-0.87)	0.32 (0.27-0.38)	12.9 (3.2-23.6)	15.3 (8.1-22.0)	8 (3-24)	6 (3-7)	4
OSB	BARS	0.4 (0.2-0.6)		0.10 (0.01-0.16)		22.0 (20.6-23.8)		20 (8-36)		
	CHNB	4.4 (1.5-8.1)	4.2 (2.1-6.3)	0.37 (0.00-0.81)	0.27 (0.09-0.46)	12.3 (3.2-23.6)	9.0 (3.7-13.5)	13 (3-140)	21 (3-140)	13
SCCL	BARS	0.5 (0.3-0.7)		0.07 (0.01-0.10)		20.6 (19.7-21.1)		14 (10-18)		
	CHNB	3.6 (1.4-8.8)	3.0 (1.8-5.1)	0.48 (0.12-0.88)	0.34 (0.12-0.84)	14.5 (3.2-25.0)	16.8 (3.7-23.6)	9 (5-21)	9 (5-21)	18

Locations with the most pallid sturgeon captures in the Fort Randall reach in 2008 included river mile 837 (31 pallid sturgeon), river mile 849 (17 pallid sturgeon), and river mile 834 (12 pallid sturgeon) (Shuman et al. 2008). Shuman et al. (2008) found some patterns of clustering in juvenile pallid sturgeon, which is likely due to habitat and food use. When compared to Shuman et al. (2008), Shuman et al. (2010) found similar trends, with most sturgeon located in segment 6 (between river miles 830 and 845) and large clusters around river mile 829 and 834 (Figure 50). Specifically, the largest clusters of pallid sturgeon found in Shuman et al. (2010) were in the Niobrara River Delta.

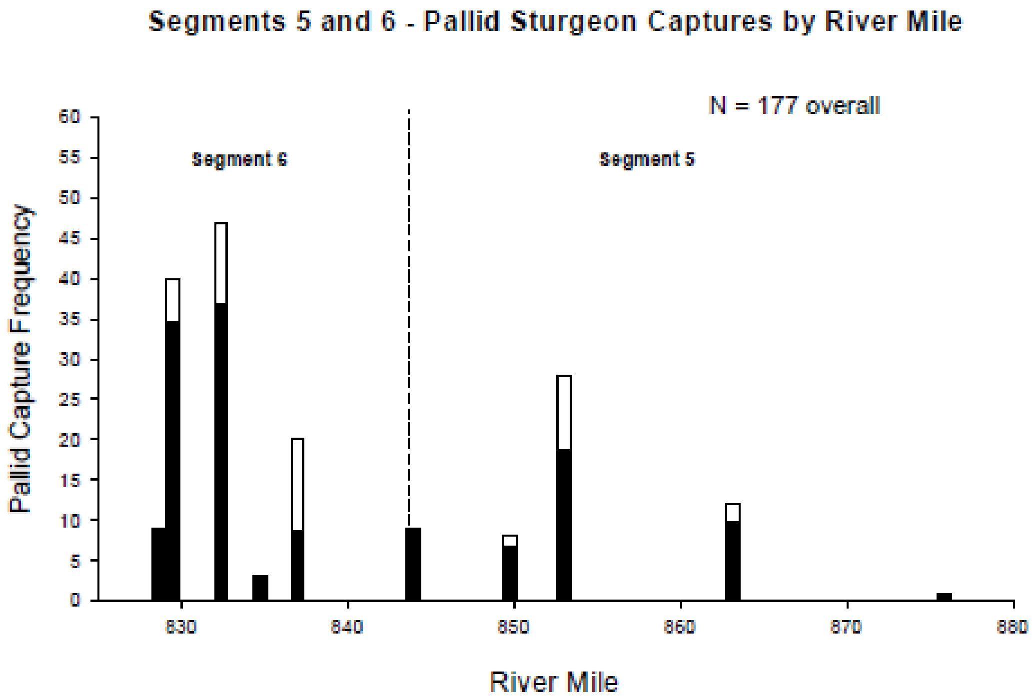

Figure 50. Distribution of pallid sturgeon captures by river mile for segments 5 and 6 (39-mile segment) of the Missouri River in 2009. Black bars represent pallid sturgeon captures during the sturgeon season (fall-spring) and white bars during the fish community season (summer). Figure includes all pallid sturgeon captures including non-random and wild samples. Directly reproduced from Shuman et al. 2010.

The Fort Randall reach currently has no confirmed native wild population of pallid sturgeon (USFWS 2005). However, Shuman et al. (2010) identified two potentially wild pallid sturgeon, though the origin of these individuals has not been genetically confirmed. The last time a wild pallid sturgeon was identified in this reach was around 1991 (USFWS 2007). Despite the concerns about no truly wild fish existing in this reach, Shuman et al. (2005) found that the hatchery-reared fish are surviving and individuals are growing in size. DeLonay (pers. comm., 2011) suggests that pallid sturgeon can survive in the Fort Randall segment, but that the segment is likely not conducive (and likely will not be conducive) to pallid sturgeon spawning for several reasons: the water in the Fort Randall segment is too cold, there are extensive power peaks from the hydroelectric Fort Randall Dam, and there are no native chubs for adult feeding.

Threats and Stressor Factors

The Missouri River's hydrograph in its pre-dam state typically included two spring flood peaks: one from the snow melt in the Great Plains and one from snow melt in the Rocky Mountains, which occurred later in the spring (Reuter et al. 2009). These flood peaks were followed by a low flow period in the summer, with short, periodic high flows from rainstorms (Reuter et al. 2009). However, flow regulation from the dams in the Missouri River has decreased spring pulses and increased summer flow, thus interrupting natural disturbance processes (Reuter et al. 2009). The former spring flood peaks would have normally washed nutrients from the banks into the river, contributing to the overall productivity of the river (USFWS 2000). However, due to the dams, natural flooding is not occurring on the Missouri River and these nutrients are not being deposited into the river.

Spawning cues are important in understanding how pallid sturgeon respond to environmental changes. Spawning cues are natural processes that act as a signal to reproducing adults that it is time to begin the upstream migration and spawn. Water temperature, water discharge, and day of the year/length of the day are three potential environmental spawning cues (DeLonay et al. 2009). Historically, sturgeon migration began during a large flow pulse that occurred in the spring. This may mean that the change in flow sent a signal to fertile sturgeon that it was time to migrate upstream and spawn (USFWS 2003, as cited in Reuter et al. 2009). Both temperature and water discharge are affected by reservoir creation thus restricting the environmental cues required to trigger their upstream migration necessary for spawning. DeLonay et al. (2009) hypothesize that once the pallid sturgeon migrate upstream, it is possible that they require another cue to begin ovulation and to release their gametes. This spawning cue is thought to be water temperature, discharge, or day of the year. Again, both water temperature and discharge are affected by impoundment, so there is a possibility that after gravid females move upstream, they never release their gametes because the proper conditions do not currently exist (DeLonay et al. 2009).

The United States Army Corps of Engineers began experimenting with controlled high flows from Gavins Point Dam in 2006 to simulate high spring flows. The goal of this experiment was to send a signal to pallid sturgeon to begin migrating upstream to spawn. Originally, the USACE planned to release two spring pulses, but since the program began, there has not been a single year in which both pulses occurred (USACE 2010). In addition, the pulses that do occur are not of the same magnitude that would have occurred naturally prior to impoundment (DeLonay, pers. comm., 2011). These shortcomings could prove the high flow efforts by the USACE to be insufficient replacements for the high flow events that would have occurred naturally.

Impoundment of the Missouri River has significantly increased predation and competition risks for young pallid sturgeon. The Missouri River dams have disrupted the natural flow, allowing the water to become less turbid, thus making sight-feeding piscivorous fishes, such as sauger (*Sander canadensis*), walleye, and smallmouth bass, a larger threat (Hesse et al. 1989, as cited in DeLonay et al. 2009).

The introduction of contaminants into river ecosystems is a major threat to pallid sturgeon habitat, as well as all plants and animals found in the Missouri River. Specifically, DeLonay (pers. comm., 2011) has documented the introduction of oral contraceptives into the river system through human waste. Waste treatment plants do not remove these oral contraceptive compounds, along with many other pharmaceuticals (DeLonay, pers. comm., 2011). Human oral contraceptives are thought to cause hormonal changes in sturgeon, and several intersex shovelnose sturgeons have been documented with eggs growing near their testicular tissue (DeLonay, pers. comm., 2011). Usually intersex characteristics are only identifiable by microscope, but these intersex characteristics were visible to the naked eye, which indicates that they were highly developed (DeLonay, pers. comm., 2011). Only a few pallid sturgeon have been detected with both male and female reproductive organs, but their anatomical and physiological similarities with shovelnose sturgeon indicate a reason to be concerned (DeLonay, pers. comm., 2011).

The expansion of Asian carp species represents a threat to pallid sturgeons (DeLonay, pers. comm., 2011). Asian carp are a direct threat as they are likely to prey on pallid sturgeon larvae. This threat becomes more imminent with the lower turbidity of much of the Missouri River. Three species of Asian carp have been documented in the 59-mile segment of MNRR, but dams have blocked upstream migration into the middle and upper Reaches of the Missouri River (Klumb 2007; Shuman et al. 2010).

Perhaps the biggest threat facing pallid sturgeon and most native Missouri River fish in the 39-mile segment are the power peaks from the Fort Randall hydroelectric dam (Shuman, pers. comm., 2011). Power peaks are periods of the day when more power is required by consumers (typically between 5:00 p.m. and 9:00 p.m.) and subsequently more power has to be generated by the dam (USACE 2009a). Whendemand for electricity is low throughout the day, there is a decrease in flow and the water levels drop, and when the power peak occurs, flow increases and water levels rise. These fluctuations and inconsistencies in water levels occurring on a daily basis are a major threat to productivity of the system and thus likely to pallid sturgeon (Shuman, pers. comm., 2011). The fluctuations in flow caused by power peaking not only affect water level but they also affect water velocity, water temperature, turbidity, and sediment load (Shuman, pers. comm., 2011). In MNRR, power peaking is a problem unique to the Fort Randall segment, because the Fort Randall Dam is a hypolimnetic discharge system designed for peaking, while the Gavins Point Dam is a top-water discharge system designed for baseload energy production (USACE 2009a). This means that the Gavins Point Dam provides a continuous supply of energy and thus releases a continuous amount of water into the 59-mile segment (USACE 2009a).

<u>Data Needs/Gaps</u>

The introduction of contaminants such as oral contraceptives into the Missouri River is of major concern, but there is little conclusive evidence regarding the implications for reproductive problems in pallid sturgeon. Research examining these complexities is important, given the low recruitment of pallid sturgeon in the lower Missouri River.

The threat of Asian carp expanding their range and increasing their population in the Missouri River is substantial. However, the prevalence of competition between Asian carp and pallid sturgeon is not well documented. Understanding how imminent of a threat Asian carp pose to pallid sturgeon is important in creating a management plan to deal with the Asian carp.

Since the USACE began simulating spring pulses to trigger upstream migration, the pulses have been insufficient in replicating the two high flows that would naturally occur on the Missouri River. Further research assessing the effectiveness of these attempts could explain what changes must be made so that pallid sturgeon recognize the high-flow period and migrate upstream to begin spawning. It would also be beneficial to further expand upon the research from DeLonay et al. (2009) to analyze if pallid sturgeon need another environmental cue to trigger ovulation, after upstream migration is complete.

Careful monitoring of hatchery-reared versus wild pallid sturgeon populations is critical. The original release of hatchery-reared pallid sturgeon was in 1995; therefore, many of these fish should be near sexual maturity. Nearly all of the captured pallid sturgeon in MNRR have been hatchery-reared, so it is important to track and monitor their spawning habits to ensure reproductive success. Since there are so few wild pallid sturgeon, the survival and successful reproduction of the hatchery-reared fish is critical for the continued existence of the species in the Missouri River.

Wanner et al. (2007a) and Gerrity et al. (2006) found major differences in feeding habits of pallid sturgeon between the Fort Randall segment and the upper reaches of the Missouri River. These differences in feeding habits were likely a result of what was available to them. Understanding the importance of sicklefin and sturgeon chub (which were determined to be the most prevalent prey by Gerrity et al. 2006) to adult pallid sturgeon survival is important, due to the absence of both of these species in the Fort Randall segment. Shuman (pers. comm., 2011) hypothesizes that pallid sturgeon are most likely opportunistic feeders, but it is important to verify this in order to understand the importance of a particular food source for adult pallid sturgeon survival.

<u>Overall Condition</u>

Measures	*Reference Condition*	*Condition*
Habitat diversity	Pre-dam	
Productivity	Pre-dam	

Figure 51. Pallid Sturgeon condition graphic.

The condition of pallid sturgeon habitat in MNRR must be broken up into the 39-mile segment and the 59-mile segment, due to the vast differences in available habitat.

The condition of pallid sturgeon habitat and productivity in the 39-mile segment of MNRR is of significant concern (Figure 51). Fort Randall Dam has greatly affected this reach in several ways: gravid female sturgeon cannot migrate upstream to spawn, the streambed is degrading, the water is too cold and clear, and the power peaks are extremely disruptive. This results in a segment that is not conducive to spawning. It is possible for adult pallid sturgeon to survive here, but the likelihood of successful reproduction in this stretch of river is unlikely (DeLonay, pers. comm., 2011). In addition, if pallid sturgeon were to spawn, the effects would likely only be noticed in the 59-mile reach due to larval drift (Shuman, pers. comm., 2011).

Pallid sturgeon habitat in the 59-mile segment of MNRR is physically in much better condition than the 39-mile segment and but should be considered of significant concern overall. There are issues of low turbidity and sediment loads being blocked by the upstream impoundments, specifically the Gavins Point Dam. However, tributaries such as the James River and the Vermillion River provide some coarse substrate and turbidity to the main channel of the Missouri River, but not enough to replace what the dam holds back. Water temperatures and turbidity levels are more conducive to spawning in the 59-mile segment than the 39-mile segment, largely due to the decreased effect of hypolimnetic releases from Fort Randall. Overall, the 59-mile segment of MNRR appears to be conducive to pallid sturgeon spawning, and the recent documentation of 10-12 spawning pallid sturgeon provides some optimism that the hatchery-reared and wild pallid sturgeon are beginning to spawn (USGS 2007; DeLonay, pers. comm., 2011).

Sources of Expertise

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4.7 Least Tern and Piping Plover

Description

Least Tern

The least tern (*Sternula antillarum*) is a migratory waterbird and is the smallest member of the tern family in North America. The species breeds along the Atlantic and Gulf coasts, Caribbean islands, on the Pacific coast of southern California and the Baja Peninsula and on sandbars of several interior rivers of the United States. The interior and California populations of the least tern are listed as endangered under the Endangered Species Act. The Atlantic and Gulf coast populations are not listed (Pavelka et al. 2009).

Photo 4. Least Tern on nest.(Courtesy of MNRR).

The least tern is a member of the order Charadriiformes (waders, gulls and auks), family Laridae (skuas, jaegers, gulls and terns) and genus *Sternula* (the little terns). The least tern is the only *Sternula* species that is found in North America. Laridae members are generally opportunistic feeders, but terns have specialized diets. The least tern is a piscivore (feeding exclusively on fish); they hover and dive over water, using sight to capture small fish (USFWS 1990).

The least tern is a slender bird with long narrow wings, a forked tail and pointed bill. The adults weigh 40 to 45 grams (1.5 ounces), are about 22 cm (8.5 inches) in length, and have a wingspan of 50 cm (20 inches). Both sexes are similar in size and color, with upper parts that are gray and under parts that are white. The least tern will undergo a molt to its alternate (breeding) plumage before leaving the wintering grounds. There are several characteristics that distinguish the least tern in its alternate plumage from other terns. These include a black head cap, black stripe from beak across the side of the head, the most distinguishing characteristic – a white triangular forehead, and a yellow beak.

Least terns arrive on the Missouri River between mid-May and early June. Nest sites on the Missouri can range from single nests to colonies with over 50 nests. The nest is a scrape in the sand with a clutch of two to three eggs. Both the male and female will incubate eggs. Chicks hatch after 17-26 days of incubation. The chicks take 18-22 days to fledge (fly). If the nest fails or the chicks are lost at a young age, the pair may re-nest. The return to the wintering grounds may begin as early as late June on the Missouri River. The majority of least terns will form flocks and depart from mid-July to mid-August. The southern migration follows the main river drainages down to the mouth of the Mississippi River in Louisiana, where the terns arrive from mid to late August. The route further south to the wintering grounds is not known and there is little information as to the location of the wintering grounds. least terns are believed to winter on the Atlantic coast as far south as Argentina and on the Pacific coast as far south as Colombia (Pavelka et al. 2009).

Least tern breeding success on the Missouri is dependent upon three ecological factors: 1) the presence of bare or nearly bare alluvial islands or sandbars, 2) the existence of favorable water levels during the nesting seasons, and 3) the availability of food (Ducey 1981, as cited in USFR 1985). Natural erosion and deposition processes create bare sandbars that the least tern uses for nesting habitat. Dams on the Missouri River, implemented for flood control and navigation, prevent natural erosion and deposition processes. Because of this, available nesting habitat for least terns in MNNR has decreased.

Piping Plover

The piping plover (*Charadrius melodus*) is a small, stocky shorebird. The species is migratory and spends the fall, winter and early spring on beaches along the south Atlantic of the United States, the Gulf coast of the United States and Mexico, the Bahamas and Caribbean islands. In March and April piping plovers will migrate to their breeding grounds, which include the mid and north Atlantic coast of the United States and Canada, the Great Lakes, the northern Great Plains of the United States and the southern prairies of Canada. In the United States, the Atlantic coast and northern Great Plains populations are listed as threatened and the Great Lakes population is listed as endangered under the Endangered Species Act (Pavelka et al. 2009).

Photo 5. Juvenile Piping Plover standing on beach (Courtesy Mike Morel, USFWS).

The piping plover is a member of the order Charadriiformes (waders, gulls and auks), family Charadriidae (lapwings, plovers and dotterels) and genus *Charadrius* (banded plovers). There are two subspecies of piping plovers: *C. m. melodus* (Atlantic coast breeders) and *C. m. circumcinctus* (Great Lakes and northern Great Plains populations). Adult piping plovers weigh between 43-63 grams (1.5 to 2.0 ounces), have a length of 17-18 cm (7 inches), and a 38 cm (15 inch) wingspread. The dorsal (upper) parts are a pale grayish brown color, resembling the color of dry sand. The ventral (under) parts are white (Pavelka et al. 2009).

Before undertaking the spring migration, the piping plover undergoes a molt into the alternate (breeding) plumage. There are several characteristics that distinguish the piping plover in its alternate plumage. These include: a black band across the forehead between the eyes, an orange, black-tipped bill, a narrow single black band below the neck that may be incomplete, and yellowish-orange legs. The piping plover eats worms, fly larvae, beetles, crustaceans, mollusks, and other invertebrates, which are plucked from the sand (Pavelka et al. 2009).

Piping plovers arrive on the Missouri River in mid-April to mid-May and nest on sand bars with little vegetation. However, this species is more tolerant of vegetation than the least tern. Courtship and nesting begins in late-April and continues through May or June (USACE 2009a). The nest is a scrape in the sand, usually lined with pebbles, with a clutch of three to four eggs. Chicks hatch after 22-30 days of incubation, and are able to fly after 25-30 days. Plovers may depart for the wintering grounds as early as late June or early July. Adults that were unsuccessful in a first nest attempt or lost chicks at an early age may re-nest a second or third time. These adults may not leave for the wintering grounds until mid to late August. Females generally leave for the wintering grounds before the males, leaving the males with the responsibility of guarding unfledged chicks. Late in the season, males may also leave before the chicks have fledged, leaving the chicks to fend for themselves. Wintering grounds include the Gulf coast from Mexico to Florida, the Atlantic coast from Florida to North Carolina, the Bahamas, Cuba and Caribbean islands (Pavelka et al. 2009).

Like the least tern, the piping plover nests on river sandbars in the MNRR and dams compromise the availability of suitable habitat. To augment nesting success of both species on the Missouri River, USACE develops and maintains artificial sand bars, also known as ESH. On the Niobrara River, dams do not compromise the habitat availability on the entire section of the river. NPS, along with NGPC and various NGOs, routinely monitor nesting on the Niobrara River.

Measures

- Available nesting habitat
- Fledge ratios
- Population size

Reference Conditions/Values

<u>Pre-dam Conditions</u>

The reference condition for these species is pre-dam sandbar habitat. Dam operations limit high discharge events, affecting natural island and bare sandbar formation and preventing scouring of vegetation from vegetated bars. Dam operations that sustain elevated flows for navigation prevent exposure of bare sand bars related to low-stage conditions that occurred prior to flow regulation (Macy, pers. comm., 2011).

Since the closure of dams on the Missouri River during the early 1950s, the hydrograph has changed significantly along with associated erosion and deposition processes. From 1931-1954, the average peak flow below present-day Gavins Point Dam was 144,758 ft^3/s. Pre-dam peak flows were quite variable as well, ranging from 46,500 to 480,000 ft^3/s (Figure 52). Compared to the pre-dam era, current yearly peak flow (41,148 ft^3/s) and the peak flow range (24,500-70,100 ft^3/s) are substantially less.

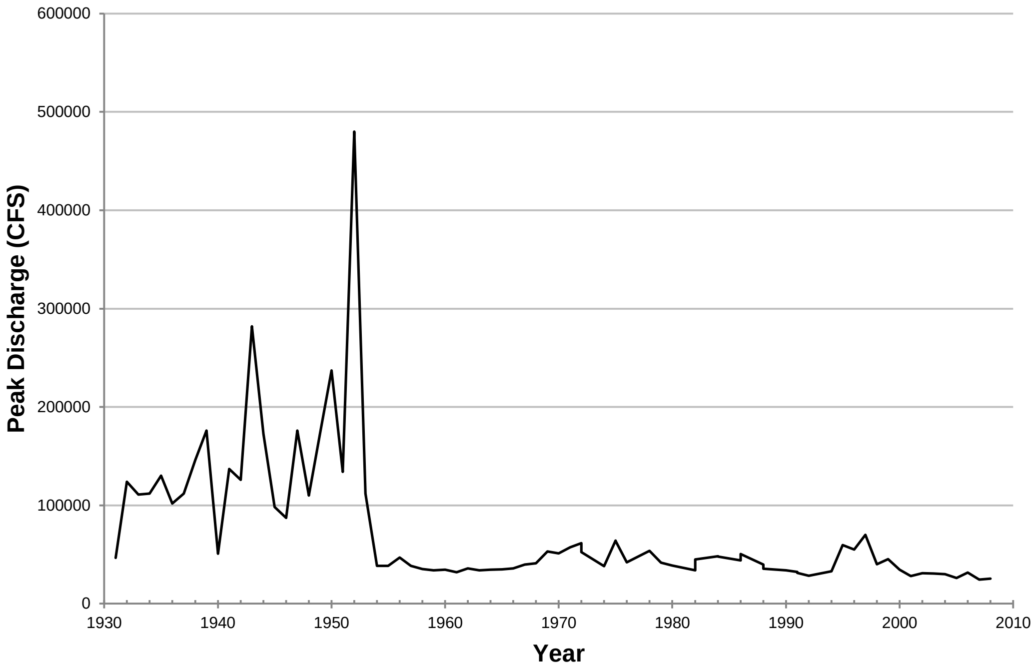


Figure 52. Yearly peak flow at Yankton, SD (below Gavins Point Dam), 1931-2008 (Data received from MNRR).

Sandbars form through depositional processes on the streambed. Leopold et al. (1964) describe the importance of changes in bed configuration as a relationship of the changing form to flow resistance and sediment transport. In natural channels, the change of bed configuration has a large effect on flow resistance (Leopold et al. 1964). Sediment caliber or grain size may help govern the nature, action, and form of the features built on the bed, which exert the greatest influence on flow resistance. Overall, the downstream reduction in flow resistance, resulting from decrease in particle size, is partly compensated by other forms of flow resistance, particularly that offered by bars and channel bends (Leopold et al. 1964). The change of bed is a mechanism or process by which the interactions of hydraulic variables (width, depth, velocity, etc.) can readjust to promote and maintain a kind of equilibrium or steady-state condition in the open system represented by the water and sediment in the adjustable channel (Leopold et al. 1964).

The number and area of bare sand bars is related to stage (discharge level), with greater amounts of bare sand bars exposed in the river corridor when the stage is low. High flow events were capable of creating new sand bars and scouring vegetation from existing low-lying bars (Elliot and Jacobson 2006).

A natural sediment source is necessary for sandbar/island formation (Ward et al. 2001). Prior to closure of Gavins Point Dam (1940-1952), the average annual sediment load transported past Omaha, NE, was 149 million metric tons. After 1954, the average annual sediment load was reduced to 29,487,600 metric tons (Slizeski et al. 1982, as cited by NRC 2002). Sandbar creation is also dependent upon a source of large, woody debris (Ward et al. 2001). Using 1999 orthophotographs, Elliot and Jacobson (2006) identified an average of 38.1 pieces of large woody debris per kilometer in the 39-mile reach and 96.2 pieces per kilometer in the 59-mile reach.

Elliot and Jacobson (2006) determined the number and area of vegetated bars (islands) and bare sandbars prior to dam construction on the Gavins Point 59-mile reach of the Missouri River from 1941 orthophotographs. The number and area of islands and sandbars were not determined for the Fort Randall 39-mile reach before dam construction. Table 23 displays the discharge (when the aerial photographs were taken) and the number and area of islands and sandbars by date for both reaches of the MNRR (Elliot and Jacobson 2006). The values obtained in 1941 represent the reference condition for island and sandbar condition, although pre-European settlement island and sandbar conditions may have been different than what was found in 1941 (Macy, pers. comm., 2011).

Table 58. Sandbar analysis for the Fort Randall and Gavins Point reaches of the Missouri River (Elliot and Jacobson 2006).

Gavins Point 59-mile Reach

Year	Discharge (m^3/sec)	Number of Bars	Bars/km	Total Bar Area (ha)	Mean Bar Area (ha)
		Vegetated Bars (Islands)			
1941	795	46	0.5	4534	99
1998	735	45	0.5	1209	27
2004	750	145	1.7	1921	13
		Bare Sand Bars			
1941	795	312	3.6	1804	6
1998	735	312	3.6	2022	6
2004	750	634	7.2	492	1

Fort Randall 39-mile Free-Flowing Reach

Year	Discharge (m^3/sec)	Number of Bars	Bars/km	Total Bar Area (ha)	Mean Bar Area (ha)
		Vegetated Bars (Islands)			
1999	680	322	5.6	1749	5.4
2004	735	164	2.9	1902	12
		Bare Sand Bars			
1999	680	82	1.4	302	3.7
2004	735	85	1.5	351	4

Fort Randall 39-mile Delta Reach

Year	Discharge (m^3/sec)	Number of Bars	Bars/km	Total Bar Area (ha)	Mean Bar Area (ha)
		Vegetated Bars (Islands)			
1999	680	703	26.9	4414	6.3
2004	735	465	17.6	4177	9
		Bare Sand Bars			
1999	680	111	4.2	232	2.1
2004	735	77	2.9	237	3

Endangered Species Act Mandates and the USFWS Biological Opinion

Section 7 of the Endangered Species Act requires all federal agencies to consult with the National Marine Fisheries Service (NMFS) or the USFWS when actions may affect listed species or their habitat (16 U.S.C. Section 1536(a)(2)). The operation of USACE dams on the Missouri River falls under this scenario because of the three endangered species that utilize the river: piping plover, least tern, and pallid sturgeon. USACE works with USFWS to minimize the effects that dam operations inflict on these species. The chief documents that explain the goals and management strategies regarding the threatened and endangered species on or in the

Missouri River are the 2000 USFWS Biological Opinion (BiOp) on the operation of the Missouri River Main Stem Reservoir System, operation and maintenance of the Missouri River Bank Stabilization and Navigation Project, and operation of the Kansas River Reservoir System and its 2003 Amendment.

The BiOp and its amendment define reasonable and prudent measures (RPM) for each threatened or endangered species on or in the Missouri River Main Stem Reservoir System. In the BiOp, RPMs are goals that –along with the terms and conditions that implement them, cannot alter the basic design, location, scope, duration, or timing of the action and may involve only minor changes (50 CFR 402.14(i)(2)).” Simplified, RPMs are goals achieved without altering the primary objective of the consulted operation. BiOp RPM goals regarding available nesting habitat are presented later in this document.

The BiOp and BiOp amendment state goals for least tern and piping plovers in terms of fledge ratios. Fledge ratio is defined as the number of flighted chicks per breeding pair (USFWS 2000). The fledge ratio goals in the BiOp amendment are:

> Habitat shall be provided as a priority and other management actions implemented to meet or exceed fledgling per pair ratio goals of 0.70 for least terns and 1.13 for piping plovers. These are to be determined as the recent (past) 3-year running average… These fledge ratios have been superseded (sic) by those found in the incidental take statement of this document (USFWS 2003).

The target fledge ratios that supersede for least terns and piping plovers are 0.94 and 1.22, respectively. In response to these goals, USACE (2009) intends to restore a sufficient amount of emergent sandbar habitat to stabilize, and eventually recover, tern and plover populations along the Missouri River Main Stem.

The BiOp and its amendment also define goals regarding the incidental take of endangered species by USACE operations. These goals and their achievement status are presented later in this document.

Population Goals
USFWS (1990) describes the population goals for least terns on the Missouri River. Below Fort Randall Dam (Missouri River and Lewis and Clark Lake combined) the goal is 80 adults. Below Gavins Point Dam, the goal is 400 individuals. For the Niobrara River, the population goal is 100 adults.

USFWS (1988) offers the population goals for the Great Lakes and Northern Great Plains populations of the piping plover. For Lake Oahe, the Fort Randall River segment, and Lewis and Clark Lake segments, the combined goal is 150 adults. For the Gavins Point reach, the population goal is 250 pairs. For the Niobrara River, the population goal is 200 adults.

Data and Methods
USFWS provided monitoring data for both species to Gia Wagner, MNRR Chief of Resources, and those data were made available to the project team. Census data for MNRR are collected by USACE, USFWS, and NPS. Data were clean upon delivery and minimal processing was required, aside from figure and table development. Some tables were reproduced from USFWS

and USACE documents for formatting and stylistic purposes. NPS staff provided data explaining population characteristics.

Current Condition and Trend

Available Nesting Habitat

Four RPMs in the BiOp amendment directly state management goals regarding piping plover and least tern habitat on the Missouri River. Least tern rpm 3 and piping plover RPM 7 direct USACE to design, construct, and manage created sandbars in a manner that will provide for the biological and ecological needs of least terns or piping plovers. Least tern RPM 4 and piping plover RPM 8 state that USACE will monitor, evaluate, and modify created and rehabilitated sandbars to determine the most effective and efficient means of restoring and maintaining existing sandbars for the conservation of both species (USFWS 2003).

In 2004, following the BiOp's mandate to establish ESH, USACE began constructing sand bars on the Gavins Point river segment in MNRR with a sole complex at RM 755.0. Since then, USACE has created seven additional sandbars on the Gavins Point river segment (USACE 2010). USACE has not constructed ESH on the Fort Randall river segment because the narrow channel and the lack of current sandbars and available sediment in this section make the process difficult (Yager, pers. comm., 2011). However, there are plans to construct ESH in the future (Wagner, pers. comm., 2011).

USACE modifies vegetation on natural sandbars to encourage least tern and piping plover nesting. Through chemical or mechanical methods, they remove vegetation to expose bare ground, which both species prefer. In 2005, USACE altered sandbar vegetation on Lewis and Clark Lake, as well as the Fort Randall and Gavins Point river segments using both methods. In 2006 and 2007, USACE utilized chemical control on sand bars in the Lake Oahe segment, and they used mechanical control on all segments that were addressed in 2005. Since 2007, vegetation on the treated bars has regrown, making them indistinguishable from untreated sandbars (USACE 2010).

For 2009, the USACE (2010) compared nest success and fledge ratios for both least terns and piping plovers on constructed and natural sandbars on the Gavins Point river segment of MNRR. They found 118 least tern nests on constructed sandbars and only five on natural bars. Least tern nests on constructed sandbars were 79.6% successful and exhibited a fledge ratio of 1.10. Three of the five nests on natural bars were successful, but chicks did not fledge (Table 59, Table 60). For piping plovers, USACE (2010) identified 138 nests on constructed sandbars and only 32 on natural bars. Piping plover nests on constructed bars were 81.2% successful and the fledge ratio was 1.17. Nests on natural bars were 19.4% successful and the fledge ratio was 0.29 (Table 61, Table 62). Yager (pers. comm., 2011) suggested some reasons for the difference in number of nests, nest success, and fledge ratio between natural and constructed sandbars: there are fewer nests on natural sandbars because there is very little natural sandbar habitat left on the Gavins Point river segment. Those natural sandbars that are left are heavily vegetated because high flows have not occurred since 1997 to scour off the vegetation.

Table 59. Least tern nest success on constructed vs. non-constructed sandbars, Gavins Point river segment, 2009 (reproduced from USACE 2010).

Habitat Type	Total Nests	Successful	Not Successful	Undetermined Fate	% Successful[1]	% of Total Nests
Constructed	118	90	23	5	79.6	95.9
Non-Constructed	5	3	2	0	60.0	4.1
Total	123	93	25	5	78.8	100

[1] % Successful = Successful Nests/(Total Nests - Undetermined Fate Nests)

Table 60. Least tern adults, fledglings, and fledge ratios on constructed vs. non-constructed sandbars, Gavins Point river segment, 2009 (reproduced from USACE 2010).

Habitat Type	Adults	% of Total Adults	Fledglings	% of Total Fledglings	Fledge Ratio
Constructed	191	90.5	105	100	1.10
Non-Constructed	20	9.5	0	0	0
Total	211	100	105	100	1

Table 61. Piping plover nest success on constructed vs. non-constructed sandbars, Gavins Point river segment, 2009 (reproduced from USACE 2010).

Habitat Type	Total Nests	Successful	Not Successful	Undetermined Fate	% Successful[1]	% of Total Nests
Constructed	138	83	50	5	62.4	81.2
Non-Constructed	32	6	25	1	19.4	18.8
Total	170	89	75	6	54.3	100

[1] % Successful = Successful Nests/(Total Nests - Undetermined Fate Nests)

Table 62. Piping plover adults, fledglings, and fledge ratios on constructed vs. non-constructed sandbars, Gavins Point river segment, 2009 (reproduced from USACE 2010).

Habitat Type	Adults	% of Total Adults	Fledglings	% of Total Fledglings	Fledge Ratio
Constructed	217	91.2	127	97.7	1.17
Non-Constructed	21	8.8	3	2.3	0.29
Total	238	100	130	100	1.09

Even though USACE develops and maintains artificial sandbars on the river, natural sandbar habitat as it was prior to dam construction is minimal. The natural sandbar habitat that is available is often overrun with vegetation, therefore the condition indicated by this measure is of significant concern to management.

Fledge Ratios

As of 2009, the 3-year running average fledge ratio for least terns on the entire Missouri River Main Stem Reservoir System was 0.84, which is below the desired goal of 0.94 fledglings per adult pair. Gavins Point river and Fort Randall river segments have also been below the target ratio. For 2007 through 2009, the Gavins Point ratio was 0.85 and the Fort Randall ratio was 0.62.

From 1986 to 1997, the 3-year running average fledge ratio for least terns for the Gavins Point segment was below the BiOp goal; from 1998 through 2006, it was above; and from 2007 to 2009 it was below again (Figure 53). The Fort Randall least tern 3-year running average fledge ratio was above the BiOp goal in one instance, 2000 (Figure 54). For three years, 1999, 2000, and 2008 the yearly fledge ratio for the Fort Randall segment exceeded the goal.

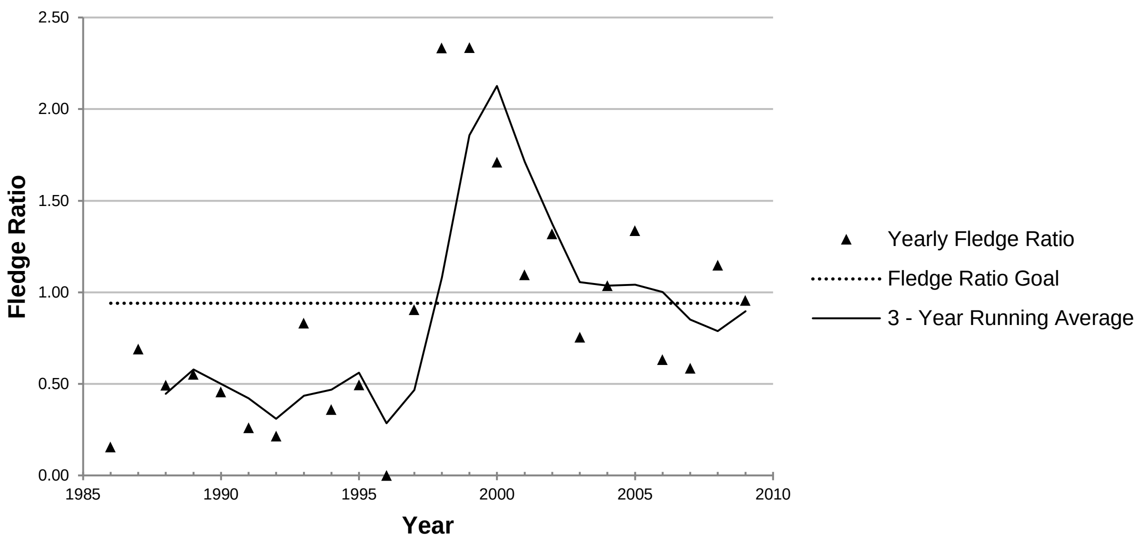


Figure 53. Least tern fledge ratio and 3-year running average for the Gavins Point segment of the Missouri River, 1986-2009 (USFWS 2010).

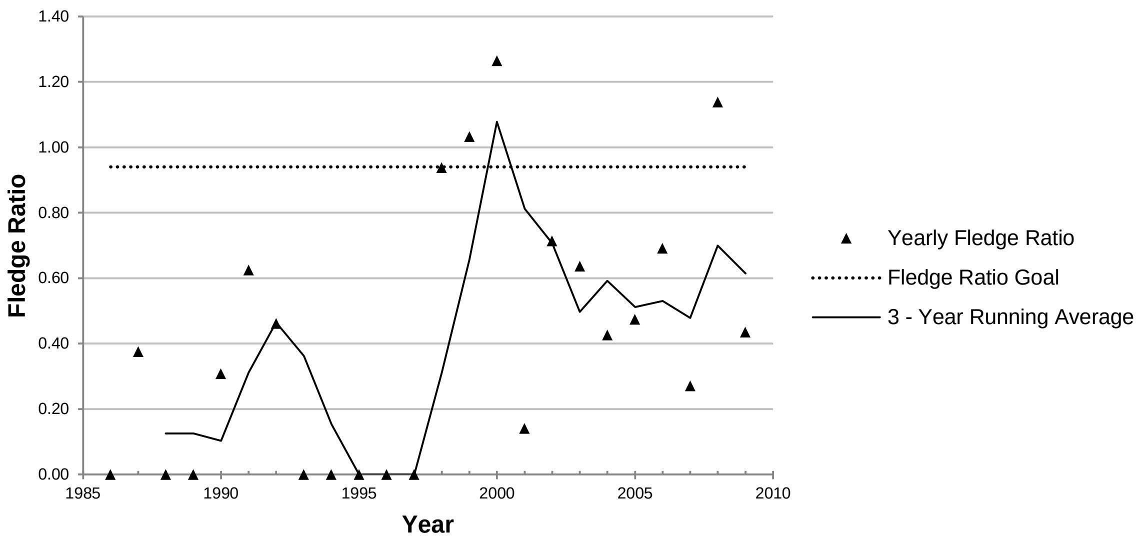


Figure 54. Least tern fledge ratio and 3-year running average for the Fort Randall segment of the Missouri River, 1986-2009 (USFWS 2010).

As of 2009, the 3-year running average fledge ratio for piping plovers on the entire Missouri River Main Stem Reservoir System was 0.88, which is below the desired goal of 1.22 fledglings per adult pair. Gavins Point river and Fort Randall river segments have also been below the target ratio. For 2007 through 2009, the Gavins Point ratio was 0.95 and the Fort Randall ratio was 0.67.

From 1999 through 2006, the 3-year running average fledge ratio for the Gavins Point segment of the Missouri River was above 1.22 (Figure 55). The Fort Randall 3-year running average has never been above 1.22. For two years, 1998 and 2003, the yearly fledge ratio for the Fort Randall segment was above 1.22 (Figure 56).

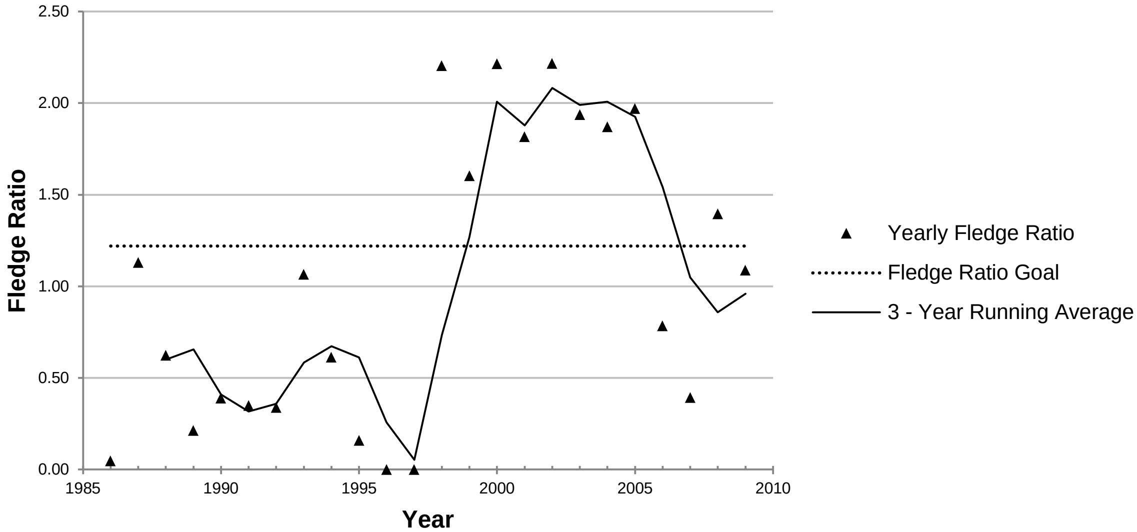


Figure 55. Yearly piping plover fledge ratio and 3-year running average for the Gavins Point segment of the Missouri River, 1986-2009 (USFWS 2010).

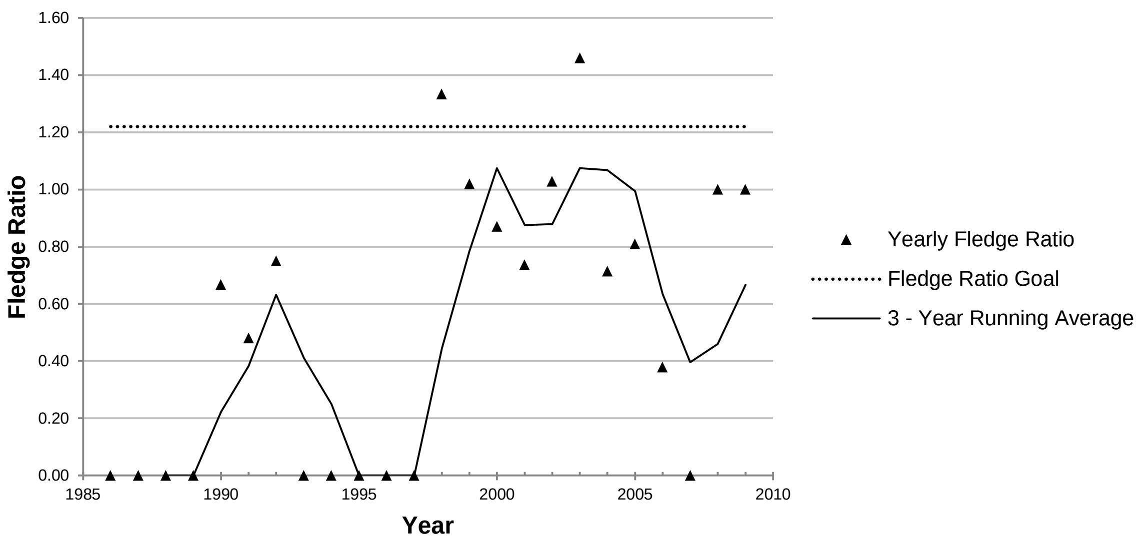


Figure 56. Yearly piping plover fledge ratio and 3-year running average for the Fort Randall segment of the Missouri River, 1986-2009 (USFWS 2010).

The fledge ratios for both sections of MNRR did not meet the goals defined in the BiOp, and this is true for most years in recent history. Therefore the condition of plovers and terns, as indicated by this measure, is of significant concern and stable.

<u>Population Size</u>

For least terns on the Missouri River survey data are available dating back to 1986. For the Gavins Point segment, the mean population size (1986-2009) is 239, ranging from 82 (1996) to

476 (2005). The population goal of 400 individuals has been met only twice since the USFWS (1990) developed population goals for this species (Figure 57).

The population goal for the Fort Randall segment is 80 adults. From 1986 through 2009, the mean population size on the Fort Randall segment is 44 individuals, well below the population goal. The goal was met during three survey years: 1999, 2000, and 2002 (Figure 58).

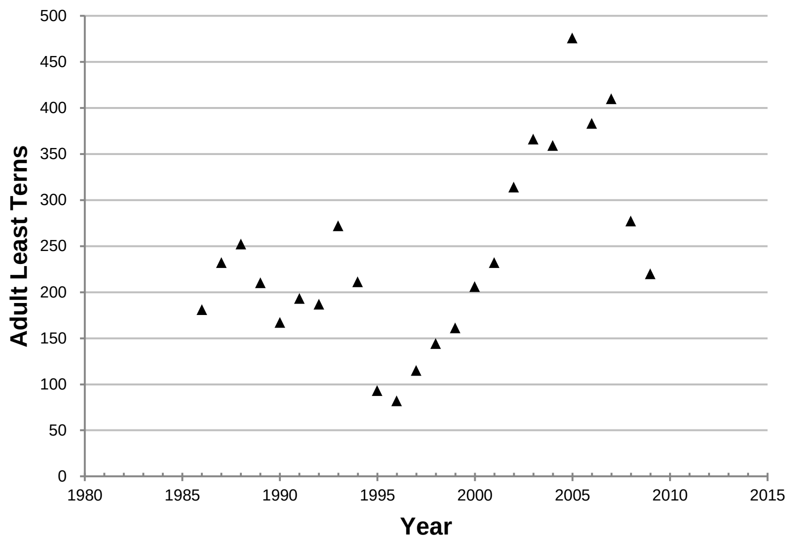


Figure 57. Least tern adults, Gavins Point River segment, 1986-2009 (USFWS 2010).

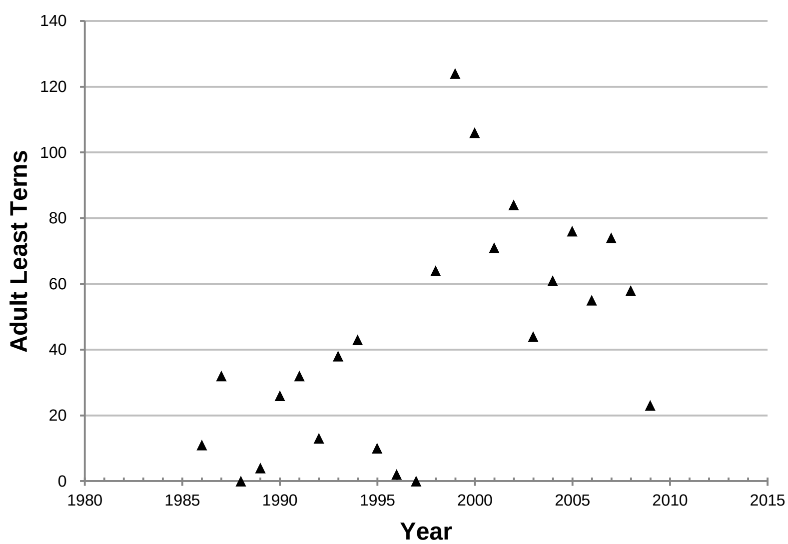


Figure 58. Least tern adults, Fort Randall River segment, 1986-2009 (USFWS 2010).

For piping plovers on the MNRR river segments, survey data are available from 1986 through 2009. For the Gavins Point river segment, from 1986 through 2009, the mean adult population size is 131, ranging from 6 (1997) to 273 (2009) (Figure 59). The population goal for this segment, established by USFWS (1988), is 250 pairs. This goal is yet to be attained since its establishment.

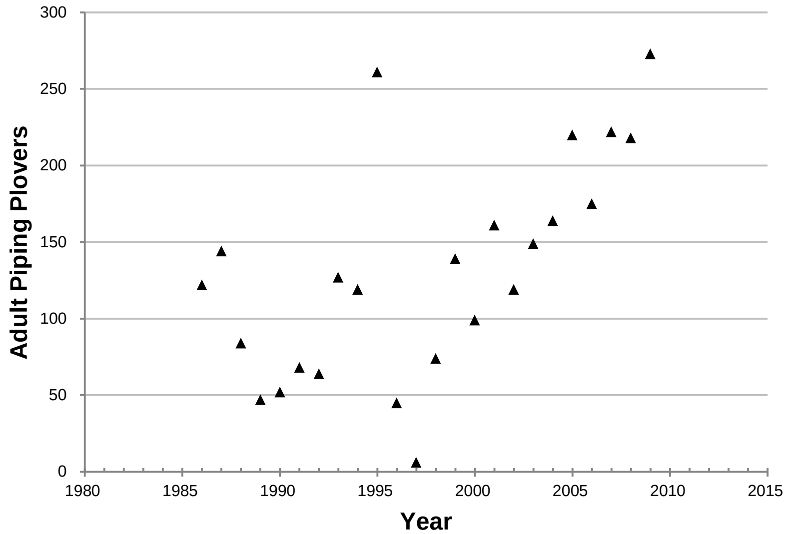


Figure 59. Piping plover adults, Gavins Point river segment, 1986-2009 (USFWS 2010).

The goal for the population on the Fort Randall segment is grouped with Lewis and Clark Lake and Lake Oahe (150 adults). Since 2000, this goal has been achieved every year (USFWS 2009c). The mean adult population size from 1986 through 2009 for only the Fort Randall segment is 22 adults, ranging from 0 (1988, 1989, 1995, 1997) to 62 (2007) (Figure 60).

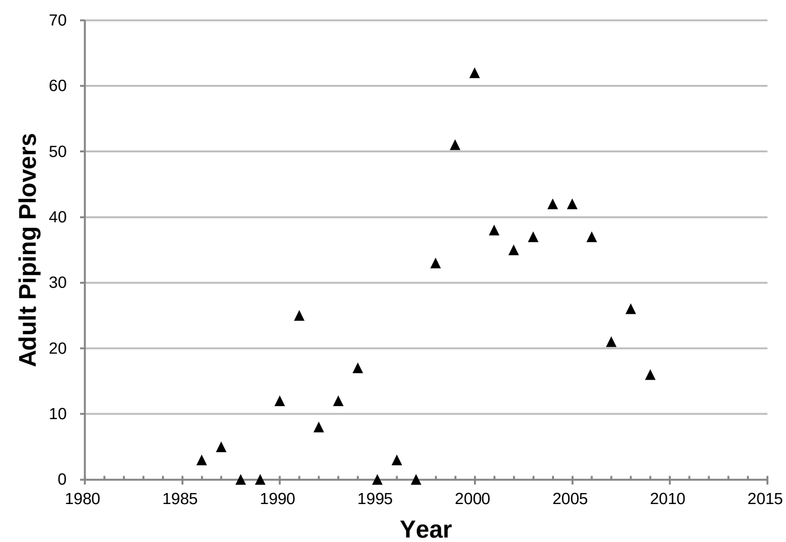


Figure 60. Piping plover adults, Fort Randall river segment, 1986-2009 (USFWS 2010).

Due to the consistently unattained population goals for both segments and both species, the condition of this species as indicated by this measure is of significant concern and stable.

Niobrara Population

Least tern and piping plover also utilize habitat on the Niobrara River in MNRR. Adolf (1998) suggests that piping plovers select habitat based on high sand and the presence of heavy vegetative clumps on sandbars. Adolf (1998) also suggests that least terns may utilize piping plover's presence as a selection criterion to determine their nest locations. NPS has collected data regarding these two populations each year since 2003. From 2003 to 2007, monitoring only encompassed the lower 24 kilometers (15 mi) of the Niobrara River. In 2008 and 2009, monitoring included the lower 32 km (20 mi). The Niobrara River is unique in that it offers some of the most natural habitat for both these species due to its free-flowing nature. Regulation does have some impact on the lower reaches of the river due to elevated flows on the main stem of the Missouri River as a result of sedimentation and the increased water table. The relationship between the number of nesting pairs observed on the Niobrara and the Main Stem Missouri is complicated as it relates to many different parameters. In years with high water on the Missouri, nesting pairs could be more prolific on the Niobrara. In other years, following new construction of ESH, nesting pairs observed on the Niobrara could be substantially less. The Niobrara River also experiences a relatively natural hydrolic regime, allowing large floods which often destory nests and habitat.

Figure 61 displays total piping plover and fledglings along with the observed fledge ratios for 2003 through 2009, for varying sections of the Niobrara River (see caption). The data presented in Figure 61 do not explain whether the goal defined in the recovery plan is met for any given year. On the Niobrara, the population goal is 100 adults (50 pairs) per year, from its intersection with Nebraska State Highway 183 to the confluence with the Missouri River (USFWS 1988). Based on other survey efforts, the number of plovers on the Niobrara during any given year is typically half the established goal (USFWS 2009c). However, all of the key population parameters for the Niobrara population are quite variable due to the reasons mentioned previously.

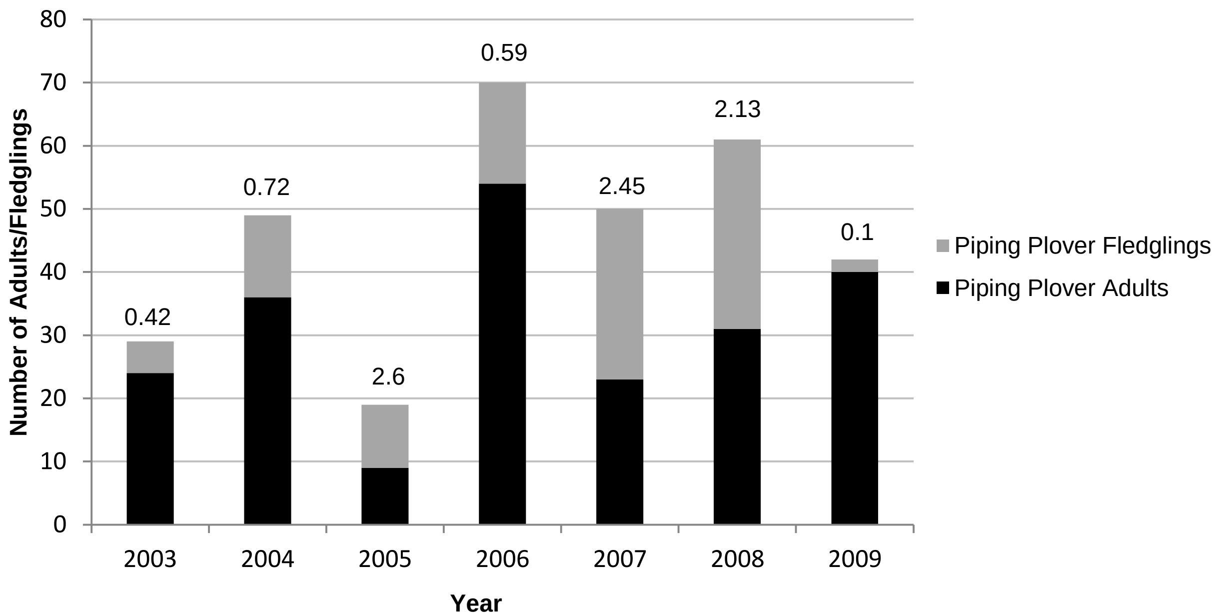


Figure 61. Piping plover adults, fledglings, and fledge ratios (above stacked bar), lower Niobrara River, 2003-2009. Data from 2003-2007 for RM 0-15, data from 2008-2009 for RM 0-20 (data provided by MNRR).

Figure 62 displays total least tern adults and fledglings along with the observed fledge ratios for 2003 through 2009, for varying sections of the Niobrara River (see caption). For least terns on the Niobrara River, the population goal is 200 adults (100 pairs) from its intersection with Nebraska State Highway 183 to the confluence with the Missouri River (USFWS 1990). From 2003 through 2009, data in Figure 62 indicate the goal was not attained, although additional terns could have been present on other stretches of the river. As with plovers, all of the key population parameters for terns on the Niobrara are quite variable, due to the reasons mentioned previously.

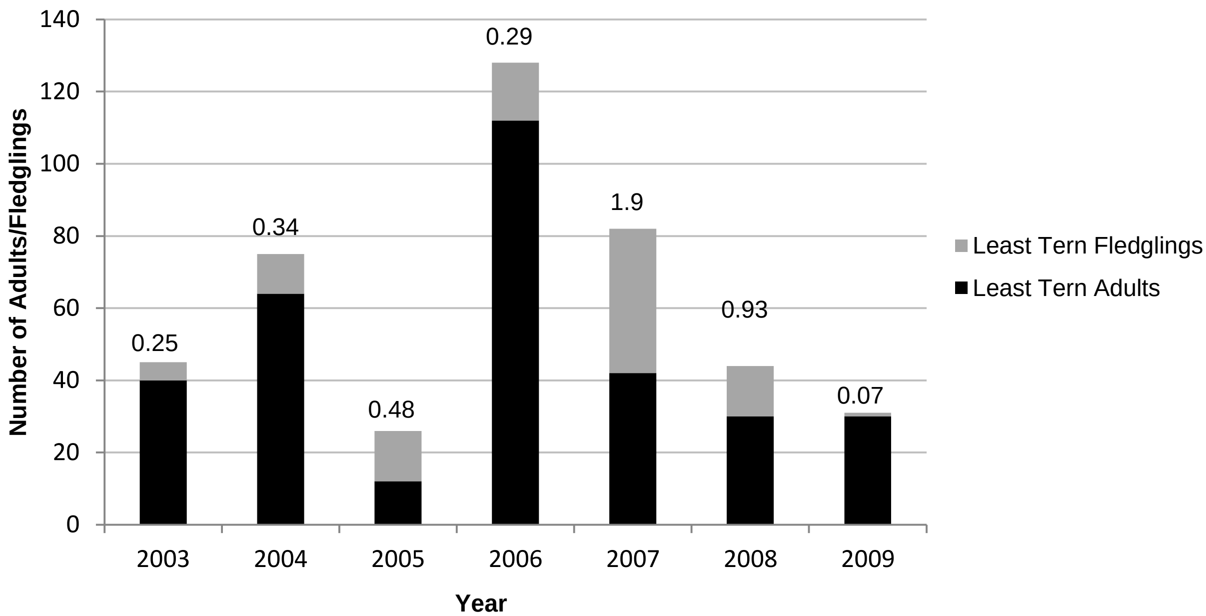


Figure 62. Least tern adults, fledglings, and fledge ratios (above stacked bar), lower Niobrara River, 2003-2009. Data from 2003-2007 for RM 0-15, data from 2008-2009 for RM 0-20 (data provided by MNRR).

Threats and Stressor Factors

On the Missouri River, the ultimate cause of the least tern and piping plover population decline is the altered hydrology from dams (refer to Chapter 4.2 and 4.3, for a detailed discussion of erosional and depositional processes and flow regime). Proximate causes for the decline include destruction and loss of sandbar nesting habitat, nesting area inundation, and predation. In addition, all piping plover populations are experiencing increased human disturbance. Emerging threats include climate change and wind turbine generators (USFR 1985,USFWS 2009b). Finally, it is unknown how the Deepwater Horizon oil spill will affect piping plovers, which winter near the Gulf of Mexico. On the Niobrara River, the leading causes of nest loss are storm and flood events (S. Wilson, pers. comm., 2011).

Incidental Take

The Endangered Species Act defines incidental take as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. For least terns, the 2003 Amendment to the BiOp defines a threshold value for incidental take of eggs and chicks by USACE operations. The value is 180 chicks or eggs in a 3-year consecutive period. USACE is currently meeting this goal. From 2007 to 2009, a total of 71 eggs and 5 chicks were lost due to USACE operations. In 2009, nine eggs were lost. In regard to incidental take, the 2003 Amendment to the BiOp also states ―The Corps should reinitiate consultation if the running 5-year average fledge ratio is less than 0.94." In 2009, the 5-year running fledge ratio (2005-2009) was 0.88 fledglings per adult pair. This was the third consecutive year the Corps failed to achieve this metric (USACE 2010).

The 2003 BiOp Amendment lists six incidental take categories for the piping plover:

1. Take (killing) of eggs and chicks by flooding on the river and reservoir reaches that result from the Corps' operation of the water control system

2. Take (harm) of eggs, chick, or adults by predation

3. Take (harm) of eggs, chicks, or adults by human disturbance

4. Take (harm) of chicks as a result of insufficient forage in river reaches affected by hypolimnetic releases

5. Take (harm) of eggs in nests assigned fates of destroyed-unknown, nest abandonment, sandbar erosion, and unknown fates

6. Take (harm) of chicks as a result of insufficient forage on created habitats

Table 63 displays the measures, lower goal limit, and actual measured value for each piping plover incidental take category as of 2009. Currently, USACE is meeting the lower limit of all incidental take goals regarding piping plovers. However, in 2009, 8 nests and 30 eggs were lost on the Gavins Point river segment because of USACE operations (e.g., inundation from high flows) (USACE 2010); this was the largest yearly loss on the segment from USACE operations (USFWS 2010).

Table 63. Incidental take goals for Missouri River Main Stem and status as of 2009 (USACE 2010).

Take Category	Measure	Lower Limit[1]	2009 Value	Achieved Goal
1a	10-year running average of eggs and chicks lost due to USACE operations.	7.6%	4.50%	Y
1b	Take should not exceed take observed from 1993-2003	294 eggs	167	Y
1c	USACE operations. Take should not exceed take observed from 1993-2003	46% of all eggs	7.8%	Y
2	10-year running average of egg, chick, or adult predation losses.	3.6%	4.30%	Y
3	10-year running average of egg, chick, or adult take from human disturbance.	1.4%	1.10%	Y
4[2]	10-year running average fledge ratio for dams with hypolimnetic releases – Fort Randall Dam (39-mile segment of MNRR)	0.83	0.83	Y
5	10-year running average fledge ratio	1.22	1.24	Y
6	10-year running average fledge ratio on created habitat structures	1.22	1.41	Y

[1] The lower limit of the accepted range of values for the parameter.
[2] Category is site specific with one category including the river below Fort Randall Dam which is included in the 39-mile portion of the MNRR.

Predation

American Crow (*Corvus brachyrhynchos*), raccoon (*Procyon lotor*), and mink (*Mustela vison*) were responsible for 98.0% of nest losses and American Kestrels (*Falco sparverius*) and Great Horned Owls (*Bubo virginianus*) caused 93.0% of chick mortalities. Kruse et al. (2002) found that piping plover nest success increased significantly with the use of predator exclosures, from 34.4% to 61.6%. On the Gavins Point river segment, from 1986 to 2009, the major known cause for failed nests is predation for both piping plover and least tern (USFWS 2010). On the Fort Randall river segment, from 1986 to 2009, predation is the second prominent known cause for nest failure, behind withdrawal (USFWS 2010).

In 2010, USACE (2011) worked with USDA Wildlife Services to trap Great Horned Owls at six ESH sites below Gavins Point Dam. In 2010, they trapped eight Great Horned Owls from four different ESH sites. The eight owls were relocated around Lincoln, NE (USACE 2011). In 2009, USACE captured and relocated six owls; in 2008, five; and in 2007, one; all at various ESH locations (USACE 2008, 2009b, 2010, 2011).

USACE uses nest cages to mitigate plover predation on some sections of the Missouri River. On the Gavins Point river segment in 2009, caged nests were more successful than non-caged nests, 70.8% versus 6.8%, respectively. There were similar results for the entire Missouri River Main Stem, 222 of 376 caged nests were successful while only 17 of 50 non-caged nests were successful (USACE 2010). Plover nests are not caged on the Niobrara River.

<u>Data Needs/Gaps</u>

Data for these species is complete and monitoring should continue into the future.

Overall Condition

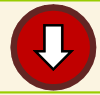
Measures	Reference Condition	Condition
Available nesting habitat	Pre-dam	
Fledge Ratios	Pre-dam	
Population Size	Pre-dam	

Figure 63. Least tern and piping plover condition graphic.

Least terns and piping plovers rely on sand bar habitat for nesting. Since the closure of dams on the Missouri River, this once abundant habitat type has declined. Today, most nesting occurs on artificial habitat that USACE builds and maintains; this is a cause for concern. Because it is safe to assume that the Missouri River Main Stem Reservoir System will continue operation, the best way to describe population conditions is through the goals defined by USFWS in the BiOp. Fledge ratios for the entire Missouri River Main Stem Reservoir System, for both species, are below the BiOp goals (USFWS 2010). However, least terns and piping plovers that are nesting on USACE developed artificial habitat are experiencing success (USACE 2010). Incidental take goals regarding both species are being met (USACE 2010).

Population goals for least terns are unattained for the Gavins Point river segment and the Fort Randall river segment. The grouped goal for piping plovers on Lewis and Clark Lake, Fort Randall river segment, and Lake Oahe is attained (USFWS 2009c). The goals for piping plovers on the Gavins Point river segment are not attained. Due to the unattained goals, the condition of all measures is of significant concern (Figure 63)

The status of least terns on the Niobrara River relative to the defined goals in the USFWS recovery plan is uncertain. The status of piping plovers on the Niobrara relative to the USFWS recovery plan is also uncertain. Regarding habitat, the Niobrara offers some of the most natural riverine habitat to piping plovers and least terns. Population parameters (i.e., number of pairs and fledglings, and fledge ratios) have been quite variable for many reasons. Overall, condition of the Niobrara population cannot be determined.

Sources of Expertise
Gia Wagner, MNRR Chief of Resources
Lisa Yager, MNRR Biologist
Greg Pavelka, USACE Wildlife Biologist

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4.8 Land Birds

Description

Land birds are bird species that have a principally terrestrial life cycle (Rich et al. 2004). Bird populations often act as excellent indicators of an ecosystem's health (Morrison 1986, Hutto 1998, NABCI 2009). Birds are typically easy to observe and identify and bird communities often reflect the abundance and distribution of other organisms with which they co-exist (Blakesley et al. 2010). The Missouri River serves as a major flyway for migratory birds. The unique habitats and bottomlands present in MNRR serve as wintering, feeding, breeding, and staging grounds for these migrating avian species; MNRR also has many year-round resident avian species (NPS 2010). Monitoring avian population health and diversity in these habitats will be important for detecting ecosystem change.

Measures

- Species richness and density
- Expected bird species
- Bald eagles
- Osprey

Reference Conditions/Values

Reference condition for MNRR land birds is defined as pre-dam conditions.

Data and Methods

The most recent NPS Certified Species List of the bird species documented in the park was used for this assessment. The list was reorganized into categories based on whether or not a species had been confirmed in the park. The categories used were: confirmed, unconfirmed, and probably present. This reorganization allowed for a more accurate assessment of what species have been verified within park boundaries. Species that were on the NPS Certified Species List that were not classified as land birds by Rich et al. (2004) were not included in this assessment.

Several studies conducted by the University of South Dakota (Gentry et al. 2006, Benson and Dixon 2009, Dixon et al. 2010a, 2010b, Benson 2011) in partnership with the NPS, were also provided for this assessment. These studies dealt primarily with the status of land birds in the park and their utilization of available landscape features.

Unpublished bald eagle (*Haliaeetus leucocephalus*) nest survey results were provided by MNRR in spreadsheet format. These surveys documented the presence and reproductive success of eagles on the 39-mile and 59-mile districts of MNRR, including the lower Niobrara River. The surveys were conducted from 2000-2010, however, the data from 2000-2003 were queried from the SDGFP, NGPC, and the USFWS databases. In 2004, NPS joined the previously mentioned agencies to expand bald eagle monitoring at MNRR. Currently, NPS monitors the majority of bald eagle nests at MNRR with assistance from the state and federal agencies (S. Wilson, pers. comm., 2011; Yager, pers. comm., 2011).

In 2001, an osprey (*Pandion haliaetus*) reintroduction program was initiated in MNRR. Chicks were taken from a nest in an area with a stable or increasing osprey population and at least one chick was always left in the source nest (SDGFP 2010). Chicks were then transported to the MNRR hacking site, where they were fed, banded, and monitored for potential health problems. The chicks were fed fish at the hacking site until they could reliably catch fish on their own. Reintroduction efforts in MNRR concluded in 2010.

Current Condition and Trend

<u>Species Richness and Density</u>
Gentry et al. (2006) used point counts to determine the species richness of neotropical migrants at four sites located on the 59-mile segment of the Missouri River in MNRR. Counts were conducted four times during the 2000-2002 breeding seasons. Five or six points were established along transects at riparian sites. These points were spaced approximately 200 m apart to avoid double observations of birds, and each point was monitored for 10 minutes (Gentry et al. 2006). 55 species were detected in MNRR during the study, and the estimated relative abundance (individual birds per point) of birds in MNRR was 15.0 (Gentry et al. 2006). Density estimates revealed the highest values for the house wren (*Troglodytes aedon*) (526 birds per km^2), gray catbird (*Dumetella carolinensis*) (255 birds per km^2), and the baltimore oriole (*Icterus galbula*) (208 birds per km^2) (Gentry et al. 2006). These values were similar to the values that Gentry et al. (2006) obtained for woodlot habitats located approximately 20 km north of the MNRR site.

Benson and Dixon (2009) conducted bird surveys in 2008 (surveys were also conducted in 2009 and 2010, but data have not been analyzed) to examine ecological responses to upland prairie and oak restoration efforts. These surveys were conducted across 14 points on, or adjacent to, the Bow Creek Recreation Area (owned by the NPS) along the 59-mile segment of the Missouri River. Points were spaced approximately 250 m apart and each survey dedicated 10 minutes to each point (auditory and visual identification cues were used) (Benson and Dixon 2009). Censuses were carried out between June and July of 2008 and were only performed on calm mornings (Benson and Dixon 2009). Thirty-six species of birds were detected (Appendix E), with the most common species being eastern towhee (*Pipilo erythrophthalmus*) (81 detections), blue jay (*Cyanocitta cristata*) (68 detections), and house wren (67 detections).

Dixon et al. (2010a) also surveyed floodplain forest songbirds in MNRR; specifically, the abundance of songbirds within specific forest types (i.e., cottonwood vs. non-cottonwood) and successional age classes were monitored. Point count surveys were used across 78 stands within both the 39-mile and 59-mile segments of MNRR during the breeding seasons of 2009 and 2010. Over 12,000 detections were recorded across the surveys, with 78 species detected. Researchers conducted suveys for 10 minutes each at two points within each stand. The points were spaced about 250 m from each other to avoid repeat detections between points (Dixon et al. 2010, Benson 2011). In analysis of the data, Dixon et al. (2010a) grouped the woodpeckers into a single guild that included red-headed (*Melanerpes erythrocephalus*), red-bellied (*Melanerpes carolinus*), downy (*Picoides pubescens*), and hairy (*Picoides villosus*) woodpeckers (northern flicker was included in a separate guild of other cavity nesters).

Results from the floodplain forest survey revealed that a number of species were strongly associated with mature (50-114 years) and older (>114 years) successional stands (Dixon et al.

2010a, Benson 2011) (Table 64). Woodpeckers, other cavity nesting species (such as northern flicker [*Colaptes auratus*] and black-capped chickadee [*Poecile atricapillus*]), ovenbirds (*Seiurus aurocapillus*), wood thrushes (*Hylocichla mustelina*), eastern wood-pewees (*Contopus virens*), red-eyed vireos (*Vireo olivaceus*), and rose-breasted grosbeaks (*Pheucticus ludovicianus*) all were found to be in greater abundance in later (> 50 years) successional stands (these stands established prior to the construction of adjacent upstream dams) (Dixon et al. 2010a). Woodpeckers and ovenbirds were found to have a significantly lower number of detections within old non-cottonwood stands compared to similarly aged cottonwood stands (Dixon et al. 2010a, Benson 2011). A long-term decrease in cottonwood stands of this age, as is likely with the limited amount of cottonwood regeneration in the park (see Chapter 4.5), would likely lead to an overall decrease of woodpecker and ovenbird abundance in MNRR.

Table 64. Bird species detections per point by stand age class in MNRR (derived from Dixon et al. (2010)). Superscripts denote significant differences in bird detections between classes within a species or guild.

Species	Detections per Point by Stand Age Class					
	CW < 25	CW 25-50	CW 50-114	CW > 114	NCW < 50	NCW > 50
woodpeckers	0.47^{A}	0.96^{AB}	2.21^{C}	2.25^{C}	0.45^{A}	1.52^{B}
other cavity nesters	1.92^{A}	4.44^{B}	5.9^{C}	5.86^{C}	2.17^{A}	5.15^{BC}
eastern wood-pewee	0.24^{A}	1.04^{B}	1.6^{B}	1.38^{B}	0.26^{A}	1.46^{B}
ovenbird	0^{A}	0.04^{A}	0.75^{C}	0.54^{BC}	0^{A}	0.25^{AB}
red-eyed vireo	0.12^{A}	0.19^{A}	1.04^{B}	1.16^{B}	0.14^{A}	0.75^{B}
rose-breasted grosbeak	0.55^{A}	0.92^{A}	1.63^{B}	1.54^{B}	0.58^{A}	1.67^{B}
Bell's vireo	1.54^{B}	0.35^{A}	0.05^{A}	0.05^{A}	1.36^{B}	0.02^{A}
orchard oriole	1.87^{BC}	1.87^{AB}	0.33^{A}	0.41^{A}	2.09^{C}	0.38^{A}
yellow warbler	3.63^{B}	3.65^{B}	1.75^{A}	1.88^{A}	3.43^{B}	1.14^{A}

CW = cottonwood; NCW = non-cottonwood

Some species detected in Dixon et al. (2010a) were early successional (<50 years and especially <25 years) specialists (e.g., Bell’s vireo, orchard oriole, yellow warbler) (Table 64). These species would be even more sensitive to declines in cottonwood recruitment. Dixon et al. (2010) also found, however, that early successional (<50 years old) non-cottonwood stands held comparable abundances of these species (Table 64). Thus, over a shorter time scale, declines in creation of early successional habitats could lead to decreased abundance of species that prefer younger cottonwood and non-cottonwood habitats (e.g., Bell’s vireo, orchard oriole, yellow warbler).

Expected Bird Species

Following adjustments made to the NPS Certified Species List as described above, number of species confirmed, unconfirmed, and probably present were calculated. In total, 154 species of land birds have been confirmed in the park (Appendix E).

Species of Conservation Concern

Beginning in 1991, Partners in Flight (PIF) began assessing species in order to provide consistent, scientific evaluations of conservation status across all bird species (RMBO 2005).

The assessments look at a species' population size, distribution, population trend, threats, and regional abundance in order to generate numerical scores that rank the species in terms of its biological vulnerability and regional status. The Rocky Mountain Bird Observatory (RMBO) maintains PIF assessment data and organizes the species on a geographic scale using Bird Conservation Regions (BCRs). BCRs are the accepted planning unit for updated regional bird conservation assessments under the North American Bird Conservation Initiative (NABCI) (RMBO 2005). MNRR is part of BCR 11 – The Prairie Potholes – and 16 species are listed by the PIF as Species of Regional Importance (Table 65).

Table 65. Status designation for bird species of conservation concern confirmed in MNRR.

Species	PIF SRI [1]	SD Level I [2]	NE PS [3]
Swainson's hawk	x	x	x
whip-poor-will			x
black-billed cuckoo	x	x	x
Le Conte's sparrow	x	x	
grasshopper sparrow	x	x	x
lark bunting	x	x	x
orchard oriole		x	
savannah sparrow		x	
dickcissel	x		x
field sparrow			x
western meadowlark	x	x	
Harris's sparrow			x
loggerhead shrike	x		x
wood thrush			x
northern bobwhite			x
ring-necked pheasant			x
northern flicker	x		x
red-headed woodpecker	x		x
Bell's vireo			x
willow flycatcher	x		
horned lark	x		
brown thrasher	x		
clay-colored sparrow	x		
black-billed magpie	x		
sedge wren	x		

[1] PIF SRI = Partners in Flight Species of Regional Importance (http://www.rmbo.org)
[2] SD Level I = South Dakota Level I Priority Species (Bakker 2005)
[3] NE PS = Nebraska Priority Species (http://www.nebraskabirds.org/)

Eight species of land birds listed on the level I priority bird species list for South Dakota were observed in MNRR (Bakker 2005) (Table 65). The priority bird species list includes birds:

- listed on the Partners in Flight (PIF) watch list with distributions in South Dakota;
- with a high proportion of their total population breeding in or wintering in South Dakota;

- endangered and threatened species federally listed under the Endangered Species Act;
- American Bird Conservancy green list species

Priority species are ranked in accordance with continental and state decline levels. Bakker (2005) defines the three levels of priority species:

> Level I species have the highest conservation priority due to high maximum abundance of the species within its range in South Dakota, South Dakota constitutes the core of the species breeding range, and/or the species is showing population declines in South Dakota or across its range. Level II species are those with moderate conservation priority due to medium abundance scores in South Dakota or management plans are already in place (e.g., Federally listed, game species). Level III species include birds with moderate conservation priority due to low abundance scores in South Dakota or South Dakota is on the periphery of the species' range, the species is unique to some habitats (i.e., Black Hills) in South Dakota, or wintering species.

In Nebraska, the Nebraska Bird Partnership (NBP) has identified 64 species of land birds (both breeding and non-breeding species) as priority birds for conservation action. Fifteen of the species identified by NBP have been observed in MNRR (Table 65).

<u>Bald Eagles</u>

Bald eagle populations in the lower 48 United States dramatically declined between the 1870s and 1970s. This decline was primarily due to the widespread use of the pesticide dichlorodiphenyltrichloroethane (DDT). However, direct human persecution and loss of habitat also played a role. The decline prompted Federal protection, and the bald eagle was listed as endangered under the Endangered Species Act in 1978 (USFWS 1978). Conservation efforts were enormously successful, and in 2007, bald eagles were removed from the federal list of threatened and endangered species (with the exception of the Sonoran Desert population which retained threatened status) (USFWS 2010). In South Dakota, the bald eagle remains on the state threatened species list (SDGFP 2011).

Photo 6. Bald Eagle (Courtesy Steve Hillebrand, USFWS).

Bald eagles had been absent from South Dakota for over 100 years before a successful nesting attempt was reported in 1993 (Usgaard 1994, Aron 2005). A reintroduction program that would utilize bald eagle hack sites along the Missouri River between Fort Randall and Gavins Point Dams was investigated in 1994 (Usgaard 1994). It was determined at that time that reintroduction via hacking in these sites was unnecessary, as eagles would likely naturally expand their range into this area in the near future (Usgaard 1994). Since 1994, bald eagle populations in the state have increased. In a 2004 state-wide nest survey, 30 active nests were reported in the state, and one-third of those nests were along the Missouri River (Aron 2005).

Bald eagles in Nebraska exhibited a similar historic trend; by 1900, the eagle had been extirpated as a breeding species in Nebraska (USFWS 1983). Eagles returned to the state in the mid-1980s, but the first successful fledging of a chick did not occur until 1992 on the Middle Loup River (Suckling and Hodges 2007). By 2006, the nesting population in Nebraska had grown to 44 pairs (Suckling and Hodges 2007).

Bald eagle survey intensities were variable among years, but intensities have generally increased in recent surveys. As a result of these inconsistencies, the analyses of the data are limited. It can be generalized with some confidence that bald eagle productivity and nesting success have increased since 2004. Bald eagle productivity in MNRR has grown from nine fledged chicks (2004), to 46 chicks (2010) (Figure 64), and a total of 47 nests have been identified within the 39-mile and 59-mile districts of MNRR, including the lower Niobrara River.

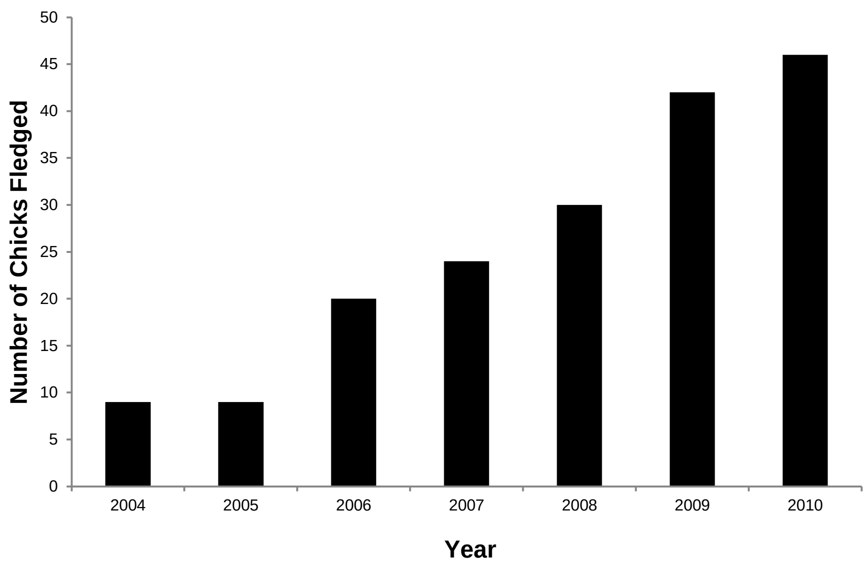

Figure 64. Bald eagle productivity in MNRR, 2004-2010.

<u>Osprey</u>

Much like the bald eagle, the osprey population suffered from the use of DDT, causing populations to decline drastically from 1950-1970 (Paige 2000). Ospreys are extremely philopatric and do not stray far from their natal breeding grounds (SDGFP 2010). This life history aspect has made range expansion following the ban on DDT problematic in some regions, such as South Dakota (SDGFP 2010).

In South Dakota, the osprey is still listed as a state threatened species (SDGFP 2011). The first osprey nest in modern times occurred in 1991 at Pactola Reservoir in the Black Hills (SDGFP 2010). In an effort to reestablish the osprey's presence in South Dakota, Usgaard (1994) investigated the feasibility of reintroducing the osprey via hacking towers. The results of this study identified ospreys as a strong candidate for this type of reintroduction, and identified potential hacking sites in MNRR as the most suitable locations (Usgaard 1994).

In 2001, funding became available for the reintroduction project and a hack tower site was established in MNRR (SDGFP 2010). The original hack tower was located at the Clay County Lakeside Use Area, and in 2006, a new hack tower was created adjacent to the Yankton Chamber of Commerce facility. In 2008, another new hacking site was constructed near Lake Yankton. In 2008, source osprey populations were identified in Minnesota and Idaho (Table 66); chicks were taken from a nest in an area with a stable or increasing population and at least one chick was always left in the source nest (SDGFP 2010). Chicks were then transported to the MNRR hacking sites, where they were fed, banded, and monitored for potential health problems. The chicks were fed fish at the hacking sites until they could reliably catch fish on their own. To date, 120 ospreys have been reintroduced into the area (Table 66). No information is available on whether any of these birds have returned or attempted to nest in MNRR.

Table 66. MNRR osprey reintroduction efforts. Reproduced from SDGFP 2010.

Year	# Reintroduced Chicks	Source	Markers
2003	9	Minnesota	Temporary color tape and paint; USGS metal band
2004	20	Idaho	Temporary color tape and paint; USGS metal band
2005	20	Idaho	Blue metal band on right leg; USGS metal band on left leg
2006	12	Idaho	Blue metal band on left leg; USGS metal band on right leg
2007	0	--	--
2008	20	Idaho	Green metal band on left leg; USGS metal band on right leg
2009	20	Idaho	Green metal band on right leg; USGS metal band on left leg
2010	19	Idaho	Orange metal band on left leg; USGS metal band on right leg

Threats and Stressor Factors

The construction of the six mainstream dams on the Missouri River in the mid 1900s, along with extensive habitat conversions to agricultural cropland, dramatically altered the configuration of the floodplain landscape in MNRR (Dixon and Johnson 2007). Flow regulation reduced floods that once maintained the ecological health of the cottonwood forests and natural sandbars in MNRR (Dixon et al. 2010a).

One of the major threats facing bird populations across all ecosystem types is habitat/land cover change (Morrison 1986). Analysis of historic land cover change shows significant declines in grassland, forest, shrubland, and sandbar habitats within MNRR from the 1890s and 1950s to present (Dixon et al. 2010a). Altered habitat, whether natural or human-induced, can compromise the reproductive success or survival rates of species adapted to that habitat.

Reduction in available stopover habitat along migratory routes has been hypothesized as a potential cause of population decline in some migratory species (Moore et al. 1995, Swanson et al. 2003). MNRR may offer refuge to several habitat specific species, especially during the migratory period. Land cover change could ultimately alter the species composition of the park.

The lack of cottonwood regeneration is an important concern in MNRR and throughout the Missouri River. Cottonwood forests have been shown to be a primary source of songbird diversity (Best et al. 1995; Knutson et al. 2005; Dixon et al. 2010b; Benson 2011). Bald eagles in MNRR have exhibited a nesting preference for cottonwoods; from 2000-2010, all bald eagle nests in MNRR have been located in cottonwood trees. A 2004 survey found that of the 30 nests in South Dakota, all but one nest were located in cottonwoods (Aron 2005). While cottonwood forests still exist within MNRR, natural regeneration has declined in the Missouri River floodplain since the construction of the Missouri River Mainstem Reservoir System and Bank Stabilization and Navigation Project (MRRP 2010). Cottonwood regeneration and health in MNRR are covered in more detail in Chapter 4.5.

Early and late seral stages of cottonwood woodlands are now scarce (Rumble and Gobeille 2004), and a diversity of plant and wildlife species depend on cottonwood stands (Dixon et al. 2010a, Benson 2011). The eventual senescence of cottonwoods in existing stands will likely pose a significant threat to songbird and woodpecker abundance in MNRR in the future. Sedgwick and Knopf (1990), and Rumble and Gobeille (2004) suggested that reductions in late stage cottonwoods would lead to a decrease in woodpecker abundance. Over a shorter time scale, declines in creation of early successional habitats (e.g., riparian shrublands, age classes < 25 years) could lead to decreased abundance of species that prefer younger cottonwood and non-cottonwood habitats (e.g., Bell’s vireo, orchard oriole, yellow warbler) (Dixon, pers. comm., 2011).

Data Needs/Gaps

Long-term trend data are needed for land birds in MNRR so that the condition of the land birds can be monitored in the future. Regular monitoring in MNRR would allow for enhanced assessment of current land bird species richness and diversity. Annual bird surveys, such as breeding bird surveys (BBS), Christmas bird counts (CBC), or continuation of the Gentry et al. (2006) and Benson and Dixon (Benson and Dixon 2009, Benson 2011) survey transects are a few ways that this monitoring could occur. Without monitoring in the park, these measures cannot be accurately assessed. Annual surveys would also help to monitor the current abundance of priority species within park boundaries. There are no data in regards to pre-dam condition, and while it is obviously not possible to regain these data, it makes it impossible to refer to the established ―pre-dam” reference condition.

Overall Condition

Measures	Reference Condition	Condition
Species Richness	Pre-dam	
Expected Bird Species	Pre-dam	
Bald Eagles	Pre-dam	
Osprey	Pre-dam	

Figure 65. Land Birds condition graphic.

MNRR riparian habitat is important for migratory land birds during migration and for the breeding land birds during the breeding season. The importance of MNRR as an "island" in a sea of agriculture cannot be overlooked. However, MNRR lacks long-term trend data for land birds which are needed to determine overall condition of land birds in the park. Because of this, a condition cannot be assigned at this time.

Several somewhat comprehensive studies have been completed within MNRR, but do not provide a scope great enough to determine overall condition. Therefore, condition for all measures is unknown (Figure 65). Gentry et al. (2006) indicated no concern in the levels of species richness or density when comparing MNRR results to other study sites. However, the data were limited to a brief time period and were not compared to any reference condition. Dixon et al. (2010a) noted potential threats to songbird population abundance, specifically cottonwood stand age and recruitment limitations.

The number of bald eagle chicks fledged has increased since monitoring began in 2004; however, survey intensities have varied over the years and the data may only represent a generalization of the overall trend (Figure 64). To date, 120 ospreys have been reintroduced into MNRR; however, no information exists on whether any of these reintroduced birds have returned to MNRR.

Sources of Expertise
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4.9 Native Fish Populations

Description

Native fish populations and the incredible species diversity of the Missouri River are a defining part of MNRR. In MNRR, there are 93 species of fish (both native and nonnative) from 20 different taxonomic families. Species such as the pallid sturgeon have a unique taxonomy and are rare in MNRR.

MNRR is a popular destination for sportsmen to pursue game fish such as walleye and sauger. In 2009, anglers from 18 different states spent approximately 372,382 hours fishing the Fort Randall reach, Lewis and Clark Lake, and the Gavins Point reach, accounting for a total of 117,750 fish harvested and $8.14 million in local economic impact (Bouska and Longhenry 2009). When looking at the entire Missouri River, 222 metric tons of fish were commercially harvested in 1945. This number gradually decreased to 35 metric tons by 1967 (Galat et al. 2005). By 1990, commercial harvest significantly increased to 432.5 metric tons of fish, but since 1990 these numbers have decreased, likely due to the closure of the commercial catfish fishery (Galat et al. 2005).

Flood control measures, such as the Gavins Point and the Fort Randall Dams, have had significant impacts on fish habitat in the Missouri River (Berry et al. 2007). These changes have allowed certain fish species to flourish while others diminish (Berry et al. 2007). The effects that the flood control measures have had on native fish populations, the historical species diversity, and the economic importance of angling in the Missouri River make it important to monitor native fish abundance in MNRR.

Measures

- Abundance

Reference Conditions/Values

The reference condition for the native fish populations of MNRR is species abundance prior to the construction of the dams. Prior to dam construction, approximately 45 fish species were documented in the Missouri River. Top predators, such as blue catfish (*Ictalurus furcatus*), flathead catfish (*Pylodictis olivaris*), and pallid sturgeon were adapted to capture prey in turbid waters. However, impoundments have disrupted the Missouri River flow regime, leaving the water less turbid than the pre-dam river (Hesse and Schmulback 1991).

When Fort Randall and Gavins Point Dams closed (in 1954 and 1957, respectively), the flooded vegetation and rich soils increased the amount of nutrients in the Missouri River reservoirs and created new habitat for species that spawn in vegetation. In the years immediately following dam closure, smallmouth buffalo (*Ictiobus bubalus*), carp (*Cyprinidae spp.*), and freshwater drum (*Aplodinotus grunniens*) populations dramatically increased in the reservoirs, only to eventually decline in response to loss of spawning habitat. Walleye are now the primary sight-feeding predator in the Missouri River reservoirs (Berry et al. 2007).

The dams also altered the natural form of the river, resulting in a lowered channel bed, loss of backwaters, oxbow lakes, and marshes, and a smaller floodplain in river stretches below the dams. Chutes experienced the greatest reduction in area and were nearly eliminated from the channelized river (Morris et al. 1968). From 1941 to 2008, off-channel areas (side channels and backwaters) saw a total and mean decrease of 70% and 55%, respectively (Yager 2010). Native chub and shiner species, which once were quite common, declined with the change in habitat. The reservoirs also changed the river's water chemistry and temperature (refer to Chapter 4.12 of this document for a summary of water quality in MNRR), and species that relied on these for spawning cues declined as they failed to reproduce (Berry et al. 2007). In addition, sediment loads of the Missouri River were reduced, decreasing turbidity and increasing the risk of predation on drifting larvae (Galat et al. 1996, as cited in Weeks et al. 2005; Galat et al. 2005). Power peaks (daily fluctuations in water levels due to changing electrical demand from consumers) from the Fort Randall Dam further compound issues related to water velocity, temperature, and turbidity (Shuman, pers. comm., 2011).

Historically, the Missouri River saw two large flow pulses; one in March or April as a result of snow and ice melt on the plains and another larger pulse in June as a result of Rocky Mountain snowmelt (Galat et al. 2005). These pulses often acted as biological cues for fish to begin spawning and also washed valuable nutrients from the banks and floodplain into the river (USFWS 2000). Impoundment management has regulated these high flow events, and has eliminated spawning cues and the introduction of important nutrients to the river.

Data and Methods

Literature provided by MNRR or acquired through searches were the primary sources of information for this assessment.

Current Condition and Trend

Abundance

There are approximately 93 species of fish in MNRR, 72 of which are native to the Missouri River (Berry and Young 2004). Of the native fish species, Berry and Young (2004) found 29 to be relatively abundant in MNRR (compared to other Missouri River segments), including eight cyprinids (minnows), six catostomids (suckers), four percids (perches), two ictalurids (catfish), and nine species from other families (Berry and Young 2004). Berry and Young (2004) found the most prevalent native species in MNRR were emerald shiner (*Notropis atherinoides*), gizzard shad (*Dorosoma cepedianum*), quillback (*Carpiodes cyprinus*), spotfin shiner (*Cyprinella spiloptera*), river carpsucker (*Carpiodes carpio*), channel catfish (*Ictalurus punctatus*), yellow perch (*Perca flavescens*), freshwater drum, sand shiner (*Notropis stramineus*), red shiner (*Cyprinella lutrensis*), shorthead redhorse sucker (*Moxostoma macrolepidotum*), goldeye (*Hiodon alosoides*), river shiner (*Notropis blennius*), white bass (*Morone chrysops*), walleye, flathead catfish, smallmouth buffalo, Johnny darter (*Etheostoma nigrum*), and sauger. Table 67 displays known native fish in MNRR, along with their relative abundance and a list of surveys in which each species was documented. Relative abundance was determined through the Berry and Young (2004) three-year survey results, which employed five sampling methods: gill nets, trammel nets, bag seines, trawl nets, and electrofishing. With the exception of shallow habitats, two of the five sampling methods were used at all sample locations.

Table 67. Native fish of MNRR, relative abundance from Berry and Young (2004), and a list of references documenting the presence of the species. Reproduced from Berry and Young (2004).

Common Name	Scientific Name	Fort Randall		Gavins Point		References*
		Total	Relative Abundance	Total	Relative Abundance	
emerald shiner	*Notropis atherinoides*	1137	30.30%	4965	31.64%	1, 2, 3, 4, 5, 6, 7
gizzard shad	*Dorosoma cepedianum*	174	4.64%	4360	27.78%	1, 2, 3, 4, 5, 6, 7, 8
quillback	*Carpiodes cyprinus*	42	1.12%	1875	11.95%	1, 2, 3, 4, 5, 7
spotfin shiner	*Cyprinella spiloptera*	718	19.13%	768	4.89%	1, 4
river carpsucker	*Carpiodes carpio*	212	5.65%	516	3.29%	1, 2, 3, 4, 5, 6, 7, 8
sand shiner	*Notropis stramineus*	12	0.32%	383	2.44%	1, 3, 4, 5, 6, 7
freshwater drum	*Aplodinotus grunniens*	47	1.25%	374	2.38%	1, 2, 3, 4, 5, 6, 7, 8
channel catfish	*Ictalurus punctatus*	403	10.74%	257	1.64%	1, 2, 3, 4, 5, 6, 7, 8
red shiner	*Cyprinella lutrensis*	55	1.47%	254	1.62%	1, 2, 3, 4, 6, 7
shorthead redhorse	*Moxostoma macrolepidotum*	22	0.59%	237	1.51%	1, 2, 3, 4, 5, 6, 7, 8
river shiner	*Notropis blennius*	23	0.61%	200	1.27%	1, 2, 3, 5, 6
white bass	*Morone chrysops*	40	1.07%	197	1.26%	1, 2, 3, 4, 5, 6, 7, 8
goldeye	*Hiodon alosoides*	56	1.49%	188	1.20%	1, 2, 3, 4, 5, 6, 7, 8
walleye	*Sander vitreum*	76	2.03%	161	1.03%	1, 2, 3, 4, 5, 6, 7, 8
yellow perch	*Perca flavescens*	492	13.11%	140	0.89%	1, 2, 3, 4, 5, 6, 7, 8
flathead catfish	*Pylodictis olivaris*	3	0.08%	133	0.85%	1, 2, 3, 4, 5, 6, 7, 8
smallmouth buffalo	*Ictiobus bubalus*	17	0.45%	97	0.62%	1, 2, 3, 4, 5, 6, 7, 8
brassy minnow	*Hybognathus hankinsoni*	2	0.05%	82	0.52%	1, 2, 3, 4, 5
sauger	*Sander canadense*	21	0.56%	79	0.50%	1, 2, 3, 4, 5, 6, 7, 8
bigmouth shiner	*Notropis dorsalis*	0	0.00%	68	0.43%	1, 2, 3, 5, 7
shovelnose sturgeon	*Scaphirhynchus platorynchus*	17	0.45%	62	0.40%	1, 2, 3, 4, 5, 6, 7, 8
golden shiner	*Notemigonus crysoleucas*	1	0.03%	55	0.35%	2, 3, 4, 5
shortnose gar	*Lepisosteus platostomus*	9	0.24%	44	0.28%	1, 2, 3, 4, 5, 6, 7, 8
longnose gar	*Lepisosteus osseus*	0	0.00%	38	0.24%	1, 2, 3, 4, 5, 6, 7, 8
blue sucker	*Cycleptus elongatus*	0	0.00%	36	0.23%	1, 3, 5, 6, 7, 8
bigmouth buffalo	*Ictiobus cyprinellus*	6	0.16%	23	0.15%	1, 2, 3, 4, 5, 6, 7, 8
Johnny darter	*Etheostoma nigrum*	80	2.13%	22	0.14%	1, 2, 3, 4, 5, 7
northern pike	*Esox lucius*	17	0.45%	17	0.11%	1, 2, 3, 4, 5, 6, 7, 8
green sunfish	*Lepomis cyanellus*	11	0.29%	16	0.10%	1, 2, 3, 4, 5, 7, 8
rock bass	*Ambloplites rupestris*	13	0.35%	9	0.06%	1, 2, 3, 4, 5, 7, 8
fathead minnow	*Pimephales promelas*	8	0.21%	8	0.05%	1, 2, 3, 4, 5, 6, 7
flathead chub	*Platygobio gracilis*	10	0.27%	7	0.04%	1, 3
stonecat	*Noturus flavus*	4	0.11%	4	0.03%	1, 2, 3, 5
mimic shiner	*Notropis volucellus*	1	0.03%	4	0.03%	5
orangespotted sunfish	*Lepomis humilis*	0	0.00%	4	0.03%	1, 2, 3, 4, 5, 7, 8
silver chub	*Macrhybopsis storeriana*	8	0.21%	1	0.01%	1, 2, 3, 4, 5, 6, 7

*1= Mestl (2003), 2= Bailey and Allum (1962), 3= Morris et al. (1974), 4= Wickstrom (1995, 1997, 2003), 5= Hesse et al. (1989), 6= Schmulbach et al. (1975), 7= Kallemeyn and Novotny (1977), 8= Mestl et al. (2001).

Table 67. Native fish of MNRR, relative abundance from Berry and Young (2004), and a list of references documenting the presence of the species. Reproduced from Berry and Young (2004). (continued)

Common Name	Scientific Name	Fort Randall		Gavins Point		References*
		Total	Relative Abundance	Total	Relative Abundance	
white sucker	*Catostomus commersoni*	6	0.16%	2	0.01%	1, 2, 3, 4, 5, 7
bluntnose minnow	*Pimephales notatus*	3	0.08%	1	0.01%	1, 2, 3, 4, 5
paddlefish	*Polyodon spathula*	1	0.03%	2	0.01%	1, 2, 3, 4, 5, 6, 7, 8
burbot	*Lota lota*	1	0.03%	1	0.01%	1, 2, 3, 5, 6, 7, 8
grass pickerel	*Esox americanus*	0	0.00%	1	0.01%	1, 3, 4, 5
western silvery minnow	*Hybognathus argyritis*	0	0.00%	1	0.01%	1, 4, 7
sicklefin chub	*Macrhybopsis meeki*	0	0.00%	1	0.01%	1, 2, 3, 5
highfin carpsucker	*Carpiodes velifer*	0	0.00%	1	0.01%	3, 5
black bullhead	*Ameiurus melas*	5	0.13%	0	0.00%	1, 2, 3, 4, 5, 6, 7, 8
silver lamprey	*Icthymoyzon unicuspis*	0	0.00%	0	0.00%	2, 5
lake sturgeon	*Acipenser fulvescens*	0	0.00%	0	0.00%	1, 3, 5
pallid sturgeon	*Scaphirhynchus albus*	0	0.00%	0	0.00%	1, 2, 3, 4, 5, 6, 7
spotted gar	*Lepisosteus oculatus*	0	0.00%	0	0.00%	1
American eel	*Anguilla rostrata*	0	0.00%	0	0.00%	1, 2, 3, 5, 7
skipjack herring	*Alosa chrysochloris*	0	0.00%	0	0.00%	1, 2, 3, 4, 5, 6, 7, 8
central stoneroller	*Campostoma anomalum*	0	0.00%	0	0.00%	1, 2, 3, 4, 5
Mississippi silvery minnow	*Hybognathus nuchalis*	0	0.00%	0	0.00%	2, 3, 5
plains minnow	*Hybognathus placitus*	0	0.00%	0	0.00%	1, 2, 3, 5
common shiner	*Luxilus cornutus*	0	0.00%	0	0.00%	3, 4
speckled chub	*Macrhybopsis aestivalis*	0	0.00%	0	0.00%	1, 3, 5
sturgeon chub	*Macrhybopsis gelida*	0	0.00%	0	0.00%	1, 2, 3, 5
ghost shiner	*Notropis buchanani*	0	0.00%	0	0.00%	1, 5
silverband shiner	*Notropis shumardi*	0	0.00%	0	0.00%	5
suckermouth minnow	*Phenacobius mirabilis*	0	0.00%	0	0.00%	1, 2, 3, 4, 5
northern redbelly dace	*Phoxinus eos*	0	0.00%	0	0.00%	1, 3, 5
blacknose dace	*Rhinichthys atratulus*	0	0.00%	0	0.00%	1, 2, 5
longnose dace	*Rhinichthys cataractae*	0	0.00%	0	0.00%	1, 2, 5
creek chub	*Semotilus atromaculatus*	0	0.00%	0	0.00%	1, 2, 3, 4, 5
black buffalo	*Ictiobus niger*	0	0.00%	0	0.00%	3, 5
golden redhorse	*Moxostoma erythrurum*	0	0.00%	0	0.00%	1, 2, 3, 5
yellow bullhead	*Ameiurus natalis*	0	0.00%	0	0.00%	1, 3, 5, 6, 8
blue catfish	*Ictalurus furcatus*	0	0.00%	0	0.00%	1, 2, 3, 4, 5, 6, 8
tadpole madtom	*Noturus gyrinus*	0	0.00%	0	0.00%	1, 2, 3, 5
plains topminnow	*Fundulus sciadicus*	0	0.00%	0	0.00%	1, 2, 3, 5
stickleback	*Culaea inconstans*	0	0.00%	0	0.00%	1, 2, 3, 5
Iowa darter	*Etheostoma exile*	0	0.00%	0	0.00%	1, 2, 3, 5, 7

*1= Mestl (2003), 2= Bailey and Allum (1962), 3= Morris et al. (1974), 4= Wickstrom (1995, 1997, 2003), 5= Hesse et al. (1989), 6= Schmulbach et al. (1975), 7= Kallemeyn and Novotny (1977), 8= Mestl et al. (2001).

Several native fish species are now rare in MNRR. The best known of these is the pallid sturgeon, which the USFWS listed as endangered in 1990 (USFWS 2010). Pallid sturgeon typically prefer free-flowing riverine habitats, such as what MNRR possessed in its pre-dam condition (DeLonay, pers. comm., 2011). In 2010, the USFWS listed shovelnose sturgeon as a threatened species under the similarity of appearance provisions of the Endangered Species Act (USFWS 2010). Until recently, shovelnose sturgeon had been harvested commercially for their roe (Zuerlein, pers. comm., 2011; USFWS 2010).Their threatened status is intended to deter any unintentional harvesting of pallid sturgeon (Zuerlein, pers. comm., 2011; USFWS 2010). Chapter 4.6 of this document discusses pallid sturgeon in more detail.

Along with pallid sturgeon, many native minnow populations (family Cyprinidae) are declining in the Missouri River. The sicklefin chub and sturgeon chub were common in the Missouri River before dam closure (Bailey and Allum 1962), but are now rare; sturgeon chub are endangered in Nebraska and both sicklefin and sturgeon chub are listed as threatened in South Dakota (Berry and Young 2004). The flathead chub (*Platygobio gracilis*) and silver chub (*Macrhybopsis storeniana*) can still be found in MNRR, but evidence suggests that their populations are declining (Berry and Young 2004). Other species in the main channel of the Missouri River that are experiencing population declines include the plains minnow, western silvery minnow, and highfin carpsucker (*Carpiodes velifer)* (Galat et al. 2005). Table 68 summarizes all endangered and threatened fishes in MNRR.

Table 68. Endangered and Threatened fishes in MNRR (NGP 2009, SDGFP 2010).

Common Name	Scientific Name	South Dakota Status	Nebraska Status	Federal Status
sturgeon chub	*Macrhybopsis gelida*	Threatened	Endangered	
sicklefin chub	*Macrhybopsis meeki*	Threatened		
shovelnose sturgeon	*Scaphirhynchus platorynchus*			Threatened
pallid sturgeon	*Scaphirhynchus albus*	Endangered	Endangered	Endangered
northern redbelly dace	*Phoxinus eos*	Threatened	Threatened	
lake sturgeon	*Acipenser fulvescens*		Threatened	

Historically, sauger were dominant predators in the river. Loss of spawning habitat and high initial harvest following dam closure caused the population to decrease. For the eight months following the formation of Lake Oahe Reservoir (300 km upstream of MNRR), over 30,000 sauger were harvested. These harvested fish weighed an average of 0.91 kilograms each, with many individuals weighing between 1.81 and 3.18 kilograms (Bailey and Allum 1962). In 2009, sauger accounted for 6.2% (7,279) of the total number of fish harvested by anglers on the Fort Randall river segment and 12.6% (5,527) on the Gavins Point river segment (Bouska and Longhenry 2009). Sauger are also seriously threatened by hybridization with walleyes, which thrive in the dam-influenced environment of MNRR (Stukel, pers. comm., 2011).

There are three restored backwaters in the 59-mile segment that were constructed by multiple parties(Stukel, pers. comm., 2011). These three backwaters are spread throughout the 59-mile segment; one is near Yankton (river mile 806), one is just south of Vermillion (river mile 777), and one is near Ponca State Park (river mile 755) (Stukel, pers. comm., 2011). These three backwaters are key spawning and nursery habitats for many species including green sunfish

(*Lepomis cyanellus*), orange-spotted sunfish (*Lepomis humilis*), largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus)*, black crappie (*Pomoxis nigromaculatus*), and white crappie (*Pomoxis annularis*) (Stukel, pers. comm., 2011). In general, these species spend their adult lives in these backwaters and are less commonly documented in other areas of the 59-mile segment (Stukel, pers. comm., 2011).

There are many primitive species of fish in the Missouri River (Berry and Young 2004). The paddlefish (*Polyodon spathula*), with its unusual rostrum or ―paddle", symbolizes the native fishes of the Missouri River (Berry and Young 2004). It is one of the largest Missouri River fishes, measuring up to two meters long and weighing up to 45 kilograms. Today, natural reproduction by this species has stopped in the 39-mile segment, and hatcheries help augment the population in the Missouri River (Berry and Young 2004). There are three species of sturgeon in the Missouri River: pallid, shovelnose, and lake (*Acipenser fulvescens*). The pallid is rare and the shovelnose is common. The lake sturgeon has rarely been documented because MNRR is on the edge of its range (Berry and Young 2004). Reproduction by pallid sturgeon is minimal, but has been confirmed in the 59-mile segment (USGS 2007). However, slow-growth and longevity can make them appear more abundant than they actually are (Hesse et al. 1993, Berry and Young 2004, Berry et al. 2007).

Other species of interest in MNRR include blue sucker (*Cycleptus elongatus*), shortnose (*Lepisosteus platostomus*) and longnose (*L. osseus*) gar, and silver (*Ichthyomyzon unicuspis*) and chestnut (*I. castaneus*) lamprey. Both longnose and shortnose gar are common in the Gavins Point reach (Berry and Young 2004). Gar are tolerant to a wide range of conditions because their swim bladder can function as a lung in low-oxygen situations and they are well armored with bony plates and ganoid scales. Native freshwater lampreys exist in the Missouri River but at extremely low prevalence (Berry andYoung 2004). These lamprey are native to the Missouri River and are not the same as the exotic sea lamprey (*Petromyzon marinus*) found in the Great Lakes.

MNRR includes 32 kilometers of the lower Niobrara River, a tributary of the Missouri River, and Verdigre Creek, a tributary of the Niobrara River. The Niobrara provides important seasonal habitats for many native fishes in MNRR. Wanner et al. (2009) used electrofishing, trammel nets, and bag seine to survey fish in the Niobrara below Spencer Dam to the confluence with the Missouri River. The most prevalent fish species in this reach included the river carpsucker, channel catfish, sauger, shorthead redhorse, common carp (*Cyprinus carpio)*, shortnose gar, flathead chub, gizzard shad, red shiner, and sand shiner (Wanner et al. 2009). In Wanner et al. (2009) and in previous Niobrara River surveys (Hesse et al. 1979, Hesse and Newcomb 1982, Gutzmer et al. 2002), the plains killifish (*Fundulus zebrinus*) was the only species of fish that was documented in the Niobrara River and not in the Missouri River. Table 69 displays the catch records from Wanner et al. (2009) for the Niobrara River.

Table 69. Total number and relative abundance of fishes in the lower Niobrara River (Wanner et al. 2009).

Common Name	Scientific Name	Total	Relative Abundance
river carpsucker	*Carpiodes carpio*	1970	23.54%
red shiner	*Notropis lutrensis*	1725	20.61%
gizzard shad	*Dorosoma cepedianum*	1326	15.84%
channel catfish	*Ictalurus punctatus*	1035	12.37%
sand shiner	*Notropis stramineus*	677	8.09%
flathead chub	*Platygobio gracilis*	357	4.27%
green sunfish	*Lepomis cyanellus*	251	3.00%
spotfin shiner	*Notropis spilopterus*	185	2.21%
largemouth bass	*Micropterus salmoides*	166	1.98%
shorthead redhorse	*Moxostoma macrolepidotum*	149	1.78%
bluegill	*Lepomis macrochirus*	103	1.23%
common carp	*Cyprinus carpio*	85	1.02%
sauger	*Sander canadense*	80	0.96%
shortnose gar	*Lepisosteus platostomus*	49	0.59%
bigmouth shiner	*Notropis dorsalis*	35	0.42%
orange-spotted sunfish	*Lepomis humilis*	32	0.38%
grass pickerel	*Esox americanus*	25	0.30%
flathead catfish	*Pylodictis olivaris*	19	0.23%
emerald shiner	*Notropis atherinoides*	16	0.19%
shovelnose sturgeon	*Lepisosteus platostomus*	14	0.17%
white bass	*Morone chrysops*	13	0.16%
white crappie	*Pomoxis annularis*	13	0.16%
silver chub	*Macrhybopsis storeriana*	11	0.13%
freshwater drum	*Aplodinotus grunniens*	7	0.08%
walleye	*Sander vitreum*	7	0.08%
black bullhead	*Ameiurus melas*	3	0.04%
bluntnose minnow	*Pimephales notatus*	3	0.04%
brassy minnow	*Hybognathus hankinsoni*	3	0.04%
bigmouth buffalo	*Ictiobus cyprinellus*	2	0.02%
stonecat	*Noturus flavus*	2	0.02%
blue sucker	*Cycleptus elongatus*	1	0.01%
longnose dace	*Rhinichthys cararactae*	1	0.01%
northern pike	*Esox lucius*	1	0.01%
pumpkinseed	*Lepomis gibbosus*	1	0.01%
saugeye	*S. canadense x S. vitreum*	1	0.01%
smallmouth buffalo	*Ictiobus bubalus*	1	0.01%

Due to the declining populations and the rarity of some of the native fish in MNRR, the condition of this resource is of moderate concern and deciling.

Threats and Stressor Factors

Human development and the resulting loss of a natural disturbance regime have been the predominant factor in determining species composition and abundance on the Missouri River. Impoundments constructed during the 1950s altered the natural hydrograph, changed the food web on the river, and have also eliminated about 75% of the historic floodplain (Berry et al. 2007). Following reservoir establishment, shallow water areas continued to decline due to channel incision and the lack of flooding; this caused the decline of many native chub and shiner species (Berry et al. 2007). Species that rely on natural river temperatures and spring rises/pulses (e.g., sturgeon and paddlefish) as cues for spawning also declined following reservoir establishment. Many of these same species face further complications because of the migratory barriers created by the six major dams on the Missouri River.

One of the biggest threats for nearly all fish in the Fort Randall segment is the power peaks from the Fort Randall hydroelectric dam (Shuman, pers. comm., 2011). Power peaks occur during periods of the day when more electricity is used, typically between 5:00 p.m. and 9:00 p.m. (Shuman, pers. comm., 2011). During this time period, the Fort Randall Dam releases more water to generate more power, and the fluctuations in flow affect water-level, velocity, temperature, and turbidity. Daily water-level changes are generally greater than one meter in the summer months, and can be particularly troublesome for the endangered pallid sturgeon (Pracheil et al. 2009; Shuman, pers. comm., 2011). Gavins Point Dam is designed for continuous baseload energy, meaning on a day-to-day basis, a continuous amount of water is released into the 59-mile segment (USACE 2009). Therefore, in MNRR, power peaking is a threat unique to the 39-mile segment.

There are 21 non-native (not endemic to North America) or introduced (native to North America, but not in their normal range) fish species in MNRR (Table 70), accounting for 22% of the total species of fish (Berry and Young 2004).

Table 70. List of nonnative fish species of MNRR (reproduced from Berry and Young 2004).

Common Name	Scientific Name
alewife	*Alosa pseudoharengus*
goldfish	*Carassius auratus*
grass carp	*Ctenopharyngodon idella*
common carp	*Cyprinus carpio*
bighead carp	*Hypophthalmichthys nobilis*
silver carp	*Hypophthalmichthys molitrix*
spottail shiner	*Notropis hudsonius*
muskellunge	*Esox masquinongy*
rainbow smelt	*Osmerus mordax*
rainbow trout	*Oncorhynchus mykiss*
brown trout	*Salmo trutta*
white perch	*Morone americana*
Sacramento perch	*Archoplites interruptus*
pumpkinseed	*Lepomis gibbosus*
redear sunfish	*Lepomis microlophus*
bluegill	*Lepomis macrochirus*
spotted bass	*Micropterus punctatus*
smallmouth bass	*Micropterus dolomieu*
largemouth bass	*Micropterus salmoides*
white crappie	*Pomoxis annularis*
black crappie	*Pomoxis nigromaculatus*

Two nonnative species of Asian carp are of particular concern to fishery managers on the Missouri River: bighead and silver carp. Despite the recent introduction of these species to North America (1970s-1980s) (Berry and Young 2004), bighead and silver carp could be the most abundant fish greater than 2.25 kilograms in the lower Missouri River (which includes the 59-mile segment) (USGS 2004). Bighead and silver carp compete with native fishes through exploitation of food resources and through predation of larval stage fishes (USGS 2004, Berry et al. 2007). It should be noted that some of these nonnative fishes are important recreational species. However, these nonnative recreational species can still alter the native fish community.

Two major threats to native fish in the Niobrara River, as stated by Wanner et al. (2009), include the invasive Asian carp and water diversion for agricultural purposes. The threats that Asian carp pose on river systems have already been discussed, and opening corridors for upstream migration of native fish runs the risk of spreading Asian carp into the Niobrara River. Water diversion is of concern because it causes a reduction in flow, which can lower productivity of native fishes and invertebrates (Wanner et al. 2009). These negative effects of water diversion are not only apparent in the Niobrara River, but also downstream of the Niobrara/Missouri confluence (Wanner et al. 2009).

Data Needs/Gaps

Recently, USACE has experimented with releasing spring high flow events to act as spawning and migratory cues. However, these pulses generally have a much lower magnitude than the natural pulses that would have occurred pre-dam (DeLonay, pers. comm., 2011). Further research examining the viability and effectiveness of more realistic simulated high flow events by the USACE would be beneficial.

Several fish species within MNRR are experiencing population declines. Thus, continued monitoring of these species is vital to ensure their survival.

There are many data needs and gaps for the endangered pallid sturgeon. Those needs and gaps are discussed in Chapter 4.6 of this document.

Overall Condition

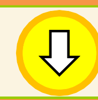
Measures	*Reference Condition*	*Condition*
Abundance	Pre-dam	

Figure 66. Native Fish Populations condition graphic.

The condition of native fish populations in MNRR is of moderate concern because several native fish species are rare, and some species are declining (Berry and Young 2004, Figure 66). The native fish populations function differently than they may have in the pre-dam era because of the altered flow regime and the suite of associated changes (Berry et al. 2007). Top to bottom, the food web is significantly different than it once was and exotic and introduced species have become more of a concern (Hesse et al. 1993, USGS 2004, Berry et al. 2007). Reproduction of many native fish species is limited due to migratory barriers (dams), loss of spawning cues, and habitat loss (Hesse et al. 1993, Berry et al. 2007). A positive aspect is that although there have been many changes to the Missouri River over the last 100 years, most native species have persisted (Berry et al. 2004).

Sources of Expertise

Aaron DeLonay, USGS Ecologist - Columbia Environmental Research Center
Dane Shuman, USFWS Fish and Wildlife Biologist
Sam Stukel, SDGFP Fisheries Biologist
Gene Zuerlein, NDGPC Fisheries Biolgist

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4.10 Northern Leopard Frog

Description

The northern leopard frog (*Rana pipiens*) is an amphibian species present in MNRR. Historically, northern leopard frogs were considered to be the most common and widely distributed Anura in South Dakota (Fischer 1998). More recently, they are thought to be abundant in some regions of the U.S., but have experienced localized extinctions in others (Smith 2003). Amphibians, such as the northern leopard frog, act as key indicator species for habitats and ecosystems because they are especially susceptible to ecological changes, largely due to their permeable skin (Smith 2007). The localized extinctions in some regions further exemplify northern leopard frog response to local environmental and habitat changes (Smith 2003). In addition, amphibians are often prey species, so toxins absorbed through their skin can quickly bioaccumulate throughout the entire food web (Smith 2007).

The construction of dams on the Missouri River and the effects of surrounding land use practices have had a significant impact on northern leopard frogs and their habitat (Kerby, pers. comm., 2010). The northern leopard frog appears to be hybridizing with plains leopard frogs *(Rana blairi*) (Smith and Keinath 2005), specifically in the 59-mile segment of MNRR (Kerby, pers. comm., 2010). In 2009, the USFWS petitioned to list the northern leopard frog as a threatened species under the Endangered Species Act of 1973 (USFWS 2009). A 12-month review period was initiated following this petition, and the review expired in December 2010. Because of the importance of the northern leopard frog as a prey species and as an indicator species, it is important to monitor the habitat availability in MNRR.

Measures

- Habitat availability

Reference Conditions/Values

Reference condition for the northern leopard frog for this assessment is habitat available during pre-dam conditions.

Data and Methods

Fogell (2003, 2005) conducted herpetofauna inventories of MNRR in 2003 and 2004 which documented the presence of northern leopard frogs in the park. The inventories involved basic encounter surveys which documented species present at particular study sites; for amphibians, this generally involved listening for frog and toad calls. Four automated recording systems or ―frog loggers" were also used at MNRR, three along the Missouri River and one placed near the confluence of the Niobrara and Missouri within the 39-mile segment (Fogell 2003). These loggers recorded frog and toad calls, and were left in place for seven days during the study (Fogell 2003). The inventories were a presence/absence study and did not attempt to estimate population size of any particular species. Fogell and Cunningham (2005) noted the difficulty in identifying leopard frogs to the species level; the other *Rana* species present in MNRR is the plains leopard frog, which is very similar in appearance. Northern leopard frogs do not possess a dot on their tympanic membrane and have a solid lateral line, while plains leopard frogs possess this dot and have a break in their lateral line near the posterior end (Kerby, pers. comm., 2010). While these traits serve as a general indicator of species type, recent genetic work has indicated that these are not always reliable indicators and that several variations may occur (Grant, pers. comm., 2010).

Smith (2007) and Smith and Keinath (2004) wrote species assessments of the northern leopard frog, which focused on summarizing current published information. The goals of both publications were to add expert interpretation to the current biological, ecological, and conservation information so that it can be used to development management plans.

Current Condition and Trend

<u>Habitat availability</u>
There are four main habitat types in MNRR: riverine/wetland, bluffs, grassland, and riparian woodland (Fogell and Cunningham 2005). Common areas to find adult northern leopard frogs in MNRR are backwaters and wetlands (Kerby, pers. comm., 2010). Inlets such as the James River and other tributaries that flow into the Missouri River appear to contain pure populations of northern leopard frogs (Kerby, pers. comm., 2010). In contrast, several sites along the main stem within MNRR possessed hybrids of northern and plains leopard frogs. Efforts by J. Kerby to distinguish plains and northern leopard frogs are based on physical traits alone. Genetic testing has not been done to confirm that the frogs in the main channel were indeed hybrids, but several individuals expressed mixed traits (i.e., break in lateral line on only one side of body) (Kerby, pers. comm., 2010).

Northern leopard frogs have three distinct habitats, with each habitat being utilized differently depending on the frog's age and the time of the year. These three habitats include breeding/tadpole habitat, adult upland habitat, and adult overwintering habitat (Smith and Keinath 2004). A close proximity to all three of these habitats is important for northern leopard frog populations (Smith and Keinath 2004).

Breeding/Tadpole Habitat
The most important characteristic of a breeding pond is that it is semi-permanent or seasonal – usually lasting from 30 days to one year (Fischer 1998, Semlisch 2000, as cited in Smith and Keinath 2007). This is an important characteristic because these types of ponds are not able to sustain predaceous fish. Breeding/tadpole habitats also are generally found in ponds that are not connected to larger bodies of water – connection of these ponds to larger bodies of water risks the introduction of predaceous fish during high flow periods (Smith and Keinath 2004). In a recent survey along MNRR, sites containing northern leopard frogs were typically less than 20 meters wide in diameter (Kerby, pers. comm., 2010). In addition, breeding ponds are typically free of overhead canopy (Smith and Keinath 2004). Breeding ponds are reasonably shallow, allowing the water to be heated to a suitable temperature by the sun (Smith and Keinath 2004); suitable water temperatures for male northern leopard frogs to begin calling are above 20° C (Fischer 1998). However, the ponds cannot be so shallow that they dry up before the 58-105 day larval period is complete (Smith and Keinath 2004). Typical depths of breeding ponds are around 1.5 to 2.0 meters (Smith 2007).

Smith (2007) used the classification system of Cowardin et al. (1979) to determine the most typical breeding habitat for the northern leopard frog in the Rocky Mountain region of the USFS (which includes Nebraska and South Dakota). These habitats are described as palustrine sites with an unconsolidated bottom that usually have a pond margin with extensive growth of cattails (Smith 2007). This description was used to query a 2002 National Wetlands Inventory (NWI) database to determine the amount and location of palustrine unconsolidated bottom habitats in MNRR. After querying the database, only a few ponds were found within MNRR that matched the Smith (2007) breeding habitat description. The majority of the ponds that were within the administrative boundaries of MNRR were listed as excavated, leaving very few naturally occurring suitable breeding ponds within MNRR. It should be noted that often times, the NWI database does not have the level of detail necessary to locate and quantify northern leopard frog breeding ponds, which are often ephemeral and are generally only 20 meters or less wide. Therefore, the NWI database is useful in determining an estimate of available palustrine sites, but will not necessarily be useful in locating small, seasonal ponds that northern leopard frogs might use for breeding.

Adult Upland Habitat
The northern leopard frog is one of the most terrestrial of the ranid frogs (Smith 2007). Adults will generally spend their summers in grassy meadows where the grass heights reach about 0.3 meters (Smith and Keinath 2004). These grassy meadows can be considerable distances away from water and frogs' natal ponds (up to 3 km away) (Smith 2007). Meadows, riparian zones, and wetlands are the most important connecting habitats between the grassy meadows and breeding habitats (Smith 2007). Data are unavailable that could help further locate specific habitat in MNRR according to Smith's (2007) description of adult upland habitat or adult overwintering habitat.

Adult Overwintering Habitat
Adult overwintering habitats are where northern leopard frogs spend the winter months. They may hibernate over winter in ponds, streams, and rivers (Smith and Keinath 2004). These habitats may be susceptible to oxygen depletion and the presence of predaceous fish. Northern leopard frogs are commonly found in areas with high oxygen saturation, such as inflow areas in ponds (Smith and Keinath 2004). In areas with few ponds or larger bodies of water, northern leopard frogs will overwinter in bottoms of flowing streams (Smith and Keinath 2004).

<u>Threats and Stressor Factors</u>
The primary threats and stressors identified for the northern leopard frog include changes in climatic patterns, human development, loss of natural disturbance regime, habitat loss, and water quality impacts.

There is little historical data on northern leopard frog habitat before the dams were built, but prior to dam construction, there were likely more side channel wetlands (Kerby, pers. comm., 2010). Many of these side channels have closed off due to changing sediment levels, resulting in backchannels instead. Yager (2010) indicated that the total area of off-channel features declined by 70% between 1941 and 2008. Within MNRR, the primary impediments to new backwaters are bank stabilization and channel degradation, with levees only impacting the lower channelized Missouri River (Yager 2010). Before the Gavins Point Dam was constructed, nearly 140 million tons of sediment flowed past Yankton, SD, each year (NPS 2010). Today, only approximately 4 million tons flow through (NPS 2010). This shift in sediment load changes the available habitat for northern leopard frogs. Now, most of the northern leopard frogs J. Kerby (pers. comm., 2010) finds near MNRR are in tributaries and small backwaters around the Missouri River.

Most of the land surrounding MNRR is privately owned cropland, currently in corn and soybean production (Dixon et al. 2010; Kerby, pers. comm., 2010). As of 2006, in the 59-mile district floodplain, 65,726 ha (162,413 acres) or 76.89% of the land cover was agricultural row crops (Dixon et al. 2010). For comparison, only 25% of the floodplain was agricultural row crops in 1892 (pre-dam). For the 39-mile district floodplain, as determined by Segment 8 in Dixon et al. (2010), 4,322 ha (10,680 acres) or 18.44% of the land cover was agricultural row crops in 2006. The 59-mile segment is of significant concern, because agricultural development can lead to destruction of northern leopard frog habitat directly through dewatering or indirectly through the introduction of contaminants (USFWS 2009). A recent survey of amphibian breeding habitats along the MNRR revealed that detectable levels of contaminants were found in 15 of the 20 sites sampled (Kerby, pers. comm., 2010). In addition, the presence of livestock can cause destruction of the surrounding habitat by increasing erosion, reducing vegetative cover in riparian zones, and reducing water depth in breeding ponds, which leads to increased water temperatures (USFWS 2009). Furthermore, fecal coliform bacteria and nitrate concentrations generally increase in ponds where there is significant cattle grazing (Smith 2007). The permeable skin of northern leopard frogs makes them especially susceptible to the introduction of contaminants in their habitat (Smith 2007), so the presence of or close proximity to cropland and cattle could be problematic.

While habitat destruction is the biggest threat to northern leopard frogs, the potential spread of diseases as a result of climate change can dramatically decrease population as well (USFWS 2009).Chytridiomycosis, caused by the fungus *Batrachochytrium dendrobatidis* (Bd), has caused mass mortalities of northern leopard frogs in nearly every western U.S. state (USFWS 2009). A recent survey of South Dakota amphibian species revealed that the fungus is present within MNRR (Kerby, pers. comm., 2010). Such diseases make it difficult for northern leopard frogs to overcome habitat destruction problems (such as a loss of side channels and accumulation of contaminants).

Fogell and Cunningham (2005) identified the plains leopard frog as a potential competitor with the northern leopard frog for resources. The plains leopard frog was not on the expected species list during the herpetofauna inventory in MNRR, but it was documented and appears to be expanding its range along the Missouri River near the Nebraska/South Dakota border (Kerby, pers. comm., 2010). It appears that many of these plains leopard frogs are now hybridizing with northern leopard frogs (Smith and Keinath 2005).

Data Needs/Gaps

Smith (2007) used the Cowardin et al. (1979) wetland classification scheme to describe tadpole/breeding habitats for northern leopard frogs, but no data exist that describe adult upland or overwintering habitats using the Cowardin et al. (1979) classification. A vegetation classification of these habitats could allow a query of a future vegetation classification database (such as the vegetation mapping proposed by Stevens et al. 2010) to determine potential adult upland and overwintering habitat availability within MNRR. However, it is important to acknowledge the lack of detail for small, seasonal ponds in the NWI. A more detailed database of small, seasonal wetlands around MNRR would be beneficial for this reason.

Currently, no data exist regarding the possibility of the plains leopard frog competing with the northern leopard frog in MNRR (Fogell and Cunningham 2005). There are also no data that analyze where and to what extent plains leopard frogs and northern leopard frogs are hybridizing in MNRR.

There is no spatial distribution information for northern leopard frogs in MNRR, although a graduate student at USD is currently researching this (Kerby, pers. comm., 2010). Further information regarding the effects of surrounding land use on northern leopard frog habitat would be beneficial for understanding habitat changes.

Overall Condition

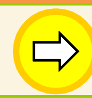
Measures	*Reference Condition*	*Condition*
Habitat availability	Pre-dam	

Figure 67. Northern Leopard Frog condition graphic.

The overall condition of habitat availability for northern leopard frogs is of moderate concern (Figure 67). The closing of side channels due to changes in sediment levels and hydraulic regime has greatly reduced northern leopard frog habitat. A large amount of development has also occurred since the dams were built. Specifically, agricultural development poses many risks to northern leopard frogs because of contaminant runoff and wetland draining. Smith and Keinath (2004) explain that there are three distinct habitats necessary for northern leopard frogs: breeding/tadpole, adult upland, and adult overwintering. A close proximity to all three habitats is necessary for the success of northern leopard frogs (Smith and Keinath 2004). After querying the National Wetlands Inventory database, it appears that there are very few suitable breeding habitats for northern leopard frogs near MNRR, thus raising some concern for habitat availability. However, there is still the possibility of small, seasonal ponds in MNRR that were not accounted for by the NWI database. Perhaps the greatest concern for northern leopard frogs along the MNRR is the loss of genetic diversity due to hybridization with plains leopard frogs (Kerby, pers. comm., 2010). However, the extent to which hybridization has occurred and is occurring is currently unknown (Kerby, pers. comm., 2010). Overall, MNRR has endured many changes since the construction of the dams and surrounding land use introduces many environmental changes to northern leopard frog habitat.

Sources of Expertise
Jake Kerby, USD, Ecologist
Alex Grant, USFS Wall Ranger District, Wildlife Biologist

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4.11 Freshwater Invertebrates

Description

Freshwater invertebrates are a diverse group of organisms ranging from aquatic insects to Unionid mollusks. Aquatic invertebrates can act as indicators of poor water quality, habitat loss, and declination in substrate quality (USGS 2004). Macroinvertebrates are also extremely important in the food web, representing a major food source for the federally endangered pallid sturgeon and piping plover (Carlson et al. 1985, as cited in Dryer and Sandvol 1993). The construction of the Fort Randall and Gavins Point Dams has led to significant changes in flow regime, aquatic and riparian habitats, water temperature, and turbidity of the Missouri River, which has affected freshwater invertebrate habitat (USFWS 2004). The importance of aquatic invertebrates as indicators of environmental stressors makes it important to monitor the habitat availability of freshwater invertebrates in MNRR.

Measures

- Habitat availability

Reference Condition

The reference condition for available freshwater invertebrate habitat is MNRR prior to dam construction. Prior to dam closure on the Missouri River (1950s), several studies (Hayden 1862; Coker and Southall 1915; Over 1915, 1942) found the river to be absent of freshwater mussels (Perkins and Backlund 2000). Researchers concluded the lack of mussels in the Missouri River was a result of unsuitable habitat due to high silt content (Perkins and Backlund 2000). In addition, Hayden (1862) and Coker and Southall (1915) documented extensive amounts of shells and mussel beds in Missouri River tributaries, such as the Big Sioux River, Vermillion River, and James River, all of which historically had a smaller silt load than the Missouri River main channel. Hoke (1983) was the first to document significant amounts of mussels in the Missouri River, and he attributed the lack of prior documentation to insufficient sampling methods and the overall lack of research – not unsuitable habitat. Perkins and Backlund (2000) concluded that at least some mussels were historically present in the Missouri River, but available habitat was marginal, with tributaries and oxbows providing most of the suitable mussel habitat.

Before the construction of six major dams on the Missouri River, macroinvertebrates utilized extensive off-channel habitats (backwaters, chutes, etc.) that were created by high flow events (Mestl and Hesse 1993). In addition, the natural meander evolution of the river continuously eroded banks, depositing trees and roots into the river system (Mestl and Hesse 1993; Weeks et al. 2005). The deposited woody debris often provided suitable habitat for aquatic insects and other macroinverterbrates (Mestl and Hesse 1993; Weeks et al. 2005). However, dam construction, bank stabilization, and channel bed degradation has extensively altered the Missouri River's hydrograph, off-channel areas, and amount of deposited woody debris, consequently altering macroinvertebrate production (Mestl and Hesse 1993; Weeks et al. 2005).

Data and Methods

Several surveys have been conducted for presence/absence of mussel and macroinvertebrate composition and habitat (Hoke 1983; Mestl and Hesse 1993; Perkins and Backlund 2000; Ecological Specialists 2005; Shearer et al. 2005; Weeks et al. 2005; Hay et al. 2007; Berg and Klumb 2007; Grohs 2008; Perkins 2009). These studies, along with personal communications with Lisa Yager, MNRR Biologist, Stephen Wilson, NGPN Data Manager, and Keith Perkins, University of Sioux Falls (USF) Biologist, were the main sources of information for this assessment.

Current Condition and Trend

<u>Mussels</u>

Mussel distribution and habitat is largely determined by substrate composition and stability, both of which are influenced by changes in flow regime (Way et al. 1989, as cited in Ecological Specialists 2005). More specifically, mussel beds are generally found “in areas with clean, stable substrate consisting of cobble, gravel, and sand, whereas they are not typically found in unstable substrate because they are unable to maintain their natural position and may be buried or displaced during fluvial events” (Strayer and Ralley 1991, as cited in Ecological Specialists 2005). High silt content and fast, frequent changes in discharge also appear to negatively affect mussel habitat (Ecological Specialists 2005).

The dams on the Missouri River have had both positive and negative effects on mussel habitat availability in MNRR. Mussels typically live in river side channels, backwaters, and oxbows with low amounts of shifting sand and silt (Perkins and Backlund 2000). Historical accounts document the absence of mussels in the Missouri River, due to high silt content; areas that mussels were found included tributaries and oxbows (Perkins and Backlund 2000). Channelization in the lower reaches of the Missouri River (below the 59-mile segment) and the hydroelectric dams in the mid/upper reaches have largely eliminated all historical mussel habitat by backing up water and filling in oxbows and backwaters with sediment (Perkins and Backlund 2000). In addition, the altered flow regime and lower water table due to degradation have led to disconnected backwaters and chutes (Yager, pers. comm., 2010). However, impoundments have also created new mussel habitat. Perkins and Backlund (2000) highlight three specific reasons why the 59-mile segment provides high-quality habitat for mussels: (1) the water below the dam has less silt and shifting sand, which would normally displace or suffocate mussels; (2) the top-water discharge from the Gavins Point Dam provides warm water, which is highly oxygenated and full of phytoplankton; and (3) the Gavins Point Dam blocks host fish from migrating upstream, resulting in a concentration below the dam. This concentration of mussels below Gavins Point Dam (known as the “bubble”) is a cobble/pebble bed where host fish drop glochidia (mussel larvae), due to the halting of their upriver movement (S. Wilson, pers. comm., 2010).

Shearer et al. (2005) conducted a mussel survey in the 39-mile segment of MNRR, and found the reach to have fewer mussels and less diversity than the 59-mile segment. Shearer et al. (2005) found the stretch of river between Fort Randall Dam and Verdel, NE, as well as the Niobrara River delta to be particularly unfit for mussel colonization. The lower amounts of mussels in the 39-mile segment are largely a result of isolation of host fish between Fort Randall Dam and Gavins Point Dam, which restricts them from dropping glochidia in segments other than the 39-mile segment (Shearer et al. 2005). Nearly all mussels collected by Shearer et al. (2005) were found in the stretch of river between Verdel, NE and the Niobrara River confluence.. This is likely due to the discontinuity between this stretch of river and the upper reaches of the 39-mile segment; alterations in water temperature, turbidity, flow regime, and nutrient cycling are not as significant in this stretch as in areas closer to Fort Randall Dam (Shearer et al. 2005).

One of the major differences between the 59-mile segment and the 39-mile segment is that the Fort Randall Dam is a power-peaking, bottom-discharge system, while the Gavins Point Dam is a top-water continuous discharge system (Shearer et al. 2005). Power peaks are periods of the day when more energy is demanded and subsequently more power has to be generated by the dam (USACE 2009). This results in significant daily fluctuations in water levels and temperature. In addition, the Gavins Point Dam restricts any upstream movement of host fish, thus limiting potential recruitment numbers for mussels from the 59-mile segment into the 39-mile segment (Shearer et al. 2005). Another difference contributing to habitat availability is the lack of mussel-rich tributaries in the 39-mile segment (Shearer et al. 2005). The Niobrara River and Verdigre Creek were not studied in Shearer et al. (2005), but the confluence of the Niobrara and Missouri Rivers contained no mussels. In contrast, the James, Vermillion, and Big Sioux Rivers all had large mussel populations near their confluence with the Missouri River (Perkins and Backlund 2000). The lack of mussel populations in the Niobrara River and Verdigre Creek are largely due to the shallow water with shifting sand whereas the James, Vermillion, and Big Sioux Rivers are deeper and do not contain shifting sand (S. Wilson, pers. comm., 2010).

The discovery of a scaleshell mussel (*Leptodea leptodon*) in MNRR by Hoke (1983) is of particular interest because it is a federally endangered species. A single dead specimen was found one kilometer east of Gavins Point Dam in the 59-mile segment (Hoke 1983). An additional fresh dead (some adductor muscle was still present) scaleshell mussel was found by Keith Perkins near the same location in 2005 (Perkins, pers. comm., 2011). Neither Perkins and Backlund (2000) nor Shearer et al. (2005) found the scaleshell mussel in MNRR. However, scaleshell mussels typically bury themselves deep in substrate so they can be difficult to find (Perkins and Backlund 2000).

In addition to the scaleshell mussel, a single dead valve of a Higgins eye pearly mussel (*Lampsilis higginsii*) was discovered in the 59-mile segment in 2004 (Shearer et al. 2005). The Higgins eye pearly mussel is endangered in both South Dakota and Nebraska and is also federally endangered (Shearer et al. 2005). Higgins eye pearly mussels are typically only found in the St. Croix and Mississippi Rivers, so the presence of a reproducing population in the Missouri River would indicate a considerable increase in the species' range (Shearer et al. 2005). However, Shearer et al. (2005) do not know the origin of the shell, and the presence of the single valve could be purely accidental.

An invasive Asian clam (*Corbicula flumniea*) has also been discovered in the 59-mile segment (Shearer et al. 2005). Grohs (2008) found 192 Asian clams in the Gavins Point reach and 18 Asian clams in the Fort Randall reach. Asian clams were found in the Gavins Point National Fish Hatchery paddlefish rearing ponds (Schilling et al. 2010, as cited in Grohs et al. 2010), which could be problematic as the hatchery reared paddlefish are released in Lake Francis Case (Sloss et al. 2009, as cited in Grohs et al. 2010). This could result in the hatchery reared paddlefish releasing glochidia in the upper reaches of the Missouri River. However, Grohs (2010) found no Asian clams in Lake Francis Case.

Table 71 summarizes the survey findings of Hoke (1983), Perkins and Backlund (2000), Shearer et al. (2005), Perkins (2009), and Ecological Specialists (2005).

Table 71. Mussels present in MNRR (Hoke 1983, Perkins and Backlund 2000, Shearer et al. 2005, Ecological Specialists 2005, and Perkins 2009).

Common Name	Scientific Name	Notes
Higgins eye pearly mussel	*Lampsilis higginisii* [1]	Federally Endangered – not endemic to Missouri River
threeridge	*Amblema plicata* [1, 4, 5]	
Asian clam	*Corbicula flumniea* [1]	Invasive
fragile papershell	*Leptodea fragilis* [1, 2, 3 ,4, 5]	Most abundant in MNRR
pink papershell	*Potamilus ohiensis* [1, 3, 4, 5]	
white heelsplitter	*Lasmigona complanata* [1, 2, 3, 4, 5]	
giant floater	*Pyganodon grandis* [1, 3, 4]	
mapleleaf	*Quadrula quadrula* [1, 2, 3, 4 ,5]	
paper pondshell	*Utterbackia imbecillis* [1]	
pink heelsplitter	*Potamilus alatus* [1, 2, 3, 4]	
flat floater	*Anodonta suborbiculata* [2, 3, 4]	
stout floater	*Anodonta grandis corpulenta* [2, 3]	
buckhorn	*Tritogonia verrucosa* [3]	
deertoe	*Truncilla truncata* [2, 3, 4, 5]	
fawnsfoot	*Truncilla donaciformis* [2, 3]	
scaleshell mussel	*Leptodea leptodon* [3, 4]	Federally Endangered
slough sandshell	*Lampsilis teres teres* [3, 4]	
rock pocketbook	*Arcidens confragosus* [2]	
fatmucket	*Lampsilis siliquoidea* [2]	
creeper	*Strophitus undulates* [2]	
lilliput	*Toxolasma parvus* [2, 4]	
yellow sandshell	*Lampsilis teres* [2]	

[1] Shearer et al. 2005
[2] Perkins and Backlund 2000
[3] Hoke 1983
[4] Perkins 2009
[5] Ecological Specialists 2005

<u>Threats and Stressor Factors – Mussels</u>

Perkins and Bucklund (2000) conclude that much of MNRR is not favorable for musselbed establishment. However, there are many microhabitats within MNRR where mussels can be found, such as oxbows, sidechannels, and backwaters but these habitats are slowly being dewatered due to streambed degradation and stabilized flow (Perkins and Backlund 2000). Periodic high flows and floods that occurred before flood control and regulation would have normally cleaned out oxbows and side channels, deepening the channel and providing higher quality habitat for mussels (Perkins and Backlund 2000). Evidence of this is provided by the restored oxbows and side channels after spring flows in 1997 (Perkins 2009). Though these flows aided in cleaning out mussel habitat, Perkins (2009) did not specify any mussel bedding response to the restoration.

Construction of ESH is a stressor for mussels in MNRR (Yager, pers. comm., 2010). These habitats disturb river sediments, possibly affecting mussels in the area (Yager, pers. comm., 2010). The concern regarding ESH construction and mussel beds began when the most recent

ESH construction program started in the mid-2000s (S. Wilson, pers. comm., 2011). There was concern that an area with high mussel density and diversity would succumb to dredging and dozing. Disturbance of this bed could also lead to unintended sedimentation on downstream mussel locations. In addition, there is concern for loss of mussels that are occupying old chutes and backwaters that are scheduled for renovation.

The potential introduction of zebra mussels poses a significant risk to native mussels, as well as the entire ecosystem. To date, no zebra mussels have colonized MNRR (Yager, pers. comm., 2011). Zebra mussel veligers (larvae) were independently confirmed in 2003; however, despite increased sampling efforts, neither veligers nor adults have been detected since (Yager, pers. comm., 2011). Conversely, Asian clams are present in the 59-mile segment of MNRR (Shearer et al. 2005). Asian clams cause many economic problems by clogging pipes and tubes (Foster et al. 2011), and are a threat to the natural environment because they alter benthic substrates and compete with native mollusks for the limited habitat available in the 59-mile segment (Sickel 1986, as cited in Foster et al. 2011; Devick 1991, as cited in Foster et al. 2011).

Power peaking from the Fort Randall Dam in the 39-mile segment is a stressor on mussel habitat. The daily fluctuations in water levels can extensively wash out mussel beds, and can also cause significant changes in water temperature, turbidity, and speed (Shearer et al. 2005).

Macroinvertebrates

Macroinvertebrates are commonly used to examine the ecological condition of an aquatic community (USGS 2004). By understanding the number of species, populations of each species, and the proportion of different feedings types, scientists can assess the quality of the surrounding ecosystem (USGS 2004). Currently, there are 263 macroinvertebrates species in the lower Missouri River (the segment from Gavins Point Dam to the confluence of the Missouri and Mississippi Rivers), with 135 living in main channel habitats (USGS 2004). 128 species are unique to wetlands and several species are unique to certain types of substrate (USGS 2004). However, it should be noted that these findings are from the entire lower Missouri River (811 river miles) and MNRR only covers 95 km (59 mi) of the lower Missouri River, so all findings from the lower Missouri River cannot be assumed to apply to either the 59-mile or 39-mile segments of MNRR.

Berg and Klumb (2007) collected macroinvertebrate samples using a Surber sampler, drift net, and ponar dredge. In the Surber samples for the Fort Randall reach, primary taxa included Diptera and Ephemeroptera (Berg and Klumb 2007). The Surber samples in the Gavins Point reach primarily consisted of Diptera, Ephemeroptera, Trichoptera, and larval fish (Berg and Klumb 2007). The drift net samples in the Fort Randall reach consisted of primarily Diptera and larval fish (Berg and Klumb 2007). Gavins Point reach drift net samples consisted of primarily Diptera, Trichoptera, and larval fish (Berg and Klumb 2007). Finally, Ponar dredge samples in the Fort Randall reach and Gavins Point reach primarily consisted of Diptera (Berg and Klumb 2007). Rust (2006) also found Diptera to be the primary taxa of invertebrates sampled in MNRR. Figure 68 and Figure 69 summarize the Berg and Klumb (2007) macroinvertebrate percent composition surveys for both the Fort Randall reach and the Gavins Point reach.

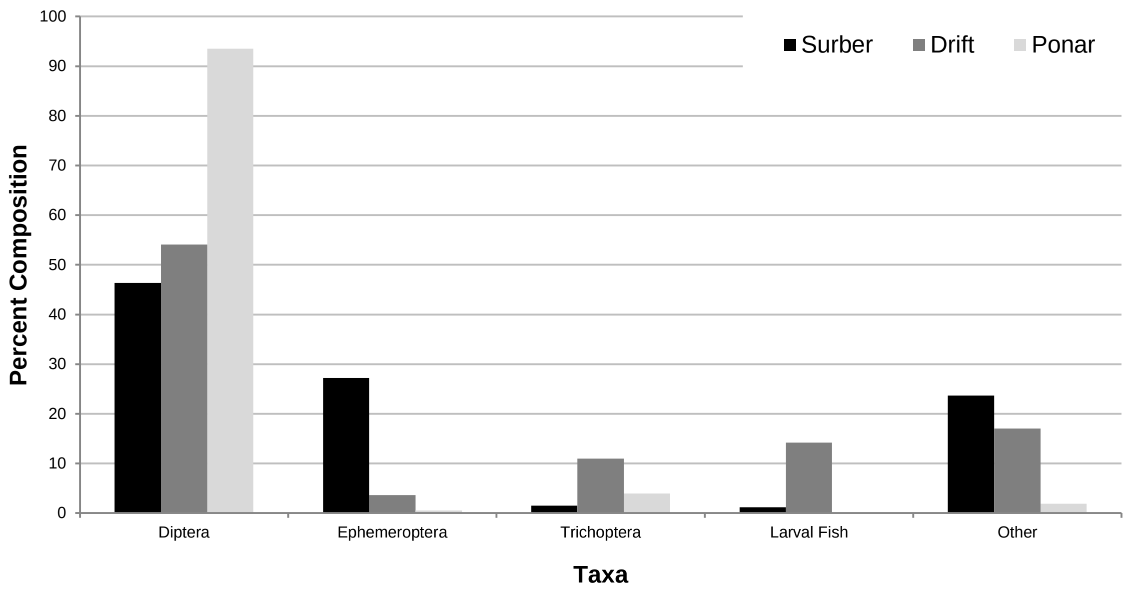


Figure 68. Percent composition of macroinvertebrates in Fort Randall reach (reproduced from Berg and Klumb 2007).

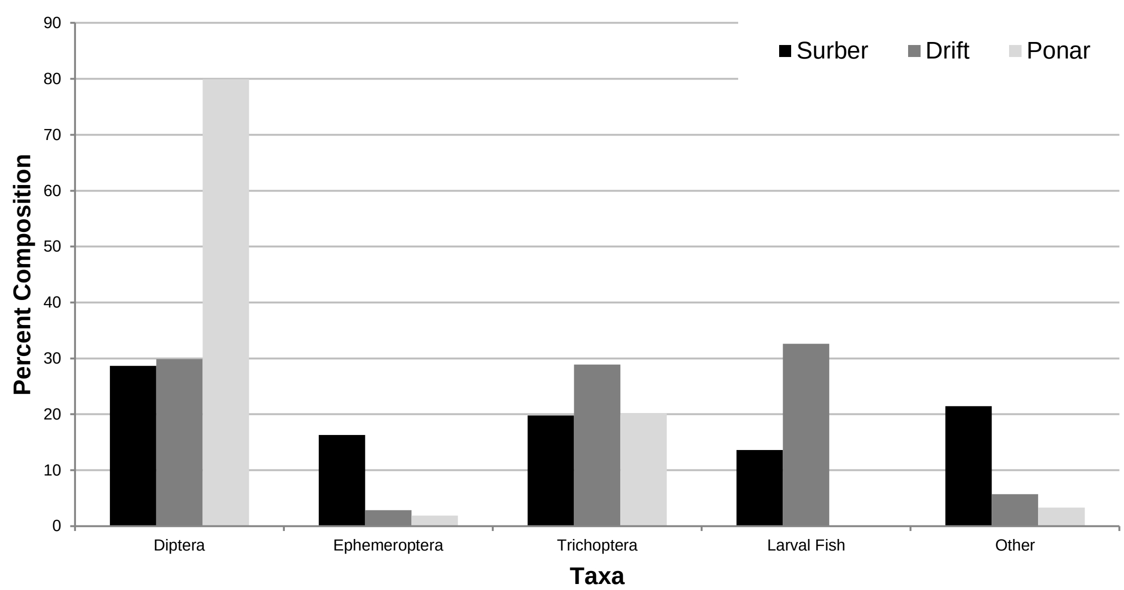


Figure 69. Percent composition of macroinvertebrates in Gavins Point reach (reproduced from Berg and Klumb 2007).

Grohs (2008) collected samples of macroinvertebrates at three sites downstream of both Fort Randall and Gavins Point Dams with over 60 macroinvertebrate taxa collected. Compared to the Fort Randall reach, mean densities of macroinvertebrates were generally higher in Gavins Point reach for both 2005 and 2006 (Grohs 2008). The lower densities in the Fort Randall reach are largely due to extreme hydrologic fluctuations as a result of power peaking (Hesse et al. 1988, as cited in Weeks et al. 2005). However, it should be noted that while the Gavins Point reach had higher densities, it has still experienced severe loss of backwater and chute habitats, which are critical for macroinvertebrates (Hesse et al. 1988, as cited in Weeks et al. 2005). Table 72 highlights notable (abundant or rare [< 1% composition by number]) macroinvertebrate taxa found in Grohs (2008).

Table 72. Notable macroinvertebrate taxa found in Grohs (2008).

Macroinvertebrate Taxa (Common Names)	Macroinvertebrate Taxa (Family))	Status
non-biting midges	Chironomidae	Abundant
biting midges	Ceratopogonidae	Abundant
brushlegged mayflies	Isonychiidae	Abundant
small minnow mayflies	Baetidae	Abundant
small squaregill mayflies	Caenidae	Abundant
flat-headed mayflies	Heptageniidae	Abundant
trumpet-net and tube-making caddisflies	Polycentropodidae	Abundant
crane flies	Tipulidae	Rare (Fort Randall reach)
giant stoneflies	Pteronarcyidae	Rare (Fort Randall reach)
brown stoneflies	Nemouridae	Rare (Fort Randall reach)
common stoneflies	Perlidae	Rare (Fort Randall reach)
broad-winged damselflies	Calopterygidae	Rare (Fort Randall reach)
dagger flies	Empididae	Rare (Gavins Point reach)
moth flies	Psychodidae	Rare (Gavins Point reach)
white flies	Polymitarcyidae	Rare (Gavins Point reach)
phantom midges	Chaoboridae	Rare (Gavins Point reach)
sessile-eyed Crustacea	Isopoda	Rare (Gavins Point reach)

Mestl and Hesse (1993) examined aquatic insect production in Missouri River backwaters in the Bazile Creek Wildlife Management Area (adjacent to Niobrara State Park) and compared change in total area and insect production between 1963 and 1980. While nearly all habitat area and production numbers decreased to some extent, the most dramatic decreases in production came from chutes and backwaters (including open water and vegetated bars) (Mestl and Hesse 1993). For example, in 1963, chute and backwater habitats accounted for 37% of secondary production, and in 1980, the same habitats accounted for only 19% of secondary production (Mestl and Hesse 1993). These dramatic decreases in overall annual production (61%) were associated with large decreases in overall area (16%) (Mestl and Hesse 1993). Mestl and Hesse (1993) conclude that the loss of backwater habitat, as a result of a reduction in flooding, disproportionally accounted for the overall large decrease in annual production. Schmulbach et al. (1981) also found a significant decrease in backwater habitats since the 1960s. Schmulbach et al. (1981) concluded that this loss is of significant concern, because backwater habitats are the primary producer of macroinvertebrates. Table 73 summarizes the findings from Mestl and Hesse (1993).

Table 73. Estimated area (ha) and annual production (kg) for the benthic and aufwuchs insect communities from Missouri River aquatic habitats, 1963 and 1980 (reproduced from Mestl and Hesse (1993).

	1963		1980	
Community/habitat	**Area (ha)**	**Production (kg)**	**Area (ha)**	**Production (kg)**
Benthos (bottom)				
Main channel and sand bar	5,097	9,786	4,829	9,272
Main channel mud bank, pool, and border	353	353	338	338
Chute	836	3,670	274	1,203
Backwater, vegetated bar	34	388	11	125
Backwater, open water	153	3,672	50	1,200
Total:	6,473	17,869	5,505	12,138
Aufwuchs (surface)				
Backwater, vegetated bar	34	433	11	140
Main channel and chute border	305	50,570	204	14,582
Total:	339	51,003	215	14,722
Grand Total:	6,812	68,872	5,720	26,860

Hay et al. (2008) examined macroinvertebrate drift in MNRR and how macroinvertebrates respond to habitat changes in both the 39-mile and 59-mile segments. Drift is the process that macroinvertebrates use to redistribute themselves, based on favorable or unfavorable environmental characteristics (discharge, temperature, turbidity, etc.) (Hay et al. 2008). Overall, drift density (the amount of macroinvertebrates drifting) appeared to increase as a result of negative changes in habitat and food availability (Hay et al. 2008). For the 39-mile segment the main conclusions were that drift was negatively correlated with the number of days since a high flow event and positively correlated with temperature. For the 59-mile segment, macroinvertebrate drift was positively correlated with degree day and negatively correlated with discharge. Specifically, Hay et al. (2008) found that reduced discharge in the 59-mile segment led to increased drift. The overall drift density in the 59-mile segment was higher than the 39-mile segment, and Hay et al. (2008) suggest that this could be a result of warmer temperatures, loss of backwater and chute habitats, and lack of organic material (stumps and roots) as a result of streambank stabilization.

Threats and Stressor Factors – Macroinvertebrates

Mestl and Hesse (1993) state that several factors contributed to significant decreases in macroinvertebrate production. First, there has been a significant loss in backwater habitat. This loss is a direct result of reduced flooding and increased degradation. In addition, the dams release water with less turbitidy that can scour channel beds and subsequently cause backwaters to drain. Second, the pre-dam Missouri River had extensive meandering, which washed trees and roots into the river, supplying aquatic insects with rich organic matter. Bank stabilization has halted the meandering process, resulting in a loss of habitat. Finally, Mestl and Hesse (1993) suggest the restoration of several natural functions is necessary to restore aquatic insect production: natural sediment loads, natural water temperatures (in accordance with historic seasonal patterns), reconnection of off channel features (chutes, backwaters), and natural flow regime.

Data Needs/Gaps
Additional research on the presence and absence of macroinvertebrates, as well as habitat availability in MNRR would be beneficial.

Overall Condition

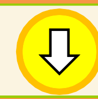
Measures	*Reference Condition*	*Condition*
Habitat availability	Pre-dam	

Figure 70. Freshwater Invertebrates condition grahic.

The overall condition of freshwater invertebrates in MNRR must be broken down into two groups: mussels and macroinvertebrates.

The condition of mussels is of moderate concern because of the degradation and dewatering of oxbows and side channels, which are critical habitats for mussels in MNRR (Figure 70). Dams and flow regulation have ceased high water events and disconnected the river from its floodplain (Yager, pers. comm., 2011). The lack of floodplain connection prevents sidechannels, wetlands, chutes, and backwaters from being created and maintained (Yager, pers. comm., 2011). The loss of the natural flow regime has threatened these areas, which are crucial for both mussels and macroinvertebrates (Yager, pers. comm., 2011). However, the 59-mile segment still has a relatively large and diverse mussel population (compared to the 39-mile segment), as the top-water discharge Gavins Point Dam helps block silt and sand, which can suffocate mussels (Perkins and Backlund 2000). In addition, the Gavins Point Dam acts as a barrier for host fish to migrate upstream from the lower Missouri River, thus resulting in a concentration of host fish in the 59-mile segment (Perkins and Backlund 2000). In addition, the bottom-discharging Fort Randall Dam releases cold, nutrient-poor water and has extensive power peaking that can scour channel beds. In summary, the implementation of dams in the MNRR has likely destroyed historical mussel habitat, but has provided some new habitat, primarily directly below Gavins Point Dam in the 59-mile segment (Perkins and Backlund 2000).

The condition of macroinvertebrates as a whole is difficult to assess, as they are a very diverse group that require different habitats. However, in general, the condition of macroinvertebrates is of moderate concern, due to a significant decrease in habitat and production. Macroinvertebrates generally require off-channel areas, such as backwaters and chutes, both of which have seen extensive declines since the 1960s (Table 73) (Mestl and Hesse 1993; Yager 2010). In addition, bank stabilization has decreased river meanders, reducing the amount of woody debris introduced into the river system (Mestl and Hesse 1993) and preventing the river from creating and maintaining new off-channel features, such as side channels and backwaters (Yager, pers. comm., 2011). Overall, off-channel areas have seen a great decline in area (approximately 250 ha from 1941-2008 in the 59-mile segment) (Yager 2010), and aquatic insect production has decreased along with area (Mestl and Hesse 1993).

Sources of Expertise
Lisa Yager, MNRR Biologist
Keith Perkins, USF Biologist

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4.12 Water Quality

Description

Water quality was selected as one of two high priority Vital Signs by the NGPN (Gitzen et al. 2010). Dissolved oxygen (DO), pH, specific conductance, water temperature, and an estimate of flow are core water quality parameters required by the NPS Water Resources Division for long-term monitoring in NPS Inventory and Monitoring Network park units (NPS 2002). Natural resource managers at MNRR are also interested in the presence and concentration of nutrients, fecal coliform bacteria, turbidity, and chemicals associated with agriculture in park waterways, as well as the natural variability of the Missouri River's velocity. While the Missouri River is the primary waterbody in the unit, several other tributaries exist within MNRR's boundary or have a significant influence on water quality entering the Missouri River. The Niobrara River, Verdigre Creek, Ponca Creek, and the Choteau Creek enter the 39-mile segment of MNRR, and Bow Creek, James River, and the Vermillion River enter the 59-mile segment (Plate 12) (Yager, pers. comm., 2011).

Dissolved oxygen is critical for organisms that live in water. Fish and zooplankton filter out or ―breathe" dissolved oxygen from the water to survive (USGS 2010a, EPA 2010c). Oxygen enters water from the atmosphere or through ground water discharge. As the amount of DO drops, it becomes more difficult for aquatic organisms to survive (USGS 2010a). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than does warm water (USGS 2010a). Thus, DO concentrations are subject to seasonal fluctuations as low temperatures in the winter and spring allow water to hold more oxygen, and warmer temperatures in the summer and fall allow water to hold less oxygen (USGS 2010a).

pH is a measure of the level of acidity or alkalinity of water and is measured on a scale from 0 to 14, with 7 being neutral (USGS 2010a). Water with a pH of less than 7.0 indicates acidity, whereas water with a pH greater than 7.0 indicates alkalinity. Aquatic organisms have a preferred pH range that is ideal for growth and survival (USGS 2010a). Chemicals in water can change the pH and harm aquatic organisms; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2010a).

Specific conductance is a measure of the ability of water to conduct electrical current, which depends largely on the amount of dissolved solids in the water (USGS 2010a). Water with low amounts of dissolved solids (such as purified or distilled water) will have a low specific conductance, while water with high amounts of dissolved solids (such as salty sea water or other minerals) will have a much higher specific conductance (USGS 2010a). Specific conductance is an important water quality parameter to monitor because high levels can indicate that water is unsuitable for drinking or aquatic life (USGS 2010a).

Water temperature greatly influences water chemistry and the organisms that live in aquatic systems. Not only can it affect the ability of water to hold oxygen, water temperature also affects biological activity and growth within water systems (USGS 2010a). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2010a). As temperature increases or decreases too far past this range, the number of individuals and species able to live there eventually decreases. In addition, higher temperatures allow some compounds or pollutants to dissolve more easily in water and can be more toxic to aquatic life (USGS 2010a).

Velocity in the Missouri River is influenced by dam operations which limit peak flows, increase low flows, and alter flow conditions temporally. While velocity is not a standard measure of water quality, it is very important to the condition of the Missouri River in MNRR.

Nutrients are chemical elements which are essential for plant and animal survival, but become contaminants at higher concentrations in water (USGS 2009). Nitrates and phosphorus are two common nutrient contaminants in water bodies (USGS 2009). Nitrates can cause a host of water quality related problems when present in high concentrations including, but not limited to, excessive plant and algae growth and depleted dissolved oxygen available to aquatic organisms (USGS 2007). Nitrogen occurs naturally in soils and thus in surface waters, but is increased by human inputs such as sewage, fertilizers, and livestock waste (NPS 2009). High levels of phosphorus are a concern for surface water quality because it can lead to eutrophication (EPA 2009). Excess nutrients enter MNRR water bodies via non-point source agricultural runoff.

Coliform contamination can originate from point source urban discharge as well as non-point source runoff. Total coliform is a measure used to assess the level of a disease-causing group of bacteria present in the water (EPA 2011a). Fecal coliform is the most commonly used indicator of fecal bacteria in water (EPA 2010a). Both total coliform and fecal coliform are used to measure bacterial contamination in MNRR water bodies.

Turbidity assesses the amount of fine particle matter (such as clay, silt, plankton, microscopic organisms, or finely divided organic or inorganic matter) that is suspended in water by measuring the scattering effect that solids have on light that passes through the water (USGS 2010a). For instance, the more light that is scattered, the higher the turbidity measurement will be. The suspended materials that make water turbid can absorb heat from sunlight, increasing the water temperature in waterways and reducing the concentration of dissolved oxygen in the water (USGS 2010a). The scattering of sunlight by suspended particles decreases photosynthesis by plants and algae, which contributes to decreased DO concentrations in the water (USGS 2010a). Suspended particles also irritate and clog the gill structures of many fish or amphibians, making it difficult to thrive (USGS 2010a).

Agricultural chemicals enter the Missouri River via non-point source runoff from the surrounding landscape, as not all agricultural chemicals remain in the soil or are utilized by plants (USGS 2010b). Herbicides including atrazine, alachlor, and metolachlor have been sampled for in MNRR water bodies (USACE 2002). Heptachlor epoxide is an insecticide that was detected in MNRR waters (NPS 1998).

Measures

- Dissolved oxygen
- pH
- Specific conductance
- Water temperature
- Nutrients
- Fecal coliform bacteria
- Turbidity
- Agricultural chemicals
- Velocity

Reference Conditions/Values

The reference condition for nutrients, agricultural chemicals, pH, and coliform bacteria in waterways at MNRR are the EPA standards for protecting freshwater aquatic life, freshwater bathing, and drinking water. The NPS Water Resources Division (WRD) has established criterion for turbidity, dissolved oxygen, total coliform, and fecal coliform concentrations. South Dakota and Nebraska surface water quality standards were used for parameters lacking an EPA standard. There are no national standards in place for specific conductance, temperature, or velocity. The reference condition for temperature and velocity is pre-dam and pre-river regulation.

Data and Methods

Gutzmer et al. (1996) examined the results from the Nebraska Public Power District's water quality and fish population monitoring following ―sluicing" events (flushing accumulated sediment from the reservoir) at the Spencer Hydropower Dam on the Niobrara River.

In 1998, the NPS published the results of surface water quality data retrievals for MNRR using six of the EPA national databases: Storage and Retrieval (STORET) water quality database management system, River Reach File (RF3), Industrial Facilities Discharge (IFD), Drinking Water Supplies (DRINKS), Water Gages (GAGES), and Water Impoundments (DAMS). This retrieval resulted in 207,941 observations for 773 separate parameters in and around MNRR (NPS 1998). Of 109 total monitoring stations used in this analysis, 33 are within MNRR boundaries (NPS 1998).

The U.S. Army Corps of Engineers (USACE) performed a water quality scoping study on the Missouri, James, and Vermillion Rivers in MNRR in August and September 2001 in order to determine baseline water quality conditions for the 59-mile segment of the unit (USACE 2002). USACE (2010) sampled several water quality parameters in sediments used to create ESH in the Missouri River.

Weeks et al. (2005) summarized a wide range of water-related issues in MNRR, including the synthesis of water quality and quantity data collected prior to the report.

Rust (2006) collected water quality samples for several parameters on the Missouri River in 2004-2005. One reach was located above Gavins Point Dam at the confluence of the Niobrara River, and two reaches were sampled below the dam.

Data collected from USGS gaging stations (Missouri River, Choteau Creek, Niobrara River, James River, and the Vermillion River) and at the Spencer Hydro Dam on the Niobrara River were summarized for water quality parameters of interest by SMU GSS (see Appendix F for mean values).

Current Condition and Trend

Dissolved Oxygen

The EPA considers dissolved oxygen levels greater than or equal to 4 mg/L to be protective of freshwater aquatic life (EPA 1986). DO was measured 25,888 times at 55 monitoring stations in and around MNRR between 1957 and 1997 (NPS 1998). Of the 16,492 measurements analyzed in the NPS study, 202 had DO levels less than or equal to 4 mg/L between 1971 and 1997 (NPS 1998).

All DO measurements taken during the 2001 USACE study were within the EPA standard (USACE 2002).

Rust (2006) measured DO 90 times at three locations on the Missouri River. The minimum DO measured was 8.0 mg/L, and the mean value was 8.9 mg/L. All measurements collected during this study were well within EPA standards.

USACE (2010) examined low DO levels in the Fort Randall Dam tailwaters during the summer of 2010. The study found that DO concentrations decreased through the summer and that the lowest levels were measured when discharge from the dam was low. During the summer months, DO levels fall below the South Dakota standard of 5 mg/L (USACE 2010).

The James River in South Dakota is listed on the EPA 303(d) list of impaired waters for dissolved oxygen in several stretches, although not within MNRR (SD DENR 2010).

Due to observations of DO levels below 5mg/L in several stretches of the Missouri River within MNRR and the listing of stretches of the James River near MNRR as impaired for dissolved oxygen, the condition of the measure is designated as being of moderate concern, while monitoring data suggest a stable trend.

pH

The EPA criterion for pH that supports freshwater aquatic life and sustains wildlife is between 6.5 and 9.0 standard units (EPA 2002). pH was measured 12,678 times at 49 monitoring stations in and around MNRR between 1956 and 1997. Of these observations, 164 were outside of the EPA-established range; 121 were greater than or equal to 9.0 and 43 were less than or equal to 6.5 (NPS 1998). NPS (1998) does not specify site locations when summarizing the overall data, therefore it is unclear what observations were within MNRR. The highest pH measurement from this analysis was 12.3 reported in 1981 at Fort Randall in the Missouri River. The lowest pH concentration measured during this study was 4.0 in the Niobrara River in 1972 (NPS 1998).

Rust (2006) measured pH 90 times at three locations on the Missouri River within MNRR. The minimum pH value was 7.7, the mean was 8.2, and the maximum pH was 8.5. All of these measurements are within the EPA standard for protecting freshwater aquatic life.

Portions of the James River are included on the EPA 303(d) list for pH impairment (SD DENR 2010). The James River enters the Missouri River in the 59-mile segment of MNRR below the Gavins Point Dam.

pH levels that exceed the range considered to be protective of aquatic life (both too high or too low) in several stretches of the Missouri River within MNRR and the James River near MNRR is listed as impaired for pH. However, recent monitoring data suggest pH in three locations on the Missouri River in MNRR remain stable. Thus, the condition of the measure is of moderate concern with a stable trend.

<u>Specific Conductance</u>
Rust (2006) collected 90 conductivity measurements (not specific conductance) from the Missouri River during 2004-2005. The minimum conductivity measurement among the three sites sampled was 272 µS/cm, the mean value was 689 µS/cm, and the maximum was 837 µS/cm (Rust 2006). Data are insufficient to be able to determine condition for this measure.

<u>Temperature</u>
Temperature is greatly affected by dam operations on the Missouri River. Prior to dam construction, water temperatures ranged from 2° C to 28° C between April and October, 1945 in the lower Missouri River (study area was not exactly defined) (Berner 1951). Two major dams directly affect the MNRR, the Fort Randall Dam which is a bottom discharge dam that releases colder water into the 39-mile segment, and Gavins Point Dam, a top discharge dam which releases warmer water into the 59-mile segment of MNRR (Yager, pers.comm., 2011). The Fort Randall Dam can reduce downstream water temperatures by up to 10° C (Hesse et al. 1993), and Rust (2006) found that temperatures above Gavins Point Dam averaged 20° C, while temperatures below the dam averaged 22.3° C. These dramatic temperature changes greatly alter the aquatic environment of MNRR. Coldwater pollution is known to have a detrimental effect on aquatic species such as native fish by disrupting spawning cycles (Weeks et al. 2005), and insects by changing emergence cues, egg hatching, diapause and maturation (Petts 1984, as cited in Weeks et al. 2005). Water temperatures in the Missouri River in MNRR are consistently different by several degrees Celcisus above and below the dams, variation that appears to be greater than natural variability in the river. Due to the concern of low water temperatures on life stages of many aquatic organisms in the river, the condition of this measure is of significant concern with a stable trend.

<u>Velocity</u>
The velocity of the Missouri River is strongly influenced by dam operations, which limit peak flows, increase low flows, and alter temporal flow conditions (Weeks et al. 2005). Dams also reduce the natural variations in velocity found in the river, creating more homogenous velocities (Yager, pers. comm., 2011). Latka et al. (1993), as cited in Weeks et al. (2005), found that late summer velocities in the Missouri River ranged between 0.3 to 0.7 m/s (1.0 to 2.5 ft/s). USACE (2002) determined channel velocity in the MNRR reach of the Missouri River ranged between 0.6 and 1.5 m/s (2.0 and 5.0 ft/s).

Rust (2006) measured maximum current velocity at three locations on the Missouri River. The minimum velocity was 0.13 m/s, the mean velocity was 0.87 m/s, and the maximum was 2.60 m/s (Rust 2006).

Due to the reduction of natural flow conditions in the river from the dams, the condition of this measure is of significant concern with a stable trend.

Nutrients

Nitrate concentrations (including dissolved and total as N and as NO_3) were sampled 1,066 times at 15 locations in and around MNRR between 1956 and 1997 (NPS 1998). One dissolved nitrate sample collected at the Gavins Point Dam Powerhouse outflow at Lewis and Clark Lake had a concentration of 11 mg/L in the 1979 (NPS 1998). Rust (2006) collected nine nitrate samples from three sites on the Missouri River, and found a mean concentration of 0.08 mg/L and a maximum of 0.20 mg/L. While the EPA does not have biological standards for nitrates, the drinking water standard is 10 mg/L (EPA 2011c).

Rust (2006) collected nine phosphorus samples at three sites on the Missouri River, finding a mean concentration of 0.07 mg/L and a maximum of 0.29 mg/L. There is no national EPA standard established for phosphorus concentrations.

Due to low concentrations of nutrients found in the Missouri River in MNRR, the condition of this measure is of low concern with a stable trend.

Coliform Bacteria

Total coliform concentrations were measured 528 times at four monitoring sites in and around MNRR between 1958 and 1974 (NPS 1998). Forty-eight observations at two monitoring locations in the Missouri and Niobrara Rivers met or exceeded the WRD standard of 1,000 Colony Forming Units/Most Probable Number per 100 milliliters (CFU/MPN/100 ml) (NPS 1998). Fecal coliform was measured 1,216 times at 30 different monitoring stations in and around MNRR between 1968 and 1997; 1,201 of these measurements were used in the analysis (NPS 1998). Of these analyzed measurements, 335 observations met or exceeded the WRD bathing water screening criterion of 200 CFU/MPN/100 ml (NPS 1998).

Rust (2006) collected eight fecal coliform samples at three sites on the Missouri River. The mean concentration of these samples was 28 organisms/100 ml, with a maximum of 110 organisms/100 ml (Rust 2006). These values fall below the state of South Dakota's beneficial use criteria for immersion waters (<200 organisms/100 mL for mean, <400 organisms/100 mL for a single sample) (SD DENR 2011).

Portions of Verdigre Creek, Ponca Creek, and the Niobrara River are listed on the Nebraska 303(d) list for *Escherichia coli* contamination under the Clean Water Act (EPA 2011b, NEDP 2011). Portions of the James River and Vermillion River are listed on the South Dakota 303(d) list for fecal coliform and *E. coli* (SD DENR 2010). Verdigre Creek, Ponca Creek, and the Niobrara River discharge into the 39-mile MNRR, while the James River and Vermillion river discharge to the 59-mile segment.

Due to the 303(d) listing of several tributaries to the Missouri River near MNRR for contamination with fecal coliform bacteria and repeated observations that exceed bathing water screening criteria, the condition of this measure is of significant concern with a declining trend.

Agricultural Chemicals

Agricultural chemicals, primarily herbicides, enter MNRR water bodies through non point source runoff from the surrounding landscape. Agricultural land comprises 672,737 hectares (1,662,363 acres) or 43.85% of land within a 30-kilometer buffer of MNRR boundaries (NPScape 2009). Atrazine, alachlor, and metolachlor are three herbicides sampled for in MNRR by the USACE in 2001. Only atrazine was present in concentrations above the detection threshold of 0.05 µg/l; site six on the Vermillion River had concentrations which ranged between 0.07 and 0.28 µg/l (USACE 2002). The EPA standard for atrazine is 1,500 µg/L for protecting freshwater aquatic life (EPA 2011d). The state of Nebraska has a more stringent freshwater standard of 330 µg/l for acute exposure and 12 µg/l for chronic exposure; however, measured values still fall well below these thresholds (NDEQ 2009).

Heptachlor epoxide, an insecticide, was measured 222 times between 1964 and 1997 at 11 monitoring stations in and around MNRR (NPS 1998). The EPA drinking water standard for heptachlor epoxide is 0.2 µg/l; one sample collected at the confluence of the Niobrara and Missouri Rivers exceeded this standard with a concentration of 0.52 µg/L in 1992 (EPA 2010b, NPS 1998). Heptachlor epoxide can remain in soil and water for many years; plants can take up the compound and it can build up in the tissue of fish and cattle (ATSDR 2007).

Due to low occurrence of agricultural chemicals in MNRR, the condition of this measure is of low concern with a stable trend.

Turbidity

The NPS WRD screening criterion for turbidity is 50 Jackson Candle/Formazin/Nephelometric Turbidity Units (JTU/FTU/NTU). Turbidity was measured 5,571 times at 24 monitoring stations in and around MNRR between 1957 and 1997 (NPS 1998). Of these samples, 343 exceeded the WRD turbidity threshold between 1958 and 1996 (NPS 1998).

There are contradictory management goals related to turbidity in the Missouri River. USACE is directed to increase the level of turbidity in the MNRR reach of the Missouri River under the Endangered Species Act to improve habitat conditions for threatened and endangered species, while state (Nebraska and South Dakota) water quality standards seek to maintain ―reduced" levels of turbidity in the river pursuant to the Clean Water Act (USACE 2002). South Dakota has a specific turbidity standard for warmwater permanent fish life propagation on the MNRR stretch of the Missouri River of ≤158 mg/l as a daily maximum, and ≤90 mg/l as a 30-day average (USACE 2002). Turbidity has been substantially reduced after the construction of dams and reservoirs along the Missouri River that trap large amounts of sediment (Love et al. 1967).

Rust (2006) measured turbidity nine times on the Missouri River at three sites. The mean turbidity was 17 NTU and the maximum was 66 NTU (Rust 2006). The average turbidity from this study fell below the NPS WRD standard, although the maximum measurement exceeded this criterion.

Due to measurements of turbitdity consistently falling below the WRD standards, the condition of this measure is of significant concern with a stable trend.

Threats and Stressor Factors

One of the major threats to water quality in MNRR is agricultural runoff from the surrounding landscape, which causes nutrient and agricultural chemical contamination of the unit’s rivers and streams. Point source discharge and non point source runoff from urban landscapes is a threat related to coliform bacteria contamination in MNRR waters. The Missouri River is affected by the water quality of its tributaries, most of which are impaired by one or more water quality parameters along the MNRR reach.

Dam operations affect a number of water quality parameters in MNRR including temperature, DO levels, and turbidity. Water temperatures can increased or decrease downstream of dams depending on the type of dam. The Fort Randall Dam has the most significant effect on water temperatures, causing major coldwater pollution downstream. Turbidity levels have decreased in the Missouri River, negatively affecting certain species which are dependent on turbid waters such as pallid sturgeon (Weeks et al. 2005).

The Nebraska Public Power District operates the Spencer Hydropower Dam on the Niobrara River, and conducts ―sluicing” which affects downstream water quality and eventually the Missouri River (Gutzmer et al. 1996). Temperature, conductivity, and suspended sediments are increased below the dam following sluicing. Suspended sediments are the pollutant of highest concern, potentially threatening spawning habitat of fish downstream of the dam (Gutzmer et al. 1996).

There are concerns regarding the potential water quality impacts from the construction of ESH for interior least tern and piping plover in the Missouri River using dredged sediments (USACE 2010). Sediments are tested for the presence of heavy metals, ammonia, pesticides, and polychlorinated biphenyls (PCBs).

Data Needs/Gaps

USACE (2002) stated that historic and ongoing water quality monitoring on the MNRR reach of the Missouri River was limited. Weeks et al. (2005) recommended a two to three year monitoring study with five sites on the Missouri, James, and Vermillion Rivers to expand upon the limited USACE 2001 study. Analysis of more recent data collected would be useful in determining any changes to water quality since the Weeks et al. (2005) analysis was conducted.

Overall Condition

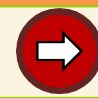
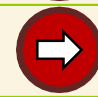
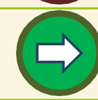
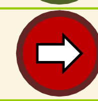
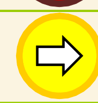
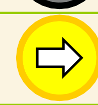
Measures	*Reference Condition*	*Condition*
Turbidity	Natural variability; "Natural" spatial/temporal patterns	
Measures of Velocity	Natural variability; "Natural" spatial/temporal patterns	
Presence of nutrients	EPA Standard; "Natural" spatial/temporal patterns	
Water Temperature	"Natural" spatial/temporal patterns	
Agricultural Chemicals	EPA Standard; "Natural" spatial/temporal patterns	
Fecal Coliform Bacteria	EPA Standard; "Natural" spatial/temporal patterns	
pH	EPA Standard; "Natural" spatial/temporal patterns	
Specific Conductance	Natural spatial/temporal patterns	
Dissolved Oxygen	EPA Standard; "Natural" spatial/temporal patterns	

Figure 71. Water Quality condition graphic.

The variability of condition indicated by water quality measures assessed in this document is high (Figure 71). Water quality in MNRR is a complex issue with many parameters of interest. Weeks et al. (2005) stated that water quality in the 59-mile segment of MNRR is in good condition based on the USACE 2001 assessment of the Missouri, James, and Vermillion Rivers. Of the parameters considered in this document, DO, pH, nitrates, fecal coliform, turbidity, and heptachlor epoxide exceeded their respective standards prior to the NPS (1998) analysis. Five tributaries (Verdigre Creek, Ponca Creek, Niobrara River, James River, and the Vermillion River) which feed into the Missouri River in MNRR are listed by the EPA as 303(d) impaired by fecal coliform or *E. coli*. Based on the available information, the condition of water quality, on a whole, is of moderate concern in MNRR.

Sources of Expertise
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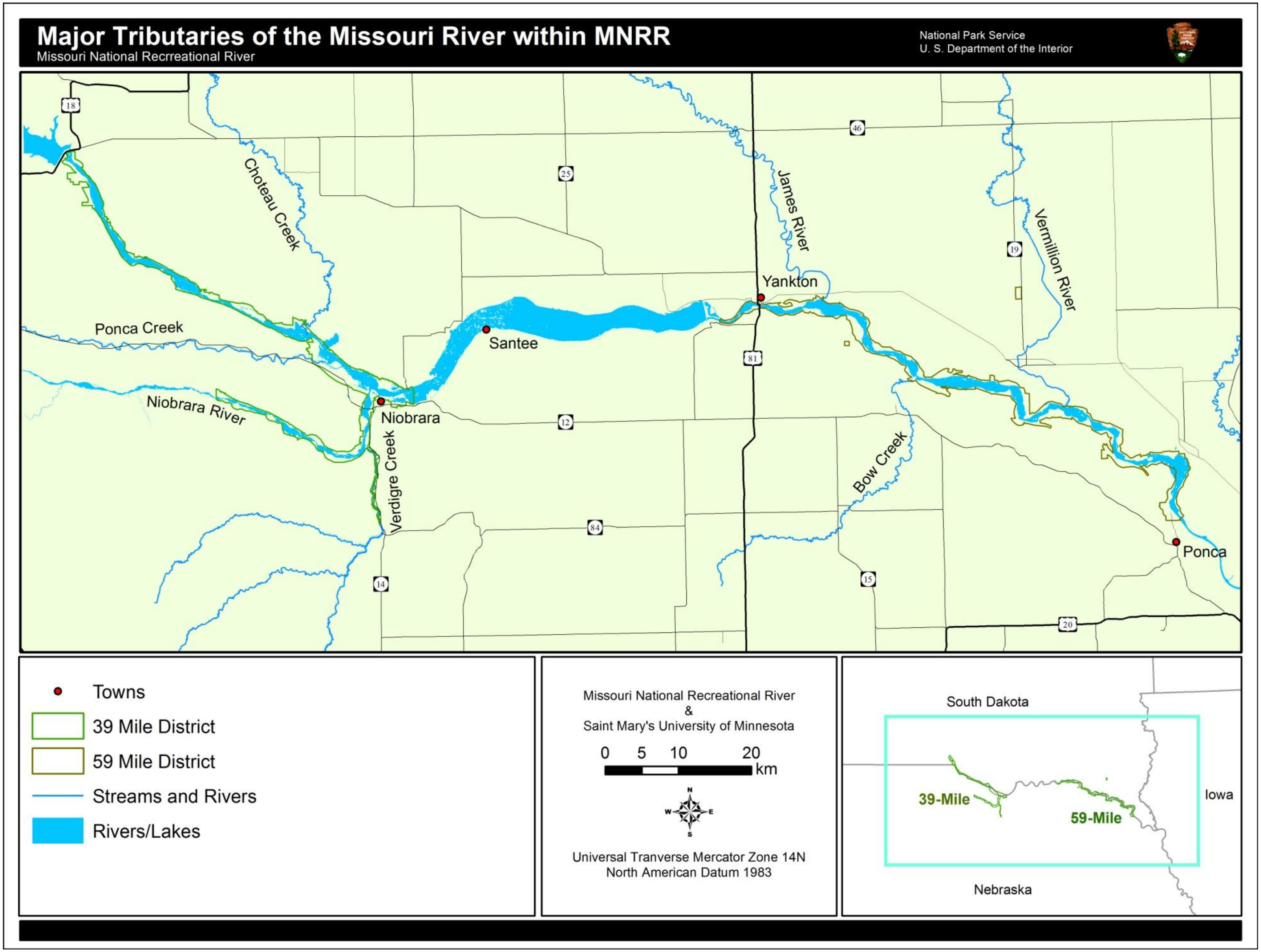


Plate 12. Major tributaries of the Missouri River within MNRR.

4.13 Air Quality

Description

Air pollution can significantly affect natural resources and their associated ecological processes. In particular, air pollution can influence water quality and soil pH, compromise plant health and distribution, accelerate the decay of geologic or cultural features, and impair the visibility and air quality within parks (NPS 2007a). Consequently, air quality in parks and wilderness areas is protected and regulated through the 1916 Organic Act and the Clean Air Act of 1977 (CAA) and its subsequent amendments (NPS 2004). In particular, the prevention of significant deterioration (PSD) title of the CAA outlines specific authority in protecting the natural and cultural resources of parks (EPA 2008). This title defines two distinct categories of protection for natural areas, Class I and Class II air sheds, into which all lands managed by the Department of the Interior in 1977 were classified. Class I air sheds receive the highest level of air quality protection as offered through the CAA; only a small amount of additional air pollution is permitted in the air shed above baseline levels. Parks designated as Class I and II air sheds typically use the EPA National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. EPA believes that these standards, if not exceeded, protect human health and the health of natural resources (EPA 2008). The CAA also establishes that current visibility impairment in these areas must be remedied and future impairment prevented (EPA 2008). However, EPA acknowledges that the NAAQS are not necessarily protective of ecosystems and is currently developing secondary NAAQS for ozone and nitrogen and sulfur compounds to protect sensitive plants, lakes, streams, and soils (EPA 2010a, EPA 2010b). To comply with CAA mandates, the NPS established a monitoring program that measures air quality trends in park units for key air quality indicators, including atmospheric deposition, which affects ecological health through acidification and fertilization; ozone, which affects native plant communities and human health; and visibility, which affects how well and how far visitors can see park landscapes (NPS 2009).

The CAA designates MNRR as a Class II air shed. Air pollutants of particular concern to managers at MNRR include wet deposition of nitrogen (N), mercury deposition (Hg), and concentration of ground-level ozone (O_3). Wet deposition of sulfur (S), ammonium (NH_4^+) compounds, and concentration of suspended particulate matter ($PM_{2.5}$ and PM_{10}) are also featured in this assessment.

Measures

- Deposition of mercury (Hg)
- Deposition of nitrogen (N) and sulfur (S)
- Concentrations of ground-level ozone (O3)
- Concentrations of suspended particulate matter (PM2.5 and PM10) (measured in terms of Haze Index (deciviews))

<u>Atmospheric deposition</u>

Atmospheric deposition of sulfur and nitrogen can have significant effects on ecosystems through altered water quality, soils and vegetation (NPS 2005). Sulfur and nitrogen emissions form compounds that acidify water and soil systems with low buffering capacities, and excess nitrogen deposition, which acts as a fertilizer, can disrupt nutrient cycling and influence plant species composition (NPS 2005). The species diversity in grassland ecosystems is particularly vulnerable to excess nitrogen deposition, as native plants that have adapted to nitrogen-poor conditions are displaced by species that prefer high levels of nitrogen (typically non-native grasses) (NPS 2005, Pohlman and Maniero 2005). Over time, this shift in nutrients can result in ecosystem-wide changes including shifts in species composition (both plants and animals), increased occurrence or likelihood of insect and disease outbreaks, and disruption of natural fire regimes (NPS 2007a).

Mercury deposition

Mercury is a naturally occurring element in the environment and is typically associated with different types of rock, including coal (EPA 2010c). However, mercury can easily make its way into the air, water and soil. For instance, when coal is burned, mercury is one by-product released into the air (EPA 2010c). The burning of sulfur-containing coal in coal-fired power plants accounts for 50% of the anthropogenic mercury emissions in the atmosphere in the United States (EPA 2010c). Airborne mercury eventually falls back to the ground with raindrops or dust (deposition) and settles into water bodies or onto land where it washes into water (EPA 2010c).

Mercury in aquatic systems is a particular concern. Microorganisms digest and transform it into methylmercury, an organic mercury compound that can be highly toxic in organisms at the top of the aquatic food web (e.g., fish and birds that eat fish or aquatic insects) (NPS 2010d, EPA 2010c). Similarly, predators that eat fish-eating animals are also at risk (EPA 2010c). Fish and shellfish consumption is the main pathway for human and wildlife exposure to methylmercury (EPA 2010c). Effects of methylmercury exposure on both wildlife and humans can include reduced reproductive success, impaired growth and development (especially in the brain), behavioral abnormalities, reduced immune response and death (NPS 2010d, EPA 2010c). Other sources of mercury in the atmosphere include utility and industrial boilers, smelting, chlor-alkali plants, gold extraction, fungicides containing mercury in latex paints, and the paper and pulp industry (NPS 2010d).

Ozone

Ozone occurs naturally throughout the earth's atmosphere. In the upper atmosphere, it protects the earth's surface against ultraviolet radiation (NPS 2005). However, it also occurs at the ground level (i.e., ground-level ozone) where, at high concentration, it is harmful to plants and human health (NPS 2005). Ground-level ozone is created by a chemical reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of heat and sunlight. Major sources of ozone-forming chemicals include motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents (NPS 2005, Pohlman and Maniero 2005). Breathing air containing ozone can aggravate asthma, reduce lung function, inflame lung tissue, cause acute respiratory problems, or impair the body's immune system (NPS 2005). At high concentrations, ozone has been linked to increased susceptibility to respiratory infections in humans (EPA 2010). This would be of particular concern for anyone engaging in strenuous aerobic activity, such as hiking in natural areas (Pohlman and Maniero 2005, EPA 2010d). Ozone is also one of the most widespread pollutants affecting vegetation in the U.S. (NPS 2005). Research has indicated that some plant species are more sensitive to ozone than humans, with some species sustaining effects or injury at concentrations that are well below the current EPA standard (NPS 2005, Pohlman and Maniero 2005). Long-term exposures can result in increased vulnerability to insects and diseases and shifts in species composition (NPS 2005).

Particulate Matter (PM) and Visibility:

Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets that become suspended in the atmosphere. It is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2009a). The EPA groups particle pollution into two categories: fine particles ($PM_{2.5}$), which are 2.5 micrometers in diameter or smaller; and inhalable coarse particles (PM_{10}), which are smaller than 10 micrometers (the width of a single human hair) (EPA 2009a). The size of particles is directly linked to their potential for causing human health and landscape visibility problems. PM_{10} and $PM_{2.5}$ are a concern to human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2009a, EPA 2010e). Short-term exposure to these particles can cause shortness of breath, fatigue, and lung irritation, while long-term exposure can cause more serious health effects, including heart and lung diseases (EPA 2009a).

Fine particles are also the major cause of reduced visibility (haze) in many parts of the United States, including many national parks and wildernesses (EPA 2010e). $PM_{2.5}$ can be directly emitted from sources such as forest fires or they can form when gases emitted from power plants, industry and/or vehicles react with air (EPA 2009a, EPA 2010e). Sources of coarse particles (PM_{10}) include grinding or crushing operations, and windblown or stirred up dust from dirt surfaces (e.g., roads, agricultural fields). These particles either absorb or scatter light. As a result, the clarity, color and distance seen by humans decreases, especially during humid conditions when additional moisture is present in the air (EPA 2010e).

Reference Conditions/Values

Park resource managers have indicated EPA standards and ecosystem thresholds to be the reference condition for air quality in MNRR. The NPS Air Resources Division (ARD) has developed an approach for rating air quality conditions in national parks, which is based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (Table 74) (NPS 2010a). Assessment of current condition of atmospheric deposition of nitrogen and sulfur compounds are based on wet deposition, primarily because many parks do not collect dry deposition data. The ozone standard established by the EPA, which was revised in 2008 to be more protective of human health, is used as the benchmark for rating current ozone condition in parks. Visibility conditions are rated in terms of a Haze Index, a measure of visibility derived from calculated light extinction (NPS 2010a). The NAAQS standard for PM_{10} is 150 $\mu g/m^3$ over a 24-hour period; this level may not be exceeded more than once per year on average over three years (EPA 2010e). The standard for $PM_{2.5}$ is 15.0 $\mu g/m^3$ weighted annual mean or 35 $\mu g/m^3$ in a 24-hour period over an average of three years (EPA 2010e). There are no EPA standards for deposition of mercury, only emissions of mercury into the atmosphere; thus, mercury deposition in MNRR will be reported here as a trend over time but will not be compared to a national standard.

Table 74. National Park Service Air Resources Division air quality index values (NPS 2010a).

Condition	Ozone concentration (ppb)	Wet Deposition of N or S (kg/ha/yr)	Current Group 50 – Estimated Group 50 Natural (dv)
Significant Concern	≥ 76	> 3	> 8
Moderate	61-75	1-3	2-8
Good	≤ 60	< 1	< 2

Data and Methods
Many sources may be used to access air quality data specific to parks and natural areas in the United States. The National Atmospheric Deposition Program–National Trends Network (NADP-NTN) database was searched for summary concentration and deposition maps of sulfate, nitrate, ammonium, and deposition maps of total inorganic nitrogen from nitrate and ammonium beginning in 1985. The NPS Explore Air website was used to obtain park specific summaries of the most current (2004-2008) interpolated air quality data for MNRR as well as tables of air quality estimates for 1999-2003. None of the datasets were adjusted or processed in any way.

Current Condition and Trend
The Northern Great Plains Inventory and Monitoring Network (NGPN), which includes MNRR, monitors air quality at AGFO, BADL, THRO, and WICA. The CASTNET and NGPN networks monitor ozone, dry deposition, and other meteorological parameters, while NADP/NTN monitors wet deposition of sulfates, nitrates, and ammonium, as well as a number of cations and anions. The nearest NADP/NTN monitors to MNRR are located in Huron, SD (110 miles/177 km north) and Meade, NE (120 miles/193 km south) (Pohlman and Maniero 2005). The nearest ozone monitors to MNRR are located at Sioux Falls, SD (60 miles/97 km north) and Pisgah, IA (70 miles/113 km southeast) (Pohlman and Maniero 2005). Visibility within the NGPN is monitored through IMPROVE, of which the closest visibility monitoring station to MNRR is located at Badlands National Park (286 miles/459 km west). The nearest mercury deposition monitor to MNRR is located in Sioux Falls, SD (60 miles/96.5 km N of MNRR); however, there is another mercury deposition monitor located in Winnebago, NE (82 miles/131 km to the SE).

<u>Atmospheric Deposition of Sulfates and Nitrates</u>
Five-year averages are used to estimate the condition of most air quality parameters; this offsets annual variations in meteorological conditions, such as heavy precipitation one year versus drought conditions in another. The most recent 5-year average for air quality parameter estimates (2004-2008) show total wet deposition of nitrogen in MNRR to be 5.0 kg/ha/yr, while total wet deposition of sulfur was found to be 2.0 kg/ha/yr. Relative to the NPS ratings for air quality conditions (see Table 74 for ratings values), the amount of atmospheric deposition of nitrogen in MNRR falls in the significant concern category and the amount of sulfur deposition falls in the middle of the moderate concern category. However, several factors are considered when rating deposition condition, including natural background deposition estimates and effects of deposition on different ecosystems (NPS 2010a). The estimate for natural background wet deposition in the Western U.S. is roughly equivalent to 0.13 kg/ha/yr each for sulfur and nitrogen (NPS 2010a), which means there is always a small amount of deposition present regardless of air quality in the region. Taking this into account, the deposition of both N and S is significantly elevated above natural background levels.

The NPS has guidelines for rating the air quality parameters of most concern to ecosystems, including wet deposition of sulfur and nitrogen, ozone concentration, and visibility. Table 75 shows the average yearly deposition data, specific to MNRR, from 2004-2008 for sulfate, nitrate, and ammonium that, when deposited in large quantities, are believed to affect ecosystems. Figure 72 displays the trends in deposition for each compound from 2004-2008. Data show that deposition has been fluctuating across the time period, with substantial decreases for nitrate, sulfate, and ammonium in 2006 followed by increases in 2007, and slight decreases again in 2008.

Table 75. Annual summary of air quality deposition for MNRR, 2004-2008 (NADP 2010).

Ambient Measure	Average Annual Deposition (kg/ha/yr)				
	2004	2005	2006	2007	2008
Ammonium (NH_4^+)	4.75	4.85	3.178	5.461	4.6
Nitrate (NO^{3-})	6.81	6.83	4.69	6.295	5.85
Sulfate (SO_4^{2-})	4.73	5.32	2.881	5.328	4.72

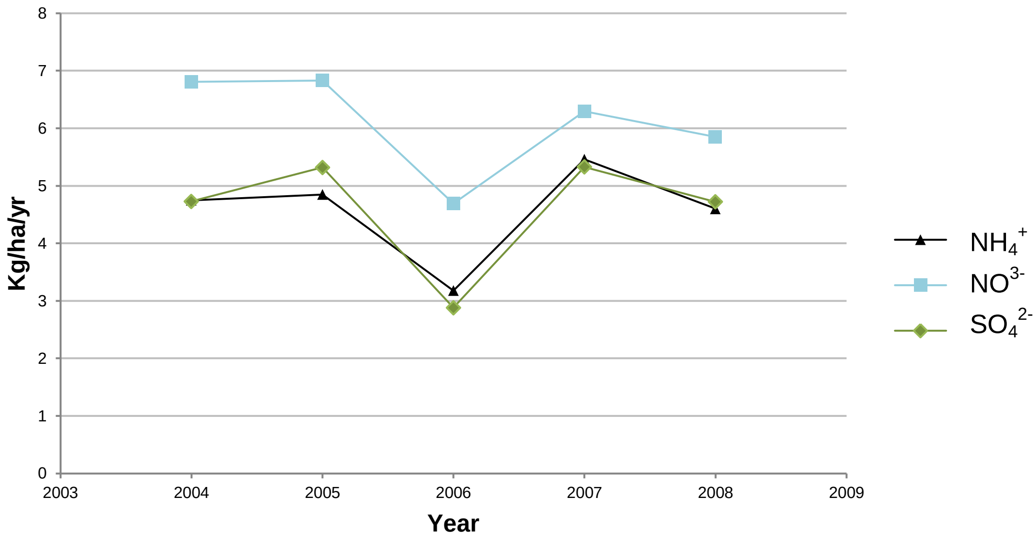


Figure 72. Trend in air quality deposition for MNRR, 2004-2008 (NADP 2010). Parameters measured at monitoring site SD99 located at Huron, SD (110 miles/177 km north of MNRR).

Concentrations of ammonium, nitrate and sulfate are also important aspects of air quality. Concentration is the measure of how much of a given substance is mixed with a standard amount of another substance. Deposition and concentration are intrinsically linked; deposition is equal to the concentration multiplied by the precipitation over a reporting period. Concentrations are expressed in the units of mg per liter of water (NADP 2011). As displayed in Figure 72, the deposition of ammonium, nitrate, and sulfate dropped significantly in 2006, but as seen in Table 76 and Figure 73, the concentrations of these compounds did not follow the same pattern. From 2005 to 2006, the concentration of ammonium and nitrate actually increased and sulfate decreased slightly. This indicates that the reason for the large dip in deposition from 2005 to 2006 is that there was little precipitation that year. However, there was a major decrease in the concentration of nitrate from 2006 to 2007 (0.367 mg/L). In summary, the stable concentrations of the three compounds from 2004-2008 indicate that there was no improvement in air quality based on these parameter during the reporting year of 2006.

Table 76. Annual summary of air quality concentrations for MNRR, 2004-2008 (NADP 2010).

Ambient Measure	Average Annual Concentration (mg/L)				
	2004	2005	2006	2007	2008
Ammonium (NH_4^+)	0.764	0.758	0.822	0.734	0.827
Nitrate (NO^{3-})	1.096	1.067	1.213	0.846	1.05
Sulfate (SO_4^{2-})	0.761	0831	0.745	0.716	0.847

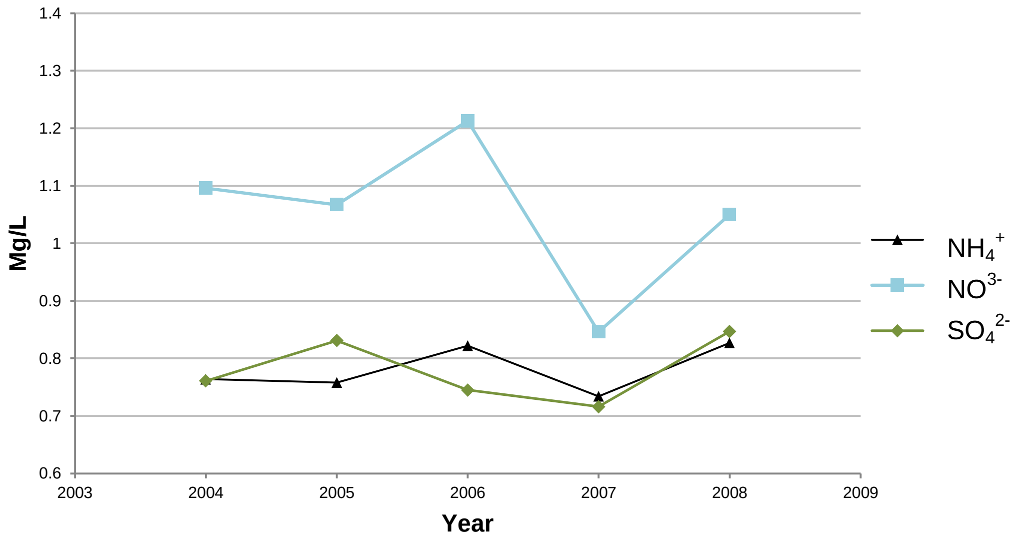


Figure 73. Trend in air quality concentrations for MNRR, 2004-2008 (NADP 2010). Parameters measured at monitoring site SD99 located at Huron, SD (110 miles/177 km north of MNRR).

Mercury Deposition

Figure 74 shows the most recent mercury deposition data for monitoring sites across the U.S. MNRR is identified on the map with a red star and the nearest mercury-monitoring site to MNRR is located in Sioux Falls, SD. For locations in the U.S. that do not have mercury-monitoring stations, mercury deposition is estimated in areas with sufficient numbers of samplers for an interpolation (Porter, pers. comm., 2010). The most current data (2008) suggest that mercury deposition is 8-10 µg/m^2. Data from this monitoring site indicate mercury deposition has fluctuated between 6-8 and 8-10 µg/m^2 from 2003-2008, with no obvious increasing or decreasing trend (NADP 2009).

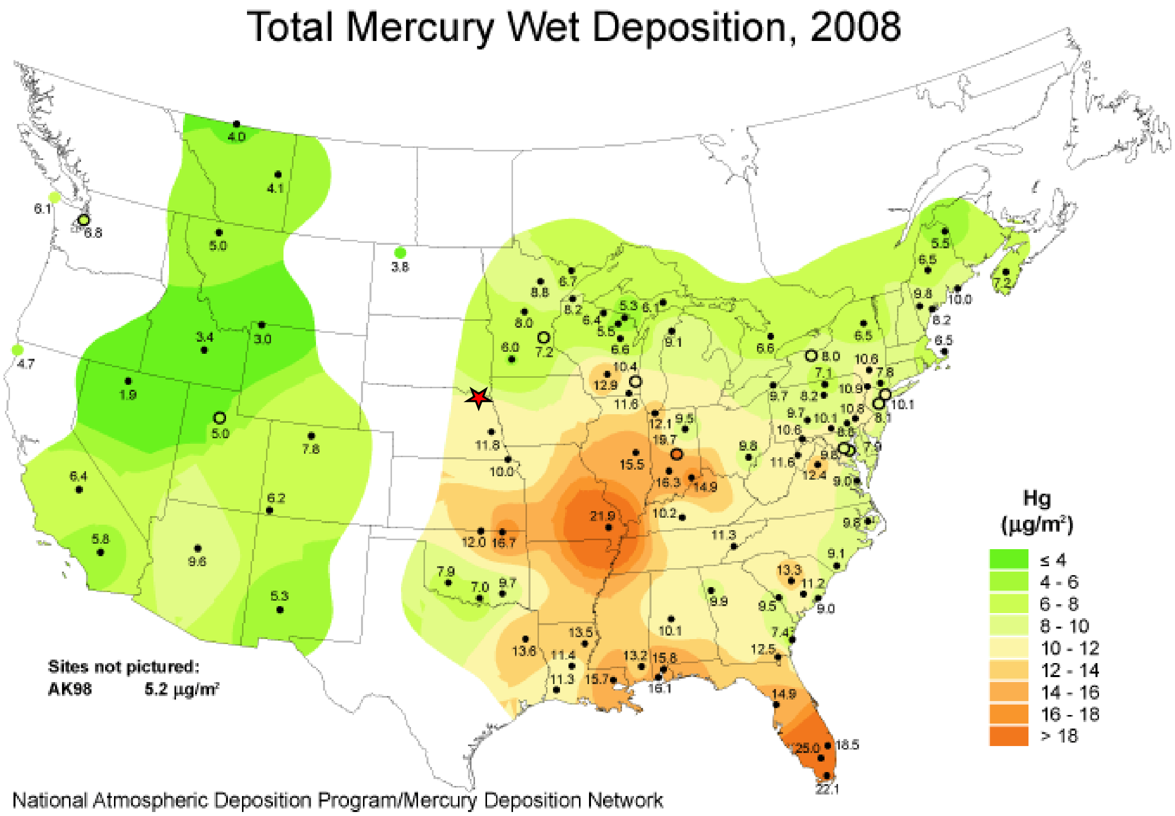


Figure 74. Total mercury deposition, 2008. Red star indicates location of MNRR (NADP/MDN 2009).

<u>Ground-level ozone</u>

Data for ground-level ozone concentrations were recorded at Sioux Falls, SD (95 km north of MNRR) from 1999 to 2007. Data from this monitor and all other regional monitors are used to estimate conditions at the park. NPS air quality condition assessment protocol uses the NAAQS for ground-level ozone as the benchmark for rating current ozone conditions within park units, as it is a standard believed to be protective of human health. Current conditions of ozone concentrations in NPS park units are determined by calculating the four-year average of the fourth-highest daily maximum of eight-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2010a). From 1999-2003, the five-year average for ozone concentration in MNRR was 65.5 ppb (NPS 2010b), and from 2004-2008, the five-year average was 61.8 ppb (NPS 2010c). Both concentrations fall in the moderate concern category for current ozone condition based on the NPS guidelines. Figure 75 shows the trend for ozone concentrations (in ppm) at a monitoring station near MNRR.

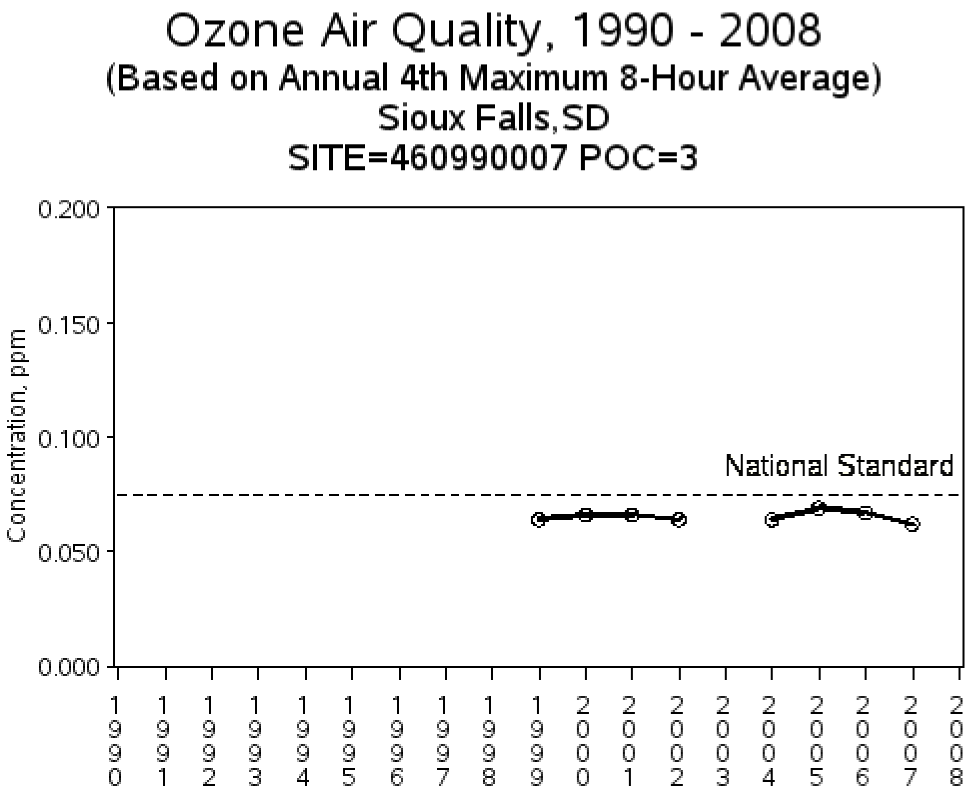


Figure 75. Average ozone (O_3) air quality for MNRR, 1999-2007 (EPA 2009c). Note: Site 460990007 is the monitor located at Sioux Falls, SD; ozone data are not collected in MNRR.

In 2005, Pohlman and Maniero completed an air quality monitoring assessment for the Northern Great Plains Network of national park units. Part of this assessment focused on ozone concentrations in parks and the risk of injury to plant species that are sensitive to sustained ozone exposure. Analyzing ozone data from 1995-1999, Pohlman and Maniero (2005) found that ozone concentrations in MNRR frequently exceeded 60-80 ppb for a few hours each year and sometimes, though very rarely, exceeded 100 ppb. Sensitive plant species begin to experience foliar injury when exposed to ozone concentrations of 80-120 ppb/hour for extended periods of time (8 hours or more) (Pohlman and Maniero 2005). The authors determined periodic peaks in concentration to be intermittent and the risk of foliar injury to be minimal in MNRR. However, if ozone concentrations should increase in the future, the authors suggested an on-site monitoring program that assesses foliar injury and growth progress would likely be necessary. Currently, there is no monitoring program in place that tracks plant sensitivities to ozone or other pollutants. Pohlman and Maniero (2005) noted there are several plant species in MNRR that are sensitive to excessive or extended concentrations of ozone, some of which could be considered bioindicators for sustained presence of unhealthy levels of ozone. An additional ozone risk assessment concluded that vegetation in MNRR was at low risk from ozone injury (Kohut 2007). A detailed list of plant species that are sensitive to ozone is included in the data needs and gaps section.

Particulate Matter ($PM_{2.5}$ and PM_{10}) and Visibility

Concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) are recorded at a site in nearby Sioux Falls, SD (95 km to the north) and values are extrapolated to MNRR. Data recorded at this site from 2000-2007 represents the most current data on particulate matter concentrations in the area. The NAAQS standard for PM_{10} is 150 µg/m^3 over a 24-hour period; this level may not be exceeded more than once per year on average over three years (EPA 2010e). The standard for $PM_{2.5}$ is a weighted annual mean of 15.0 µg/m^3 or 35 µg/m^3 in a 24-hour period over an average of three years (EPA 2010e). $PM_{2.5}$ concentrations have remained stable around 8-9 µg/m^3 from 2002-2006 (Figure 76). Concentrations of PM_{10} from 2001 through 2007 show a significant decrease in concentration from 2002 to 2003, followed by a stable trend at 40-50 µg/m^3 (Figure 77). These values, and those for fine particulate matter, are well within the EPA standards for levels that are protective of human health and visibility.

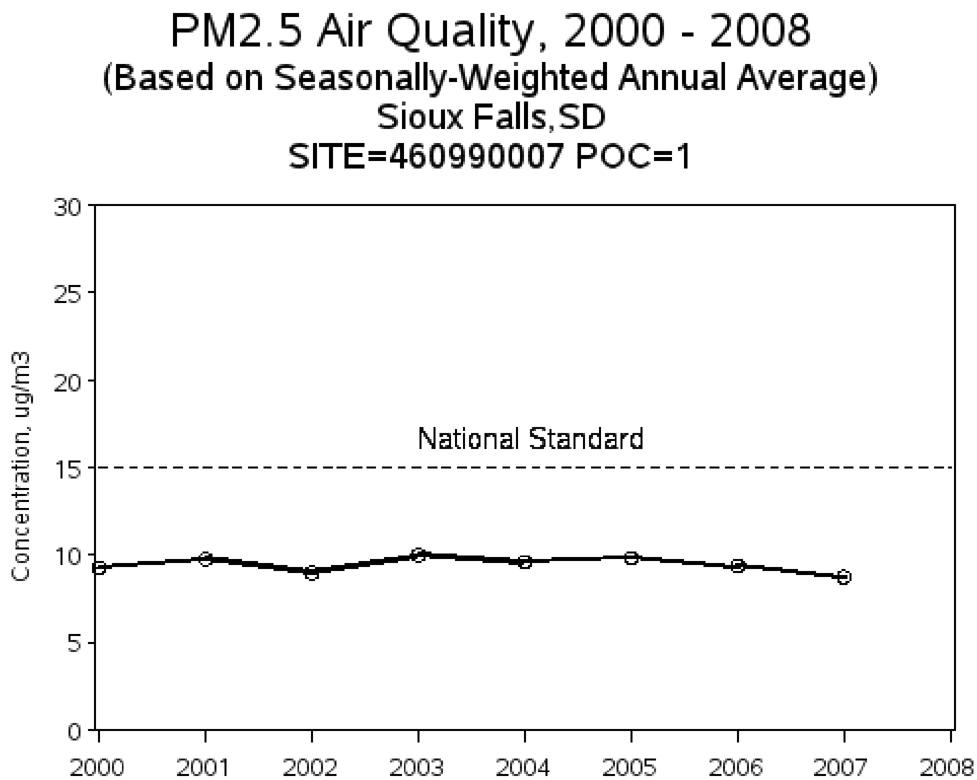


Figure 76. Trends in particulate matter ($PM_{2.5}$) near MNRR, 2000-2007 (EPA 2009b).

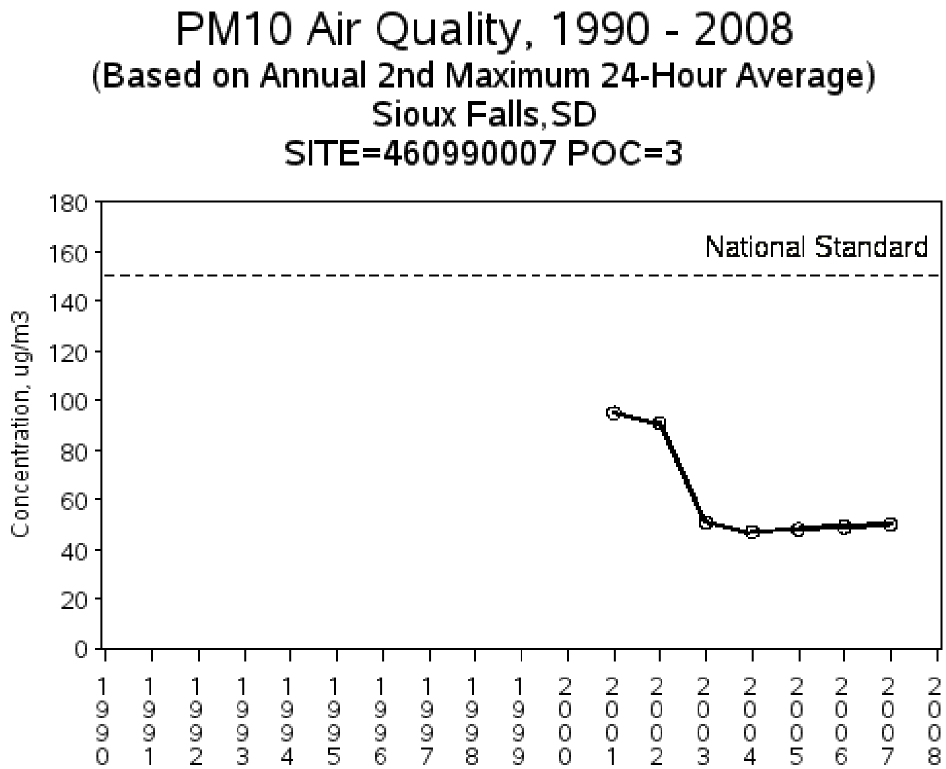


Figure 77. Trends in particulate matter (PM_{10}) near MNRR, 2001-2007 (EPA 2009b).

In response to the mandates of the CAA of 1977, federal and regional organizations established IMPROVE in 1985 to aid in monitoring visibility conditions in Class I air sheds (Pohlman and Maniero 2005). The goals of the program are to 1) establish current visibility conditions in Class I air sheds; 2) identify pollutants and emission sources causing the existing visibility problems; and 3) document long-term trends in visibility (NPS 2009a). Based on aerosol data collected in Badlands National Park from 1996-1998, Pohlman and Maniero (2005) indicate that the primary sources of visibility impairment in the Northern Great Plains region are sulfates from coal combustion and oil refineries, organics from vehicle emissions and chemical manufacturing, soils (e.g., windblown dusts), light-absorbing particulates (likely from wood smoke and fires), and nitrates from coal and natural gas combustion. These particles and gases impair visibility when they scatter or absorb light; the net effect is called ―light extinction", a reduction in the amount of light from a scene that is returned to an observer (EPA 2003). The IMPROVE monitoring site nearest MNRR is in Badlands National Park (BADL) (~ 280 miles/450 km west of MNRR). Figure 78 depicts visibility (in dv) on the 20% best and 20% worst days in BADL, as well as the default natural conditions for both. Because BADL is a substantial distance west of MNRR and humidity levels and prevailing winds vary to some degree between the two parks, trends shown in Figure 78 should be interpreted with caution in terms of their relevance to visibility trends at MNRR. These instead should be used merely as a point of reference for MNRR managers in interpreting visibility averages extrapolated to MNRR. NPS air quality estimates from 2004-2008 show that visibility in MNRR on average is 10.3 deciviews (dv) (this is an estimate above the estimated natural conditions), which falls into the significant concern category for NPS air quality condition assessment (guideline for significant concern is >8 dv) (NPS 2010c). Park managers believe the main cause for impacted visibility in the area is likely windblown dust from neighboring agricultural fields or development sites; airborne dust is especially noticeable during the harvest and field-tilling seasons (Wagner,pers. comm., 2010).

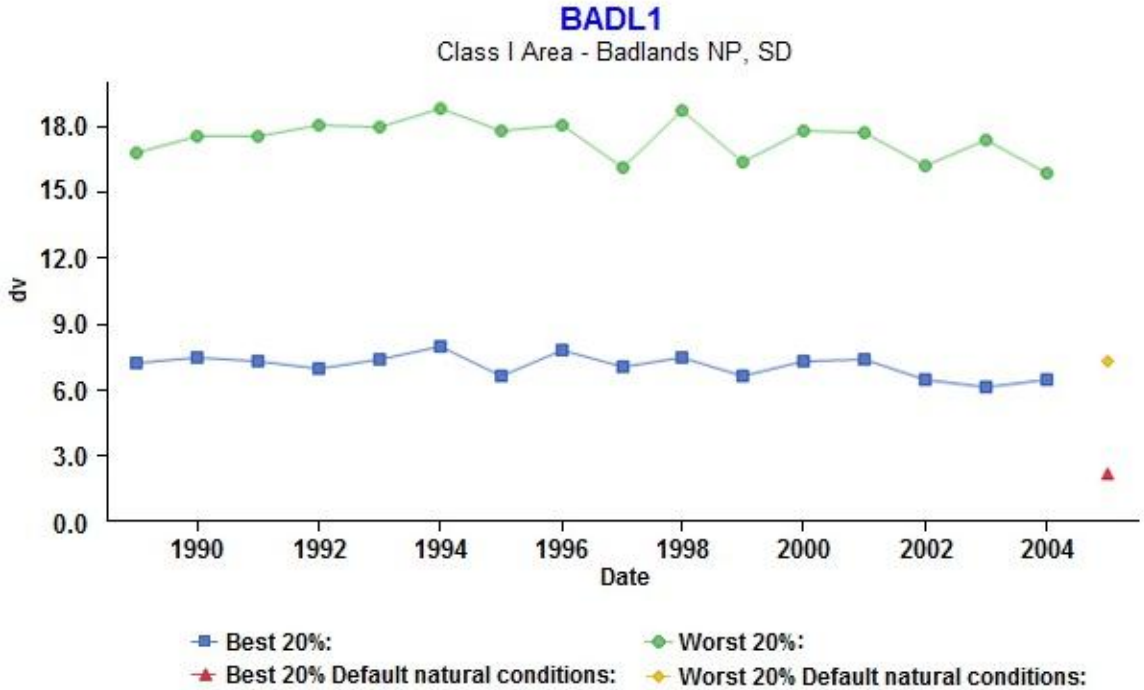


Figure 78. Annual visibility in BADL, 1989-2004 (VIEWS 2010). Note: BADL is the closest IMPROVE visibility monitoring station to MNRR but is still 280 miles/450 km west of MNRR. The relevance of these measurments should be interpreted cautiously and should serve only as a point of reference for visibility for MNRR, as humidity levels and prevailing winds at MNRR vary from that of BADL.

Threats and Stressor Factors

Agriculture is the dominant land use in the immediate vicinity of MNRR. Park managers have noticed an increase in airborne dust during times of harvest and tilling (spring and fall) of agricultural fields surrounding MNRR (Wagner, pers. comm., 2010). In addition to dust that hinders visibility, harvest and tilling practices may also release into the air nitrates and other compounds (present in the soil from fertilizers, agricultural pesticides, or atmospheric deposition), which may settle out again as deposition in MNRR. Ammonia and ammonium from agricultural activities dominates nitrogen deposition, as opposed to nitrate from emissions of nitrogen oxides from vehicles, power plants, and industry (Figure 79). There is a large fertilizer plant in Sergeant Bluff, Iowa (~70 miles/112 km east of MNRR), that emits ammonia into the air during manufacturing. This may impact MNRR air quality and deposition (Porter, pers. comm., 2010).

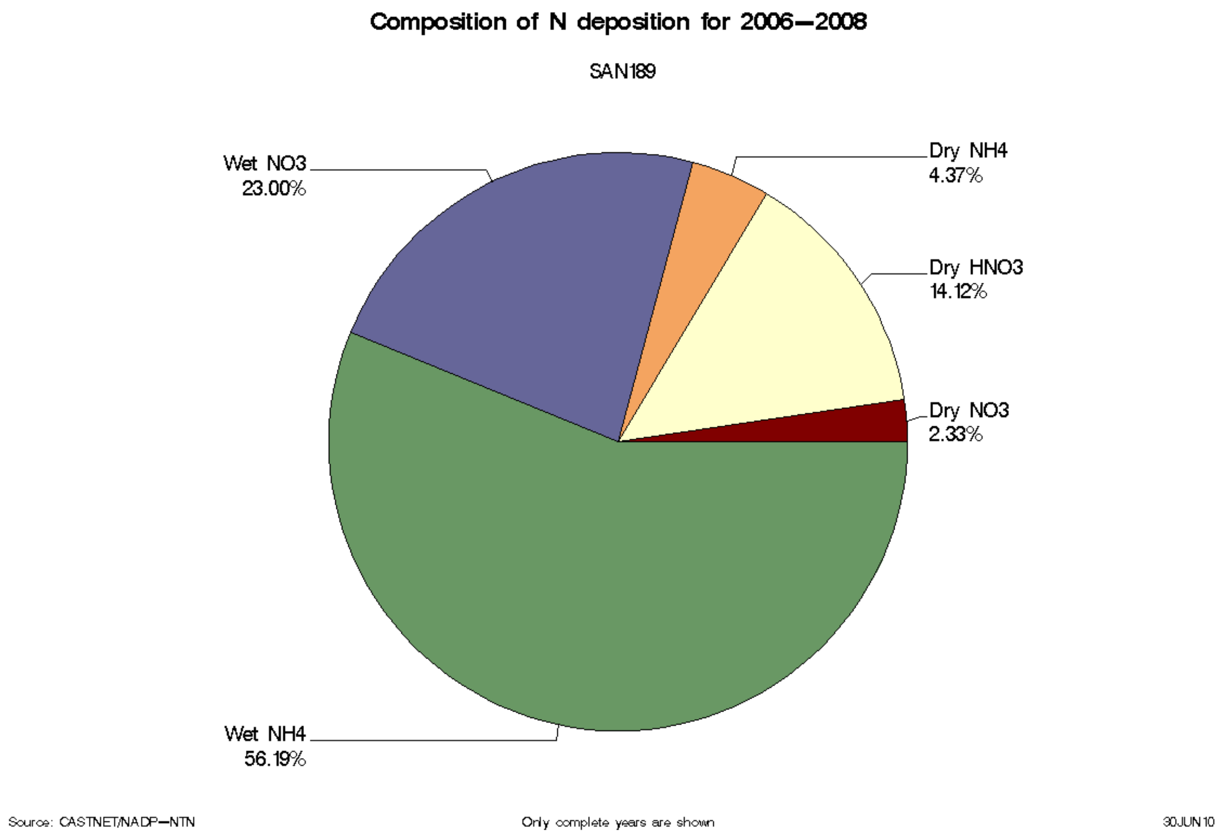


Figure 79. Composition of nitrogen deposition at the CASTNET site SAN189 (Santee Sioux). Wet deposition estimates are from the NADP site SD99.

Though small in size (less than 160,000 people), the nearby cities of Sioux Falls, SD, and Sioux City, IA (within 65 miles/~100 km from MNRR) support some industrial operations. Under certain weather conditions, emissions from these industrial operations could impair air quality in MNRR. Additional industrial development in northeastern South Dakota and northwestern Iowa would certainly increase the emissions transported to MNRR.

<u>Data Needs/Gaps</u>

To date there is no monitoring effort that tracks the plant and animal species that are particularly sensitive to increases in certain pollutants. No direct evidence suggests current air pollution is threatening MNRR vegetation, but nitrate, ammonium, and sulfate deposition and ozone could become a greater concern in the future if new point and area sources of pollution emerge and increase ambient pollution levels. Nitrogen deposition can affect plant communities, promoting invasive species and loss of biodiversity. If air pollution increases in the future, plant and tree species can be monitored to track air pollution impacts. MNRR has several species that are sensitive to increases in ozone (Pohlman and Maneiro 2005). These species could be used as bioindicators to track potential increases in ozone pollution as well as long-term impacts to the health of the ecosystem. Table 77 summarizes the plant and tree species that have known sensitivities to ozone. This list may help park staff identify key species to use as bioindicators.

Table 77. Plant and tree species of MNRR with sensitivities to ozone (Adapted from Pohlman and Maniero 2005 and NPS 2006).

Scientific Name	Common Name
Amelanchier alnifolia	Saskatoon serviceberry
Apocynum androsaemifolium	Spreading dogbane
Artemisia ludoviciana	White sagebrush
Asclepias incarnata	Swamp milkweed
Asclepias syriaca	Common milkweed
Clematis virginiana	Virgin’s bower
Corylus americana	American hazelnut
Eupatorium rugosum	White snakeroot
Fraxinus pennsylvanica	Green ash
Parthenocissus quinquefolia	Virginia creeper
Pinus ponderosa	Ponderosa pine
Populus tremuloides	Quaking aspen
Prunus virginiana	Chokecherry
Robinia pseudoacacia	Black locust
Rudbeckia laciniata	Cutleaf coneflower
Sambucus candensis	American elder
Symphoricarpos albus	Common snowberry

In an effort to quantify harmful pollution levels and set goals for resource protection on federal lands, natural resources managers are increasingly using a “critical loads” approach for tracking and monitoring a variety of pollutants, in particular nitrogen and sulfur compounds (Porter et al. 2005). Critical loads are defined as “the quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge” (Nilsson and Grennfelt 1988, as cited in Porter et al. 2005). Essentially, critical loads describe the amount of pollution that stimulates negative impacts or harmful changes to sensitive ecosystems (Porter et al. 2005, NPS 2007a). Porter et al. (2005) developed an approach for determining critical loads for nitrogen and sulfur using two national parks as case studies, and research is underway in other park units to aid in communicating resource condition. Their methodology can be tailored to most national park lands, depending on available baseline information. Since plant communities in MNRR are likely sensitive to increases in nitrogen, park managers at MNRR may be able to develop and implement a critical load approach for managing air pollutants and to set goals for resource protection within the park.

Overall Condition

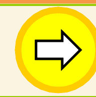
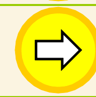
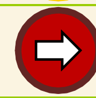
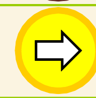
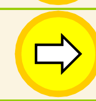
Measures	*Reference Condition*	*Condition*
Mercury	EPA Air Quality Criterion; "Natural" spatial/temporal patterns	
Nitrogen	EPA Air Quality Criterion; "Natural" spatial/temporal patterns	
Particulate Matter	EPA Air Quality Criterion; "Natural" spatial/temporal patterns	
Ozone	EPA Air Quality Criterion; "Natural" spatial/temporal patterns	
Sulfer	EPA Air Quality Criterion; "Natural" spatial/temporal patterns	

Figure 80. Air Quality condition graphic.

Based on NPS condition assessment protocol for air quality, the overall condition for air quality in MNRR is of moderate to significant concern. Nitrogen deposition in MNRR falls into the significant concern category, while sulfur deposition falls into the moderate concern category. Wet deposition of compounds has fluctuated over the most recent 5-year period for which data are available. Yet trend data suggest that average concentrations of sulfate and nitrate compounds have remained relatively stable between the 1999-2003 and 2004-2008 sampling periods with the exception of slight increases and decreases over this time (Figure 80). Mercury deposition is at moderate levels compared to other parts of the country and has remained stable/persistent at 6-8 and 8-10 µg/m^2. Ground-level ozone concentrations are of moderate concern based on NPS standards, and data suggest that ozone concentrations in MNRR are declining slightly. Concentrations of both $PM_{2.5}$ and PM_{10} are well within EPA standards for allowable levels that are protective of human health, with PM_{10} concentrations showing significant decreases in the last 8 years; however, these particles still contribute to haze in the air and, thus, visibility in MNRR remains of significant concern. Although many of the designations for air quality parameters indicate a moderate or significant concern for air quality in the park, nearly all of the parameters are exhibiting stability or slight declines in concentrations or deposition. Overall, this suggests air quality in MNRR is not deteriorating, but remaining stable.

Sources of Expertise

Gia Wagner, MNRR Chief of Resources

Ellen Porter, NPS-ARD Air Resource Scientist

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4.14 Climate

Description

Climate is defined as the collection of statistical parameters that describe atmospheric conditions across space and time. This is different from weather, which is defined as the current atmospheric conditions in real-time (Davey et al. 2007). Climate is widely recognized as a fundamental driver of most physical and ecological processes in the NGPN (Licht et al. 2005, as cited in Davey et al. 2007). In order to understand changes and patterns in ecosystems in MNRR, it is important to understand if and how current and historical climate patterns in the region have shifted or changed.

Changes in the overall climate of the region, particularly with regard to average temperatures and amount of precipitation, could significantly alter the unique microclimates that exist along the Missouri River in MNRR. This could ultimately disrupt and change the niche habitats that have become established due to the microclimates. Changes in temperature and precipitation may also alter and expand the range within which invasive or exotic species are able to thrive, resulting in competitive pressure on native species in the region.

One important dynamic of ecosystems and communities is phenology: the recurring life cycle events of plants and animals (USA National Phenology Network 2010). Phenology affects the number, diversity, and behavior of organisms, interactions between organisms, and food webs (USA National Phenology Network 2010). Changes in timing of phenophases have been observed globally, but changes are not all occurring at the same rate. These varying rates of change are altering ecosystem processes and interactions between organisms (USA National Phenology Network 2010).

Measures

- Patterns in precipitation over the period of record (change in frequency and amount)
- Patterns in temperature over the period of record (change in pattern and range)
- Patterns in phenologic relationships (changes in the onset and duration of greenness)

Reference Conditions/Values

The reference condition for this component is the period of record for which data are available and for which trends or patterns in the recorded data may be distinguishable. For temperature and precipitation, the period of recorded data is 1895 to 2010.

Data and Methods

Data provided by the PRISM Climate Group of Oregon State University were queried and used to examine any patterns in average monthly precipitation and temperature for two 2.5-minute by 2.5-minute grids (approximately 4-km by 4-km) (PRISM 2010a). The two selected locations represent the locations of the two dams located near the park (Fort Randall near Pickstown, SD, and Gavins Point near Yankton, SD). The data sets made available through this group have been created using the PRISM (Parameter-elevation Regressions on Independent Slopes Model) climate mapping system, which uses point measurements of climate factors, such as precipitation and temperature, to produce digital grid estimates of monthly, annual, or event-based climate patterns (PRISM 2010a).

Historical data sets (from 1895-2010) for minimum and maximum average monthly temperatures and average monthly precipitation were queried in the PRISM database using the Internet Map Server function. Data were downloaded into an Excel spreadsheet and grouped into six relatively equal time period blocks for analysis. The time period blocks are as follows: 1895-1910; 1911-1930; 1931-1950; 1951-1970; 1971-1990; 1991-2010. Each time block contains a span of 19 years with the exception of the 1895-1910 time block, which is 15 years. The time blocks were graphed and charted to examine any patterns that may have occurred in temperature and precipitation in the region over the past 115 years. Time periods were then compared for differences in yearly temperature and precipitation patterns.

Current Condition and Trend

Patterns in precipitation in the Yankton and Pickstown, SD region from 1895-2010

According to the weather and climate inventory for NGPN, precipitation in the NGPN region is categorized as light to moderate (Davey et al. 2007). Mean annual precipitation (not including snow) for the MNRR area (according to real-time weather stations within 40 km of MNRR and NIOB) ranged from 600-750 mm (data from 1961-1990), and average annual snowfall ranged from 510-750 mm (Davey et al. 2007).

Data from the PRISM database show that average precipitation in the MNRR region has been steadily increasing over the past 115 years, more so at Yankton than Pickstown (PRISM 2010b, Figure 81). For Yankton, SD, and Pickstown, SD, the average precipitation for the last two decades is higher than any previous decade with recorded data; this difference is more pronounced for Yankton. In comparing the average precipitation for the most recent decade on record (2001-2010) to the average for the first 5 years on record (1895-1900), there is a difference of 205.9 mm (8.1 inches) of precipitation at Yankton.

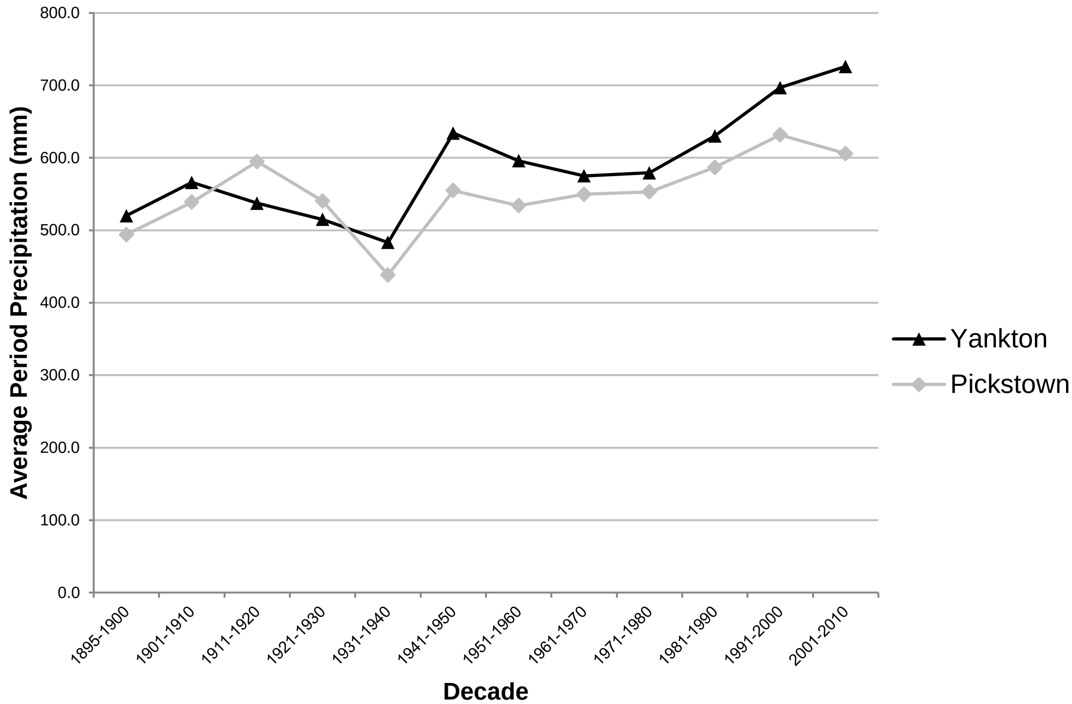

Figure 81. Average annual precipitation (in millimeters) per decade from 1895 to 2010 for 2.5-minute by 2.5-minute grids centered at Yankton and Pickstown, SD (PRISM 2010b).

The PRISM databases provide the opportunity to examine average precipitation by month across the period of recorded data (Figure 82, Figure 83). For Yankton, the most recent time (1991-2010) experienced a marked increase in average precipitation across most months. The 1971-1990 time period experienced an increase in average precipitation during the spring and fall seasons compared to earlier time periods. For Pickstown, precipitation during most months did not show an obvious trend, with the exception of September, October, and November which showed an increasing trend in precipitation across the period of recorded data.

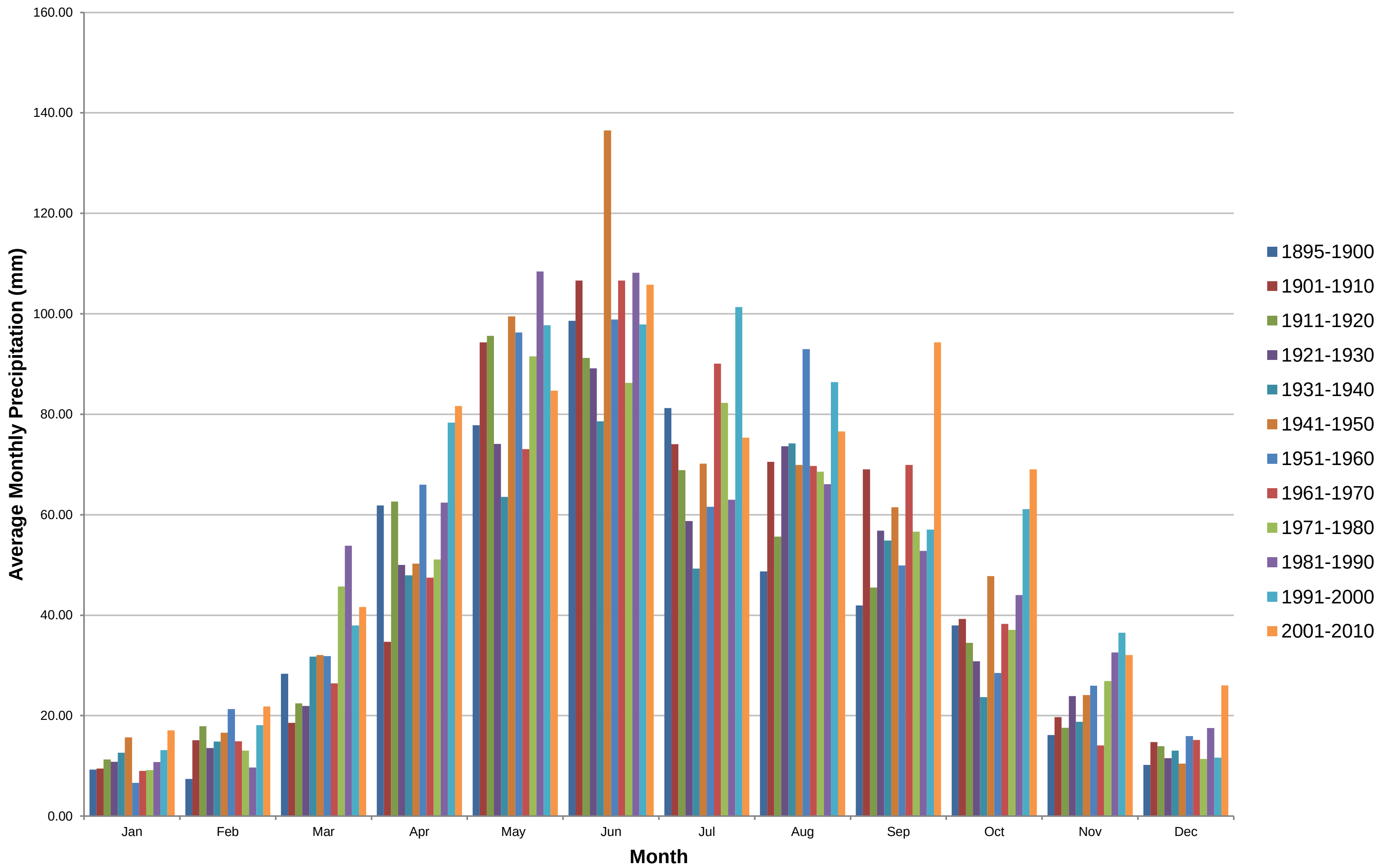

Figure 82. Average monthly precipitation (in millimeters) by decade from 1895 to 2010 for a 2.5-minute by 2.5-minute grid centered at Yankton, SD (PRISM 2010b).

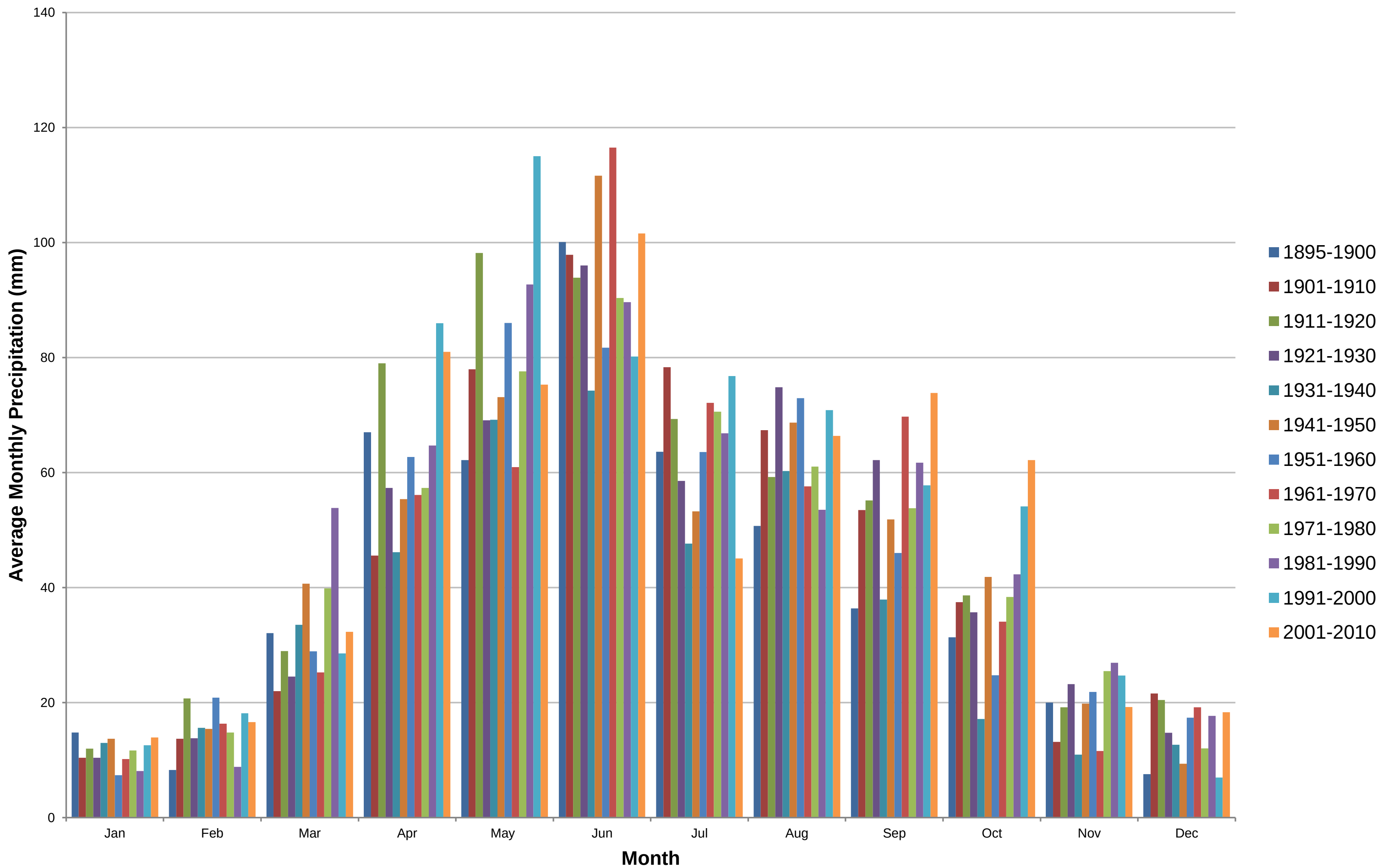

Figure 83. Average monthly precipitation (in millimeters) by decade from 1895 to 2010 for a 2.5-minute by 2.5-minute grid centered at Pickstown, SD (PRISM 2010b).

Patterns in temperature for the Yankton and Pickstown, SD areas from 1895-2010

In examining average annual temperatures in the NGPN region, Davey et al. (2007) describe a strong warming trend occurring in the first part of the 20th century, followed by a cooling trend from the 1950s through the 1970s (Davey et al. 2007). However, after the 1970s, steady warming occurred again in the region; long-term temperature trends suggest that temperatures have been steadily warming over the past three to four decades (Davey et al. 2007).

Decadal Average Annual Maximum Temperatures

Overall, average annual maximum temperatures per decade for both the Yankton and Pickstown areas have fluctuated over the last 115 years, but show no increasing or decreasing trend (Figure 84). For Yankton, the mean is 31.1° C, ranging from 29.4 (1991-2000) to 33.58° C (1931-1940) . For Pickstown, the mean is 30.61° C, ranging from 30.06 (1991-2000) to 35.28° C (1931-1940).

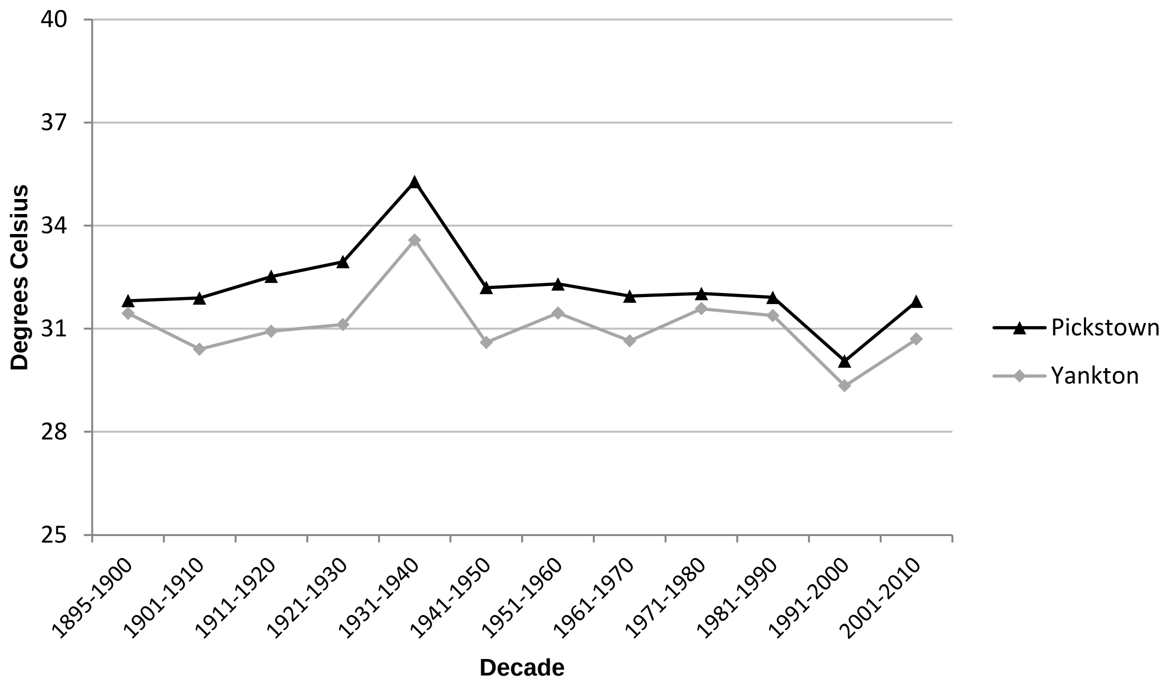

Figure 84. Decadal average annual maximum temperature (degrees Celsius) from 1895 to 2010 for two 2.5-minute by 2.5-minute grids centered at Yankton and Pickstown, SD (PRISM 2010c).

Average monthly maximum temperatures

Average monthly maximum temperatures were examined for possible patterns. For the Yankton, SD area, average maximum monthly temperatures have remained consistent across the last 115 years (Figure 85). The same is true for the Pickstown, SD area (Figure 86).

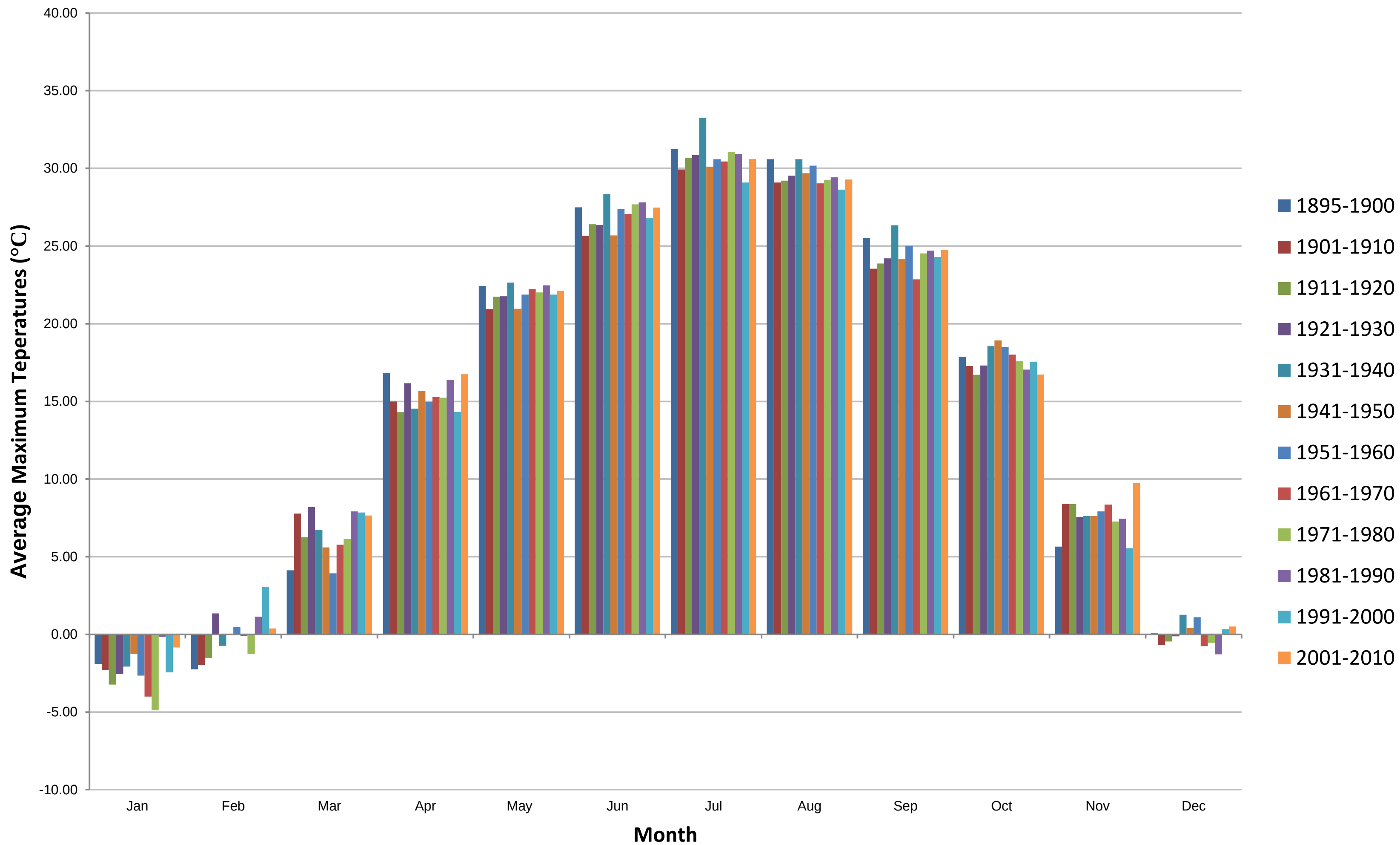

Figure 85. Average monthly maximum temperatures (degrees Celsius) by decade from 1895 to 2010 for a 2.5-minute by 2.5-minute grid centered at Yankton, SD (PRISM 2010c).

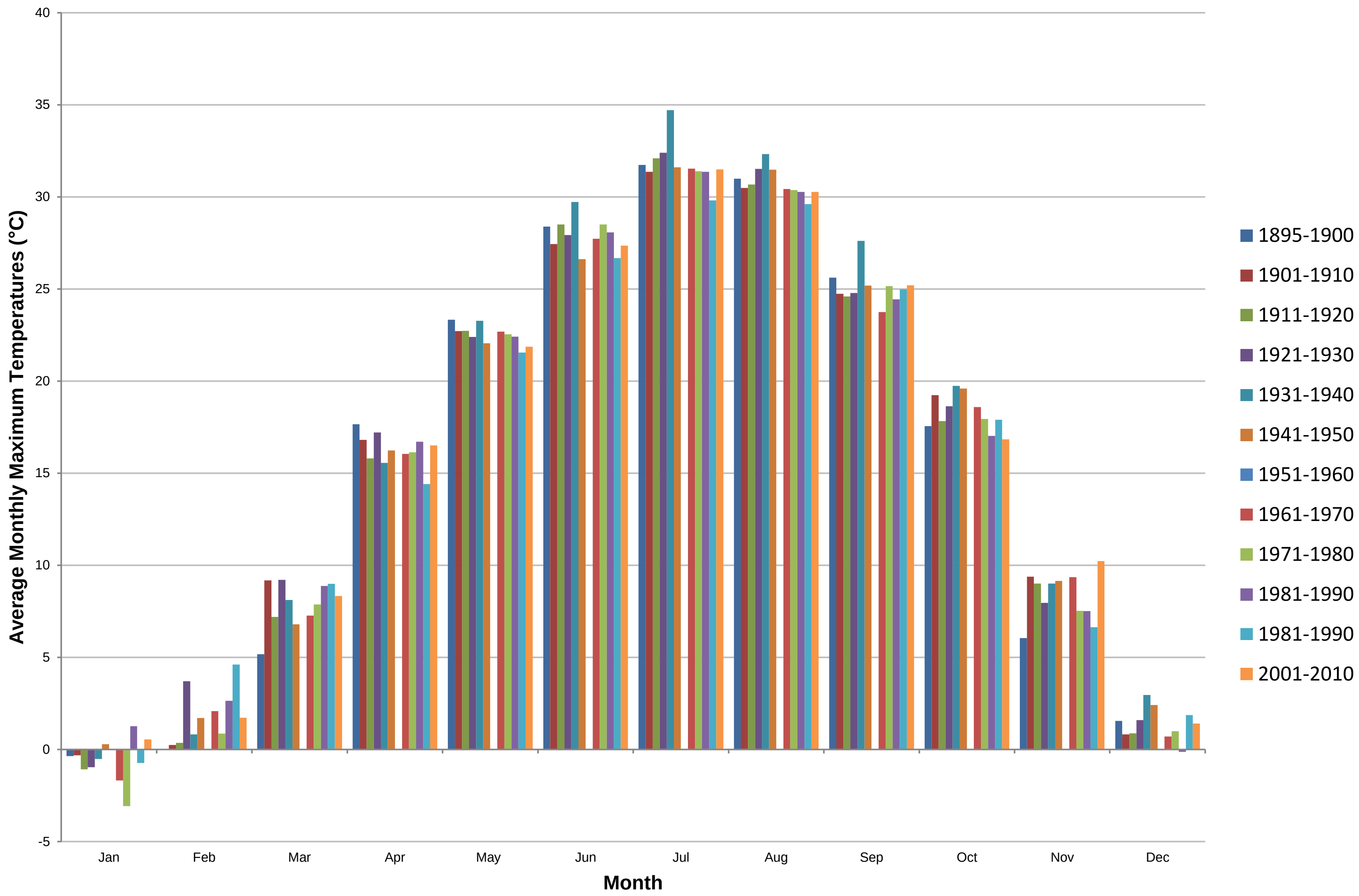

Figure 86. Average monthly maximum temperatures (degrees Celsius) by decade from 1895 to 2010 for a 2.5-minute by 2.5-minute grid centered at Pickstown, SD (PRISM 2010c).

Decadal Average Annual Minimum Temperatures
Overall, average annual minimum temperatures by decade have fluctuated over the past 115 years (Figure 87). For decades spanning 1895 to 1960, there is no apparent trend for either the Pickstown or Yankton areas. However, from 1960 to present-day, annual minimum temperatures have consistently increased (3.3° C for Yankton and 2.2° C for Pickstown).

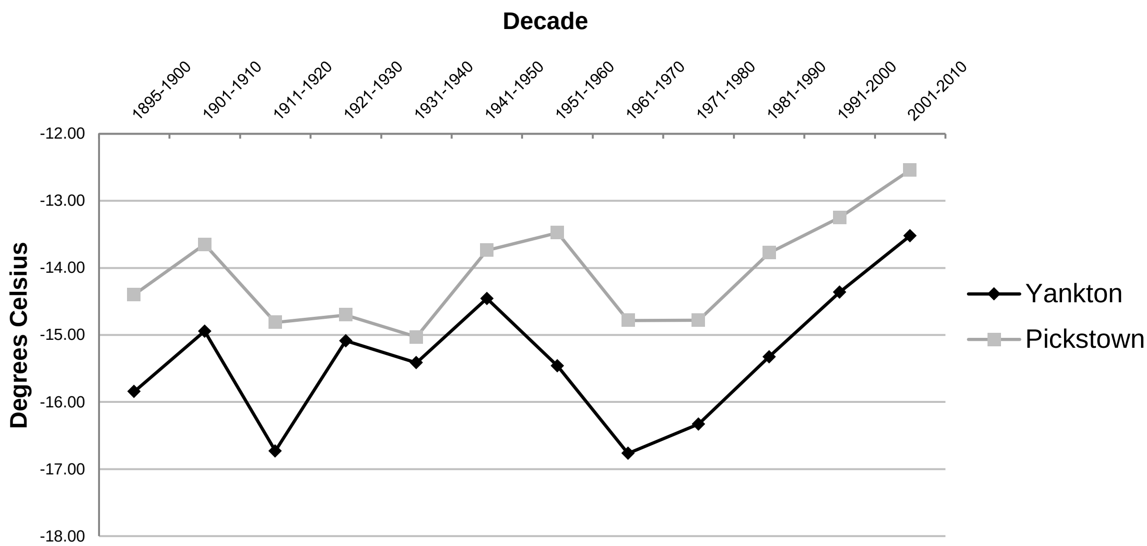

Figure 87. Average annual minimum temperatures (degrees Celsius) by decade from 1895 to 2010 for two 2.5-minute by 2.5-minute grids centered at Yankton and Pickstown, SD (PRISM 2010d).

Average monthly minimum temperatures
Average monthly minimum temperatures were also examined for possible patterns. Figure 88 and Figure 89 show that monthly minimum temperatures have been warmer in the last century, particularly in the 1931-1940 decade, for both the Yankton and Pickstown areas. These temperatures appeared to decrease again in the subsequent decade (1941-1950). However, the data show that minimum monthly temperatures have been increasing on average consistently since the 1950s. This is particularly evident in the later spring months, through the summer months, and into the beginning of the fall (May through September).

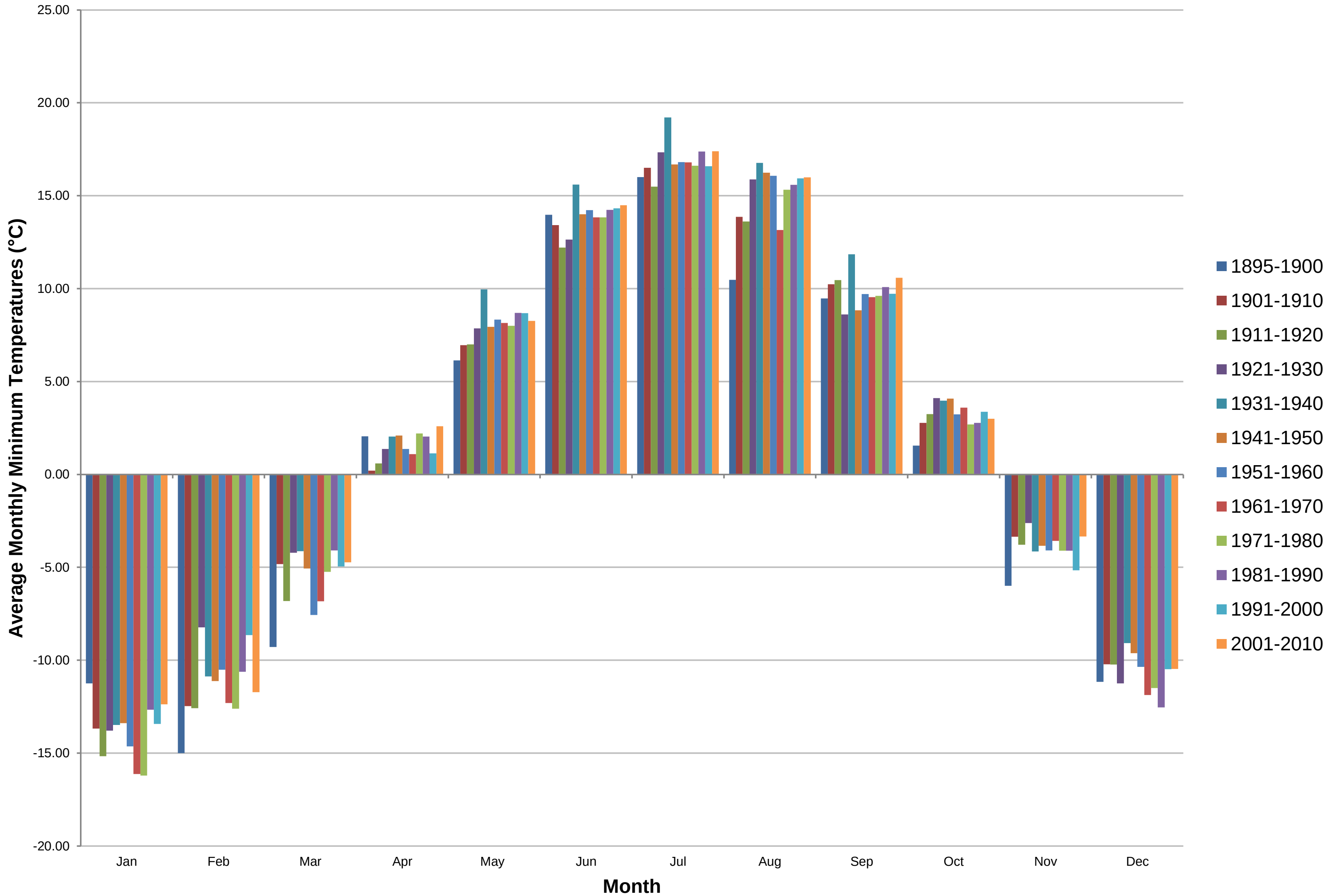

Figure 88. Average monthly minimum temperatures (degrees Celsius) by decade from 1895 to 2010 for a 2.5-minute by 2.5-minute grid centered at Yankton, SD (PRISM 2010d).

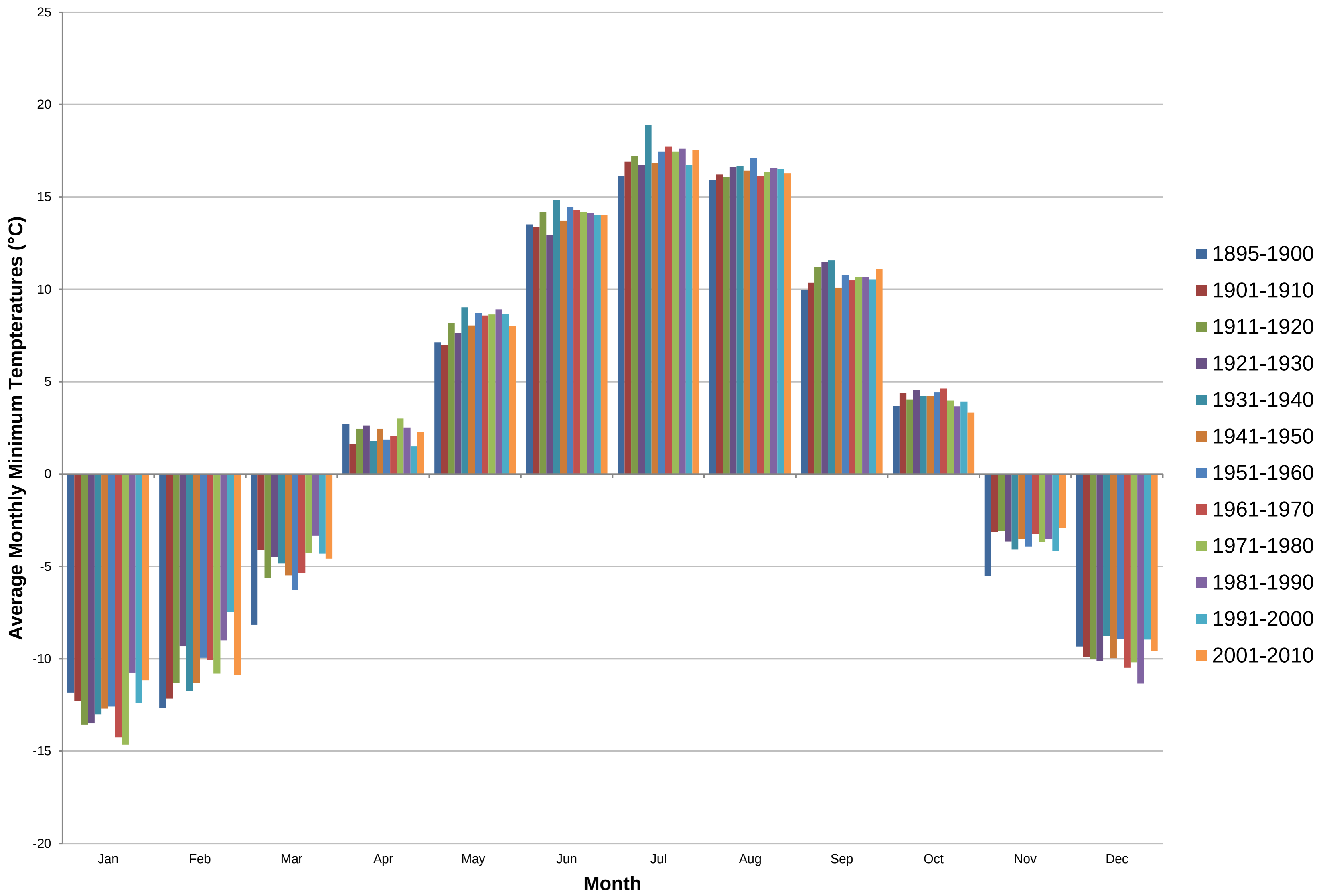

Figure 89. Average monthly minimum temperatures (degrees Celsius) by decade from 1895 to 2010 for a 2.5-minute by 2.5-minute grid centered at Pickstown, SD (PRISM 2010d).

Patterns in phenologic relationships
Data regarding phenologic relationships in the park are not available.

Threats and Stressor Factors
There is a scientific consensus that a general warming trend in global climate has some anthropogenic cause (Morris 2007). Concentrations of carbon dioxide and other greenhouse gases such as methane, nitrous oxide, and halogen-containing gases have increased in the atmosphere because of human activity (Denman et al. 2007). Human sources of carbon dioxide include fossil fuel combustion, cement manufacturing, deforestation, biomass burning, and some agricultural practices (Denman et al. 2007). Human sources of methane include energy production from coal and natural gas, waste disposal in landfills, raising ruminant animals, rice agriculture, and biomass burning. Certain agricultural practices, such as application of nitrogen fertilizer and raising cattle, as well as some industrial activities contribute to increases in nitrous oxide concentrations (Denman et al. 2007).

Data Needs/Gaps
Implementation of a monitoring protocol for phenology in the park could provide insight regarding changes in climate in the future.

Overall Condition

Measures	*Reference Condition*	*Condition*
Phenologic relationships (onset and duration of greeness)	Period of record	
Precipitation pattern (change in frequency and amount)	Period of record	
Temperature (change in pattern and range)	Period of record	

Figure 90. Climate condition graphic.

The condition of climate in MNRR is unknown (Figure 90). Average annual temperatures seem to be increasing in the region, as is also evident in the average monthly maximum and minimum temperatures. This could indicate a more sustained warming trend which may have implications for plant communities that have adapted to cooler temperatures (primarily the microclimate zones and niche species). However, the topography of the region (containing significant drainages that tend to be cooler) may counterbalance the increases in temperatures for the microclimate zones.

Average annual precipitation has been increasing in the region over the last 115 years. This may have implications for plant communities as well, as they must adapt to warmer and wetter conditions in the region.

It is not clear how the increases in temperature and precipitation will affect phenological relationships, such as the onset of greenness in the region. This appears to be a data gap for the park.

Sources of Expertise

Lisa Yager, MNRR Biologist

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PRISM Climate Group. 2010c. PRISM data explorer. Average maximum temperatures for the Yankton (longitude: -97.392; latitude: 42.876) and Pickstown (longitude: -98.5325; latitude: 43.0661), SD regions, 1895-2010 (longitude:-97.392; latitude: 42.876). Oregon State University. Online. (http://prismmap.nacse.org/nn/). Accessed 1 April 2011.

PRISM Climate Group. 2010d. PRISM data explorer. Average minimum temperatures for the Yankton (longitude: -97.392; latitude: 42.876) and Pickstown (longitude: -98.5325; latitude: 43.0661), SD regions, 1895-2010 (longitude: -97.392; latitude: 42.876). Oregon State University. Online. (http://prismmap.nacse.org/nn/). Accessed 1 April 2011.

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4.15 Soundscape

Description

The definition of soundscape in a national park is the total ambient sound level of the park, comprised of both natural ambient sound and human-made sounds (NPS 2000). The mission of the NPS is to preserve natural resources, including natural soundscape, associated with the national park units. According to a survey conducted by the NPS, many visitors come to national parks to enjoy, equally, the natural soundscape and natural scenery. Intrusive sounds are of concern to park visitors, as they detract from their natural and cultural resource experiences (Gramann 1999).

Measures

- Ambient sound level: ambient sounds measured in A-weighted decibels (dBA).
- Distribution of non-natural sounds: any sound that is not part of the natural soundscape (e.g., vehicles, trains, airplanes/helicopters, and other human uses).

Reference Conditions/Values

The reference condition for soundscape in MNRR is an undeveloped park experience, which is presumed to consist of natural sounds such as wind, bird songs, and rushing water.

<u>Monitoring</u>

No baseline measurements for soundscape have been collected for pre-European settlement, post-dam, or since MNRR park inception.

NPS (2010) explains that soundscape protocols are being developed during the next five years. This protocol will include selected locations for each park to determine the soundscape status over one to ten years. The protocol also includes various metrics involving natural ambient sound levels, time above ambient levels, natural sound frequencies, and source of sounds. Additionally, the protocol will address soundscape changes, visitor numbers, developments, and bird communities.

Data and Methods

No data have been collected by the NPS in MNRR related to soundscape.

Current Condition and Trend

<u>Ambient Sound Level</u>

No ambient sound level data have been collected in MNRR to date.

<u>Distribution of Non-Natural Sounds</u>

No data regarding the distributionof non-natural sound have been collected to date.

<u>Threats and Stressor Factors</u>

MNRR park staff report development, trails, roads, bridges, occasional air traffic, and recreational usage, including motor boats and other motorized personal watercrafts, as the main sources of soundscape impacts. Fort Randall Dam and Gavins Point Dam may be other sources of non-natural sounds contributing to MNRR soundscape.

Data Needs/Gaps
Baseline data needs to be collected describing the existing MNRR soundscape, and periodic monitoring of soundscape in the future would allow for trend analysis of ambient sound levels and stressors, such as development, trails and roads.

Overall Condition

Measures	*Reference Condition*	*Condition*
Ambient Sound Level	Undeveloped park experience	
Distribution of Non-natural sounds	Undeveloped park experience	

Figure 91. Soundscape condition graphic.

Due to the lack of data, a quantitative assessment of soundscape cannot be completed at this time and condition is unknown (Figure 91).

Sources of Expertise
MNRR, network staff, and literature cited were used for sources of expertise.

Literature Cited

Gramann, J. 1999. The effects of mechanical noise and natural sound on visitor experiences in units of the National Park System. NPS Social Science Research Review 1:1–16.

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Gitzen, R. A., M. Wilson, J. Brumm, M. Bynum, J. Wrede, J. J. Millspaugh, and K. J. Paintner. 2010. Northern Great Plains Network Vital Signs monitoring plan. Natural Resource Report NPS/NGPN/NRR – 2010/186. National Park Service, Fort Collins, Colorado.

4.16 Dark Night Skies

Description

A lightscape is a place or environment characterized by the natural rhythm of the sun and moon cycles, clean air, and of dark nights unperturbed by artificial light (NPS 2007). The NPS directs each of its units to preserve, to the greatest extent possible, these natural lightscapes (NPS 2006). Natural cycles of dark and light periods during the course of a day affect the evolution of species and other natural resource processes such as plant phenology (NPS 2006, 2007). Several species require darkness to hunt, hide their location, navigate, or reproduce (NPS 2007). In addition to the ecological importance of dark night skies, park visitors may expect skies to be free of light pollution to allow for star observation.

Measures

- Darkness- V magnitude
- Schaaf scale scores

Reference Conditions/Values

The reference condition for dark night skies in MNRR is the absence of anthropogenic light. It is assumed that night skies were pristine during pre-European settlement; only natural disturbances, such as fires or volcanic ash, would alter night views (Macy, pers. comm., 2011).

Data and Methods

No data have been collected by the NPS in MNRR related to dark night skies. Albers and Duriscoe (2001) assigned a Schaaf scale score to the park, but data used in this assignment were not collected in the park.

Current Condition and Trend

<u>Darkness - V Magnitude</u>

Night sky assessments have not been completed at MNRR. When NPS assessments are conducted, the NPS uses a charged coupled device (CCD) digital camera connected to a robotic mount and laptop computer to conduct night sky assessments and to determine darkness of park nightscapes (NPS 2007). A mosaic image of the entire night sky is created by stitching together multiple short exposure images (NPS 2007). The images are filtered using a green filter to approximate human night vision sensitivity, and the data are calibrated using the known brightness of certain stars. The resulting data are reported in units of V magnitude, which is an astronomical brightness system (NPS 2007). Weather conditions and phases of the moon limit the number of suitable nights for measuring V magnitude (NPS 2007).

<u>Schaaf Scale Scores</u>

Albers and Duriscoe (2001) developed a GIS process that evaluated the nighttime visibility of NPS units. This model used the Schaaf scale, a 1 through 7 scale with 1 representing extreme light pollution and 7 representing pristine skies. Albers and Duriscoe (2001) overlaid Schaaf scale score maps with park boundaries and then extracted the mean Schaaf score for the entire area of a given park. MNRR received a Schaaf score of 6.49 out of 7.00 (Albers and Duriscoe 2001). This value must be interpreted with caution though, as the original Schaaf scale score maps were from 1991 and no park-specific data were used in the calculation.

Threats and Stressor Factors

Light pollution is defined by the NPS as —the illumination of the night sky caused by artificial light sources, decreasing the visibility of stars and other natural sky phenomena" (NPS 2007). Light pollution is highest in areas with high human densities and can include glare, the use of light or intrusion of light in areas not requiring lighting, and any other disturbance of the natural nighttime lightscape (NPS 2007). In addition to human sources of light, airborne particulates can also affect night sky brightness (NPS 2007).

Several sources of anthropogenic light exist in MNRR and are primarily related to areas of residential use. The city of Yankton, SD, is located on the park's northern boundary adjacent to the Missouri River and near Lewis and Clark Lake. Larger cities, such as Sioux Falls, SD, and Sioux City, IA, are within 145 km (90 mi) of the park and may contribute marginal levels of light pollution.

Data Needs/Gaps

Quantitative dark night skies monitoring is needed in MNRR in order to report condition.

Overall Condition

Measures	*Reference Condition*	*Condition*
Schaff scale scores	Pre-European settlement - absence of anthropogenic light	
Darkness - V Magnitude	Pre-European settlement - absence of anthropogenic light	

Figure 92. Dark Night Skies condition graphic.

Albers and Duriscoe (2001) rated the night skies in the park as 6.49 out of 7.00 which is the only quantitative estimate of dark night skies for MNRR. As points for comparison, Big Bend National Park received a Schaff score of 7.00, while Muir Woods National Monument received a Schaff score of 1.00 (Albers and Duriscoe 2001). Big Bend National Park is in a very rural part of southern Texas and receives little light pollution, while Muir Woods National Monument is located just miles from Oakland and San Francisco, CA, and receives extremely high levels of light pollution.

These ratings must be taken with caution, however, as no measurements were taken within the NPS units and conditions may have changed since their modeling and rating. Because of MNRR's close proximity to residential areas such as Yankton, SD, the quality of MNRR's night skies is influenced by anthropogenic light sources. Due to the lack of data, a quantitative assessment of dark night skies cannot be completed at this time and condition is unknown (Figure 92).

Sources of Expertise

John Macy, MNRR Hydrologist

Literature Cited

Albers, S., and D. Duriscoe. 2001. Modeling light pollution from population data and implications for National Park Service lands. The George Wright FORUM 18(4): 56-68.

National Park Service. 2006. Management policies 2006. ISBM 0-16-076874-8. U.S. Department of the Interior. National Park Service, Washington, D.C..

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4.17 Odorscape

Description

The odorscape of MNRR is the collection of natural and anthropogenic odors present within the administrative boundaries of the park unit. The assessment of odorscape in MNRR is primarily a qualitative look at some of the anthropogenic contributions of scents that are not present in the natural ambient environment.

Measures

- presence of undesirable anthropogenic odors that detract from the visitor's natural experience.

Reference Conditions/Values

The reference condition for MNRR's odorscape is the natural ambient condition prior to human development in and around the park. John Macy, MNRR Hydrologist, identified smoke as the most likely and prominent pre-European natural odor. Animal carcasses, such as those from buffalo and other animals falling through river ice and drowning, may have also contributed to the natural ambient odors of MNRR (Macy, pers. comm., 2011).

Data and Methods

There is no quantitative data available to assess the odorscape in MNRR.

Current Condition and Trend

<u>Anthropogenic Odors</u>

Macy (pers. comm., 2011) identified several possible anthropogenic contributions to the odorscape of MNRR. Some of these include a sewage treatment plant near Yankton, SD, individual land owners burning garbage, and vehicle (cars, boats, tractors, etc.) exhaust. Much of the privately held land around MNRR is used for agriculture, and many of the possible anthropogenic odors are likely linked to agriculture. In particular, feedlots may be located near MNRR, and some may cover substantial acreage (Macy, pers. comm., 2011). Depending on wind direction and speed, these feedlot odors and other agricultural odors have the potential to be very potent and quite noticeable in MNRR. Figure 93 is an example of the size of feedlots near MNRR and their proximity to the Missouri River. In addition to feedlots, cut-hay odors can be detected from the river. These odors are considered unpleasant by some.

Figure 93. Example of feedlots within two kilometers of MNRR. Scale: 1:32,000 (USGS SDSS Imagery).

<u>Threats and Stressor Factors</u>

Though there are no data collected regarding anthropogenic contributions to the natural ambient odorscape of MNRR, there are several possible man-made odors in the park (burning garbage, vehicle exhaust, and feedlots). Park staff note that cut-hay odors are detectable from the river, and to some this is unpleasant. In addition, MNRR staff have observed decomposing cattle, fish, and wildlife carcasses on the shorelines and sandbars. These could also be considered negative contributions to the odorscape. Future threats and stressors include further development along the river, specifically of feedlots and factories.

<u>Data Needs/Gaps</u>
Quantitative data would be useful to measure anthropogenic odor contributions to MNRR. Unfortunately, odor is difficult to measure. Currently, the best way to monitor odors (specifically of livestock facilities) is through trained human panels or gas chromatography/mass spectrometry, which separates compounds and analyzes ―peaks” and their ―retention times” (Brewer and Cadwallader 2004). Inconsistent and changing wind patterns further complicate gathering useful odor data.

The Center for Rural Design at the University of Minnesota has developed a GIS model to estimate average odor impacts from feedlots. This model identifies the distance feedlot odors can be identified from, and the intensity of these smells are based on a variety of conditions: number of animals, size of facility, and type of facility. The impact of odor on surrounding areas is then determined by analyzing the frequency of odor annoyance free days. Feedlot GIS data for this study were derived from the Natural Resources Conservation Service (NRCS), but similar data is often available from county or state level government. This same methodology could be applied to MNRR to help identify the source of anthropogenic odors and the intensity of those odors at given locations.

<u>Overall Condition</u>

Measures	*Reference Condition*	*Condition*
Anthropogenic Odors	Natural ambient condition	

Figure 94. Odorscape condition graphic.

Due to the lack of quantitative data regarding MNRR's odorscape, assessing condition is not possible at this time (Figure 94). Possible anthropogenic odors include feedlots, sewage treatment facilities, and vehicle exhaust. However, these are merely possible odors and other anthropogenic odors may exist. Nevertheless, odorscape has not been measured to analyze intensity or spatial trends in MNRR.

Sources of Expertise
John Macy, Hydrologist, MNRR

Literature Cited

Brewer, S. M., and K. R. Cadwallader. 2004. Overview of odor measurement techniques. Department of Food Science and Human Nutrition. University of Illinois, Urbana, IL.

United States Geological Survey (USGS). 2009. SDSS_1_meter_imagery. GIS Data. Online. (http://seamless.usgs.gov/). Accessed 15 February 2011.

University of Minnesota, Center for Rural Design. No Date. Visualizing OFFSET: identifying and analyzing the spatial relationships between feedlot odor and residential dwellings. University of Minnesota, Center for Rural Design, St. Paul, Minnesota.

4.18 Viewshed

Description
A viewshed is the area that is visible from a particular location. The NPS Organic Act (16 U.S.C. l) implies the need to protect the viewsheds of national parks, monuments, and reservations. Viewsheds can be determined using GIS software; a digital elevation model (DEM) is used in conjunction with a point or line to determine the visible area from that point or line. The points and lines used to calculate viewsheds often represent areas of high visitor use, such as roads, trails, and overlooks. The resulting viewshed layers are analyzed in order to determine the predominant visible characteristics within a viewshed. Important aspects to analyze relate to what management or patrons of the park consider valuable. Often, non-natural features (e.g., agriculture land, buildings, and roads) are considered detrimental to the viewshed in a national park. Missouri National Recreational River was established in part to protect the viewshed of the area.

Measures
- The scenic attributes associated with natural, undeveloped viewsheds.

Reference Conditions/Values
There are two potential reference conditions for viewsheds in MNRR: pre-European settlement and pre-dam. Prior to European settlement along the Missouri River, the area that is now MNRR was largely unaffected by humans, with perhaps some minor impacts from Native American use (Yager, pers. comm., 2011). Post-European settlement and pre-dam, the river system was still natural, but agriculture, industry, and communities were present (Yager, pers. comm., 2011). Often, land cover and land use data provide adequate data for determining the prevalence of non-desired features within a viewshed.

Data and Methods
Staff at MNRR conducted a GIS viewshed analysis, which used a 30-meter DEM layer to calculate areas that are visible from particular points on the river. The objective of this assessment was to identify lands that were highly visible from the Missouri River, lower Niobrara River, and Verdigre Creek, and to use these data to formulate a landscape protection strategy for use in daily management decisions. Line features were digitized for the center of the channel, and along the left and right banklines. Observation points were then generated at half-mile intervals along each line. The viewshed analysis was completed using ArcGIS Spatial Analyst, and represented the lands that are likely visible from the observation points. The analysis did not account for visual obstructions such as trees or developments that rise from the land surface, and thus the area truly visible from the rivers was likely inflated. In this analysis, a one-mile buffer was established out from the park boundary (Yager, pers. comm., 2011). The intent of the one-mile buffer was to limit the area captured in the analysis to represent the distance at which a river recreationalist could identify most artificial intrusions (S. Wilson, pers. comm., 2011)

MNRR also monitors bankline changes in both the 39-mile and 59-mile districts. This effort was initiated in 2004 to establish a baseline for linear feet of bank stabilization, and determine locations of man-made features. Point coordinates were collected using GPS units at the upstream and downstream ends of each bank stabilization segment. Shoreline development

–clusters” contained multiple housing units and those too were mapped by collecting point features at the upstream and downstream location. All other features, such as isolated development structures, boat ramps, boat docks, and water intakes, were mapped as single points.

MNRR also uses photopoint monitoring to document short term and long term changes in viewshed quality. This monitoring includes capturing reference digital images in four directions (downstream, upstream, right bank, and left bank) at each river mile. The method used relies on GPS coordinates and compass bearings to repeat digital photographs year to year. Because of inaccuracies with GPS points, new GPS coordinates and compass bearings are recorded for future reference every time a photograph is taken (Wilson 2010).

Current Condition and Trend

<u>Park Viewsheds</u>

The viewshed of MNRR is no longer in a natural, undeveloped state (Photo 7-10). Human development in and around the river has altered the viewshed in the form of dams, bank stabilization structures, and residential and commercial development. Many of these obstructions enhance the recreational qualities of the park (e.g., boat ramps), but MNRR staff intends to maintain and improve the viewshed on the river. Viewshed is considered when staff review potential development projects along the river. In fact, maintaining a natural viewshed is a primary reason for a recent decline in bank stabilization requests (Yager, pers. comm., 2011). Many measures can be taken to minimize the effects of bank stabilization on viewsheds: soil and seed on bank stabilization, screening of houses with vegetation as presented in the park general management plans, and working with local zoning boards (S. Wilson, pers. comm., 2011). MNRR performs, organizes, and participates in river cleanup events to improve the viewshed via the removal of garbage and other anthropogenic debris (Yager, pers. comm., 2011). Plate 13 displays the viewshed of a portion of 59-Mile district of MNRR (NPS 2009a, b).

Photo 7. Shoreline development in MNRR (Courtesy MNRR).

Photo 8. Shoreline development in MNRR (Courtesy MNRR).

Photo 9. Shoreline development in MNRR (Courtesy MNRR).

Photo 10. Shoreline development in MNRR (Courtesy MNRR).

Threats and Stressor Factors

There are a number of threats to viewsheds in MNRR, especially considering the narrow width of the park. Development around and within the park is a major threat to viewsheds, including houses, agriculture, wind farms, boat ramps and docks, city water towers, and other structures (Yager, pers. comm., 2011). On a larger scale, the greatest impact to viewsheds is the dams on the river and the subsequent power production that not only obstruct the view by their presence but also by changing the natural landscape in the park (Yager, pers. comm., 2011). Finally, bank stabilization features (e.g., rock, broken concrete, and old cars) placed since dam-construction on the Missouri River have altered the natural views of the shoreline (Yager, pers. comm., 2011).

Because private individuals own most of the land surrounding the river, MNRR actively pursues conservation easements to protect viewshed integrity. Some of these easements are cooperative, with state, federal, and non-profit agencies that have similar conservation goals. NPS has also purchased land parcels to protect viewsheds. Even though many private landowners cooperate with the NPS to maintain viewshed integrity, the park cannot directly control all development along the river.

Bridges across the river are another factor that alters viewsheds in MNRR; there are a number of existing bridges, including two across the lower Niobrara River portion of MNRR, one across Veridgre Creek, three within the 59-mile district, and one bridge within the 39-mile district of the park (Yager, pers. comm., 2011). Roads and trails in general are another potential threat to the park's viewshed.

To a lesser degree, transportation such as boats and other watercraft on the river, as well as airplanes, pose a minor threat to the user experience of MNRR's viewshed (Yager, pers. comm., 2011). Trash in the form of old dumps, cars, and other items can also diminish the views for park users (Yager, pers. comm., 2011).

Construction of conservation-related projects also impairs viewsheds in the park. Temporary viewshed obstruction occurs during construction of ESH, in the form of large equipment and barges. Following construction, this habitat appears unnatural: devoid of vegetation and perfectly sculpted for maximum habitat benefit. This habitat is necessary though, as it provides habitat for the endangered bird species in the park (see Chapter 4.7, least tern and piping plover). In order to minimize the negative effects, construction is not allowed from Memorial Day to Labor Day, when most tourist activity occurs in the park.

Data Needs/Gaps

The bankline stabilization shapefiles should continue to be updated as necessary. In addition, photopoint monitoring should continue according to the defined procedures.

Overall Condition

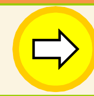
Measures	Reference Condition	Condition
Natural undeveloped viewsheds	Pre-European settlement, pre-dam	

Figure 95. Viewshed condition graphic.

Viewsheds in MNRR are of moderate concern (Figure 95). They are no longer in a completely natural condition, primarily because of human development in and around the park prior to its designation. MNRR strives to keep natural views intact to the greatest degree possible, but some development is inevitable. Although developments such as boat ramps and access areas are not considered part of a natural viewshed, they offer recreational benefits, which correspond with the park's purpose. Maintaining and improving natural viewsheds is also a park priority.

Sources of Expertise

Lisa Yager, MNRR Biologist
Suzanne Gucciardo, LECL Natural Resource Specialist

Literature Cited

National Park Service (NPS). 2009a. mn59buff_view.img. Raster Dataset. GIS Raster. Received from MNRR, 2009.

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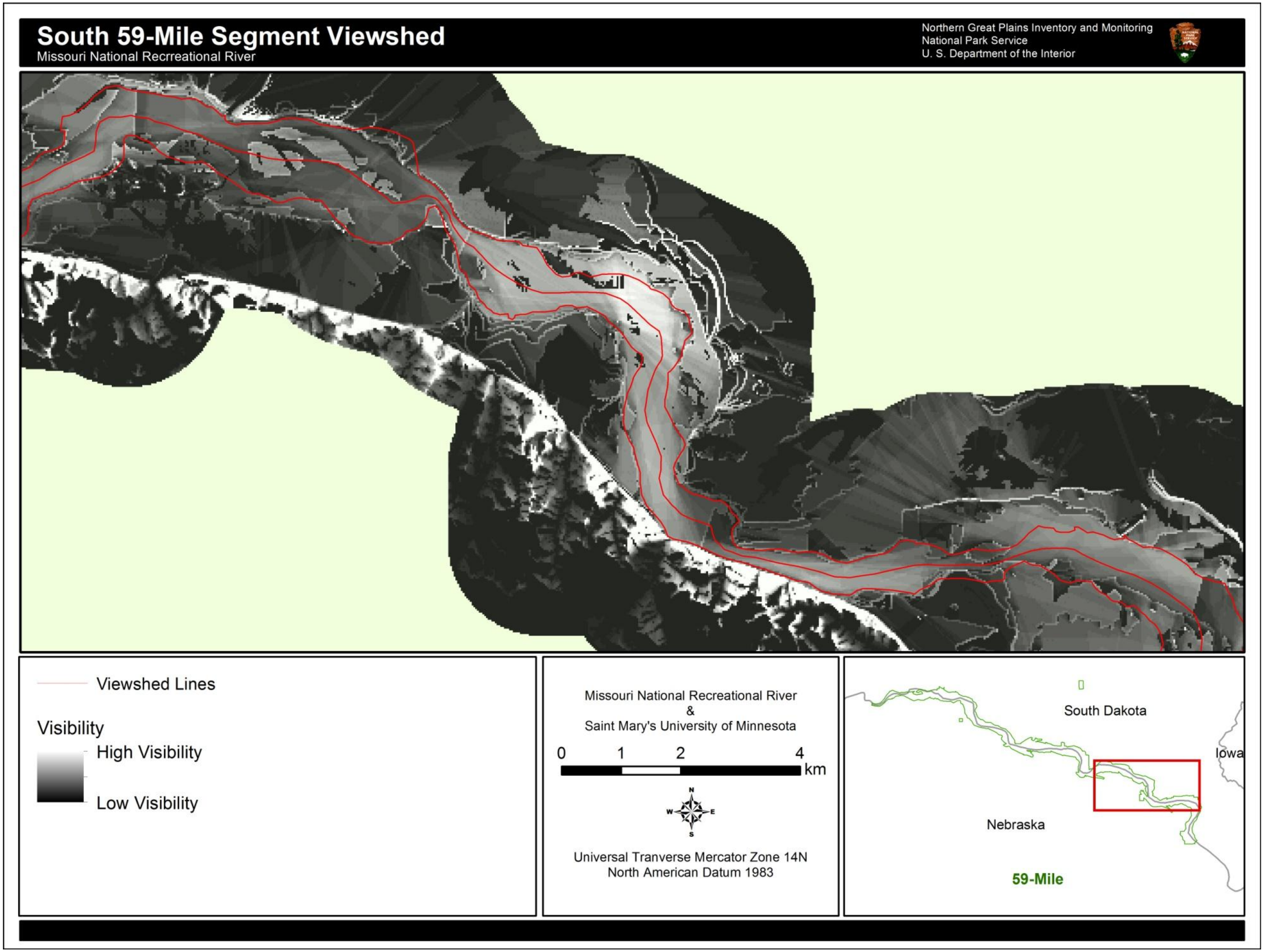


Plate 13. South 59-Mile district viewshed (NPS 2009a, b).

Chapter 5 Discussion

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps/needs are those pieces of information that are currently unavailable, but would help to inform the status or overall condition of a key resource component. Data gaps/needs exist for nearly every key resource component assessed in this NRCA. Table 78 provides a detailed list of the key data gaps by component. Each component section in Chapter 4 discusses these and additional data gaps in more detail.

Some data gaps, if addressed, would provide managers with more information for resource preservation and enhancement for multiple components in the project framework. The data gaps regarding erosional and depositional processes, and aquatic and terrestrial habitats primarily focus on understanding and addressing overarching natural physical and biological processes and how they affect nearly every individual component, such as freshwater invertebrates, pallid sturgeon, and piping plovers.

For many biological components, conducting updated population surveys or increasing the accuracy of current survey methods would provide a more complete understanding of resource conditions. Flow regulation's effect on ecosystem function is a data gap that involves multiple park resources. The Missouri River is an extremely complex system; while a substantial amount of research exists on the effects of flow regulation and general ecological relationships have been identified, there are manyeffects that are not yet understood.

For chemical and physical components (i.e., water quality, air quality, flow regime, and climate) the data gaps relate to continued monitoring or developing more accurate methods for collecting data. Research has not been conducted for some component measures, (i.e., the phenology measure for climate) and baseline data is needed to better understand the overall condition.

There are four components in the framework designated as –goods and services" components: soundscape, odorscape, viewshed, and dark night skies. Quantitative data related to these components in the park is limited, so the current condition could not be determined. For soundscape and dark night skies, national sampling standards have been developed by NPS. Implementing the NPS protocol for these resources would provide a better understanding of the components' conditions. Sampling methods or standards have not been developed for odorscape.

Table 78. Data gaps for MNRR NRCA components.

Component	Data Need / Gap
Interior Least Tern and Piping Plover	- No current data gaps.
Flow Regime	- Minimum daily release data at Fort Randall Dam. - Current flow regime's effect on ecosystem function.
Erosion and Deposition	- There are few studies that document pre-dam erosion.
	- USACE bank and bed analyses are only current through 1994-95 (cross-sections) and 1997-98 (aerial photographs).
	- The sediment budget is not current.
Dark Night Skies	- Quantitative baseline dark night skies monitoring is needed.
Aquatic and Terrestrial Habitats	- An updated wetland distribution study post 1991 is needed to indicate changes and current trends.
	- There are no studies regarding climate patterns and temporal variation effects on MNRR habitats.
	- There are no studies regarding vegetation in diverse seral stages within MNRR (aside from cottonwoods).
	- More information is needed on the red cedar's rate of spread on uplands of MNRR. - Quantification of shallow water habitat
Land Cover Extent / Land Use	- LCLU estimates for Niobrara River and Verdigre Creek are only offered in coarse scale NLCD (2001) data, and a finer resolution dataset is needed.
Soundscape	- Quantitative baseline soundscape monitoring is needed
Native fish populations	- Further research examining the viability and effectiveness of more realistic simulated high flow events by the USACE would be beneficial.
Land Birds	- There are no data documenting pre-dam land bird populations.
	- Continued annual surveys are needed to monitor the current populations of priority species within park boundaries.
Air Quality	- There are no monitoring efforts to track plant and animal species particularly sensitive to increases in pollution.
	- Critical load approach for managing air pollutants and to set goals for resource protection within MNRR.
Northern Leopard Frog	- A vegetation classification (such as the vegetation mapping proposed by Stevens et al. 2010) could help determine potential adult upland and overwintering habitat availability within MNRR.
	- There are currently no data relating to possible competition between plains leopard frogs and northern leopard frogs.
	- There is no spatial distribution information for northern leopard frog in MNRR.
Water Quality	- Analysis of more recently collected data would be useful in determining any changes to water quality since the Weeks et al. (2005) analysis was conducted.
Cottonwood	- No information is currently available describing the extent, regeneration status, or overall condition of cottonwood habitats along the Niobrara River and Verdigre Creek areas within the 39-mile district.

Table 78. Data gaps for MNRR NRCA components. (continued)

Component	Data Need / Gap
Pallid Sturgeon	- Research examining the impacts of introduced contaminants, such as endocrine disruptors, on reproductive ability and success is needed. - Understanding how imminent of a threat Asian carp pose to pallid sturgeon. - Further research examining the viability and effectiveness of more realistic simulated high flow events by the USACE would be beneficial. - Careful monitoring of hatchery-reared versus wild pallid sturgeon populations must continue. - Understand the importance of sicklefin and sturgeon chub for adult feeding.
Odorscape	- There are no quantitative data for natural ambient or anthropogenic odors in MNRR. - The application of the University of Minnesota GIS model to predict feedlot odors would be beneficial in determining the severity of anthropogenic odors.
Freshwater Invertebrates	- There are no studies examining the extent of mussel habitat within rock armored banks, largely due to the complexities of conducting a survey in these areas.
Viewshed	- A viewshed analysis that factors in potential obstructions, such as park development is needed.
Climate	- There are currently no studies related to phenology around MNRR.

5.2 Component Condition Designations

Figure 96 provides a visual representation of the condition assigned to each resource component presented in Chapter 4. It is important to remember that the graphics are simple symbols that display the overall condition and trend assigned to each of the measures. These graphics are beneficial in drawing broad, overarching conclusions, but can be misleading without referring to each component in Chapter 4. The Missouri River is an extremely complex system, and while trends and relationships can be described, understanding all of the factors that determine the condition of a component is more difficult. For example, the number of sand bars from 1941-2006 has increased (from 312 to 634) (Dixon et al. 2010), possibly suggesting the condition of MNRR sandbars is of low concern and that piping plovers and least terns have a large amount of nesting habitat. However, despite the overall increase in total number of sand bars, the total area of sand bars has decreased (1,804 acres to 492 acres) (Dixon et al. 2010), suggesting the condition of MNRR sandbars is of significant concern. Another complication for condition assessments is exemplified by total areal extent of bare sandbar habitat, which was greater in 1998 (2,022 acres) following the high release period (1995-1997) than in pre-dam 1941 (1,804 acres) (Elliot and Jacobson 2006). Overall, this river ecosystem and its physical and biological processes are complex, so it is necessary to refer to the overall condition section for each component for a more in-depth account and explanation of the assigned condition.

Figure 96. Component condition designations.

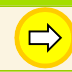
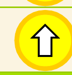
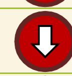
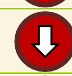
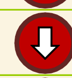
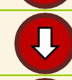
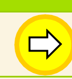
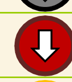
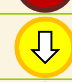
Components	Measures	Reference Condition	Condition
Geographic Extent and Pattern			
Landscape Composition			
Land cover / land use	Land cover/use distribution	Pre-exotics and invasives	
	Ownership pattern	Pre-exotics and invasives	
	Dynamics	Pre-exotics and invasives	
Geomorphology and Hydrology			
Erosional and depositional processes	Island and sandbar development and maintenance processes	Pre-dam	
	Sediment transport and deposition	Pre-dam	
	Bank erosion and channel meander	Pre-dam	
	Channel elevation	Pre-dam	
	Amount and areal extent of armoured streambed	Pre-dam	
Flow regime	Frequency of flood pulses (hydrograph)	Pre-dam	
	Frequency, timing, and duration of discharge	Pre-dam	
Biological Components			
Ecosystem and Community			
Aquatic and terrestrial habitats	Distribution and abundance of diverse native plant communities	Pre-dam	
	Amount of vegetation in diverse seral stages	Pre-dam	
	Amount of vegetated island and sandbar habitat	Pre-dam	
	Wetland distribution, type, and location	Pre-dam	
	Depth and substrate diversity	Pre-dam	
	Amount of chutes, backwater, and shallow-water habitat	Pre-dam	
	Presence of exotics and invasives	Pre-exotics and invasive	

Figure 96. Component condition designations (continued).

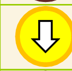
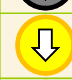
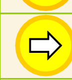
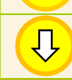
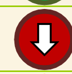
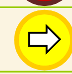
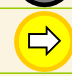
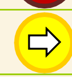
Components	Measures	Reference Condition	Condition
Biological Components			
Biotic Composition			
Cottonwood	Cottonwood age	Pre-dam	
	Cottonwood habitat extent	Predam	
Pallid sturgeon	Habitat diversity	Pre-dam	
	Productivity	Pre-dam	
Piping Plover & Interior Least Tern	Available nesting habitat	Pre-dam	
	Fledge ratios	Pre-dam	
	Population size	Pre-dam	
Land Birds	Species richness and density	Pre-dam	
	Expected bird species	Pre-dam	
	Bald Eagles	Pre-dam	
	Osprey	Pre-dam	
Native fish populations	Abundance	Pre-dam	
Northern leopard frog	Habitat availability	Pre-dam	
Freshwater invertebrates	Habitat availability	Pre-dam	

Figure 96. Component condition designations (continued).

Components	Measures	Reference Condition	Condition
Chemical and Physical Characteristics			
Water quality	Turbidity	Natural variability; "Natural" spatial/temporal patterns	
	Measures of velocity	Natural variability; "Natural" spatial/temporal patterns	
	Presence of nutrients	EPA standard; "Natural" spatial/temporal patterns	
	Water temperature	"Natural" spatial/temporal patterns	
	Agricultural chemicals	EPA standard; "Natural" spatial/temporal patterns	
	Fecal coliform bacteria	EPA standard; "Natural" spatial/temporal patterns	
	pH	EPA standard; "Natural" spatial/temporal patterns	
	Specific conductance	Natural spatial/temporal patterns	
	Dissolved oxygen	EPA Standard; "Natural" spatial/temporal patterns	
Air quality	Mercury	EPA air quality criterion; "Natural" spatial/temporal patterns	
	Nitrogen	EPA air quality criterion; "Natural" spatial/temporal patterns	
	Particulate matter (Visibility)	EPA air quality criterion; "Natural" spatial/temporal patterns	
	Ozone	EPA air quality criterion; "Natural" spatial/temporal patterns	
	Sulfer	EPA air quality criterion; "Natural" spatial/temporal patterns	
Climate	Phenologic relationships (onset and duration of greeness)	Period of record	
	Precipitation pattern (change in frequency and amount)	Period of record	
	Temperature (change in pattern and range)	Period of record	
Goods and Services			
Human Values			
Soundscape	Ambient sound level	Undeveloped park experience	
	Distribution of non-natural sounds	Undeveloped park experience	
Dark night skies	Schaff scale scores	Pre-European settlement - absence of anthropogenic light	
	Darkness - V magnitude	Pre-European settlement - absence of anthropogenic light	
Odorscape	Anthropogenic odors	Natural ambient condition	
Viewshed	Natural undeveloped viewsheds	Pre-European settlement, pre-dam	

The assigned condition for component measures in the project framework was variable. Data are unavailable or insufficient for many component measures and because of this, condition is not defined. Many condition designations relied on the expert knowledge of park staff, NGPN resource experts, or non-NPS researchers. In other instances, reference condition data were unavailable making quantitative comparison invalid.

For nearly every MNRR component, the reference condition assigned was pre-dam or natural state. This reference condition showcases the major changes the Missouri River has undergone since flow regulation began, and the effect flow regulation can have on an entire river ecosystem. However, when comparing the current condition of a component to its pre-dam condition, nearly every component rates lower today. This results in a rather grim picture of the Missouri River as it stands today, with nearly every component of moderate or significant concern (yellow or red in the condition graphic table). However, the pre-dam reference condition may not be an attainable management goal due to differing interests (navigation, power generation, recreation, biodiversity). While the Missouri River may never return to its pre-dam condition, many organizations (NPS, USGS, USFWS, USACE, SDGFP, NGP, local universities, and others) are working to restore the ecosystem to the best attainable condition.

5.3 Park-wide Condition Observations

The relationship between flow regime, erosional and depositional processes, and aquatic and terrestrial habitats is the crux for understanding natural physical and biological processes and interactions and how these affect nearly every individual component, such as riparian vegetation, freshwater invertebrates, pallid sturgeon, and piping plovers.

The natural physical processes in unregulated rivers include geomorphically effective floods responsible for fluvial disturbance causing habitat turnover (Petts and Gurnell 2005), channel form adjusted to available discharge and character and quantity of sediment (Leopold et al. 1964), lateral connectivity and inundation of floodplains with direct inputs of riparian detritus (Ward et al. 2001), water temperature flux, and channel form determining water distribution within the channel expressed as physical habitat – the spatial distribution of depth, velocity and substrate (Jacobson and Galat 2008).

Ward et al. (2001) conclude that there is –an incomplete appreciation of the complex nature of ecological patterns and processes in natural river ecosystems, including the critical role of natural disturbance.” Stanford et al. (1996) found that levels of ecosystem biodiversity and bioproduction generally are related to the intensity, frequency, and duration of disturbance events.

Making the connection between natural processes and biological interactions in rivers is a difficult task due to a lack of fundamental knowledge of their natural complexity and dynamics (Ward et al. 2001) and because rivers are open systems whose physical structure changes dramatically over many spatial and temporal scales (Thorp et al. 2006). Regulated rivers still have some of the physical processes of unregulated rivers: a channel form adjusted to available discharge and character and quantity of sediment; channel form determining water distribution within the channel expressed as physical habitat – the spatial distribution of depth, velocity and substrate; direct inputs of riparian detritus from eroding river banks; and some lateral connectivity and inundation of floodplains. Graf (2006) suggests that ―regulated rivers are shrunken, simplified versions of former unregulated rivers."

Stanford et al. (1996) identify three fundamental commonalities that emerge from the large literature on the ecology of regulated rivers:

- Habitat diversity is substantially reduced,
- Native biodiversity decreases and non-native species proliferate,
- Biophysical conditions reset predictably in relation to influences of tributaries and as distance downstream from the dam increases.

The following discussion will attempt to address specific changes in physical and biological processes and interactions on the MNRR 39-mile and 59-mile reaches.

The resource landscape at MNRR is diverse and complex, with nearly every component affected by flow regime in some way. Changes in flow regime altered erosional and depositional processes, which affects aquatic and terrestrial habitats that are necessary for native plants and animals of the Missouri River ecosystem. Specifically, dam operations have substantially altered the flow regimes of the 39-mile and 59-mile reaches, compared to a ―natural" or ―pre-dam" condition. Overall, the Missouri River post-dam flow regime has become largely homogenized, with smaller peak flows and larger low flows:

- Post-dam average peak flow is about 27% of the pre-dam average; average post-dam low flows are about 34% higher than average pre-dam low flows.
- The highest post-dam peak flow is about 15% of the highest pre-dam peak flow.
- Pre-dam peak flows were typically bi-modal, occurred from March to July, and were of short duration; post-dam peak flows typically are plateau-like, occurring over long periods of time from July to December.
- Duration of post-dam peak flows is longer than pre-dam conditions; post-dam low flow period averages 24% less than the pre-dam low flow period.

Pre-dam conditions supported a river system in dynamic equilibrium. The natural processes and interactions of the river were modified by flow regulation, with components of the ecosystem influencing and reacting to other components. For example, not only does flow affect cottonwood regeneration, but cottonwood regeneration also affects flow (by the amount of woody debris entering the river). After the dams were installed, the Missouri River channel went through a period of rapid adjustment to the altered sediment and flow regimes. Today, the river is not responding as aggressively as it did from 1955 to 1985, but is still adjusting to the altered sediment and flow regimes. As a result of dam construction and flow regulation, the Missouri River experienced extensive changes in sediment transport and deposition, amounts of woody debris, and channel migration. In addition, sediment transport rates have changed as peak discharges in the post-dam era have been lowered (lower stream power leads to reduced transport capacity). Bank stabilization and changes in sediment supply and transport have led to increased erosion of stream beds, sandbars, and islands, subsequently altering aquatic and terrestrial habitats. Additionally, the absence of spring floods (comparable to pre-dam levels) has altered riparian forests, backwaters, chutes, and wetlands.

Due to the lack of high flow events and changes in land use, cottonwood regeneration is not matching the pace of the losses in MNRR (Dixon et al. 2010). Seedling establishment is limited because of a lack of sandbar formation and reduced rates of channel migration due to the loss of periodic flooding and the effects of bank stabilization. In total, riparian forests in the historic floodplain have seen a decrease of 18% and 45% in the 39 and 59-mile reaches, respectively (Dixon et al. 2010). These decreases are largely due to lack of cottonwood regeneration, the forming of the Niobrara River delta, and land conversion to agriculture since 1892 (Dixon et al. 2010). These decreases are significant, because species such as bald eagles and other birds utilize these trees for nesting habitat. In addition, the loss of riparian forests, coupled with significant decreases in bank erosion, has reduced woody debris in the Missouri River. This reduction in woody debris has affected the entire ecosystem: contributing to early channel incision, decreasing bar and island formation, increasing sediment transport rates, altering channel migration, and eliminating habitat for many aquatic insects (Montgomery et al. 2003).

The condition of least tern and piping plover is of significant concern due to sandbar habitat reduction compared to pre-dam conditions. While total number of sandbars has increased from 1941 to 2006 (from 312 to 634), the total area of sandbars has significantly decreased (from 1,804 to 492 acres) during that same time period (Dixon et al. 2010). This decrease in sandbar habitat area is due to several factors, including lowered intensity, frequency, and duration of flooding events, loss of woody debris in the main channel, and channel incision (Elliot and Jacobson 2006). The overall change in sediment load as a result of altered flow regime also affects sandbar habitat formation. USACE is constructing sandbar habitat to provide nesting areas for piping plovers and interior least terns. In addition, many of the goals regarding population size and fledge rations defined in the least tern and piping plover recovery plans and BiOp are unattained.

Native fish populations of MNRR were determined to be of moderate concern; because of the altered hydrograph and the suite of associated changes (Berry et al. 2007), loss of habitat and spawning cues may be affecting population viability. The post-dam food web has a different composition of macroinvertebrates and minnows as a result of changes in flow regime and habitat availability (Hesse et al. 1993, USGS 2004, Berry et al. 2007). Sicklefin and sturgeon chubs are now federally endangered. The loss of backwater and off-channel habitats has significantly decreased the amount of macroinvertebrate prey in the Missouri River available for native fish (Mestl and Hesse 1993). In addition, fish that require upstream migration for spawning are limited by the Gavins Point and Fort Randall Dam (Hesse et al. 1993, Berry et al. 2007). Specifically, fish in the 39-mile segment cannot travel up or downstream. This not only affects their spawning behavior, but also limits the amount of mussel larvae that can attach to host fish and move upstream, resulting in a concentration of unionid mollusks below the Gavins Point Dam in the lower Missouri River and potentially threatening native mussel populations of the Missouri River.

Pallid sturgeon were determined to be of significant concern, because while some spawning in the 59-mile reach has been documented (USGS 2007), they do not appear to be reproducing in large numbers. No firm conclusions have been drawn as to why pallid sturgeon are not flourishing in the Missouri River, but there are several factors that likely influence their low numbers: elimination of upstream migratory movement, obstructed normal flow patterns, reduction in sediment loads, lower turbidity levels, and altered water temperatures (Hesse and

Schmulback 1991). In addition, pallid sturgeon are thought to require spawning cues (a high flow event in the spring), and the homogenized flow of the Missouri River may be eliminating the cues necessary for pallid sturgeon to begin upstream migration for spawning (DeLonay et al. 2009). Many of the problems that pallid sturgeon experience relate to food and habitat availability and spawning capabilities which are affected by dams and flow regulation. In the 39-mile reach, power peaking from the Fort Randall Dam is altering the turbidity, temperature, and depth of water on a daily basis. These daily changes in habitat, along with a suite of other post-dam habitat changes (i.e., migratory barriers and changes in substrate), make it difficult for pallid sturgeon to successfully survive and reproduce in the 39-mile reach.

The presence of non-native species poses a significant threat for several components in MNRR. While no adult zebra mussels have colonized MNRR, various species of Asian carp are known to exist in the 59-mile reach of MNRR. The Gavins Point Dam acts as a barrier for upstream dispersal of Asian Carp, limiting them to the lower Missouri River. Asian carp can alter the natural food web of the Missouri River, as they compete with filter feeding fish for zooplankton and phytoplankton food sources (CERC 2003). Some terrestrial invasive species, such as leafy spurge and Canada thistle , are present near MNRR (Bow Creek bottoms, and they have the ability to overtake plant communities if left unchecked (Kottas and Stubbendieck 2005).

The flow regime of the Missouri River is the primary driver for the condition of most components in MNRR, but releases from dams are based on reservoir inflow, which is driven by climate/weather patterns. High inflow can fill drought reduced reservoirs or fill reservoirs to flood pool levels. In addition, releases from dams are higher when reservoirs are full and lower during times of drought (Macy, pers. comm., 2011). The extent to which climate patterns affect MNRR has not yet been studied, but the influence climate has on dam operations directly influences several components throughout the Missouri River ecosystem.

Land development along the Missouri River is mainly associated with agricultural uses, with percent composition of agricultural land use in the 59-mile reach increasing from less than one percent of the historic floodplain (bluff to bluff) in 1892 to more than 76% today (Dixon et al. 2010). This increase affects many different habitats throughout MNRR. Land conversion to agricultural use has greatly reduced riparian forests, which are a vital part of balancing the dynamic equilibrium of the Missouri River. In total, Yager (2010) found a 64.6% decrease in total off-channel habitats from 1941 to 2008, and while development is only one factor in this net decrease, it still plays an extensive role in eliminating natural habitat.

The lack of an ecosystem management strategy is a concern for sustaining natural ecological processes of the Missouri River. Several management strategies have been developed and implemented for individual components (i.e., pallid sturgeon, least tern, piping plover, and a cottonwood management plan), but an overall management strategy needs to be developed that looks to restore the physical processes of the river (i.e., sediment and flow regimes), which would benefit biodiversity and biocomplexity. Rather, management strategies are focused at the individual resource level and do not consider the overall changes in physical processes that are needed. In addition, several different agencies are working to ensure the Missouri River is in the best condition possible, but many of these agencies have differing goals and responsibilities. Many of the problems affecting the condition of the analyzed components are due to flow regulation and the loss of a naturalized flow regime (Galat and Lipkin 2000). According to

Jacobson and Galat (2008), the efficacy of restoration of a ―naturalized" flow regime to support ecosystem function requires ―naturalized morphology" of the stream channel, which is available to some degree in MNRR reaches. However, current management goals constrain restoration of a naturalized flow regime. For example, USACE must ensure the lower Missouri River receives navigation flow levels, but this requires flow alteration to the Missouri River that may be unfavorable to certain native species. These are complications and challenges that Missouri River natural resource managers must resolve for a management strategy beneficial to ecosystem function.

Sources of Expertise
John Macy, MNRR Hydrologist

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Appendices

Appendix A. Land cover change in MNRR by district from 1992 to 2001 (Fry et al. 2009, 1992/2001 NLCD change dataset – clipped to park boundaries).

Land Cover (Anderson Level 1)		59-mile District				39-mile District			
Unchanged	**Change Class**	**ha**	**acres**	**% composition by total area**	**% composition of total change area**	**ha**	**acres**	**% composition (by total area)**	**% composition of total change area**
Open Water		5.976	14,768	41.2	--	5,613	13,871	41.6	--
Wetlands		2,560	6,325	17.7	--	4,668	11,535	34.6	--
Agriculture		2,363	5,840	16.3	--	258	638	1.9	--
Forest		1,693	4,185	11.7	--	596	1,472	4.4	--
Grassland/Shrub		687	1,698	4.7	--	1,113	2,749	8.2	--
Urban		304	752	2.1	--	224	554	1.7	--
Barren		63	155	0.4	--	14	34	0.1	--
	Agriculture to Open Water	475	1,174	3.3	56.4	203	503	1.5	20.2
	Open Water to Barren	208	514	1.4	24.7	15	36	0.1	1.5
	Open Water to Wetlands	99	244	0.7	11.7	52	128	0.4	5.1
	Open Water to Agriculture	21	52	0.1	2.5	--	--	--	--
	Open Water to Grassland/Shrub	16	41	0.1	2.0	0	1	0.0	0.0
	Agriculture to Wetlands	11	26	0.1	1.3	61	150	0.4	6.0
	Agriculture to Urban	6	15	0.0	0.7	7	17	0.1	0.7
	Open Water to Urban	4	10	0.0	0.5	1	1	0.0	0.1
	Agriculture to Grassland/Shrub	2	4	0.0	0.2	103	253	0.8	10.2
	Agriculture to Barren	0	1	0.0	0.1	1	2	0.0	0.1

The total area of classified as change was 843 ha (2,082 acres) in the 59-mile district and 1009 ha (2,494 acres) in the 39-mile district .

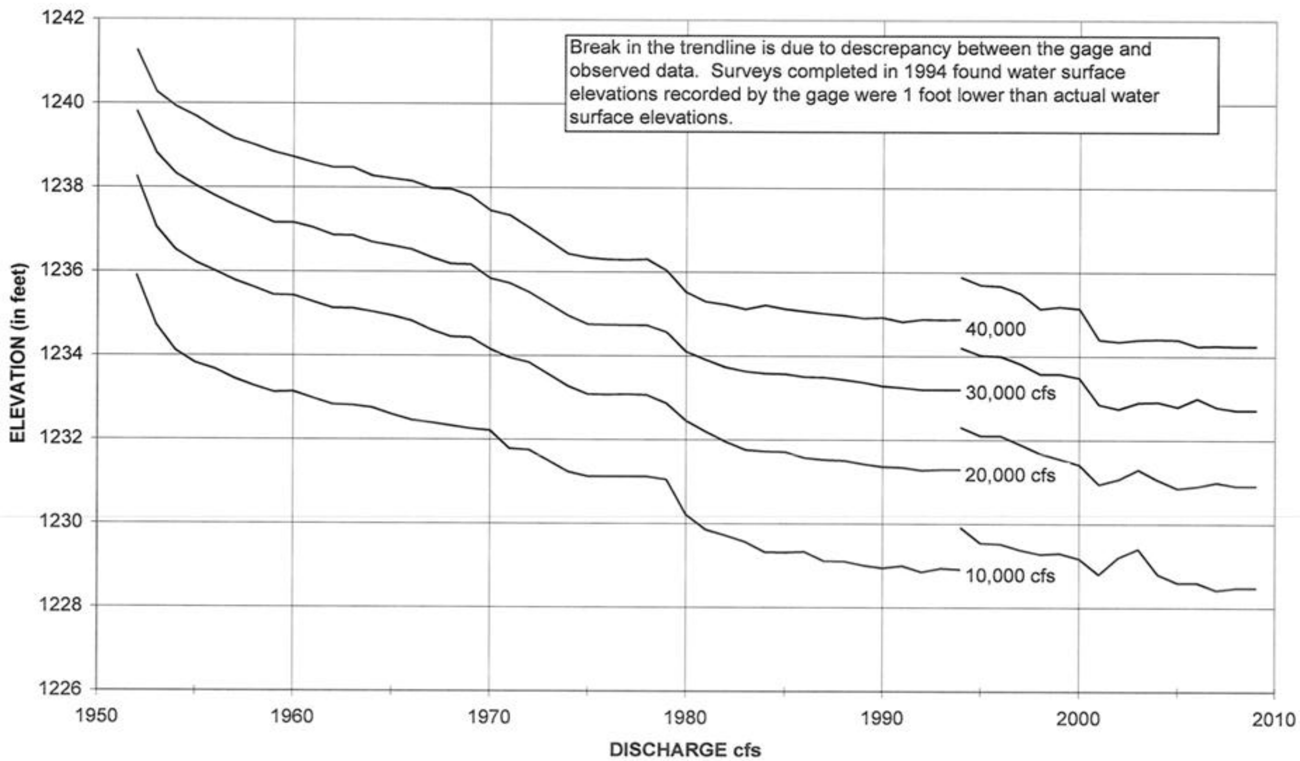
Appendix A. Land cover change in MNRR by district from 1992 to 2001 (Fry et al. 2009, 1992/2001 NLCD change dataset – clipped to park boundaries). (continued)

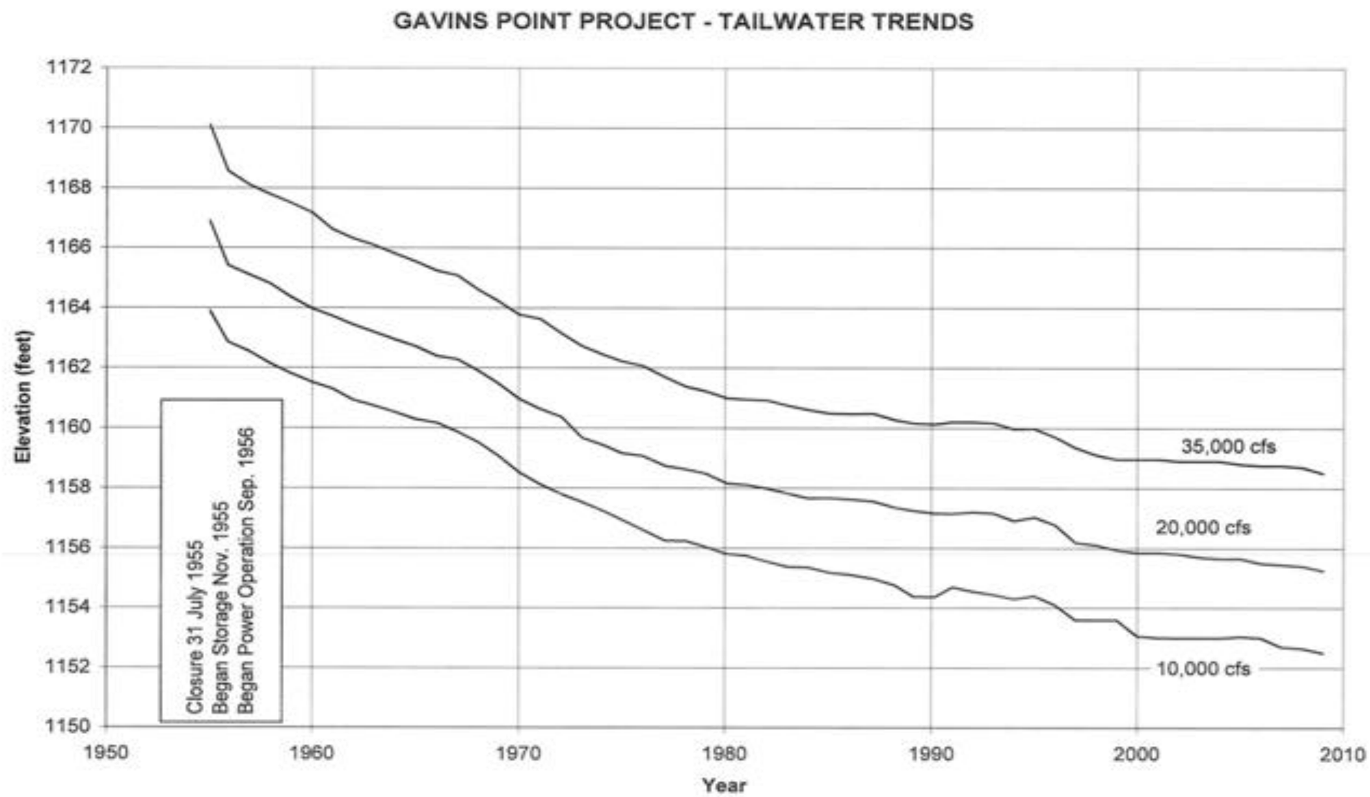
Land Cover (Anderson Level 1)		**59-mile District**				**39-mile District**			
Unchanged	**Change Class**	**ha**	**acres**	**% composition by total area**	**% composition of total change area**	**ha**	**acres**	**% composition (by total area)**	**% composition of total change area**
	Wetlands to Open Water	--	--	--	--	337	833	2.5	33.4
	Grassland/Shrub to Wetlands	--	--	--	--	173	428	1.3	17.2
	Grassland/Shrub to Open Water	--	--	--	--	35	86	0.3	3.5
	Grassland/Shrub to Urban	--	--	--	--	8	19	0.1	0.8
	Grassland/Shrub to Agriculture	--	--	--	--	7	17	0.1	0.7
	Grassland/Shrub to Forest	--	--	--	--	6	14	0.0	0.6
	Wetlands to Urban	--	--	--	--	1	2	0.0	0.1
	Wetlands to Barren	--	--	--	--	1	2	0.0	0.1
	Wetlands to Grassland/Shrub	--	--	--	--	0	0	0.0	0.0
	totals:	8,518	35,8045			13,495*	33,347		

The total area of classified as change was 843 ha (2,082 acres) in the 59-mile district and 1009 ha (2,494 acres) in the 39-mile district .

Appendix B. Missouri River tailwater trends.

FORT RANDALL PROJECT - TAILWATER TRENDS




GAVINS POINT PROJECT - TAILWATER TRENDS
Elevation (feet)
1172
1170
1168
1166
1164
1162
1160
1158
1156
1154
1152
1150
1950
1960
1970
1980
1990
2000
2010
Year
Closure 31 July 1955
Began Storage Nov. 1955
Began Power Operation Sep. 1956
35,000 cfs
20,000 cfs
10,000 cfs

Appendix C. Land cover categories used for GIS mapping of 2006 land cover (Dixon et al. 2010).

1. Water/bare sandbar
    11. river main channel (open water, sand, submersed aquatic vegetation)
    12. oxbows lake/backwater – off channel or connected
    13. unvegetated sandbar
    14. farm ponds, other open water habitats
    15. Missouri River reservoir
    16. tributary river channel
    17. constructed sandbar (emergent sandbar habitat - ESH)
    18. unvegetated sandbar tributary
2. Forest and woodland (forest has woody plants >6 m tall with >50% cover, woodland has woody plants >6m tall with 25-50% overstory)
    20. non-cottonwood (cottonwood <15%) floodplain forest
    21. forest (cottonwood at least 15%)
    22. woodland (cottonwood at least 15%)
    23. planted trees (farm woodlots, shelterbelts, orchards)
    24. upland forest (not in floodplain)
    25. non-cottonwood (cottonwood <15%) woodland
    27. planted cottonwood trees
3. Shrubland – woody plants <6 m tall account for 25-100% cover
    30. shrubland (with cottonwood)
    31. non-cottonwood shrubland
4. Low vegetation – herbaceous or woody
    41. upland grassland, pasture
    42. riparian low shrub with cottonwood (successional sandbar sites, may include a mixture of low woody and herbaceous vegetation)
    42. riparian low shrub with cottonwood (successional sandbar sites, may include a mixture of low woody and herbaceous vegetation)
    43. emergent wetland (off river)
    44. riparian low herbaceous vegetation
    45. riparian low shrub w/o cottonwood
    46. wet meadow / mesic grassland
5. Planted/cultivated – row crops
    50. agricultural row crops
6. Developed/urban
    61. town, city (e.g., Vermillion)
    62. farmstead and building complex (excluding woodlots)
    63. commercial/Industrial/Transportation (roads, parking lots, boat landings)
    64. urban/recreational grasses (developed right-of-ways, golf courses)
    65. cabin or managed cottonwood areas
7. Barren – bare sand, etc. (not in river channel, but could include island interior)
    70. barren
8. Other – specify in notes
    80. other, disturbed

    81. other, abandoned agriculture

9. Areas inundated by filling reservoir (1950s for segment 9 only)
    91. flooded forest
    92. flooded open area (probably agricultural cropland)

Appendix D. Definitions and codes used to classify standard Missouri River habitats in the long-term pallid sturgeon and associated fish community sampling program. Directly reproduced from Stukel et al. 2010 and Shuman et al. 2010.

Code	Habitat	Scale	Definition
BRAD	Braided Channel	Macro	An area of the river that contains multiple smaller channels and is lacking a readily identifiable main channel (typically associated with unchannelized sections)
CHXO	Main Channel Cross Over	Macro	The inflection point of the thalweg where the thalweg crosses from one concave side of the river to the other concave side of the river, (i.e., transition zone from one-bend to the next bend). The upstream CHXO for a respective bend is the one sampled.
CONF	Tributary Confluence	Macro	Area immediately downstream, extending up to one bend in length, from a junction of a large tributary and the main river where this tributary has influence on the physical features of the main river
DEND	Dendric	Macro	An area of the river where the river transitions from meandering or braided channel to more of a treelike pattern with multiple channels (typically associated with unchannelized sections)
DRNG	Deranged	Macro	An area of the river where the river transitions from a series of multiple channels into a meandering or braided channel (typically associated with unchannelized sections)
ISB	Main Channel Inside Bend	Macro	The convex side of a river bend
OSB	Main Channel Outside Bend	Macro	The concave side of a river bend
SCCL	Secondary Channel-Connected Large	Macro	A side channel, open on upstream and downstream ends, with less flow than the main channel, "large" indicates this habitat can be sampled with trammel nets and trawls based on width and/or depths > 1.2 m
SCCS	Secondary Channel-Connected Small	Macro	A side channel, open on upstream and downstream ends, with less flow than the main channel, "small" indicates this habitat cannot be sampled with trammel nets and trawls based on width and/or on depths < 1.2 m
SCN	Secondary Channel-non-connected	Macro	A side channel that is blocked at one end
TRIB	Tributary	Macro	Any river or stream flowing into the Missouri River
TRML	Tributary Mouth Large	Macro	Mouth of entering tributary whose mean annual discharge is > 20 m3/s, and the sample area extends 300 m into the tributary
TRMS	Tributary Mouth Small	Macro	Mouth of entering tributary whose mean annual discharge is < 20 m3/s, mouth width is > 6 m wide and the sample area extends 300 m into the tributary
WILD	Wild	Macro	All habitats not covered in the previous habitat descriptions
BARS	Bars	Meso	Sandbar or shallow bank-line areas with depth < 1.2 m
POOL	Pools	Meso	Areas immediately downstream from sandbars, dikes, snags, or other obstructions with a formed scour hole > 1.2 m
CHNB	Channel Border	Meso	Area in the channelized river between the toe and the thalweg, area in the unchannelized river between the toe and the maximum depth
TLWG	Thalweg	Meso	Main channel between the channel borders conveying the majority of the flow
ITIP	Island tip	Meso	Area immediately downstream of a bar or island where two channels converge with water depths > 1.2 m

Appendix E. Species of land birds that have been detected in MNRR. Lists used include the NPS Certified Species List, Benson and Dixon (2009), and Benson (2011).

Species Common Name	NPS Certified Species List	Benson and Dixon (2009)	Benson (2011)
Cooper's hawk	x		
sharp-shinned hawk	x		
red-tailed hawk	x		x
rough-legged hawk	x		
broad-winged hawk	x		
Swainson's hawk	x		
bald eagle	x		x
osprey	x		
horned lark	x		x
belted kingfisher	x		x
chimney swift	x		
cedar waxwing	x	x	x
whip-poor-will	x		x
common nighthawk	x		
brown creeper	x		
blue-gray gnatcatcher	x		
turkey vulture	x		x
yellow-billed cuckoo	x		x
black-billed cuckoo	x		x
rock dove	x		
mourning dove	x	x	x
american crow	x		x
blue jay	x	x	x
black-billed magpie	x		
merlin	x		
american kestrel	x		x
red-winged blackbird	x		x
Le Conte's sparrow	x		
grasshopper sparrow	x		

Appendix E. Species of land birds that have been detected in MNRR. Lists used include the NPS Certified Species List, Benson and Dixon (2009), and Benson (2011). (continued)

Species Common Name	NPS Certified Species List	Benson and Dixon (2009)	Benson (2011)
lark bunting	x		
lapland longspur	x		
northern cardinal	x	x	x
pine siskin	x		
American goldfinch	x	x	x
house finch	x		
purple finch	x		
lark sparrow	x	x	x
black-throated blue warbler	x		
bay-breasted warbler	x		
yellow-rumped warbler	x		
yellow-throated warbler		x	
blackburnian warbler	x		
magnolia warbler	x		
palm warbler	x		
chestnut-sided warbler	x		
yellow warbler	x	x	x
pine warbler	x		
blackpoll warbler	x		
cape may warbler	x		
black-throated green warbler	x		
bobolink	x		
common yellowthroat	x		x
yellow-breasted chat	x		x
Baltimore oriole	x		x
orchard oriole	x		x
dark-eyed junco	x		
swamp sparrow	x		
Lincoln's sparrow	x		

Appendix E. Species of land birds that have been detected in MNRR. Lists used include the NPS Certified Species List, Benson and Dixon (2009), and Benson (2011). (continued)

Species Common Name	NPS Certified Species List	Benson and Dixon (2009)	Benson (2011)
song sparrow	x	x	x
black-and-white warbler	x		x
brown-headed cowbird	x	x	x
Connecticut warbler	x		
mourning warbler	x		
northern parula	x		
savannah sparrow	x		
fox sparrow	x		
blue grosbeak	x		
indigo bunting	x		x
rose-breasted grosbeak	x	x	x
eastern towhee	x	x	x
spotted towhee	x		x
scarlet tanager	x	x	x
snow bunting	x		
vesper sparrow	x		
great-tailed grackle	x		
common grackle	x	x	x
ovenbird	x	x	x
northern waterthrush	x		
American redstart	x	x	x
dickcissel	x		x
American tree sparrow	x		
clay-colored sparrow	x		
chipping sparrow	x	x	x
field sparrow	x	x	x
western meadowlark	x		x
orange-crowned warbler	x		
golden-winged warbler	x		

Appendix E. Species of land birds that have been detected in MNRR. Lists used include the NPS Certified Species List, Benson and Dixon (2009), and Benson (2011). (continued)

Species Common Name	NPS Certified Species List	Benson and Dixon (2009)	Benson (2011)
Tennessee warbler	x		x
blue-winged warbler	x		
Nashville warbler	x		
Canada warbler	x		
Wilson's warbler	x		
yellow-headed blackbird	x		x
white-throated sparrow	x		
white-crowned sparrow	x		
Harris's sparrow	x		
barn swallow	x		x
cliff swallow	x		x
purple martin	x		
bank swallow	x		x
northern rough-winged swallow	x		x
tree swallow	x		x
northern shrike	x		
loggerhead shrike	x		
gray catbird	x		x
brown thrasher	x	x	x
American pipit	x		
hermit thrush	x		
gray-cheeked thrush	x		
Swainson's thrush	x		
wood thrush	x	x	x
eastern bluebird	x	x	x
American Robin	x	x	x
northern bobwhite	x		x
black-capped chickadee	x	x	x
house sparrow	x		

Appendix E. Species of land birds that have been detected in MNRR. Lists used include the NPS Certified Species List, Benson and Dixon (2009), and Benson (2011). (continued)

Species Common Name	NPS Certified Species List	Benson and Dixon (2009)	Benson (2011)
wild turkey	x		x
gray partridge	x		
ring-necked pheasant	x		x
northern flicker	x	x	x
red-bellied woodpecker	x		x
red-headed woodpecker	x	x	x
downy woodpecker	x		x
hairy woodpecker	x	x	x
yellow-bellied sapsucker	x		
ruby-crowned kinglet	x		
golden-crowned kinglet	x		
red-breasted nuthatch	x		
white-breasted nuthatch	x	x	x
long-eared owl	x		
great horned owl	x		x
eastern screech-owl	x		
ruby-throated hummingbird	x		x
marsh wren	x		x
sedge wren	x		x
carolina wren	x		
house wren	x	x	x
eastern wood-pewee	x	x	x
alder flycatcher	x		x
yellow-bellied flycatcher	x		
least flycatcher	x		x
willow flycatcher	x	x	x
great crested flycatcher	x	x	x
eastern phoebe	x	x	x
Say's phoebe	x		

Appendix E. Species of land birds that have been detected in MNRR. Lists used include the NPS Certified Species List, Benson and Dixon (2009), and Benson (2011). (continued)

Species Common Name	NPS Certified Species List	Benson and Dixon (2009)	Benson (2011)
eastern kingbird	x	x	x
western kingbird	x		x
Bell's vireo	x		x
yellow-throated vireo	x		x
warbling vireo	x	x	x
red-eyed vireo	x	x	x
Philadelphia vireo	x		
blue-headed vireo	x		
northern mockingbird			x

Appendix F. USGS gaging station data: Missouri River, Choteau Creek, Niobrara River, James River, and Vermillion River. NPPD data from Spencer Hydro Dam on the Niobrara River.

Site	DO (mg/L)	Turbidity (NTU)	pH	Phosphorus (filtered, as mg/L)	Specific Conductance (μS/cm @ @25°C)	Temperature (°C)	Atrazine
06453120 Missouri River above Choteau Creek near Verdel, NE (1990 – 2002)	10 (103) [1]		8.1 (104)		787 (104)	13.0 (103)	
06453252 Choteau Creek near Dante, SD (1985 – 2002)	9.7 (84)	24.4 (25)	7.9 (99)	0.17 (37)	2233 (99)	13.3 (100)	
06453255 Choteau Creek near Avon, SD (1985 – 2009)					1659 (201)	12.9 (204)	
06453300 Choteau Creek below Avon, SD (1990-2002)	10.6 (72)		8.0 (74)		1819 (75)	16.1 (10)	
06453305 Missouri River below Choteau Creek near Verdel, NE (1985 – 2010)	10.4 (260)	2.9 (19)	8.3 (281)	0.006 (9)	762 (280)	13.2 (280)	0.023 (8)
06465500 Niobrara River at Verdel, NE	10.3 (78)	67.7 (39)	8.2 (76)	0.07 (34)	280 (75)	13.1 (79)	
06467500 Missouri River at Yankton, SD (1985 -2008)	11.5 (301)	9.2 (5)	8.3 (319)	0.01 (42)	727 (435)	11.1 (453)	0.04 (58)
06478513 James River near Yankton, SD (1985 - 2004)					1372 (131)	13.1 (138)	
06478920 Vermillion River near Centerville, SD (1992-1993)					599 (7)	11.8 (7)	
06479000 Vermillion River near Wakonda, SD (1985 - 2009)			8.1 (46)		1260 (95)	13.3 (46)	

Appendix F. USGS gaging station data: Missouri River, Choteau Creek, Niobrara River, James River, and Vermillion River. NPPD data from Spencer Hydro Dam on the Niobrara River. (continued)

Site	DO (mg/L)	Turbidity (NTU)	pH	Phosphorus (filtered, as mg/L)	Specific Conductance (µS/cm @ @25°C)	Temperature (°C)	Atrazine
06479010 Vermillion River near Vermillion, SD (1985 - 2009)	9.7 (45)		8.1 (48)		1414 (302)	13.0 (305)	
Spencer Hydro Dam (Spring, 2006-2011) [2]	9.9 (40)		8.3 (39)			9.4 (40)	
Spencer Hydro Dam (Fall, 2006-2010) [2]	8.2 (30)		8.0 (30)			13.8 (30)	

[1]Values in parentheses refer to number of samples.
[2]Samples collected at Highway 281.

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