National Park Service
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Natural Resource Stewardship and Science

Knife River Indian Villages National Historic Site

Natural Resource Condition Assessment

Natural Resource Report NPS/ NPS/KRI/NRR—2014/775

ON THE COVER
North American porcupine browsing in a silver buffaloberry at Knife River Indian Villages National Historic Site
Photograph by: John Moeykens, Knife River Indian Villages National Historic Site

Knife River Indian Villages National Historic Site

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program aims to provide documentation about the current conditions of important park natural 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 KNRI 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); and report program performance (e.g., Department of the Interior's Strategic Plan "land health" goals, Government Performance and Results Act).

The objectives of this assessment are to evaluate and to report on current conditions of key park resources, to evaluate critical data and knowledge gaps, and to highlight selected existing stressors and emerging threats to resources or processes. For the purpose of this NRCA, staff from the National Park Service (NPS) and Saint Mary's University of Minnesota – GeoSpatial Services (SMUMN GSS) identified key resources, referred to as "components" in the project. The selected components include natural resources and processes that are currently of the greatest concern to park management at KNRI. The final project framework contains 10 resource components, each featuring discussions of measures, stressors, and reference conditions.

This study involved reviewing existing literature and, where appropriate, analyzing data for each natural resource component in the framework to provide summaries of current condition and trends in resources. When possible, existing data for the established measures of each component were analyzed and compared to designated reference conditions. A weighted scoring system was applied to calculate the current condition of the components. Weighted condition scores, ranging from zero to one, were divided into three categories of condition: low concern, moderate concern, and significant concern. These weighted condition scores help to determine the overall current condition of each resource.

Existing literature and short- or long-term datasets, as well as expertise from NPS and other outside agency or organization scientists support condition designations for components in this assessment. However, in a number of cases, KNRI components lack historic data, a clear delineation of a reference condition, and current data or monitoring information. Thus, in these cases, it was not possible to assign condition for these components. The discussions for each component, found in Chapter 4 of this report, represent a comprehensive summary of current available data and information for these resources, as well as unpublished park information and perspectives of park resource managers, and present a current condition designation when appropriate. Each component assessment was subjected to review by KNRI park resource managers, Northern Great Plains Inventory and Monitoring Network (NGPN) staff, and other specialists.

Data are unavailable or insufficient for many of the measures of the featured components in this assessment. In other instances, data that establishes reference condition were limited or unavailable for components, making comparisons with current information inappropriate or invalid. Thus, current condition was not able to be determined for five of the 10 components (50%) due to these significant data gaps.

For those components with sufficient available data, the overall condition assignments varied. Two components were determined to be of moderate concern: terrace prairie communities and water quality. The terrace prairie communities and the water quality in KNRI were determined to have a stable trend (indicating that current condition is not believed to be degrading or improving compared to past conditions). The landcover, riparian forests community, and the Knife River geomorphology/watershed components were determined to be of significant concern. Landcover had a trend that was undefined, while the riparian forests community and the Knife River geomorphology/watershed had trends that were declining when compared to reference conditions. A detailed discussion of these designations is presented in Chapters 4 and 5 of this report.

Several park-wide threats and stressors influence the condition of priority resources in KNRI. Those of primary concern include establishment of exotic species, increased oil and gas industry development, bank erosion along the Knife River, and air pollution, especially from increased emissions from nearby oil, gas, and power plant developments. Understanding these threats, and how they relate to the condition of these resources, can help managers prioritize management objectives and better focus conservation strategies to maintain the health and integrity of these ecosystems.

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Acronyms and Abbreviations

ARD – Air Resources Division

ASCS – Agricultural Stabilization and Conservation Service

BBS – Breeding Bird Survey

BCR – Bird Conservation Region

BTU – British Thermal Units

CAA – Clean Air Act of 1977

CASTNet – Clean Air Status and Trends Network

CBC – Christmas Bird Count

CCD – Charged Coupled Device

CL – Condition Level

DAMS – Water Impoundments

dBA – A-weighted Decibel Scale

DDT/DDE – dichlorodiphenyltrichloroethane

DEM – Digital Elevation Model

DO – Dissolved Oxygen

DRINKS – Drinking Water Supplies

Dv - Deciviews

EIS – Environmental Impact Statement

EPA – Environmental Protection Agency

EPMT – Northern Great Plains Exotic Plant Management Team

FMP – Fire Management Plan

GAGES – Water Gages

GIS – Geographic Information System

GMP – General Management Plan

Acronyms and Abbreviations (continued)

GPRA – Government Performance and Results Act

IFD – Industrial Facilities Discharge

IRMA – Integrated Resource Management Application

KNRI – Knife River Indian Villages National Historic Site

LCLU – Land Cover and Land Use

LiDAR – Light Detection and Radar

MRLC – Multi-Resolution Land Characteristics Consortium

MWAC – Midwest Archeological Center

NAAQS – National Ambient Air Quality Standards

NABCI - North American Bird Conservation Initiative

NADP – National Atmospheric Deposition Program National Trends Network

NAIP – National Agriculture Image Program

NDDH – North Dakota Department of Health

NDSU – North Dakota State University

NGP – Northern Great Plains

NGP FireEP – Northern Great Plains Fire Ecology Program

NGPN – Northern Great Plains Inventory and Monitoring Network

NLCD – National Land Cover Dataset

NPS – National Park Service

NRCA – Natural Resource Condition Assessment

NRCS – Natural Resource Conservation Service

NTU – Nephelometric Turbidity Unit

NVCS – National Vegetation Classification System

Acronyms and Abbreviations (continued)

PIF – Partners in Flight

PM – Particulate Matter

PM_{10} – Particulate Matter Smaller than 10 micrometers

$PM_{2.5}$ – Particulate Matter Smaller than 2.5 micrometers

PMP – Prairie Management Plan

RF3 – River Reach File

RMBO – Rocky Mountain Bird Observatory

RMP – Resource Management Plan

RSS – Resource Stewardship Strategy

SL – Significance Level

SMUMN GSS – Saint Mary's University of Minnesota GeoSpatial Services

STORET – Storage and Retrieval Water Quality Database Management System

THRO – Theodore Roosevelt National Park

USDA – United States Department of Agriculture

USGS – United States Geological Survey

VIEWS – Visibility Information Exchange Web System

VOCs – Volatile Organic Compounds

WCS – Weighted Condition Score

WNDD – Wyoming Natural Diversity Database

Chapter 1 NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators 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 indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators 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 indicators.

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:

> ***NRCAs Strive to Provide…***
>
> *Credible condition reporting for a subset of important park natural resources and indicators*
>
> *Useful condition summaries by broader resource categories or topics, and by park areas*

- are multi-disciplinary in scope[1]
- employ hierarchical indicator 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

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 indicators 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

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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 a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested

park resource conditions. It also includes present-day condition influences (threats and stressors) 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 indicator 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 indicators; 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 indicators. 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.

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 indicators. 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 their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks

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 ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

[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

report to government accountability measures[8].

Due to their modest funding, 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 indicator, 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 development of useful documentation regarding 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 is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

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)

[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

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 Enabling Legislation

Knife River Indian Villages National Historic Site (KNRI) was established on 26 October 1974 by Public Law 93-486, which states:

> For establishment as the Knife River Indian Villages National Historic Site, North Dakota, those lands depicted on the map entitled Boundary Map, Knife River Indian Villages National Historic Site, North Dakota Numbered 468-20, 012 and dated July 1970 (NPS 2008, p. 11).

KNRI was created to serve three major purposes: preservation, interpretation, and research (NPS 2008). As also stated in House Report No. 93-1285 and Senate Report No. 93-1233, KNRI was established to “preserve certain historic and archaeological remnants of the cultural and agricultural lifestyle of the Plains Indians” (NPS 2008, p. 12).

An additional acquisition of a 188.2-ha parcel of land (Kreiger Parcel) was authorized by Public Law 101-430, on 15 October 1990 (NPS 2008).

Photo 1. Interior of a reconstructed Hidatsa earthlodge at KNRI (SMUMN GSS photo, 2010).

2.1.2 Geographic Setting

KNRI is located in west-central North Dakota in Mercer County, and is approximately 711 ha (1,757 ac) in area. The Knife River passes through the middle of the park and the Missouri River runs along most of the eastern boundary (NPS 2008). Mercer County has a human population density of 3.2 persons per square kilometer, which is slightly below the average for North Dakota (3.6 persons per square kilometer) (USCB 2010).

The bedrock of KNRI is of Paleocene age, with local formations of poorly lithified sandsilt, silty clay, and clay with shale and lignite (Salas and Pucherelli 2003). The Knife River riverbed consists of well-consolidated sandstone. During the Late Cenozoic, KNRI experienced many periods of glaciation, although erosional processes have since removed much of the glacial deposits (Salas and Pucherelli 2003). The soil in KNRI is generally characterized by a sandy substrate. The Hensler Terrace soil is composed of deep, well-drained, moderately to highly permeable, fine sand loam. The Stanton Terrace is composed of poorly sorted, flat to unbedded sand and gravel, and is overlain by silt (NPS 2005).

Generally, KNRI experiences cold winters accompanied by short, warm to hot summers, with average temperatures ranging from -19.5 to 27 ºC (Table 1). Snow accumulation is usually light, and on average, 75% of the annual precipitation received in KNRI occurs as rainfall from April to September. Severe thunderstorms typically occur from June through August. Table 1 displays temperature and precipitation normals for KNRI.

Table 1. Monthly temperature and precipitation normals (1971-2000) for KNRI (Station 056, Garrison 1 NNW) (NOAA 2002).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Temperature (°C)													
Max	-7.7	-3.7	2.7	11.9	19.6	24.1	27.3	27.2	20.7	13.4	2.4	-4.7	11.1
Min	-19.5	-15.5	-8.8	-1.4	5.5	10.5	12.9	12.1	6.1	-0.7	-8.6	-15.7	-1.9
Average Precipitation (cm)													
Total	0.99	0.91	1.60	3.22	5.33	7.92	6.65	4.85	3.66	3.01	1.44	0.99	42.09

2.1.3 Visitation Statistics

In 2010, approximately 21,721 people visited KNRI for recreational purposes, and 662 visited for other purposes (NPS 2011). Most visitors came between May and September, with the busiest month being June, and the least busy being December.

KNRI hosts the Northern Plains Indian Culture Fest annually during the last week in July. During the festival, visitors engage in many activities: archeological talks, flint knapping, beadworking, porcupine quillwork, tanning hides, blacksmith trade items, North Plains dances, Indian flute music, Sahnish and Three Affiliated Tribes cultural demonstrations, and children's activities (NPS 2006a).

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

KNRI is part of the Environmental Protection Agency's (EPA) Northern Glaciated Plains and Northwestern Great Plains Level III Ecoregions (Plate 1). The following is a description of these Level III Ecoregions:

> Northern Glaciated Plains: "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).
>
> Northwestern Great Plains: "Encompasses the Missouri Plateau section of the Great Plains. It is a semiarid rolling plain of shale, siltstone, and sandstone punctuated by occasional buttes and badlands. Native grasslands persist in areas of steep or broken topography, but they have been largely replaced by spring wheat and alfalfa over most of the ecoregion. Agriculture is limited by erratic precipitation patterns and limited opportunities for irrigation" (Bryce et al. 1998).

The EPA divides Level III Ecoregions into smaller Level IV Ecoregions. KNRI is located in three of these Level IV Ecoregions: the River Breaks (southern reaches of the park), Missouri Plateau (northwest section of the park), and Glaciated Dark Brown Prairie (small portion of the park to the east) (Plate 2). The United States Geological Survey's (USGS) Northern Prairie Wildlife Research Center offers descriptions of these ecoregions:

> River Breaks: "The River Breaks form broken terraces and uplands that descend to the Missouri River and its major tributaries. They have formed particularly in soft, easily erodible strata, such as Pierre shale. The dissected topography, wooded draws, and uncultivated areas provide a haven for wildlife. Riparian gallery forests of cottonwood and green ash persist along major tributaries such as the Moreau and Cheyenne rivers, but they have largely been eliminated along the Missouri River by impoundments" (Bryce et al. 1998).
>
> Missouri Plateau: "On the Missouri Plateau, west of the Missouri River, the landscape opens up to become the 'wide open spaces' of the American West. The topography of this ecoregion was largely unaffected by glaciation and retains its original soils and complex stream drainage pattern. A mosaic of spring wheat, alfalfa, and grazing land covers the shortgrass prairie where herds of bison, antelope and elk once grazed" (Bryce et al. 1998).
>
> Glaciated Dark Brown Prairie: "The boundary of the Glaciated Dark Brown Prairie region marks a transition to drier conditions. Ecoregion 42i has a well-defined drainage system and fewer wetlands compared to the more recently glaciated Missouri Coteau Slope to the east. Land use is a mosaic of cropland and rangeland" (Bryce et al. 1998).

KNRI is located on the boundary of two watersheds; a northern section and a small section to the south are located in the Painted Woods–Square Butte watershed. The area in this watershed is approximately 6,148 square kilometers (NRCS 2011). The middle section of KNRI is located in the Knife watershed, which is roughly 6,483 square kilometers (Plate 3).

2.2.2 Resource Descriptions

KNRI staff encourages visitors to show sensitivity towards the cultural, historical, and archeological values at the park (Salas and Pucherelli 2003). KNRI also manages vegetative communities, soundscape, viewshed, and the darkness of night skies to maintain the historic scene and to maximize the ecological value of the area (NPS 2005).

Landcover in KNRI is primarily a mix of grasslands and a woodland community, which is in close proximity to the Missouri River. The grasslands consist of mixed grass prairies with abundant midgrasses, shortgrasses, and upland sedges. The woodland community contains ash (*Fraxinus* spp.),

Photo 2. Prairie and woodlands at KNRI (NPS photo).

elm (*Ulmus* spp.), and cottonwood (*Populus deltoides*). Smaller shrub species such as snowberry *(Symphoricarpos* spp.*)* and wolfberry (*Lycium* spp.) are also found in this area (Salas and Pucherelli 2003).

A natural soundscape (the absence of human-caused sound [NPS 2005]) is important to help visitors better understand and embrace the Plain Indian's heritage (NPS 2009). A natural soundscape is also important to Native Americans who use the park for traditional practices (Gitzen et al. 2010). Highway and train traffic, future mining, and power plants are examples of threats to the natural soundscape of KNRI. There is currently discussion of establishing a mining operation along the Missouri River on the opposite bank from KNRI. Future mining endeavors such as this could have a major impact on the park's soundscape.

The natural viewshed is also of particular importance for KNRI. The primary reason for visitation is to observe the 164 depressions that mark where traditional wood and sod homes were once located in the Big Hidatsa and Lower Hidatsa Village, and the three to four dozen earthlodges located in the Sakakawea village (NPCA 2006). Currently, there are a number of negative impacts on the KNRI viewshed including the Stanton city water tower, overhead utilities, power plants, wind generators, barns, abandoned vehicles, and farm equipment. These intrusions do not compliment the historical and physical attributes of the historical site (NPS 1999).

Dark night skies are a valuable resource in KNRI as 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 2006b, 2007). Several wildlife 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 expect skies to be free of light pollution and allow for star observation. While KNRI is located in rural North Dakota, the lights marking wind generators, high-tension power lines, coal fired power plant smokestacks, and streetlights are visible on all of the park horizons at night.

Photo 3. Ring-necked pheasant (USFWS photo).

KNRI has many diverse habitats that sustain a wide variety of bird species. These habitats include wetlands, shrub lands, native grasslands, hay fields, riparian woodlands, the Knife and Missouri Rivers, and sandbars. The North Woods, a mature riparian forest, hosts many of the different bird species in the park (Panjabi 2005). Wild turkey *(Meleagris gallopavo)*, ring-necked pheasants *(Phasianus colchicus)*, Canada geese *(Branta canadensis)*, and mourning doves *(Zenaida macroura)* are game birds that are often seen within the park. Owls *(Strigidae* and *Tytonidae)*, American white pelican *(Pelecanus erythrorhynchos)*, snow geese *(Chen caerulescens)*, and great blue herons *(Ardea herodias)* are also present. Songbirds are common in areas where prairie transitions to wooded areas (NPS 2006c). Northern harriers *(Circus cyaneus)*, red-tailed hawks *(Buteo jamaicensis)*, American kestrels *(Falco sparverius)*, and bald eagles *(Haliaeetus leucocephalus)* are common raptors in the park (NPS 2006c).

2.2.3. Resource Issues Overview

The cultural and natural resources are tightly interrelated in KNRI. Natural resource processes and communities can have significant impacts on the preservation of archeological resources if not managed with an emphasis on historic preservation. The primary overarching resource issues in KNRI are related to the preservation of archeological resources. Among the primary areas of concern in the park are:

1. Riverbank erosion is impacting the Elbee and Sakakawea Village archeological sites;

2. Uncontrolled populations of burrowing mammals are causing widespread damage to archeological resources throughout the park;

3. Vegetation management practices are degrading archeological resources, and are making other areas of the park inaccessible to future studies;

4. The effects of mowing on vegetation and burrowing mammal communities are poorly understood at this time.

The development of nearby power, oil, and gas facilities are a threat facing KNRI's air quality, soundscape, viewshed, and dark night skies. KNRI lies within one of the largest structural and sedimentary basins in North America, and this basin has been active in oil and gas development since the mid 1970s (NPS 1991). In 2006, there were four surface-mining operations, six coal-fired electric generation plants, and one coal gasification plant within an 80.5-km radius of the park boundary (NPCA 2006).

Garrison Dam, completed in 1954, is located upstream from KNRI on the Missouri River. The primary effects of Garrison Dam's flow regulation include changes in the hydrologic regime, such as causing the flood peaks to become non-synchronous between the Knife and Missouri Rivers (Ellis 2005). There has been a severe reduction in magnitude, frequency, and timing of large floods on the Missouri River, which has caused the "backing up" of floodwaters into the Knife River (Ellis 2005). These back-ups have the potential to affect upstream morphology of the Knife River (Ellis 2005). However, the Knife River is largely in a natural state, so only the lower reaches are likely to experience habitat and morphological alterations due to the Garrison Dam (Ellis 2005). On the Knife River, there is an angular meander bend, known as Elbee Bluff, which is eroding along the outer bank. The Elbee archeological site is located adjacent to the Elbee Bluff and is in danger or eroding away. Erosion along Elbee Bluff is likely due to river-ice gouging and abrasion of saturated banks during spring break-up, which frequently occurs in late March (Ellis 2005).

Due to the lack of flooding, cottonwood and willow (*Salix* spp.) regeneration is no longer occurring (Ellis 2005). However, the altered flow regime is not the only factor that threatens the riparian community. Seventy-five percent of the forest has a fungal disease (*Fomes fomentarius*), which decreases natural succession by killing mature and sapling ash trees (NPS 2006d).

Photo 4. Leafy spurge (yellow flowers) in a grassland (NPS photo).

There are many exotic plants present in KNRI. These species include absinth wormwood *(Artemisia absinthium)*, leafy spurge *(Euphorbia esula)*, Canada thistle *(Cirsium arvense)*, smooth brome *(Bromus inermis)*, crested wheatgrass *(Agropyron cristatum)*, field bindweed (*Convolvulus arvensis)*, Russian olive (*Elaeagnus angustifolia)*, Chinese elm *(Ulmus parvifolia)*, and Siberian elm *(Ulmus pumila)*. Exotic species occupy approximately 160 ha (1,235 ac) of the park, mostly in the riparian floodplain (NPS 2005).

<u>Viewshed</u>

A viewshed is the area that is visible from a particular location. The National Park Service Organic Act (16 U.S.C. l) implies the need to protect the viewsheds of National Parks, Monuments, and Reservations. At KNRI, and many other National Parks, viewsheds are of particular importance because a primary reason visitors frequent the park is to view the landscape. From much of the park, land not managed by the NPS is visible; this means that neighboring landowner management is an important aspect of visitor's perceptions of the park. Currently, the oil development, energy production, and coal industries are expanding in western North Dakota, representing a cause of concern for the viewsheds in KNRI.

Due to the current dynamic nature of the landscape surrounding the park, a detailed viewshed analysis was not appropriate for this document. The evidence of oil development and energy production is increasing in North Dakota making the quality of the viewsheds in the park variable in the short-term. Therefore, conducting an all-inclusive viewshed analysis at this time was not appropriate, because the data would likely be irrelevant quickly.

Even though a park-wide viewshed analysis is not appropriate at this time, KNRI uses viewshed analyses as needed to provide specific data regarding anthropogenic development concerns. Developed data enrich the understanding of anthropogenic effects on the park's viewsheds. These data allow park management to make informed decisions and pursue appropriate actions regarding development. For example, Chad Sexton (Theodore Roosevelt National Park GIS Analyst) performed a viewshed analysis for KNRI that explains the potential visual impacts that structures of various heights would exhibit on viewsheds in the park (Plate 4). The park utilized Sexton's analysis to portray the potential impacts of wind farm development to a local planning board, and mitigate the visual impacts of cell phone tower construction.

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

KNRI does not currently have a General Management Plan in place. However, KNRI has created a Fire Management Plan, Prairie Management Plan, Forest Resource Management Plan, and Resource Management Plan. They are also a part of the Northern Great Plains Exotic Plant Management Plan and Environmental Assessment.

The Fire Management Plan (NPS 2008) for KNRI was created to protect the ecosystems along the Knife and Missouri Rivers, as well as the cultural resources resulting from human habitation. According to this plan, the resource management objectives of the park are to:

- use prairie restoration processes to return old-field areas to native prairie;
- promote hardwood generation in the floodplain forests as well as the woody draws that border grassland areas;
- shift species composition in natural areas from exotic species (Kentucky bluegrass, smooth brome) to native plant species;
- restore the mosaic pattern of different plant communities associated with post fire stages;
- restore fire as a critical component of the ecosystem;
- use fire as a tool to restore the ecosystem to a condition that resembles pre-European settlement periods (NPS 2008).

The Prairie Management Plan (DeKeyser and Krabbenhoft 2006) was created to encourage "the expansion of native species presenting visitors with a representative cultural landscape" (DeKeyser and Krabbenhoft 2006, p. 1). Specific goals of the plan were:

- restoring and/or maintaining the mixed grass prairie ecosystem;
- controlling undesirable exotics;
- natural process utilization;
- native wildlife perpetuation;
- reintroduction of native plant species.

The Forest Resource Management Plan (NDFS 2001) for KNRI was created to assist with management of woodlands and windbreaks to improve:

- fish and wildlife habitat;
- soil protection;

- water quality;
- timber resources;
- recreation benefits;
- aesthetic quality;
- cultural resources;
- threatened and endangered species.

The Resource Management Plan (NPS 1999) for KNRI was created to preserve and interpret the archeological resources, to interpret the culture and lifestyle of the Northern Plains Indians, and to manage and maintain the historic scene. Specific goals were to:

- interface the natural resources into the management of the area to preserve and interpret the cultural resources;
- protect park resources from human and natural impacts;
- maintain or improve natural habitat for the maximum positive effect on wildlife where it is compatible with the primary purposes of the park (NPS 1999).

The Northern Great Plains Exotic Plant Management Plan and Environmental Assessment (NPS 2005) was created to manage exotic plants and reduce the negative effects on native plant communities as well as other natural and cultural resources within the network parks. Specific goals and objectives for the Northern Great Plains Exotic Plant Management Plan were to:

- restore native plant communities to reduce the need for ongoing exotic plant management;
- prevent unacceptable levels of exotic plant damage, using environmentally sound, cost-effective management strategies that pose the least possible risk to people, park resources, and the environment;
- standardize exotic plant management at parks so their actions can be more effectively implemented and explained to the public;
- decrease exotic plant cover and increase native plant cover (NPS 2005).

2.3.2 Status of Supporting Science

The NGPN identifies key resources (called Vital Signs) network-wide that can be used to determine the overall health of the parks. In 2010, the NGPN completed and released a Vital Signs monitoring plan (Gitzen et al. 2010, Table 2).

Table 2. NGPN Vital Signs selected for monitoring in KNRI (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 & river channel characteristics
Water	**Surface water dynamics,** surface water chemistry, aquatic contaminants, aquatic microorganisms, and aquatic macroinvertebrates
Biological integrity	Exotic plant early detection, riparian lowland and upland plant communities, and land birds
Human use	**Treatments of exotic infestations and 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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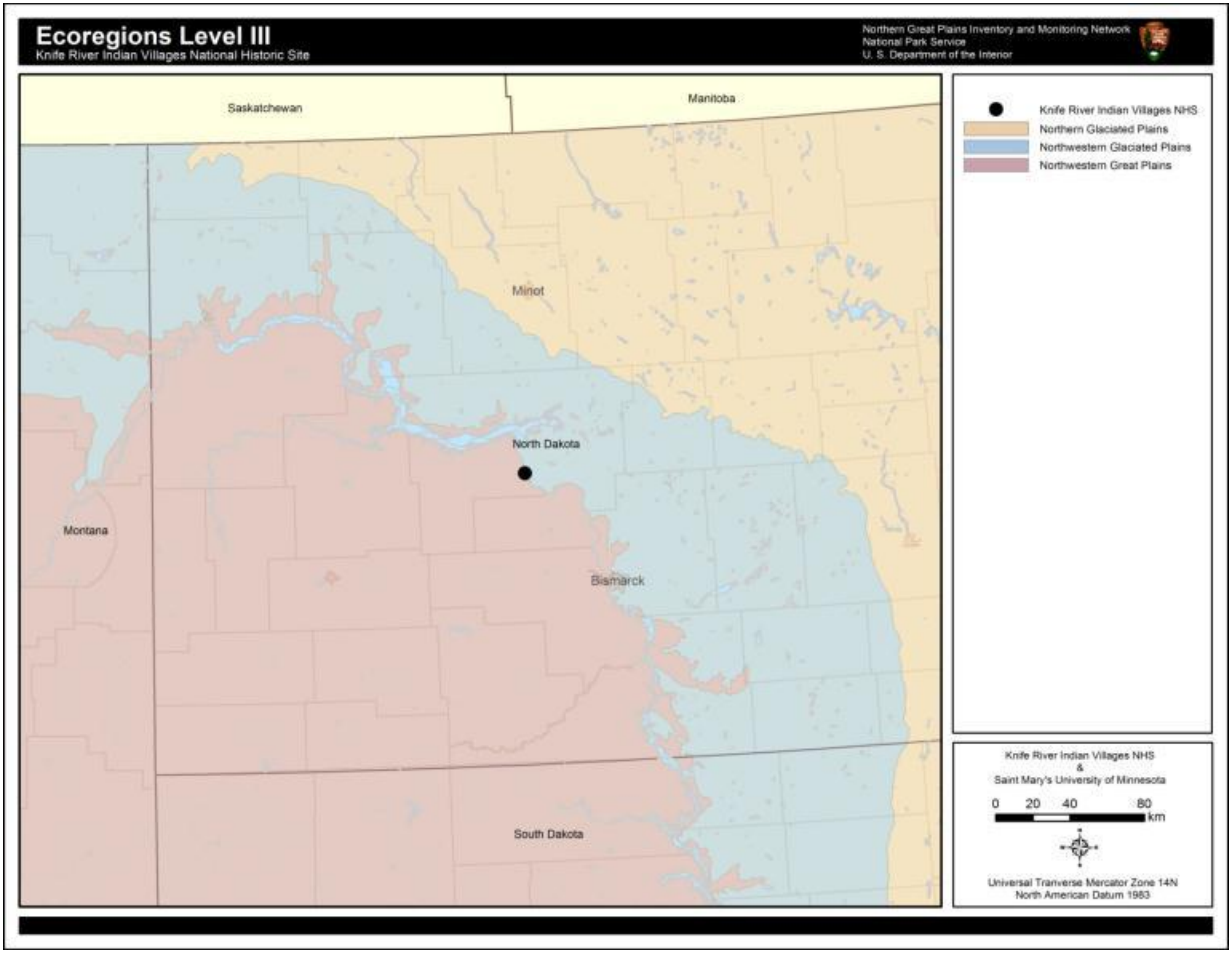

Plate 1. Regional EPA Level III Ecoregions.

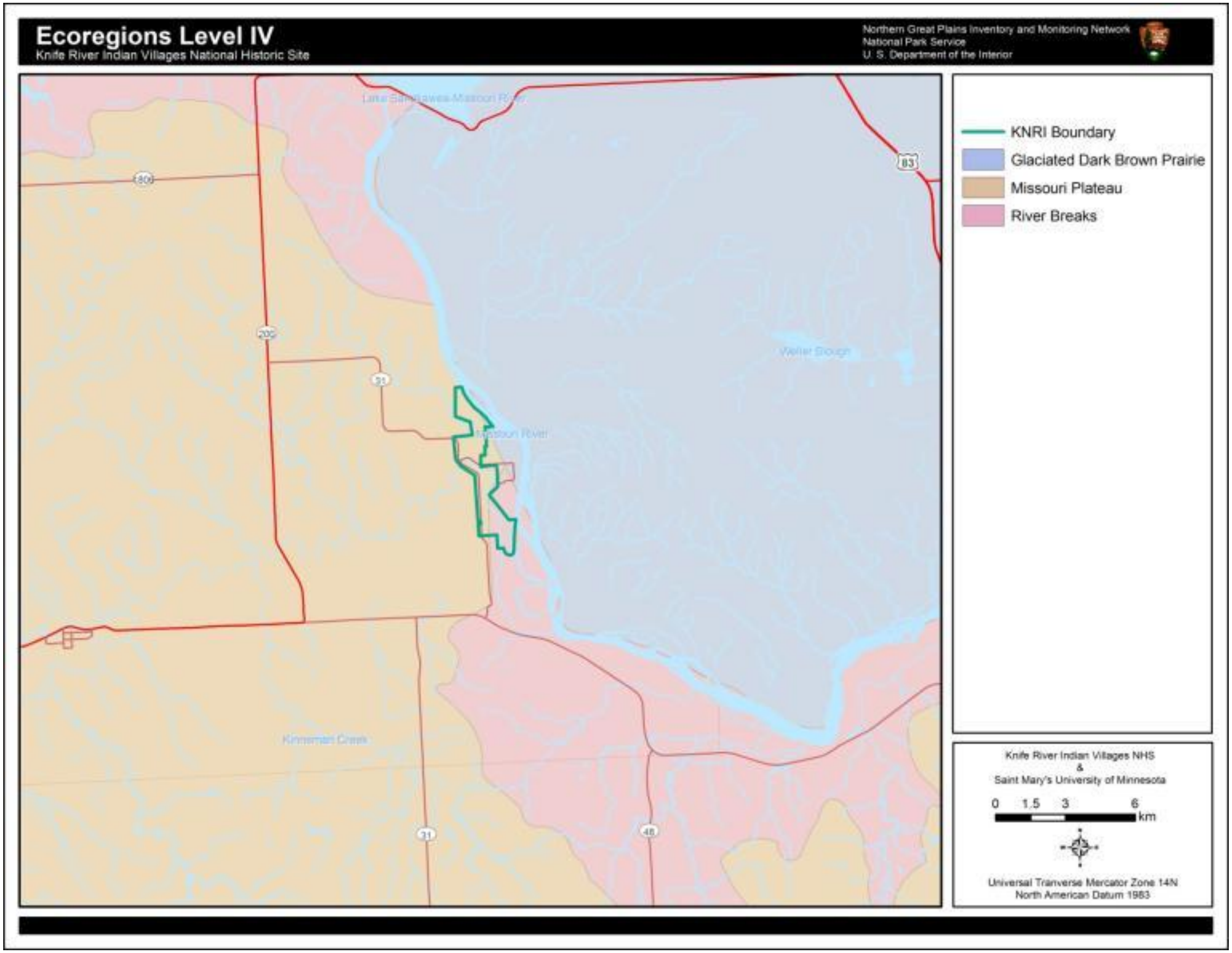

Plate 2. Regional EPA Level IV Ecoregions.

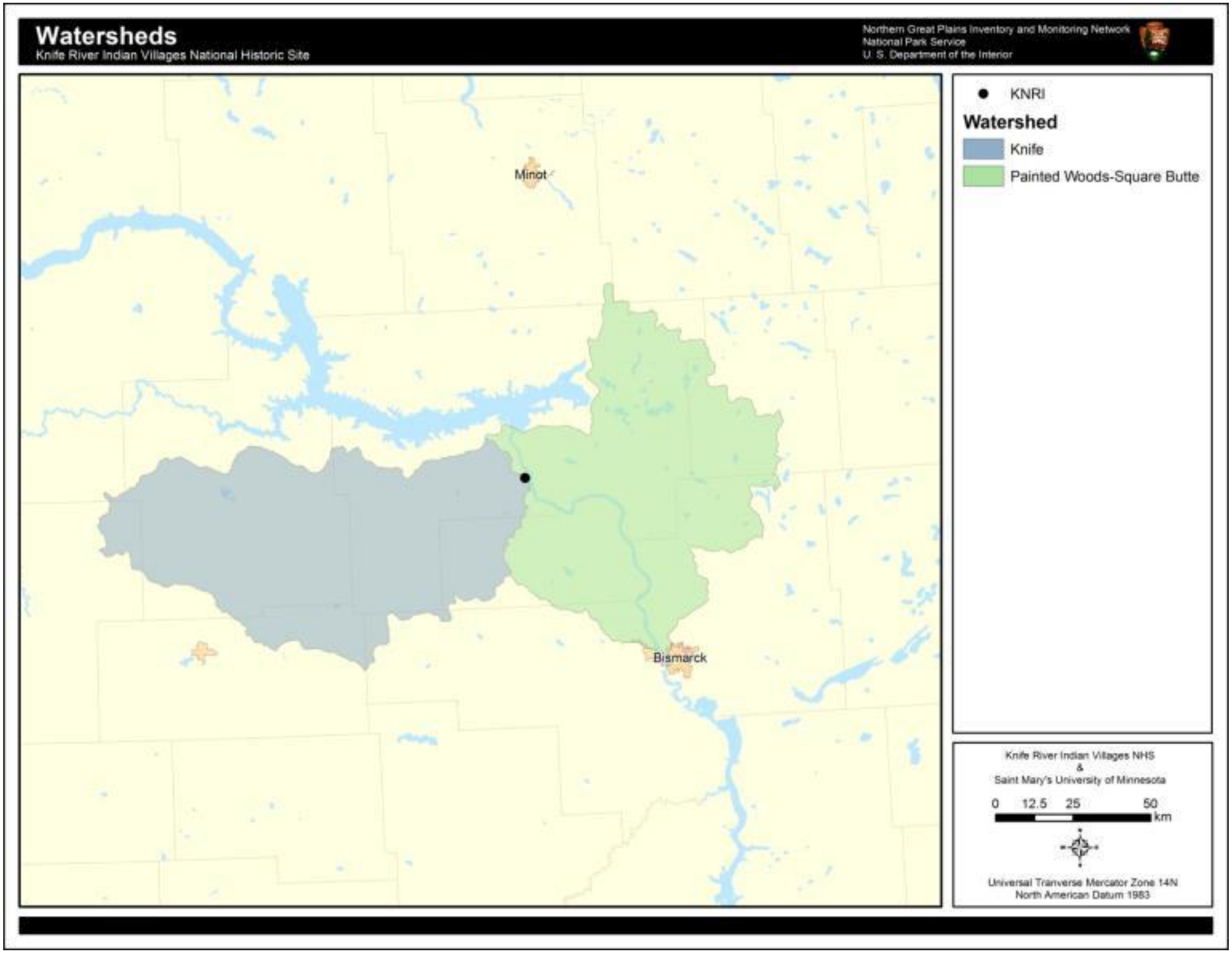

Plate 3. KNRI Hydrologic Unit Code watersheds, cataloging unit level.

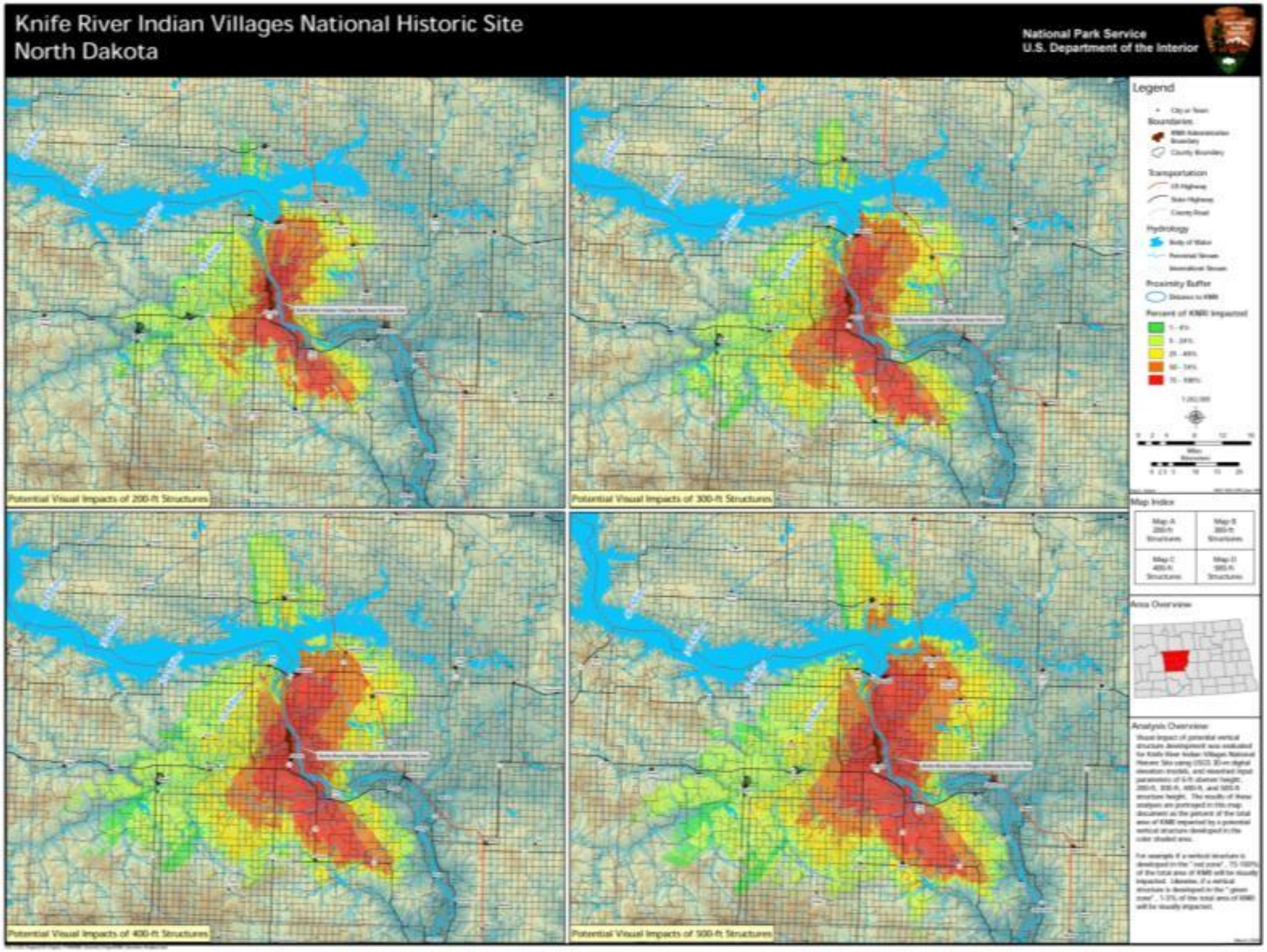

Plate 4. Visual impacts of potential vertical structure development, KNRI area (Sexton, unpublished).

Chapter 3 Study Scoping and Design

This NRCA is a collaborative project between the NPS and SMUMN GSS. Project stakeholders include the KNRI park staff, NGPN staff and other experts. Before embarking on the project, it was necessary to identify the specific roles of the NPS and SMUMN GSS. Preliminary scoping meetings were held, and a task agreement and a scope of work document were created cooperatively between the NPS and SMUMN GSS.

3.1 Preliminary scoping

A preliminary scoping meeting was held on 13 October 2010. At this meeting, SMUMN GSS and NPS staff confirmed that the purpose of the KNRI NRCA was to evaluate and report on current conditions, critical data and knowledge gaps, and selected existing and emerging resource condition influences of concern to KNRI managers. Certain constraints were placed on this NRCA, including the following:

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

This condition assessment provides a “snapshot-in-time” evaluation of the condition of a select set of park natural resources that were identified and agreed upon by the project team. Project findings will aid KNRI resource managers in the following objectives:

- Develop near-term management priorities (how to allocate limited staff and funding resources);
- Engage in watershed or landscape scale partnership and education efforts;
- Consider new park planning goals and take steps to further these;
- Report program performance (e.g., Department of Interior Strategic Plan “land health” goals, Government Performance and Results Act [GPRA]).

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available data, reports, and spatial information from appropriate sources including: KNRI resource staff, the NPS Integrated Resource Management Application (IRMA) website, Inventory and Monitoring Vital Signs, and available third-party sources. The NRCA report will provide a resource assessment and summary of pertinent data evaluated through this project;

- When appropriate, define a reference condition so that statements of current condition may be developed. The statements will describe the current state of a particular resource with respect to an agreed upon reference point;
- Clearly identify "management critical" data (i.e., those data relevant to the key resources). This will drive the data mining and gap definition process;
- Where applicable, develop GIS products that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually;
- Utilize "gray literature" and reports from third party research to the extent practicable.

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

Selection of Resources and Measures

As defined by SMUMN GSS in the NRCA process, a "framework" is developed for a park or preserve. 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., birds), ecological processes or patterns (e.g., natural fire regime), or specific natural features or values (e.g., geological formations) 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 the 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," which are also considered during assessment. A "stressor" is defined as any agent that imposes adverse changes upon a component. These 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 KNRI 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, or are of greatest concern or highest management priority in KNRI. Several measures for each component, as well as known or potential stressors, were also identified in collaboration with NPS resource staff.

Selection of Reference Conditions

A "reference condition" is a benchmark to which current values of a given component's measures can be compared to determine the 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 [*Bison bison*] herd of at least 200 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 before human activity and disturbance was a major driver of ecological populations and processes, such as “pre-fire suppression.” 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” (Heinz Center 2008). Key resources for the park were adapted from the NGPN Vital Signs monitoring plan (Gitzen et al. 2010). This initial framework was presented to park resource staff to stimulate meaningful dialogue about key resources that should be assessed. Significant collaboration between SMUMN 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 2011 following acceptance from NPS resource staff. It contains 10 components (Table 3) and was used to drive analysis in this NRCA. This framework outlines the components (resources), most appropriate measures, known or perceived stressors and threats to the resources, and the reference conditions for each component for comparison to current conditions.

Table 3. Knife River Indian Villages natural resource condition assessment framework.

Knife River Indian Villages NHS Framework
Natural Resource Condition Assessment Framework

	Component	Measures (Significance Level)	Stressors	Reference Condition
Ecosystem Extent and Function				
Landcover				
	Landcover	Plant Species Composition (2), Patch Distribution (2), Percent Land Cover Change (2), Percent Land Designated as a Cultural Resource (3).	Undefined	Undefined
Biotic Composition				
Ecological Communities				
	Riparian Forest Community	Age Class (3), Historic and Contemporary Vegetation Work (2)	Lack of Flooding, Lack of Regeneration, White-Tailed Deer Browsing, Overabundance of *Fomes* Fungus	Composition and Structure Before the Construction of the Garrison Dam.
	Terrace Prairie Communities	Exotic Plant Density (3), Precipitation (2), Deer Population (1)	Exotic species encroachment, drought, lack of appropriate staff needed to maintain native prairie communities	The Condition of the Grasslands Prior to European Settlement
Birds				
	Raptors	Population Abundance and Fluctuation (2), Habitat Availability (2), Species Density (1).	Loss of Nesting/Perch Trees	Moore (1989) Baseline Raptor Inventory
	Land Birds	Species observed vs. Species Expected (2), Species Abundance (2).	Forest Degradation	Undefined
Environmental Quality				
	Air Quality	Mercury (2), Ozone (2), Nitrogen Oxides (2), Sulfur Oxides (2), Visibility (2), Particulate Matter (2), Mercury Deposition (2)	Nearby Power Plants, Coal Mines	NPS Air Resources Division Air Quality Rating Conditions
	Water Quality	Temperature (2), Turbidity (2), Sedimentation (2), *E. coli* (2), pH (2), Fecal Coliform (2)	Grazing Animals, Farm Runoff, Flood Events	EPA Water Quality Criterion for Surface Waters
	Soundscape	Occurrence of Human-caused Sound (3), Natural Ambient Sound Level (2)	Powerplants, Future Mining, Windmills	Soundscape Comparable to the Period of Active Indian Villages in the Area
	Dark Night Skies	Ambient Light Pollution (3)	Power Plants, Coal Mines	Absence of Anthropogenic Light
Physical Characteristics				
Geologic & Hydrologic				
	Knife River Geomorphology/Watershed	River Bank/Bluff Erosion (3), Movement of Knife River (2)	Flow Regulation from Garrison Dam	Condition of the Area Prior to the Construction of the Garrison Dam

3.2.2 General Approach and Methods

This study involved gathering and reviewing 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 further analyzed to provide summaries of resource condition 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 to the reference condition when possible.

Data Mining

The data mining process (acquiring as much relevant data about key resources as possible) began at the initial scoping meeting, at which time KNRI 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, databases, tabular data, and charts. GIS data were provided by NPS staff. 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 for the component and recommendations from NPS reviewers and sources of expertise including NPS staff from KNRI, NGPN, the Midwest Archeological Center (MWAC), the Northern Great Plains Fire Ecology Program (NGP FireEP), and regional staff. Specific approaches to data development and analysis can be found within the respective component assessment sections located in Chapter 4 of this report.

Scoring Methods and Assigning Condition

A set of measures are useful in describing the condition of a particular component, but all measures may not be equally important. A "significance level" represents a numeric categorization (integer of 1-3) of the importance of each measure in explaining the condition of the component; each significance level is defined in Table 4. This categorization allows measures that are more important for determining condition (higher significance level) of a component to be more heavily weighted in calculating an overall condition.

Table 4. Scale for a measure's significance level in determining a component's overall condition.

Significance Level (SL)	Description
1	Measure is of low importance in defining the condition of this component.
2	Measure is of moderate importance in defining the condition of this component.
3	Measure is of high importance in defining the condition of this component.

After each component assessment is completed (including any possible data analysis), a condition level is assigned for each measure. This is based on a 0-3 integer scale and reflects the data mining efforts and communications with park experts (Table 5).

Table 5. Scale for condition level of individual measures.

Condition Level (CL)	Description
0	Of **NO** concern. No net loss, degradation, negative change, or alteration.
1	Of **LOW** concern. Signs of limited and isolated degradation of the component.
2	Of **MODERATE** concern. Pronounced signs of widespread and uncontrolled degradation.
3	Of **HIGH** concern. Nearing catastrophic, complete, and irreparable degradation of the component.

After the significance levels (SL) and condition levels (CL) are assigned, a weighted condition score (WCS) is calculated via the following equation:

$$WCS = \frac{\sum_{i=1}^{\#\ of\ measures} SL_i * CL_i}{3 * \sum_{i=1}^{\#\ of\ measures} SL_i}$$

The resulting WCS value is placed into one of three possible categories: condition of low concern (WCS = 0.0 – 0.33); condition of moderate concern (WCS = 0.34 - 0.66); and condition of significant concern (WCS = 0.67 to 1.00). Figure 1 displays all of the potential graphics used to represent a component's condition in this assessment. The colored circles represent the categorized WCS; red circles signify a significant concern, yellow circles a moderate concern and green circles a condition of low concern. Gray circles are used to represent situations in which there is currently insufficient data to make a statement about the condition of a component. The arrows inside the circles indicate the trend of the condition of a resource component. An upward pointing arrow indicates the condition of the component has been improving in recent times. A right-pointing arrow indicates a stable condition or trend and an arrow pointing down indicates a decline in the condition of a component in recent times. These are only used when it is appropriate to comment on the trend of condition of a component. A gray, triple-pointed arrow is reserved for situations in which the trend of the component's condition is currently unknown.

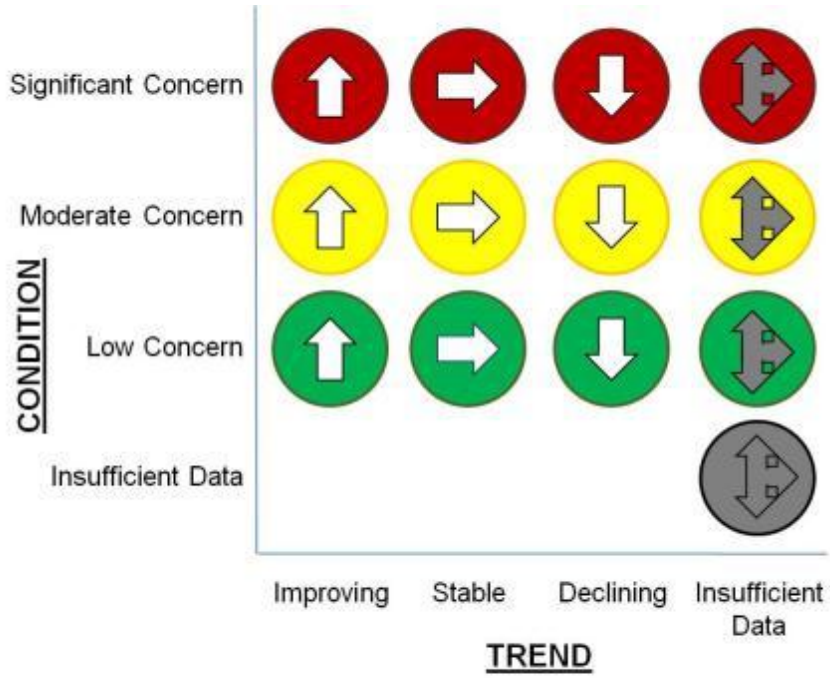

Figure 1. Symbols used for individual component assessments with condition or concern designations along the vertical axis and trend designations along the horizontal.

Preparation and Review of Component Draft Assessments

The preparation of draft assessments for each component was a highly cooperative process among SMUMN GSS analysts and KNRI and other NPS staff. Though SMUMN 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 data or literature are limited for a resource component.

The process of developing draft documents for each component began with a detailed phone or conference call with an individual or multiple individuals considered local experts on the resource components 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 NPS staff opinions. Upon completion, draft assessments were forwarded to component experts for initial review and comments.

Development and Review of Final Component Assessments

Following review of the component draft assessments, analysts used the review feedback from resource experts to compile the final component assessments. As a result of this process, and based on the recommendations and insights provided by KNRI resource staff and other experts, the final component assessments represent the most relevant and current data available for each component 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. The format and structure of these 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. For example, a component may represent a unique feature of the park, it 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. Also emphasized are interrelationships that occur among a given component and other resource components included in the broader assessment.

Measures
Resource component measures were defined in the scoping process and refined through 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.

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 NPS experts or SMUMN 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 for the reader or 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. Due to their low importance, measures that are assigned a significance level of 1 do not receive an in-depth analysis and are not addressed in the current condition section. These measures are briefly discussed in the overall condition section of the document (see below).

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 resource experts and NPS natural resources staff.

Data Needs/Gaps
This section outlines critical data needs or gaps for the resource component. Specifically, what is discussed is how these data needs/gaps, if addressed, would provide further insight in

determining the current condition or trend 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 that was determined for the resource component using the WCS method. Condition is determined after thoughtful review of available literature, data, and any insights from NPS 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. Also included in this section are the graphics used to represent the component condition.

Sources of Expertise

This is a listing of the individuals (including their title and affiliation with offices or programs) 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. Note, citations used in appendices and plates referenced in each section (component) of Chapter 4 are listed in that section's "Literature Cited" section.

Literature Cited

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

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Chapter 4 Natural Resource Conditions

This chapter presents the background, analysis, and condition summaries for the 10 key resource components in the project framework. The following sections discuss the key resources and their measures, stressors, and reference conditions. The summary for each component is arranged around the following sections:

1. Description
2. Measures
3. Reference Condition
4. Data and Methods
5. Current Condition and Trend (including threats and stressor factors, data needs/gaps, and overall condition)
6. Sources of Expertise
7. Literature Cited

The order of components follows the project framework (Table 3):

4.1 Landcover
4.2 Riparian Forest Community
4.3 Terrace Prairie Communities
4.4 Raptors
4.5 Land Birds
4.6 Air Quality
4.7 Water Quality
4.8 Soundscape
4.9 Dark Night Skies
4.10 Knife River Geomorphology/Watershed

4.1 Land Cover

4.1.1 Description

Land cover is the physical surface of the earth described by vegetation classes and often combined with land use classifications (e.g. agriculture, developed, transportation) (Comber et al. 2005). Land cover is portrayed in digital maps created through field surveys and/or analysis of remotely sensed imagery (Comber et al. 2005). The NGPN recognizes "land cover and land use" (LCLU), within a 1.6 km (1 mi) buffer of NPS units, 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 the vertebrate and invertebrate communities in those units (Vinton and Collins 1997, as cited in NPS 2010). The protocol for monitoring this Vital Sign is currently under development by the NGPN and is projected to be completed in the next 1 to 5 years; therefore, a short list of land cover-related measures specific to KNRI are reported here.

4.1.2 Measures

- Plant community composition
- Patch distribution
- Percent land cover change
- Percent land designated as cultural resource

4.1.3 Reference Conditions/Values

<u>Historic Indications of Land Cover</u>

Historic accounts of the land surface are contained within journals from the Lewis and Clark expedition during 1804, and later by the Prince Maximilian expedition (circa 1830s). Other early visitors to the area (Euro-Americans) included Nuttall, Bradbury, Brackenridge, and Audubon (Clambey 1985). Clambey (1985) notes that the descriptions of vegetation are limited as many early explorers tended to focus on the fauna and the Native American people of the area. Many of the Lewis and Clark journal entries recorded the prevalence of timber, while other explorers' descriptions tended to focus on individual species; neither plant systematics nor plant ecology were developed at the time (Clambey 1985). In addition, the individual species documented were often woody species along the Missouri River and other tributaries. However, some plant collectors documented new prairie plant species (Clambey 1985).

A summary of Meriwether Lewis' notes by Cutright (1969), quoted by Clambey (1985, p. 56-57), provides Lewis' general description of the KNRI area when he traveled on the Missouri River from the mouth of the Knife River to the Yellowstone River:

> The country on both sides of the Missouri was a flat, treeless plain as far as the eye could see and 'generally covered with a short grass resembling very much the blue grass.' The timber bordering the river consisted almost altogether of cottonwood, elm, ash, willow, and boxelder, and the undergrowth of such plants

as wild rose, honeysuckle, currant, red berry (buffaloberry), chokecherry, arrowwood and serviceberry. On the bluffs grew clumps of dwarf cedar and great quantities of sagebrush.

Figure 2. Oil painting of winter village at Fort Clark, North Dakota (Carl Bodmer 1832).

Some of the oldest visual depictions of the area that includes the present-day Knife River Indian Villages were captured in oil paintings by artists such as George Catlin, or similar, nearby native villages painted by Carl Bodmer. Several oil paintings depict scenes in and around the area that is now KNRI. Figure 2 shows a Native American winter village located in a river bottom. The following figures (Figure 3, Figure 4, and Figure 5) depict a native village along the Missouri River near present-day KNRI. Notice the woody vegetation in the river bottoms and the openness of the prairie (lack of woody vegetation) outside of the river bottoms. In online entries of the Lewis and Clark journals from a University of Nebraska Press website (UNL 2012), John Ordway of the Lewis and Clark expedition referred to the Knife River as a "handsome river" and noted that two villages were "...in a bottom but little timber. Back of which is high open plain which is the same on the N. S." (April 1805). Ordway also described nearby islands as "covered with timber" and other areas as "bottom of cottonwood timber" (UNL 2012). It is also noted by Joseph Whitehouse, another member of the Lewis and Clark expedition, that "The Natives have large fields, which they cultivate, and plant the same as those of the first Village" (UNL 2012). More recently, Clambey (1985) suggests that during the early 19th century, most of the area's floodplains would have been wooded, and native grasslands would have dominated higher elevations outside the floodplains.

Figure 3. Oil painting of Mandan Village and Fort Clark along the Knife River by George Catlin (1832). Located less than 25 km down the Missouri River from KNRI.

Figure 4. Oil painting of a Mandan Village by George Catlin (1837-1839).

Figure 5. Oil painting of village of the Hidatsa tribe at Knife River (Sakakawea Village in present day KNRI) (George Catlin 1832).

Present-day Resource Management Objectives Relevant to Vegetation (Land Cover)

The revised fire management plan (FMP) (NPS 2008) for KNRI outlines a set of desired conditions related to vegetation in KNRI. As the FMP describes, the NPS RSS is still in development. The RSS document, adding to the general management plan (GMP) and superseding the Resource Management Plan (RMP), will focus on park-specific desired conditions and comprehensive strategies in order for strategic planning to facilitate achieving the identified desired conditions. Until the RSS is completed for KNRI, the fire management plan (FMP) strives to reach the objectives of the park's GMP and RMP (NPS 2008).

The following goals from the FMP pertain to how some vegetation at KNRI is to be managed using prescribed fire. However, these do not define how overall vegetation (i.e., land cover) at KNRI is to be maintained, especially for cultural resource areas. Presently, a vegetation management plan that addresses cultural landscape vegetation management for culture site protection, preservation, or interpretation does not exist. The park will examine this in future planning efforts as a part of an Archeological Protection Plan.

The resource management objectives, which relate to the reference conditions for the broad concept of land cover in KNRI, include the following introduction and list of goals from the FMP (NPS 2008, pp. 15-16):

> KNRI will be managed to protect and interpret the ecosystems along the Knife and Missouri Rivers and the cultural resources resulting from human habitation of the area. Of primary importance is the management of the park as a natural ecosystem, influenced by human activities over time, and the continuation of natural process function.

1) Use prairie restoration processes to return old-field areas to native prairie. If left alone, natural plant succession would take over 100 years if at all, to complete and this is without the presence of exotics. With the presence of persistent exotic species smooth brome, Kentucky bluegrass (*Poa pratensis*), and crested wheatgrass, natural succession of native species may never occur. Restoration of fire dependent native grasses is only one benefit of maintaining historic fire intervals on the park's prairies.

2) Promote hardwood generation in the floodplain forests as well as the woody draws that border grassland areas. Without the presence of flooding and fire, many of these areas have become decadent and without these rejuvenating effects, nutrient levels in these areas will remain low, thus reducing natural regeneration, species composition and ecosystem diversity.

3) Shift species composition in natural areas from exotic species (Kentucky bluegrass, smooth brome) to native plant species.

4) Restore the mosaic pattern of different plant communities associated with post fire stages.

5) Restore fire as a critical component of the ecosystem.

6) To the extent practical, use fire as a tool to restore the ecosystem to a condition that resembles pre-European settlement periods. This may be accomplished by reproducing natural fires as well as Native American ignited fires.

7) Incorporate prescribed burning in accordance with strategies outlined in the park's draft prairie management plan (NPS 2006) to enhance the vigor of native grassland while reducing exotic species populations to levels determined by the prairie management plan.

It is important to note that prescribed fire can be used in KNRI as a management tool acting to mimic or partially restore fire as a natural ecosystem process. However, there isn't a particular "cultural time-period" to which the ecosystems of the park are to be restored. The three purposes of the park's establishment, according to Public Law 93-486, were to serve, preserve, and interpret the park's archeological resources as well as to study those resources (Thiessen 1993). An archaeology/fire memo in the revised 2008 FMP provides a list of 10 best alternatives to minimize the potential impacts fire may have on surface archaeological materials on "Medium Density" archeological sites (NPS 2008, p. 29-30):

1) Burning in the Spring/Early Summer (April-May) is preferred since this will help to reduce the intensity and duration of the prescribed burns due to increased live fuel moistures, higher soil moistures and lower ambient air temperatures. If summer/fall burning is required, executing the burns during times of higher humidity and/or increased soil and thatch moistures would be desirable. The higher moisture contents in the thatch and soil will serve as a buffer to offset lower live and dead fuel moistures. Schedule prescribed burns when conditions will avoid the upper end of the

wind prescription. Avoiding the upper end of the wind prescription will decrease the flaming area, thereby decreasing flame depth, durations, and intensities.

2) Utilize, to the maximum extent possible, flanking fires and/or backing fires, avoiding the use of head fires, which uniformly achieved maximum temperatures above acceptable limits. If head fire is required, short strip head is recommended to minimize intensities.
3) Reduce the amount of 10, 100, and 1,000 hour fuels (such as bushes, trees, and fallen timber) in the burn units. Reduction of these fuels will ensure shorter durations and decreased BTU's (British Thermal Units).
4) Ground disturbing activities, such as hand dug fire breaks, should not be undertaken at any of the archeological sites outside of the full Sec. 106 compliance framework unless in an emergency situation where lives and property are at risk.
5) Archeological sites with known human burials should be excluded from the prescribed burn units.
6) Each Fire Monitoring Report should contain documentation of fire conditions observed in order to determine if the prescription targets are being met and to evaluate the effectiveness of the 2005 experimental burn program.
7) Copies of the Fire Monitoring Report from each prescribed burn or wildfire should be filled with the Midwest Archeological Center in order to maintain an active record of the KNRI burn program.
8) KNRI staff should request a review of its burn program by Midwest Archeological Center personnel after 5 years following the initial prescribed burn.
9) KNRI staff should work with the Midwest Archeological Center to set up a small experimental plot in a non-site area representative of the conditions found at Medium Density sites in order to monitor the cumulative short- and long-term effects on replica and/or de-accessioned archeological materials that are subjected to multiple prescribed burns over a 5 to 10 year period.

4.1.4 Data and Methods

<u>Select Land Cover Data Sources</u>
Clambey (1985) provides the earliest vegetation map of KNRI. Lenz (1993) provides another vegetation map of KNRI. The authors identified eight major habitats including wetlands, shrub/grasslands, cultural areas, old fields, prairies, restored prairies, sandbars, and woodlands. These areas were subdivided into multiple map units indicating the dominant species in each map unit. These data are now outdated, as a prescribed fire program has been established (resulting in a change in the landscape), additional archeological sites have been identified, and plant community composition has changed.

Salas and Pucherelli (2003) provided GIS data that detailed vegetation polygons within the park boundaries and a buffer of approximately 1 km (0.6 mi) surrounding the park. The GIS data were developed from 1:12,000 scale aerial photographs acquired 20 June 2002 (Salas and Pucherelli 2003). Each polygon delineated via aerial photo interpretation was visited in the field for verification and therefore the stakeholders of the project decided an accuracy assessment was not necessary. These data represent the most detailed and recent map information regarding land cover for KNRI.

The NPScape Program outputs provide coarser map scale information compared to that of the Salas and Pucherelli (2003) data. This NPS program provides several GIS graphical and data outputs of regional scale land cover information and other land cover-related datasets (e.g., population, roads, and other landscape patterns) for 270 national park units. NPScape outputs utilize the satellite image-derived National Land Cover Dataset (NLCD) as its primary data source for land cover-related outputs. The outputs present a 30 km buffer of the park as the area of interest.

The Multi-Resolution Land Characteristics Consortium (MRLC) produces the NLCD data, which are a LCLU data product created for the contiguous United States. Products include 1992, 2001 (2.0), and 2006 LCLU data. Also, change products exist including a 1992/2001 change product, and a more recent land cover change product called NLCD 2001/2006 Land Cover Change, containing the pixels identified as changed between the NLCD 2001 Land Cover version 2.0 and the NLCD 2006 Land Cover products. These data are also at a much coarser map scale (30 m cell size) in comparison to the GIS data created by Salas and Pucherelli (2003) (vector data created from 1:12,00 aerial photography with significant ground-truthing). The NLCD data use the Anderson land use and land cover classification system (Anderson et al. 1976). The 1992/2001 change product indicated some class changes within the KNRI boundaries such as agriculture to wetlands, grassland/shrub to wetlands, etc.; however, these change classifications may be erroneous due to the practice of applying a fine spatial resolution to a coarse dataset. In addition, the NLCD 2001/2006 change product identified areas of "woody wetland to agriculture" change category (Anderson Level 1 classifications), in examining mid- and late-1990s aerial photography; this change classification appears to be erroneous for multiple agricultural fields within 3.2 km (2 mi) of KNRI. No change was found within the KNRI boundaries according to the 2001/2006 land cover change data product.

Archeological GIS Data Sources

The MWAC produced point, line, and polygon GIS data (NPS 2002) representing known locations of archeological features in KNRI. These data were created by digitizing mylar copies of 7.5 degree topographic quadrangles.

4.1.5 Current Condition and Trend

Land Cover / Plant Community Composition

Clambey (1985) used ground reconnaissance and point sampling methods to estimate relative composition of several surface cover types within the park (

Table **6**). Note, an addition of the 188 ha (465 ac) Kreiger parcel in the northern portion of the park occurred since this composition estimate by Clambey (1985).

Table 6. Relative composition of surface cover in KNRI (Reproduced from Clambey 1985).

Surface cover	% composition
Knife River water surface	5.2
Grass and shrub cover	16.6
Cropland	4.4
Prairie	18.2
Re-vegetated former cropland	25.8
Sandbars	3.8
Forest	25.3
Roads and Trails	0.6

Area not determined in original document. Percentages created based on ground reconnaissance and point sampling of 1983 aerial photographs.

Detailed vegetation mapping efforts by Lenz (1993) used a different classification of the land surface than that of Clambey (1985), and found a total of eight habitat types (i.e., endemic vegetation communities); at that time, most of the park was old fields, woodlands, or prairies (Table 7).

Table 7. Habitat area and relative composition in KNRI (Lenz 1993).

Habitat type	Area (ac)	Area (ha)	% composition
Wetland	22	9	1
Shrub/grassland	58	23	4
Cultural area	43	17	3
Old field	435	176	28
Prairie	368	149	24
Restored prairie	65	26	4
Sandbars	65	26	4
Woodland	475	192	31
Totals	1,531	620	100

56 ha (138 ac) of scenic easements that exist west of county road 37 were excluded from the table, along with approximately 250 acres (Krieger Parcel) the NPS added to KNRI after 1993.

The most recent vegetation mapping at KNRI was completed using 2002 aerial photos (Salas and Pucherelli 2003). These data are not immediately comparable to the earlier work by Clambey (1985) and Lenz (1993) in terms of vegetation or land cover classes. A total of 17 different plant associations and land use categories (agricultural, undifferentiated urban, and archeological site) were identified. This vegetation map provided a more robust and detailed set of vegetation classes. The map uses the standardized National Vegetation Classification System (NVCS), a hierarchical classification system containing several levels, both physiognomic and floristic. Park staff indicates that these data are generally still representative of current conditions in KNRI, except for recently restored native prairie acreage. Table 8 displays the area and percent composition in the park to the plant association level, the finest floristic class of this system.

Table 8. Area and percent composition of plant associations found within the boundaries of KNRI. Modified from Table 3 in Salas and Pucherelli (2003).

Vegetation / Map Unit (Association) Description	Area (ac)	Area (ha)	% composition
Agricultural	115.2	46.6	7.2
Archaeological Site*	34.4	13.9	2.2
Undifferentiated Urban	16.8	6.8	1.1
Forest - Green Ash / Snowberry	108.6	43.9	6.8
Woodland - Green Ash / Chokecherry	259.4	105.0	16.2
Herbaceous - Big Bluestem / Little Bluestem	124.3	50.3	7.8
Herbaceous - Smooth Brome	314.9	127.4	19.7
Herbaceous - Canada Thistle	8.9	3.6	0.6
Herbaceous - Needle-and-Thread / Blue Grama	115.6	46.8	7.2
Herbaceous - Western Wheatgrass / Blue Grama	93.1	37.7	5.8
Herbaceous - Crested Wheatgrass	1.2	0.5	0.1
Herbaceous - Riverine Sand Flats	4.2	1.7	0.3
Planted - Big Bluestem	62.7	25.4	3.9
Planted - Sideoats Grama / Western Wheatgrass	97.4	39.4	6.1
Planted - Smooth Brome	52.2	21.1	3.3
Planted - Grass Forb Mix	23.6	9.6	1.5
Shrub - Dwarf Sagebrush	2.3	0.9	0.1
Shrub - Coyote Willow	39.1	15.8	2.4
Shrub - Western Snowberry	35.5	14.4	2.2
Water	67.2	15.1	2.3
Hardstem Bulrush Marsh	2.7	1.1	0.2
Totals:	**1,579.3**	**646.4**	**100.0**

*Archaeological Site acreage reported here by Salas and Pucherelli (2003) are not up to date; according to a recent GIS polygon layer created by the MWAC; known archaeological features exist on 157 ha (388 ac) of KNRI.

NPS (2008) offers assemblages of the above vegetation associations; they are mixed grass communities/herbaceous and planted communities, forest/woodland and shrub communities, and former croplands, covering 52%, 25%, and 16%, respectively. The remaining 47.7 ha (118 ac), or 7% of the park, are in easements and are not available for NPS management (e.g., prescribed fire) other than scenic (NPS 2008).

Patch Distribution

Patches (e.g., habitats or vegetation types) are relatively homogeneous areas that differ from their surroundings (Forman 1995). Patch is a concept of ecosystem and habitat analysis used in the field of landscape ecology (Forman 1995). In KNRI, the distribution of patches can be specifically relevant to the restoration of native prairie communities. One of the goals in the KNRI FMP is to "restore the mosaic pattern of different plant communities associated with post fire stages remnants" (NPS 2008, p. 15). As prairie restoration efforts continue, understanding how the patches are spatially distributed may help management decide how and where to connect them through restoration efforts. Similarly, the use of prescribed fire through established burn units will help KNRI achieve the FMP goal of “restoring fuel and vegetation mosaics (patches) to pre-European contact conditions on 50% of the landscape within the next fifteen years” (NPS 2008, p. 37). Since many of the prairie restoration efforts have occurred since the publication of Salas and Pucherelli (2003), map information is not available for analysis or graphic representation in this assessment. Therefore, patch distribution in KNRI represents a data gap.

Vegetation in KNRI is managed as a component of the cultural landscape and site preservation and interpretation. For example, areas are mowed around village sites, and where possible, vegetation restoration efforts that use native plant species assemblages are ongoing. Both the use of prescribed fire and exotic (i.e., invasive nonnative) plant management techniques are components of the restoration efforts. There is not, however, a specific time period defined for the efforts to restore native vegetation.

Percent Land Cover Change

Vegetation classifications and mapping methods from Clambey (1985) and Lenz (1993) are not immediately comparable to those used by Salas and Pucherelli (2003). Also, an analysis quantifying land cover change in KNRI occurring since the mapping efforts of Salas and Pucherelli (2003) has not been attempted. In the absence of comparable map classes and an updated vegetation or land cover map created using the same methodology, quantitative land cover change statistics are not possible at the map scale provided by the Salas and Pucherelli (2003) GIS data. Therefore, the percent of KNRI that has experienced recent land cover change is a data gap for this assessment.

However, a few driving factors of land cover change suggest that some areas of KNRI may be reclassified if aerial photo interpretation and ground-truthing were conducting using current aerial photographs. Several factors may continue to alter land cover in KNRI: the natural disturbances associated with river flooding (e.g., channel migration), expansion of invasive plants, prairie restoration (e.g., planting, mowing, invasive plant treatments), and prescribed burns.

Morphological changes in the river result in changes to the land cover of KNRI. Providing a quantification of these changes is beyond the scope of this assessment. However, given the bank changes measured by Sexton (2012), changes in land cover have been occurring since 1965; 2002 aerial photography (Salas and Pucherelli 2003) also shows evidence of land cover change occurring from 2002 – present in the park. Sexton (2012) measured bank movement along each major bend in the Knife River (except Peninsula Bend in the southern portion of the park) from 1965 to 2009. The author found mean distances of river bend bank movements from 1965 to 2011 ranged from 14 to 77 m (48 ft to 253 ft), and in some sections of river bends, the bank moved nearly 91 m (300 ft). Sexton (2012) offers a repeatable set of methods to measure future river bank movement. Although not mapped in the Sexton (2012) study, park staff indicates that the Peninsula Bend in the area referred to as “Peninsula Woods” has also experienced notable morphological change. This area is a strip of land between the Missouri and Knife Rivers containing riparian woodlands. Some of the recent changes due to migration of the Missouri and Knife Rivers (i.e., erosion and deposition processes) are illustrated in paired aerial photos from 2004 and 2009 (Figure 6). Further, detailed illustrations and measurements of river bend migration from 1965 to 2011 are found in Sexton (2012).

Figure 6. Examples of recent river migration in KNRI (2004 to 2009): 27 July 2004 QuickBird Satellite imagery (left), and 24 July 2009 United States Department of Agriculture (USDA) National Agriculture Image Program (NAIP) aerial photography (right). Image pairs (2004/2009) are left to right. Arrows identify some of the visual evidence of river migration between photo paris.

Erosion associated with periods of increased flow is a concern to park management because of the threat it poses to archeological sites in the park. It is important to note that while much of the Knife River migration is likely occurring naturally, bank stabilization features (rip-rap) have altered natural erosion and deposition in some areas of KNRI. Bank stabilization was installed along the Sakakawea Village by the USACE in 1979 (Ahler 1984), then additional bank stabilization was installed at Taylor's Bluff in 1984-85 (Clambey 1985). In a 2009 spring flooding event, portions of the Tri-lock bank stabilization system failed. In response, riverbank stabilization restoration work was completed on approximately 183 m (600 ft) of river bank along Taylor's Bluff, repairing damage by filling and installing rip-rap (Figure 7). The Taylor Bluff bank is now a combination of rip-rap and tri-lock, and the stabilization features at Sakakawea Village are comprised of rip-rap.

Figure 7. Photos of riverbank repair along Taylor's Bluff in KNRI, August 2009. On the left, Taylor's Bluff prior to major excavation, fill, and rip rap installation; on the right, Taylor's Bluff in the process of rip-rap installation.

While it is likely that much of the erosion occurring throughout the park may largely be a natural function of the river and varying hydrologic conditions, the park is legislated to protect the cultural and historic (archeological) resources of the park. KNRI recently applied for funds to conduct an Environmental Impact Statement (EIS) examining management options related to flooding, but was not awarded the funds. Alternative options are now being considered. KNRI is beginning to develop an archeological protection plan that will address several topics including erosion of archeological sites; location of maintenance facility at Big Hidatsa National Historical Landmark, burrowing mammal impacts on archeological resources and vegetation management. The plan will be listed as a need in the park's Foundation Statement.

Another source of plant community change (i.e., land cover change) is through the colonization and expansion of invasive plant species. For example, much of the park contains or is dominated by smooth brome. Salas and Pucherelli (2003) warned that areas mapped as former croplands will likely continue to be colonized by this species.

Another source of plant community change is the results of the ongoing prairie restoration efforts in the park. Some areas may have experienced shifts in species composition and abundance such that the plant associations of certain areas would require reassignment from the original Salas and Pucherelli (2003) map units in order to reflect current conditions. Included in the prairie restoration efforts is the use of prescribed fire at KNRI. Prior to the prescribed burn program that began in 1999, all fires were to be immediately suppressed within the park. Since the inception of the prescribed fire program, the park has identified 18 distinct burn units (NPS 2008). The FMP indicates a goal of burning approximately 40-162 ha (100-400 ac) of grassland each year. The FMP also states a goal of restoring fire to 95% of the vegetated landscape of KNRI over the next 10 years. However, as of 2008, only seven fires have occurred since record keeping began in 1979, approximately one fire every 4 years (NPS 2008).

Percent Land Designated as a Cultural Resource

While the purpose of the park was not stated in its authorizing legislation, the House Report No. 93-1285 and Senate Report No. 93-1233 specifically state that the park was to be established to "preserve certain historic and archaeological remnants of the cultural and agricultural lifestyle of the Plains Indians" (NPS 2008, p. 12). Therefore, as Salas and Pucherelli (2003) assert, careful consideration must be given to cultural, historical, and archeological values of KNRI when managing the park's natural resources. Salas and Pucherelli (2003, p. 4) state that vegetative communities in the park "must be managed to compliment the historic scene and to maximize the ecological value of the area." Likewise, the FMP lists strategies (e.g., use of swatters, burning out to create a black line, direct attack with water resources) to protect all indentified historic, ethnographic and archeological resources and cultural landscapes from fire (NPS 2008). Ongoing vegetation research is intended to describe natural processes taking place in the park and to define optimum ecological communities (Salas and Pucherelli 2003).

More recently the Midwest Archeological Program has experimented with local fire conditions and effects on surface or near-surface archeological resources in KNRI and other Midwest Region NPS units (Sturdevant et al. 2009). Researchers conducted a pilot study at KNRI in 2005, studying the effects of prescribed fire in grasslands with medium density archeological sites. This resulted in the identification of different types of burns and prescribed fire techniques that would have the least potential impact on surface archeological resources (Sturdevant et al. 2009). The authors found that impacts on surface archeological resources varied based on several parameters such as fire technique, fuel loads, material type, fire residence time, and fire intensity.

According to Thiessen (1993), the entire park can be considered a culturally significant property. Likewise, KNRI is comprised of various historic, cultural, and archeological features of interest. NPS (n.d.) organizes the KNRI cultural landscape into a hierarchy, with KNRI as a "parent" landscape that contains landscape features made up of "component" landscapes, and each component containing landscape features. The four component landscapes in KNRI are the archeological sites of the Big Hidatsa, Sakakawea, and Lower Hidatsa Villages, and the Taylor Bluff component landscape. Features of the villages include a trail system, earth lodge footprints, midden piles, viewsheds, fortification ditches, cache pits, linear mounds that radiate out from the villages' periphery, off-village activity area, village periphery zones, and cemeteries. The park landscape contains a diversity of cultural features; the Hidatsa used areas for village sites, hunting grounds, cemeteries, ceremonial sites, and agricultural zones. Cultural resources and archeological sites and features occur throughout the park at varying densities and levels of significance; they provide research opportunities to understand past civilizations. At the same time, the park remains a culturally significant area for three affiliated Native American tribes: the Hidatsa, Mandan, and Arikara.

According to Salas and Pucherelli (2003), approximately 10.8 ha (26.8 ac) are mapped as an archeological site. However, the MWAC created a detailed record of known archeological resources at KNRI (a geodatabase with point, line, and polygon feature classes). A MWAC GIS polygon feature class last updated in 2009, titled "KNRI_CULP", represents known areas of archeological resources at KNRI. The total area of known features covers approximately 159 ha (393 ac). However, a few of these polygons overlap the park boundaries; clipping the dataset to KNRI boundaries reveals approximately 157 ha (388 ac) or 23% of KNRI. A GIS line feature class entitled "KNRI_CULL" indicates approximately 6,309 m (20,699 ft) of known linear archeological features existing near KNRI. Like the polygon dataset, some features overlap KNRI boundaries; clipping reveals a total length of 5,150 m (16,895 ft). These data are current as of April 2009, though no new sites have been discovered since 1994.

Threats and Stressor Factors

Prior to park establishment, the KNRI area was affected by a long history of human disturbance by European peoples (Clambey 1986, Lenz 1993, Thiessen 1993, Salas and Pucherelli 2003). However, for nearly 500 years prior to European peoples' influence on the land, archeological evidence suggests that landscapes were also highly altered by horticultural peoples (Hidasta and Mandan) (Thiessen 1993). Some of this disturbance included hydrologic alterations of the Missouri River from the installation of the Garrison Dam upstream of the park. Other, more direct human influences on the land were from years of cultivation, livestock grazing, and the introduction of non-native plant species (Lenz 1993). The river bottoms were grazed by livestock and trees were harvested, creating river-bottom woodlands that were open, generally limiting woodland species regeneration. Likewise, Clambey (1985) described much of the park as being "ruderal" in nature, because of various human disturbances. In addition to former croplands and some woodlands, the ruderal areas included former farmyards, roadways, and gravel pits.

Hydrologic Alterations

The Garrison Dam upstream of KNRI on the Missouri River has altered the river hydrology and the natural erosion/deposition and flooding regimes. The flow regulation of the dam has altered the riparian vegetation of KNRI along the Missouri River, reducing overbank flooding and moisture availability in riparian-adapted woodlands. Other stressors to the riparian woodlands, as mentioned in the Riparian Forest Community component (Chapter 4.2) of this document, include white-tailed deer (*Odocoileus virginianus*) browsing, heart rot fungus, and tree disease. A detailed discussion of KNRI hydrology is provided in Chapter 4.10 of this document.

Non-native invasive plants

Non-native invasive plants are a threat to native plant communities and therefore to land cover as a whole in KNRI. Clambey (1985) noted several invasive species in KNRI, including leafy spurge, kochia (*Kochia scoparia*), field mustard (*Brassica kaber*), sweetclover (*Melilotus officinalis*), and Canada thistle. Later, Lenz (1993) noted that non-native plant species were one of the important management issues that broadly concern the natural resources of KNRI. The author specifically noted leafy spurge and smooth brome as abundant invasive plants, and also noted that tree diseases such as heart rot and Dutch elm disease stressed forests and woodlands in the park.

In 2006, the NPS created a draft PMP as an update to the 1996 PMP (DeKeyser and Krabbenhoft 2006). The authors found the primary invasive species of concern were crested wheatgrass, smooth brome, Kentucky bluegrass, leafy spurge, Canada thistle, and absinth wormwood. Also noted in NPS (n.d.) were non-natives such as honeysuckle (*Lonicera* spp.) and sweet clover. DeKeyser and Krabbenhoft (2006) replicated the work of Clambey (1985) along the prairie/fields, generally finding a large decline in native vegetation since 1985.

KNRI contains a large proportion of human-disturbed herbaceous vegetation, as much of the area was cultivated by the original inhabitants, the Mandans and Hidatsas, and then by Euro-American settlers (Clambey 1985, Salas and Pucherelli 2003). Clambey (1985) states that formerly cultivated lands that became part of KNRI were required to be seeded with a perennial grass cover before the NPS took ownership from 1976-1980, and this resulted in a mix of vegetation with very little successful establishment of the original species planted. Salas and Pucherelli (2003) noted that many of the original planted species did not persist through the early 2000s, and that conditions no longer resembled an original map of the species planted in former cropland areas presented in Clambey (1985). In fact, much of the area seeded into various grass species was taken over by smooth brome (Salas and Pucherelli 2003). In combining planted and agricultural map units, the GIS data indicate nearly half of the park's total area is disturbed plant communities. Much of this is dominated by non-native smooth brome communities; Salas and Pucherelli (2003) also mapped several areas dominated by Canada thistle.

Unintended Consequences of Management Actions
Small woody shrubs are establishing themselves surrounding some of the archeological sites between mowed areas and surrounding prairies. Park staff suggests that the presence of this woody vegetation is undoubtedly having an impact on archeological preservation, and will need to be monitored/managed by KNRI managers in the future.

<u>Data Needs/Gaps</u>

Remotely Sensed Images Available for KNRI
Presently, the historic condition overall land cover in present-day KNRI is not well quantified. To address this, a variety of historic, remotely sensed images (satellite images and aerial photography) are available for the KNRI area. These could be used to map historic land cover conditions and changes between image dates. In conjunction with the Sexton (2012) study, the NPS acquired and ortho-rectified several satellite images and aerial photographs. Images listed in Sexton (2012) could also be used to understand historic land cover. Some additional aerial photography is available for the KNRI area from 1928 and 1943 from Digital Horizons (2012) and the photo gallery of the Center for Regional Studies at North Dakota State University (NDSU). Examples of two of these historic aerial photos are displayed in Figure 8. Another source for obtaining images is the USGS Earth Explorer website. Sexton (2012) warns that many of the aerial photographs prior to 2003, when high quality NAIP images became consistently available, were collected by several agencies with various objectives and with variable resolutions/image qualities. Therefore, the utility of the older photos for examining land cover may also vary.

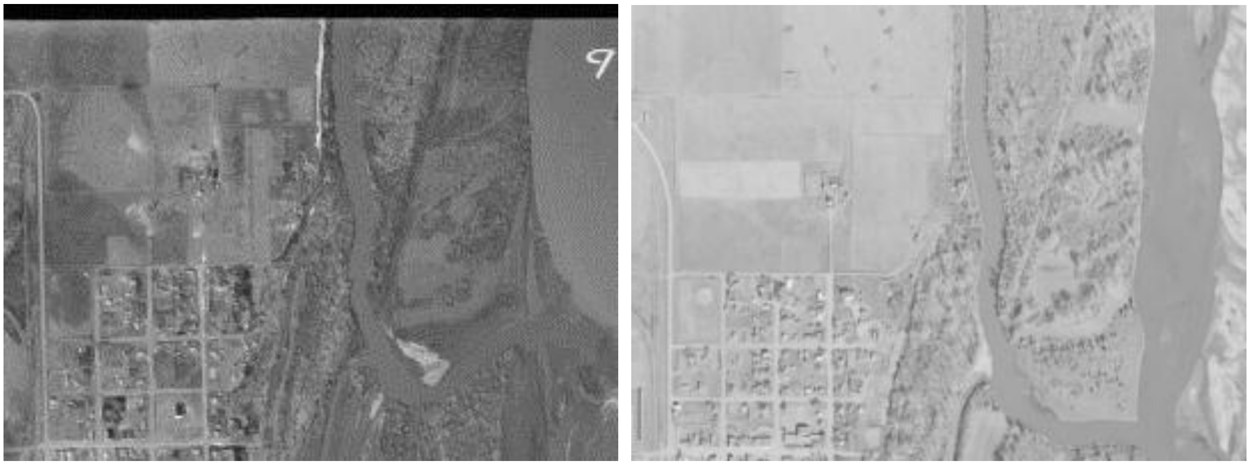


Figure 8. Portion of an aerial photo of Stanton/Knife River area captured 4 April 1943 (left), and 8 October 1965 (right) (Digital Horizons 2012).

Additional documentation of historic aerial photography of the KNRI area is listed in Table 9.2 (p. 170) of Thiessen (1993). The USDA Agricultural Stabilization and Conservation Service (ASCS), now the Natural Resource Conservation Service (NRCS), took historic black and white aerial photography as early as 9 July 1938 at a scale of 1:20,000. Similar photography was taken again on 15 October 1950, 28 June 1958, and 19 September 1966. Various oblique photos and other similar scale vertical aerial photography were taken by the USGS through 1976. Additionally, Thiessen (1993) lists several aerial photography dates, formats, scales, and locations from 1976-1988 of KNRI. Thiessen (1993) also concluded that mapping using mid 1970s aerial photography was useful in successfully documenting archeological resources of KNRI, and that older historic images could be used in future research.

Recent high resolution satellite imagery and aerial photography may provide a contemporary source for interpreting land cover or vegetation classes in the park. They could potentially be used to update the Salas and Pucherelli (2003) vegetation map (GIS data).

A joint project between the NGPN, KNRI, and the MWAC will soon (late 2012) result in a 9 cm (0.39 in) vertical resolution Light Detection and Radar (LiDAR) dataset. A high resolution digital elevation model (DEM) produced from these data will be useful for the park, MWAC, and NGPN. Among other uses (e.g., hydrologic modeling), the data may be helpful for future examinations of land cover and land cover change, as processed LiDAR data can depict land surface conditions with and without vegetation. That is, LiDAR products can allow for ground visualization (i.e., digital elevation models) and for modeling vegetation height (e.g., forest structure, crown cover, crown canopy profile) because a raw LiDAR point cloud (first, second, third, fourth, last returns) can be classified into different values such as low vegetation, medium vegetation, water or buildings (Sumerling 2010). In addition, some analyses of LiDAR data can produce high land cover classification accuracies as demonstrated by Antonarakis et al. (2007).

While survey efforts to date have identified 58 archaeological sites and resulted in relatively precise measurements for the surficial extent of these sites, the measure "percent land designated as an archeological resource" in this assessment 1acks a definition of what is considered desirable or undesirable in terms of land cover. One suggestion is that archeologists, park, and NGPN staff could work on developing a measure of condition to address this need.

Overall Condition

Plant Community Composition
The plant community composition measure was assigned a *Significance Level* of 2 during initial scoping. Much of KNRI was cultivated for agriculture or grazed by livestock. Because of this, non-native plant species are present, and in some cases abundant, in much of the park. However, prairie restoration efforts, prescribed burning, and other non-fire fuel treatment activities by the NPS are ongoing, with the goal to eventually establish and maintain native plant communities. In the early 1990s, Lenz (1993) produced a qualitative assessment of the "natural" conditions for each of the study's map units. The author ranked them as very poor, poor, fair-poor, fair, fair-good, or good, finding that the majority of the map units were of poor or lower ranking. All of the old fields were ranked "very poor", and much of the shrub/grasslands were poor; only a few of the prairie community map units were ranked as good. Lenz (1993) listed detailed management concerns for each of the map units in the study.

As indicated by the 2008 FMP, the two areas of native mixed grass prairie, totaling about 370 ha (915 ac) or 52% of the park, are in degraded condition. According to the recent observations by the NGP FireEP, restoring prairie areas might not be accomplished by spring burning alone. The results of the fire effects monitoring are not yet published for KNRI.

Initial, unpublished NGP FireEP monitoring results indicate that prescribed burning alone hasn't been effective in reducing the non-native cool season grass cover at KNRI. Dan Swanson, NGP Fire Ecologist, (pers. comm., 2012) provided the following observations regarding the vegetation related to prescribed fire effects in KNRI, and some possible adjusted strategies going forward:

> Kentucky bluegrass and smooth brome are the dominant grasses in most burn units at KNRI. Late spring prescribed burning generally is the most effective at reducing smooth brome or Kentucky bluegrass, but the NGP fire effects team we [sic] haven't seen much positive results with prescribed burning alone. The higher the smooth brome or Kentucky bluegrass cover, the harder it will be for spring prescribed fire alone to restore the mixed-grass prairie.
>
> The North Dakota Fire Management Office is now trying a combination of mowing, herbicide treatment, reseeding with native grasses, and prescribed fire in areas that have extremely high smooth brome cover. In situations where the burn unit has extremely high smooth brome cover, the best management treatment may be to apply herbicide over the entire unit and then reseed with a combination of native grasses and forbs. The effectiveness of the spring burns will also be tied to the precipitation that follows later that spring and summer following the treatment. In the Big Hidatsa unit, Kentucky bluegrass has increased significantly following three prescribed burns (one fall and two spring burns). This may be due to the fact that Kentucky bluegrass is taking the niche that Needle & Thread grass previously occupied since N&T is deleteriously effected [sic] by spring burning and recovery takes between two and ten years. Kentucky bluegrass also

has responded positively to the wetter springs that the Northern Great Plains experienced from 2009 to 2011.

Given these observations, the plant community composition of KNRI was assigned a *Condition Level* of 3, indicating a significant concern.

Patch Distribution

KNRI staff assigned the patch distribution measure a *Significance Level* of 2. Definitions and methods for this measure are not yet developed at KNRI. Further consideration of the applicability of this measure in relation to broad vegetation management goals is needed. In addition, the most recent vegetation GIS data are not current for depicting or analyzing patch distribution for KNRI. Therefore, this measure is a data gap for the park and was not assigned a *Condition Level*.

Percent Land Cover Change

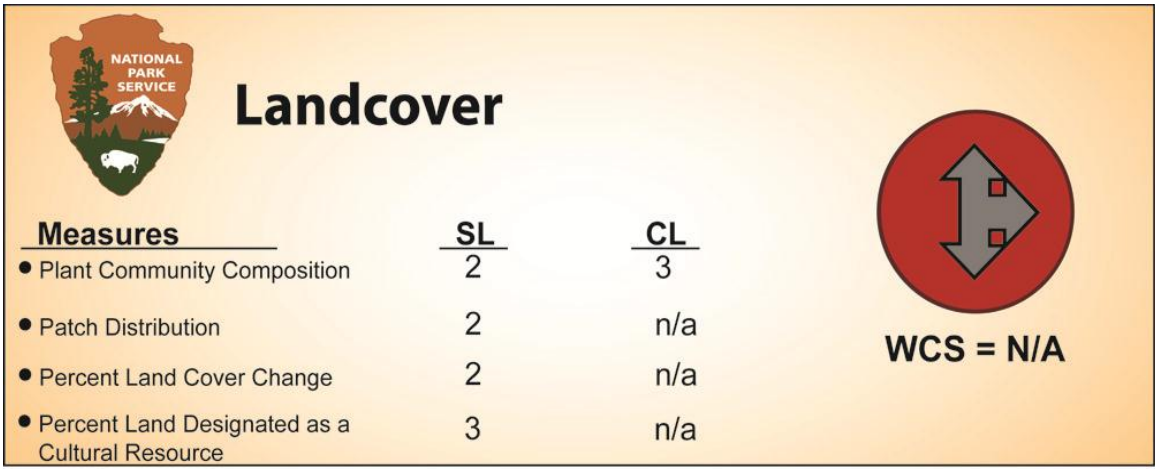
Percent land cover change was assigned a *Significance Level* of 2. However, this measure is largely a data gap for the park. Typically, the detection of land cover change requires remote sensing techniques or aerial photo interpretation using time series aerial photography or other remotely sensed images (e.g., satellite imagery). While some coarse scale (compared to Salas and Pucherelli [2003] GIS data) data are available from the MRLC as NLCD change products, visual examination of the 2001 to 2006 NLCD change product indicates erroneous change classification. The only change category, "woody wetland to agriculture" from 2001 to 2006 immediately surrounding KNRI (1.6-3.2 km [1-2 mi]) appears to be erroneous as aerial photography prior to the mid to late 1990s reveals many areas as agriculture. In this case the Salas and Pucherelli (2003) GIS data can act as a baseline dataset to which future conditions can be compared for change detection. Previous vegetation map information by Clambey (1985) is not readily comparable to more recent work (Salas and Pucherelli 2003) in terms of map classification or resolution. The percent land cover change would provide information to the park as to what areas are subject to change and what type of change is occurring in order to inform management decisions. The *Condition Level* was not determined for this measure as changes in land cover are not quantified at this time.

Percent Land Designated as a Cultural Resource

The measure of percent land designated as cultural resource was assigned a *Significance Level* of 3. Since the primary purposes of the park include the preservation, protection, research, and interpretation of archeological features, the amount of land that has been designated as a cultural resource is important to KNRI managers. Of particular importance are the potential effects that managing vegetation and land cover may have on the park's cultural resources. Cultural resource inventory GIS datasets indicate that a large portion of the park contains known archeological sites. However, there are not clear indications of what is considered positive or negative in relation to land cover; rather, it is important to recognize the extent of known archeological features and to relate the landscape to what is known of historic conditions at KNRI. A *Condition Level* was not determined for this measure.

Weighted Condition Score (WCS)

A *Weighted Condition Score* was not created for this measure, as a clear definition of desired conditions (i.e., reference conditions) for each measure is not yet created, nor is it clear how each measure contributes to the overall condition of land cover at KNRI. Finally, current data that express overall land cover conditions are limited as only one year of NPS vegetation monitoring results have been published and NPS fire effects monitoring data are limited. Despite this, land cover is of significant concern in KNRI as many of the plant communities are known to be in poor condition. Non-native invasive plant species have expanded in distribution and total cover and in some cases have become dominant in recent decades. The age class of forested areas is of concern as many areas have poor tree regeneration. Finally, much of the park contains known archeological features or other culturally or historically significant areas, and therefore, must be taken into consideration in managing and restoring native plant communities.



4.1.6 Sources of Expertise

John Moeykens, KNRI Chief of Law Enforcement and Resource Management

Jay Sturdevant, Archeologist, NPS Midwest Archeological Center

Dan Swanson, NGP Fire Ecologist

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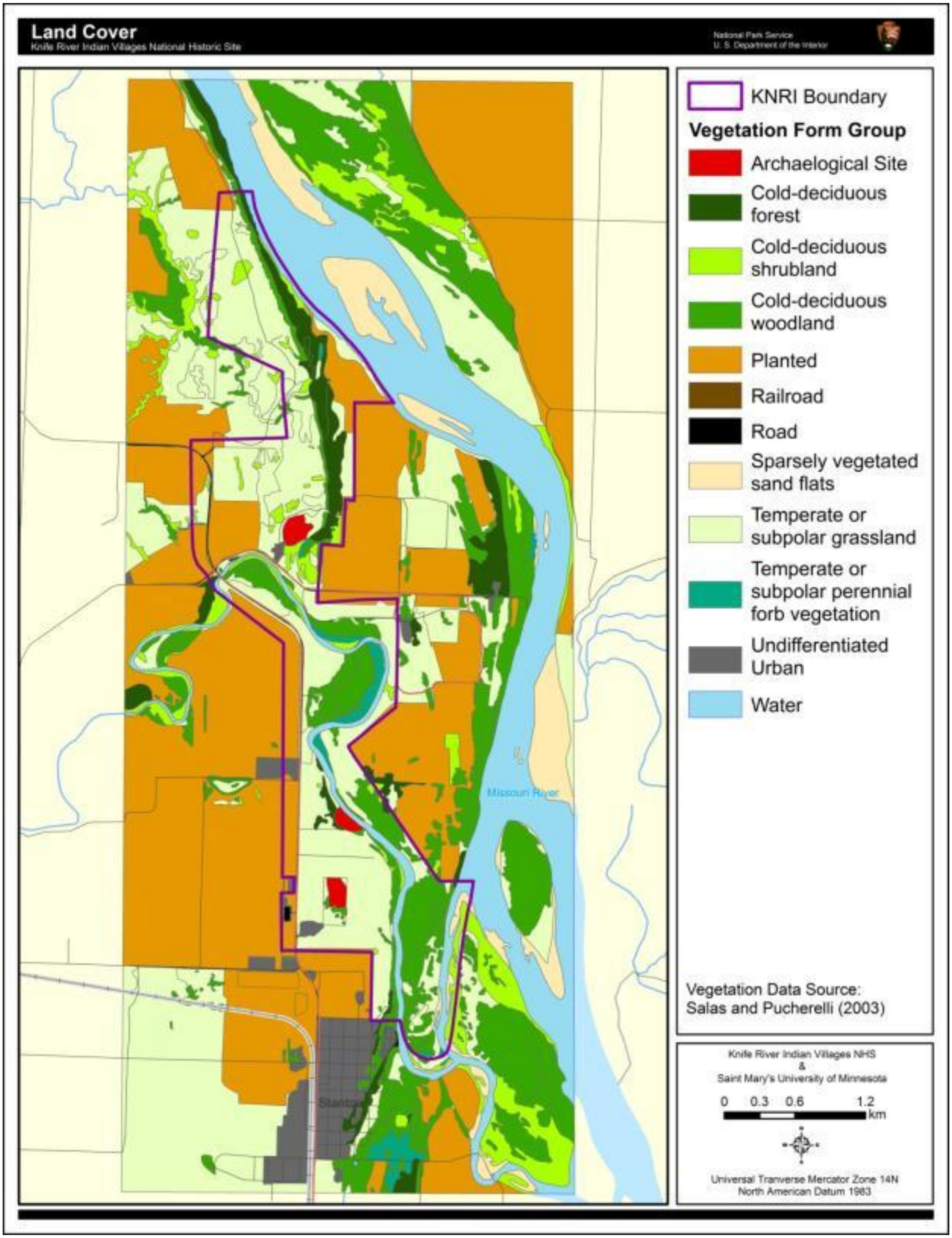


Plate 5. Land cover in KNRI based on the vegetation formation group of the Salas and Pucherelli (2003) GIS data.

4.2 Riparian Forest Community

4.2.1 Description

Situated between the historic Knife and Missouri River floodplains, KNRI is home to several unique ecological and plant communities. Forested communities in North Dakota are particularly rare, as only a little more than one percent of the land area in the state is tree-covered (Jakes and Smith 1982). In KNRI, approximately one fourth of the total park area is comprised of riparian forest communities (Clambey 1985, Salas and Pucherelli 2003). There are two primary types of riparian forests in KNRI, the green ash (*Fraxinus pennsylvanica*)/boxelder (*Acer negundo*)/American elm (*Ulmus americana*) forest, and the eastern cottonwood forest (Clambey 1985) (Plate 6).

The completion of the Garrison Dam in 1955 (approximately 16 km [10 mi] from the Knife River's confluence), and the subsequent regulation of the Missouri River, greatly affected the Missouri and Knife Rivers and the surrounding ecological communities (USACE 2000, Ellis 2005). One of these effects was a decline in the magnitude and frequency of annual flood events (NPS 2006). A reduction in flood events reduced the amount of regeneration of native trees and shrubs in the riparian forest communities along the Missouri River, because common species, such as cottonwood and willow, require periods of inundation to regenerate and become established (Ellis 2005). This lack of seedling establishment becomes especially problematic as older cottonwood stands die out and are lost in these riparian communities (Simon et al. 1999, Hoganson and Murphy 2003).

4.2.2 Measures

- Age class
- Historic and contemporary vegetation work

4.2.3 Reference Conditions/Values

Riparian forest composition and structure before the construction of the Garrison Dam is the reference condition for this assessment. Johnson (1992) calculated the relative proportions of overall forest types by age categories along a stretch of the Missouri River between the Garrison Dam and the Oahe Dam (Table 9). No such estimate or condition is available for forest types along the Knife River.

Table 9. Changes in the area of forest types on the Missouri River from Garrison Dam to the Oahe Dam. 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

4.2.4 Data and Methods

There are several studies completed in KNRI that add to the understanding of current riparian forest condition. In the summer of 1984, Clambey (1985) conducted a baseline vegetation survey for KNRI. The survey identified 257 plant taxa; voucher specimens were collected for most taxa. Clambey (1985) had several specific objectives:

- conduct a floristic inventory and establish a reference plant collection for use at KNRI;
- analyze the contemporary vegetation;
- clarify the earlier vegetation patterns;
- evaluate current vegetation management issues and recommend measures to be used in the future.

Johnson (1992) investigated the effects of the Missouri River's altered hydrologic regime on the compositional dynamics of riparian forest communities. 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 (Table 9). These simulations suggested that a mix of young, transitional, and equilibrium forest stands create the highest biodiversity in the riparian ecosystem.

In 1993, Lenz (1993) surveyed the vegetation at KNRI in order to inventory rare plants, describe plant communities, and develop a vegetation map for the park. After surveying the vegetative communities of the park, Lenz (1993) assessed the natural condition or quality of each community unit (45 units in total).

Salas and Pucherelli (2003) completed a vegetation mapping project for KNRI in 2002. During this mapping project, Salas and Pucherelli (2003) compared a list of potential vegetation types developed by NatureServe to the vegetation types found during the site visit. All of the vegetation types that could be differentiated and delineated were identified and each of the delineated polygons was visited to verify their vegetation type (Salas and Pucherelli 2003). A vegetation map was created for KNRI, and overall thematic map accuracy is considered 100% (all interpreted polygons received a field visit for verification).

Wienk et al. (2007) summarizes the NGP FireEP prescribed fire and mechanical fuel reduction projects in all of the NGP FireEP parks from 1997-2007. In KNRI, five green ash/boxelder plots were established within the Sakakawea burn unit. According to Wienk et al. (2007), specific objectives for these green ash/boxelder woodlands in KNRI were to:

- Reduce dead and downed woody fuels by 30-50% (immediate post-burn objective);
- Limit overstory mortality to 10-20% within two years post burn;
- Reduce frequency and relative cover of non-native herbaceous species by 20-30% with each burn cycle;
- Increase the number of seedling and pole-size native deciduous trees.

Beginning in 2011, the NGPN began a plant community monitoring effort in KNRI. This monitoring project will be a multiple year/multiple survey project and will describe the status of the plant community in KNRI at 5-year intervals. According to Ashton et al. (2011), specific long-term objectives of the project are to:

1. determine park-wide status and long-term trends in vegetation species composition (e.g., non-native vs. native, forb vs. graminoid vs. shrub) and structure (e.g., cover, height) of herbaceous and shrub species;

2. determine status (at 5-year intervals) and long-term trends of tree density by species, height class, and diameter class in lowland riparian areas;

3. improve our [NGPN] understanding of the effects of external drivers and management actions on plant community species composition and structure by correlating changes in vegetation composition and structure with changes in climate, landscape patterns, atmospheric chemical composition, fire, and invasive plant control.

Ashton et al. (2011) summarizes the results of the 2011 field sampling at eight plots in KNRI. Complete descriptions of the monitoring protocol are found in Symstad et al. (2011) (the reports and protocol are available from http://science.nature.nps.gov/im/units/ngpn/monitor/plants/plants.cfm).

4.2.5 Current Condition and Trend

Age Class

The Garrison reach of the Missouri River (i.e., the stretch of the river between the Garrison and Oahe Dams) supports approximately 25% of the riparian vegetation along the upper Missouri River (USACE 2010). The dominant forest tree species along this segment of the Missouri River are cottonwood, slippery elm (*Ulmus rubra*), green ash, and boxelder (USACE 2010).

The installation of the Missouri River dam system continues to affect the regeneration and succession of riparian forest communities. Specifically, the reduced frequency of flooding along the Missouri River has led to a dramatic decline in cottonwood regeneration. Cottonwoods require bare, moist soil to regenerate; annual overbank flooding historically created these conditions. The majority of the cottonwoods found along the Missouri River began growing before the dams were built and are considered late-growth or mature forests (USACE 2010). With no cottonwood regeneration in the understory, projections for the riparian forest communities along the Missouri River indicate that cottonwood forests will reach senescence and be replaced by green ash, boxelder, and other late successional forest species (USACE 2010).

In 1984, Clambey (1985) sampled tree cores from 30 subjectively selected trees in KNRI. Estimated ages of the trees sampled in 1984 indicated that the trees were mature (50-114 years old; USACE 2010), and virtually no cottonwood regeneration was evident. Clambey (1985) also stated that a major impediment to regeneration was a thick herbaceous understory dominated by smooth brome. Despite the age of the stands in KNRI, none of the sampled trees were old enough to have existed at the time of European or Plains Indian settlement; the current forest type and distribution in KNRI is most likely representative of what was present during that time.

USACE (2010) reported that, from 2007-2009, 66 tree stands along the Garrison reach were sampled for community type and stand age. Of the stands sampled, 35 were cottonwood communities, 10 were disturbed cottonwood communities, and 21 were non-cottonwood communities (USACE 2010). The majority of the cottonwood communities were very old (50-140 years old), and less than 15% of the cottonwood communities were comprised of stands <50 years old.

Much like Clambey (1985) and USACE (2010), Lenz (1993) also found limited regeneration of overstory riparian trees. Instead of having an understory of native shrubs and forbs, Lenz (1993) found brome grass and other grass species. It appears as though regeneration of riparian tree species (especially cottonwood) has largely halted in KNRI. This will ultimately lead to a transition from a cottonwood-dominated riparian community to a forest dominated by late successional species (e.g., green ash, boxelder). Late successional forests are comprised of smaller tree species and support a lower diversity of bird species (USACE 2010). Furthermore, these forests will likely be lower in vegetative diversity due to "the loss of pioneer plant species, loss of vertical structural complexity, and the loss of nesting cavities found mostly in old cottonwood trees" (USACE 2010, p. 3-19; Johnson 1992, Rumble and Gobeille 2004). Maintaining and supplementing cottonwood regeneration along the Missouri River and its tributaries could have dramatic impacts on the organisms that are dependent on riparian forests.

Historic and Contemporary Vegetation Work

Clambey (1985) Baseline Vegetation Study

In 1984, Clambey (1985) conducted a baseline vegetation survey in KNRI and identified 257 taxa. Voucher specimens were collected for 223 taxa; these specimens were deposited with the NPS. While the inventory was not restricted to the riparian forests of KNRI, Clambey (1985) did identify six tree species that typified the forests of the area (Table 10). The forests consisted of two types: green ash/boxelder/American elm forests, and eastern cottonwood forests (Clambey 1985). The acreage of the green ash/boxelder/American elm forests was approximately six times as large as the cottonwood forests in KNRI (Clambey 1985).

Table 10. Tree species identified in KNRI during the Clambey (1985) baseline vegetation survey.

Latin Name	Common Name
Acer negundo	boxelder
Elaeagnus angustifolia	Russian olive
Fraxinus pennsylvanica var. *subintegerrima*	green ash
Populus deltoides	eastern cottonwood
Salix amygdaloides	peachleaf willow
Ulmus americana	American elm

Despite the fact that forests account for 25% of the park's total area, Clambey (1985) found that only 16% of the park's vegetative species were forest species. Clambey (1985) suggests that the limited forest diversity in KNRI may be due to prolonged human disturbance in the area (e.g., cultivation, livestock grazing, and construction) that has further reduced the diversity of the community.

Lenz (1993) Vegetation Inventory

Lenz (1993) had two research objectives: 1) inventory KNRI for rare plant species, and 2) survey the site and describe natural and disturbed plant communities to develop a vegetation map. The surveys at KNRI found no rare plants and only limited potential for rare plants in the park; these findings were attributed to high levels of disturbance throughout the park, and limited unique habitat for rare plants (Lenz 1993). The forest species identified in Lenz (1993) are represented in Table 11.

Table 11. Woodland community species as identified during the Lenz (1993) vegetative survey of KNRI.

Latin Name	Common Name
Acer negundo	boxelder
Pascopyrum smithii	western wheatgrass
Amelanchier alnifolia	juneberry
Andropogon gerardii	big bluestem
Arctium minus	burdock
Artemisia absinthium	wormwood
Asclepias syriaca	common milkweed
Symphyotrichum laeve	smooth blue aster
Bromus inermis	smooth brome
Eleagnus angustifolia	Russian olive
Elymus virginiana	Virginia wildrye
Fragaria virginiana	strawberry
Fraxinus pennsylvanica	green ash
Galium boreale	northern bedstraw
Hesperia matronalis	Dame's rocket
Monarda fistulosa	bergamot
Nepeta cataria	catnip
Poa pratensis	Kentucky bluegrass
Populus deltoides	cottonwood
Prunus americana	wild plum
Prunus virginiana	chokecherry
Rhus radicans	poison ivy
Rosa woodsia	western wildrose
Salix amygdaloides	peach-leaved willow
Shepherdia argentea	buffaloberry
Symphoricarpos occidentalis	buckbrush
Ulmus americana	American elm
Urtica dioica	stinging nettle

Lenz (1993) described eight community types in KNRI and assessed the “natural quality” of each community type in KNRI using the following categories: excellent, good, fair, poor, and very poor. There were 14 woodland communities described in Lenz (1993) that covered 191 ha (473 ac) (approximately 31% of KNRI). Of these 14 communities, only three woodland areas had a condition described as either “good” or “fair”. These communities were located near overflow sites along rivers and received enough supplemental moisture to regenerate. They appeared to be viable communities with limited amounts of vegetation and disturbance. The remaining 11 communities were heavily impacted by disease, disturbance, and had almost no regeneration (Lenz 1993).

Salas and Pucherelli (2003) Vegetation Mapping Project
Salas and Pucherelli (2003) identified 17 vegetative classes within KNRI and the immediately surrounding areas. Of the 17 classes identified, only two dealt with the riparian forest communities in the park: the forest class, and the woodland class. In KNRI, the forest class was restricted to the Russel Floodplain in the northeast of the park. In this floodplain, the forest class included two specific types of forests:

1. Temporarily flooded cold-deciduous forests – This forest included the green ash/American elm alliance. The forest was largely made up of green ash, while a small amount of elms were also present. The green ash grew quite large, and averaged 15 m (50 ft) in height. Canopy cover was almost 100%, while the understory was comprised of a few shrub species. Boxelder was present, but usually on the periphery of the forests (Salas and Pucherelli 2003).

2. Eastern cottonwood temporarily flooded forests – This forest contains the riverfront floodplain forests of KNRI. These forests have relatively tall canopies (30 m) and have limited diversity due to the dynamics of flooding and the associated erosion and depositional processes. A cottonwood area in the Russel Floodplain was identified by Clambey (1985), but this area was since burned (2001), and only a few cottonwoods remain. There are currently only small areas of this forest type scattered throughout KNRI (Salas and Pucherelli 2003).

Similar to the forest class in Salas and Pucherelli (2003), the woodlands class was divided into two specific types of forests:

1. Cold-deciduous woodlands – This is the most common class of wooded vegetation in the park and is dominated by green ash and American elm. The canopy trees are around 10 m in height and allow significant levels of light to penetrate to the understory. Most of these woodlands were burned in 2001, and the result of these burns changed the canopy and understory composition. The canopy is now much more open, and smooth brome is near 100% in coverage of the burned understory (Salas and Pucherelli 2003).

2. Temporarily flooded cold-deciduous woodlands – This community type is dominated by eastern cottonwoods, with secondary canopy species including American elm, green ash, and willows. However, Salas and Pucherelli (2003) mapped these regions as predominantly green ash/American elm/chokecherry (*Prunus virginiana*) woodlands, as cottonwoods stands (excluding the floodplain forest class) are sporadic across KNRI and are difficult to map.

Northern Great Plains Fire Program Review (1997-2007; Wienk et al. 2007)
Fire plot monitoring in KNRI began in 1998, and three green ash/boxelder woodland plots were established within the Sakakawea burn unit. Since 1998, two burns have been initiated on the

Sakakawea unit (2001 and 2006) (Wienk et al. 2007). Pre- and post-burn vegetative coverage in the Sakakawea burn unit is reported in Table 12.

Table 12. Pre- and post-burn vegetative coverage in the Sakakawea burn unit of KNRI. Units reported are hectares (acres). Data reproduced from Wienk et al. (2007).

Vegetation Type	Pre-burn cover	Year 2 cover	% Change
Non-native Forb	10.7 (26.5)	16.5 (40.8)	54
Native Forb	5.22 (12.9)	5.4 (13.3)	3
Non-native Grass	41.6 (102.8)	42.9 (106.0)	3
Native Grass	5.0 (12.4)	0.8 (2.0)	-84

Following the burn on the Sakakawea unit, the native grasses on the unit experienced an 84% decrease in cover (decreasing from 5.0 ha to 0.8 ha) (Table 12). Non-native forbs, however, experienced a 54% increase in cover. Pole trees and overstory species in the Sakakawea burn unit decreased in density following burns, exhibiting a 71% and 19% decline, respectively (Table 13).

Table 13. Pre- and post-burn pole and overstory density after one burn in the Sakakawea burn unit of KNRI. Units reported are stems/acre. Data reproduced from Wienk et al. (2007).

	Pre-burn density	Year 2 density	% Change
Poles	91.7	27	-71
Overstory	107.2	86.6	-19

NGPN Plant Community Monitoring

During plant community monitoring in 2011, Ashton et al. (2011) reported only three of eight monitoring plots containing woody species. Density of these species (both shrubs and trees) were measured and are reported in Table 14.

Table 14. Tree and tall shrub density in three forested plots at KNRI in 2011. Values are reported as stems per hectare. Table reproduced from Ashton et al. (2011).

Plot	Size class	Boxelder	Green ash	Chokecherry	Silver buffaloberry	Snag
KNRI_PCM_002	Trees	-	40	-	-	50
	Poles [a]	-	32	-	127	955
	Seedlings [b]	32	509	-	223	-
KNRI_PCM_019	Trees	-	30	-	-	20
	Poles [a]	-	-	-	-	32
	Seedlings [b]	-	-	-	-	-
KNRI_PCM_020	Trees	-	-	-	-	-
	Poles [a]	-	-	-	-	96
	Seedlings [b]	-	-	2069	95	-

a = diameter 30 cm above the root collar >2.54cm. Green ash are measured at breast height, and silver buffaloberry are measured at root collar (except in special circumstances).
b = plant height less than 1.37cm in height, are >1 year old.

Ashton et al. (2011) found only three sample plots that contained evidence of tree and tall shrub species. At these sites, no saplings were observed, and only five living trees were documented. These trees were not in optimal health, as two of the five trees exhibited more than 10% mortality on their branches. Snag trees with high amounts of dieback were common across these plots (Photo 5). Across two sites (KNRI_PCM_002 and KNRI_PCM_020), seedlings were observed for boxelder, green ash, chokecherry, and silver buffaloberry (*Shepherdia argentea*) (Table 14).

Photo 5. A forested plot in KNRI showing evidence of tree mortality (photo from Ashton et al. 2011).

Threats and Stressor Factors

The Garrison Dam's regulation of the Missouri River has had dramatic effects on the riparian communities of KNRI. The absence of annual floods represents a serious threat for these communities in the park; without the erosion, deposition, and supplemental moisture provided by these floods, regeneration of the riparian forests in KNRI would largely cease for species such as the eastern cottonwood (Lenz 1993, USACE 2010). Further complicating regeneration and succession in KNRI is heavy browsing by white-tailed deer, which creates distinctive browse lines. Park staff believe that this browsing pressure is partially responsible for the absence of vegetative succession in KNRI.

Another threat to the riparian forest community is the presence of heart rot fungus (*Fomes fomentarius*) and disease. Heart rot fungus is prevalent in KNRI and affects nearly 75% of the forest; the fungus has killed primarily mature green ash trees as well as younger saplings (NPS 2006). Dutch elm disease has been present in the park (Lenz 1993, NDFS 2001) and removed a great deal of American elm from the canopy of the forests. From 1997-2002, many of the American elm trees were removed by park staff to combat Dutch elm disease. While some healthy, larger elm trees do exist, elm trees are extremely rare in KNRI at this point.

From 2009-2010, KNRI was hit heavily by a cankerworm (linden looper [*Erannis tiliaria*]) infestation which defoliated almost all of the ash and boxelder trees. Park staff notes that occurrences like this can occur every decade or so, but these outbreaks are not predictable and can occur in both the spring and fall. While these infestations do not appear to kill the trees (only the leaves are consumed), they do represent a threat to the forest that will likely need to be managed when an infestation flares again.

Recently, a natural threat to the riparian forest community has become more prominent in KNRI, as the North American beaver (*Castor canadensis*) has had impacts on this community. Extended flood conditions along the Missouri and Knife Rivers in 2011 resulted in the Missouri River byway (previously extending from the Missouri River to the eastern edge of the “peninsula”) being filled in by sand and silt (Photo 6). This change in land form has forced beavers to new locations in the area, and several have become established in an area where the Knife River meets the park’s boundary. Beavers in this area have started to remove cottonwoods that are >100 years old (some of the last large cottonwoods in the park), and several smaller cottonwoods have also been removed (Photo 7). While beavers removing trees is a natural aspect of the riparian forest community, it has become a larger issue in KNRI as cottonwood regeneration has largely ceased. Because of this, the large trees being removed by beavers are not being replaced, and this could result in a decrease in the overall size and age class structure of the forest community if regeneration does not resume.

Photo 6. Missouri River byway near KNRI during the prolonged 2011 flood event (top), and Missouri River byway filled in with silt and sand after the prolonged 2011 flood event (bottom) (photos from John Moeykens, NPS).

Photo 7. Example of a fresh beaver cut in KNRI. An 18-inch ruler is located in the cut to provide context for how large the cut/tree are (photo by John Moeykens, NPS).

The presence of exotic species is a threat to all native plant communities within KNRI. Smooth brome occurs in the understory of many riparian forest stands in the park. These stands often only receive water in the spring and fall when the dense smooth brome is dormant and does not absorb all of the water (NDFS 2001). Exotic species have thrived in burned areas in the park (e.g., Sakakawea burn unit) and could completely choke out native vegetation from the understory. The NPS Northern Great Plains Exotic Plant Management Team (EPMT) began treating the park for exotic species infestations in 2002. The species of primary concern are Canada thistle, leafy spurge, and absinth wormwood. In 2010, the EPMT began removing common buckthorn (*Rhamnus cathartica*) from the park. Common buckthorn is an exotic tree species that has established along the west side of the Knife River (NPS 2011). In 2010, almost 2.5 ha (6 ac) of 90% canopy cover common buckthorn was treated by the EPMT; the park was revisited in 2011 to remove remaining common buckthorn (NPS 2011).

Russian olive trees were historically considered a beneficial species and were planted across North Dakota, frequently for use as a property snow fence. However, KNRI and the EPMT have spent hundreds of hours removing Russian olive from the park. For the most part, all Russian olive trees have been removed from the park, and the species is continually monitored within KNRI's boundaries.

While the current threat of human disturbance in KNRI is marginal, there has been a long history of human disturbance in the park. These disturbance events have had a negative effect on the diversity and sustainability of the riparian forest communities (Lenz 1993). Continued monitoring of potential disturbance regimes or events is needed so that additional degradation does not occur.

Data Needs/Gaps

Current and sustained monitoring of KNRI's riparian forest community is needed. In 2014, a set of 20 woody riparian plots in KNRI will be visited as part of the NGPN's plant community monitoring (Ashton et al. 2011). This survey will provide a more accurate depiction of the status of the riparian forests in KNRI. Furthermore, a research team out of the University of Minnesota is currently completing a project that will replicate the vegetative surveys that appear in Clambey (1985).

No studies have looked extensively at core samples from riparian trees. Without this knowledge, the park has little information regarding the age classes of the current forest community. An analysis of this data would allow for a condition assessment for the age class measure.

Overall Condition

Age Class

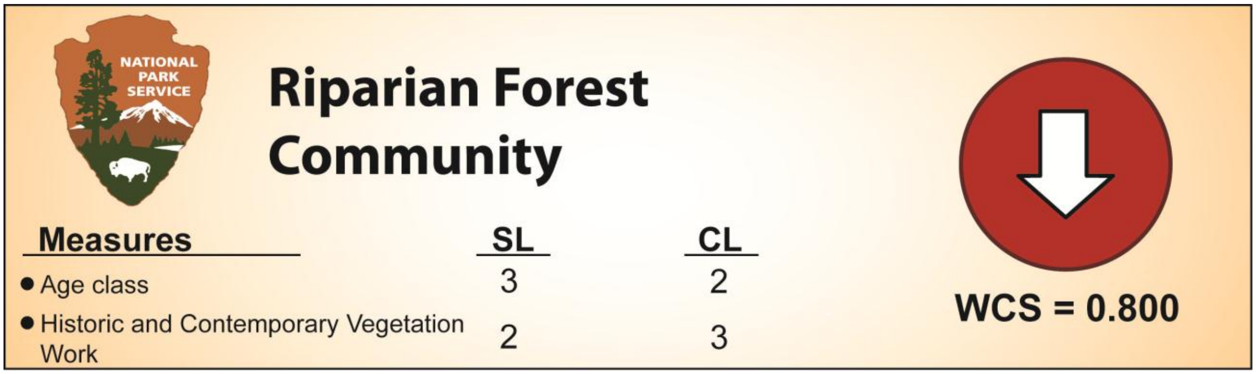
The KNRI project team defined the *Significance Level* for age class as a 3. The most recent estimates for age classes in the riparian forest community come from a very limited sample in 1984 (Clambey [1985] sampled only 30 trees). The sample from 1984 showed trees in KNRI that were mature and had limited regeneration, suggesting that age classes would remain high in the park. Late successional species such as elm and boxelder have established in the park and are present in young age classes. Although there has been no formal investigation of the age class of these stands, indications suggest that the age class structure of KNRI is of concern (especially for cottonwood). For this reason, the measure of age class was assigned a *Condition Level* of 2.

Historic and Contemporary Vegetation Work

A *Significance Level* of 2 was assigned to the measure historic and contemporary vegetation work. It is apparent that the riparian forest community in KNRI is under a significant amount of stress. Almost all work completed in the park identified tree regeneration, understory composition, and tree health as major concerns for this community. The Garrison Dam's regulation of the Missouri River, limiting the occurrence of floods in KNRI, and the understory dominance of non-native species in several locations in KNRI are significant threats to this community. The vegetation inventories and monitoring efforts in the park have revealed that this measure is of high concern in the riparian forest community. Because of this, this measure was assigned a *Condition Level* of 3.

Weighted Condition Score (WCS)

The riparian forest community component was assigned a *Weighted Condition Score* of 0.800, indicating a component of high concern. Because of altered flood regimes and the lack of regeneration in recent time, a decreasing trend graphic was assigned to this component.



4.2.6 Sources of Expertise

John Moeykens, KNRI Chief of Law Enforcement and Resource Management

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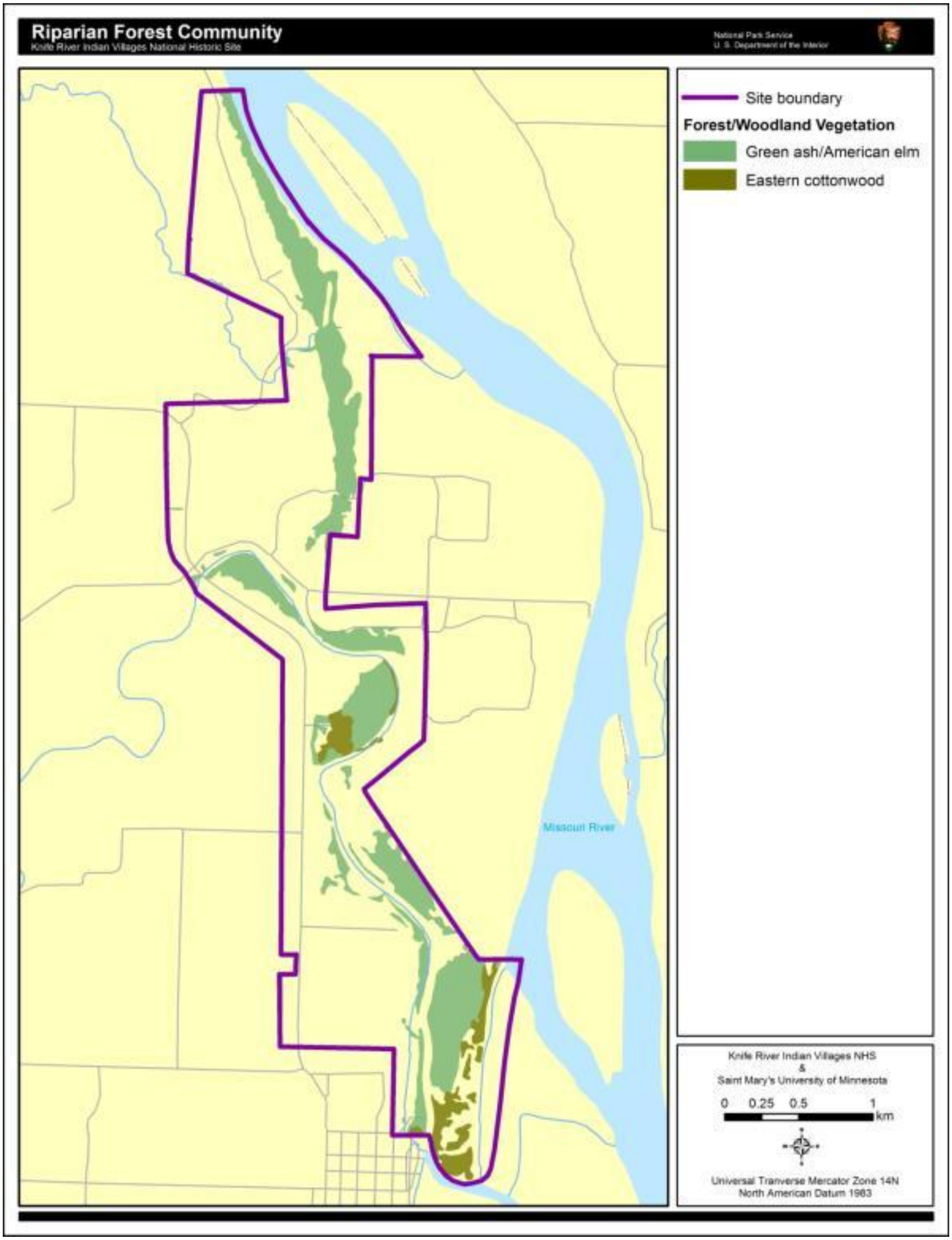


Plate 6. The distribution of riparian forest/woodland vegetation in KNRI.

4.3 Terrace Prairie Communities

4.3.1 Description

Photo 8. Big Hidatsa prairie (NPS photo).

Prairie communities comprise nearly one-fifth of KNRI and are found in two areas: lower and upper terraces. The lower terrace contains mesic prairies and a sand dune community, while the upper terrace supports drier mixed grass prairie (Clambey 1985, Plate 7, Plate 8). Plant species composition varies throughout KNRI due to differences in topography and soils, but it is generally typical of the northern Great Plains mixed-grass prairies with shortgrasses, mid-height grasses, and upland sedges (Clambey 1985, Salas and Pucherelli 2003). This mosaic of grassland provides habitat for numerous wildlife species including coyote (*Canis latrans*), small mammals, a wide variety of birds, reptiles, and numerous invertebrates (Moore et al. 1989). Recent monitoring efforts show that the prairies at KNRI appear more productive but less diverse than other grasslands in the NGPN (Ashton et al. 2012). Average native species richness in eight 10-m^2 sampling plots was 8.2 (±5.23) species. Forbs represented most of this diversity, although grasses and sedges made up a greater portion of the total cover (Ashton et al. 2012).

The lower terrace in KNRI contains primarily fine-textured soils with silt and loam, which typically contain more available moisture than the upper terrace (Plate 7). Lower terraces support mesic prairie communities dominated by big bluestem (*Andropogon gerardii*) and western wheatgrass/green needlegrass (*Pascopyrum smithii/Nassella viridula*) (Clambey 1985). In some lower terrace areas big bluestem reaches over 60% of total plant cover, while western wheatgrass covers 25-30% of prairies where it is the dominant plant. Kentucky bluegrass is an exotic species that has become dominant in some areas, accounting for nearly 35% of plant cover. Smooth brome, another exotic grass, also occurs here (Salas and Pucherelli 2003). Other common grasses in the lower terrace include sideoats grama (*Bouteloua curtipendula*), blue grama (*B. gracilis*), needle-and-thread (*Hesperostipa comata*), and little bluestem (*Schizachyrium scoparium*). Some of the most common forbs in this terrace are white sagebrush (*Artemisia ludoviciana*), white heath aster (*Symphyotrichum ericoides*), silverleaf Indian breadroot (*Pediomelum argophyllum*), and blue lettuce (*Mulgedium oblongifolium*). Patches of shrubs such as western snowberry (*Symphoricarpos occidentalis*) and silver buffaloberry occur in some of these prairies (Clambey 1985). Other graminoid and forb species documented in the lower terrace are shown in Table 15.

Table 15. Additional plant species documented in the lower terrace mesic prairie communities (Clambey 1985).

Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Graminoids		Forbs	
junegrass	*Koeleria macrantha*	Canada anemone	*Anemone canadensis*
sun sedge	*Carex inops* ssp. *heliophila*	Flodman's thistle	*Cirsium flodmanii*
threadleaf sedge	*Carex filifolia*	scarlet globemallow	*Sphaeralcea coccinea*
plains muhly	*Muhlenbergia cuspidata*	rush skeletonplant	*Lygodesmia juncea*
prairie sandreed	*Calamovilfa longifolia*	fringed sage	*Artemisia frigida*
		purple coneflower	*Echinacea angustifolia*
		narrowleaf stoneseed	*Lithospermum incisum*

In addition to mesic prairies, the lower terrace also contains a dune area with sandy soils that supports a unique plant community (Clambey 1985, Plate 7). Graminoid species here are more typical of a drier upland site, including blue grama, needle-and-thread, junegrass (*Koeleria macrantha*), threadleaf sedge (*Carex filifolia*), and prairie sandreed (*Calamovilfa longifolia*). Common forbs are fringed sage (*Artemisia frigida*), hairy false goldenaster (*Heterotheca villosa*), dotted blazing star (*Liatris punctata*), and lemon scurfpea (*Psoralidium lanceolatum*). Several forbs in this area are found nowhere else in KNRI, such as large-flowered beardtongue (*Penstemon grandiflorus*), spiderwort (*Tradescantia occidentalis*), and spinystar cactus (*Escobaria vivipara*) (Clambey 1985).

Upper terrace communities are often drier than the lower terrace, typically with sandier soils, and support a grama-needlegrass-sedge prairie type typical of southwestern North Dakota (Clambey 1985, citing Hanson and Whitman 1938). The dominant graminoids are blue grama, needle-and-thread, and threadleaf sedge. Other common graminoids include junegrass, western wheatgrass, sixweeks fescue (*Vulpia octoflora*), sun sedge (*Carex inops* ssp. *heliophila*), and plains muhly (*Muhlenbergia cuspidata*) (Clambey 1985). Smooth brome has invaded most of these upland prairie areas. Forbs typical of these communities include tarragon (*Artemisia dracunculus*), fringed sage, white heath aster, dotted blazing star, rush skeletonplant (*Lygodesmia juncea*), and rough false pennyroyal (*Hedeoma hispida*). Additional forb species observed in the upper terrace prairie communities are listed in Table 16.

Table 16. Additional forbs documented in upper terrace prairie communities (Clambey 1985, Lenz 1993, Salas and Pucherelli 2003). An asterisk indicates a non-native species.

Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
scarlet globemallow	*Sphaeralcea coccinea*	lacy tansyaster	*Machaeranthera pinnatifida*
purple coneflower	*Echinacea angustifolia*	prairie coneflower	*Ratibida columnifera*
silverleaf Indian breadroot	*Pediomelum argophyllum*	white sagebrush	*Artemisia ludoviciana*
blue lettuce	*Lactuca oblongifolia*	yellow salsify*	*Tragopogon dubius*
hairy false goldenaster	*Heterotheca villosa*	Canadian horseweed	*Conyza canadensis*
common yarrow	*Achillea millefolium*	rigid goldenrod	*Solidago rigida*

Fire and grazing were historically important processes for maintaining the productivity and diversity of prairies (NPS 1996, 2008). Due to its small size, limited staff, and the presence of archeological sites, controlled grazing by bison or other range animals would be a challenging management option for maintaining native prairie at KNRI (NPS 1996). Prescribed burning, however, is a key tool in managing the site's prairies. Fire reduces woody species encroachment and can control some exotic species such as Kentucky bluegrass and smooth brome (Clambey 1985). In the past 15 years, NPS staff have burned at least one of the site's various prairie units nearly every year. More information regarding the locations, management goals, and impacts of these fires can be found in Wienk et al. (2010).

Photo 9. Prescribed fire in a KNRI prairie (NPS photo).

4.3.2 Measures

- Exotic plant density
- Precipitation
- Deer population

4.3.3 Reference Conditions/Values

According to the NPS (1996, p. 2), "The primary goals of prairie management at Knife River Indian villages are to maintain or restore the mixed grass prairie ecosystem, thereby encouraging the expansion of native species presenting visitors with a representative cultural landscape." While no historical information is available regarding prairie community composition, the exotic plants currently in KNRI are known to have been introduced in the past 200 years (e.g., Canada thistle, leafy spurge) and would not have been part of the cultural landscape KNRI strives to represent. The complete eradication of these species is most likely not feasible, but the current management goal is to maintain "the total exotic species population below 10% relative to the entire grassland communities" (DeKeyser and Krabbenhoft 2006, p. 12). For precipitation, the most recent 30-year normals (1971-2000 and 1981-2010) will serve as reference condition. No reference condition has been determined for deer population. While demographic studies of deer have been planned in the past, challenges due to the park's elongated shape, neighboring properties (e.g., land uses such as agriculture), and study timing relative to hunting season have prevented the completion of any research.

4.3.4 Data and Methods

A detailed baseline inventory of KNRI's vegetation was conducted by Clambey (1985). This work describes the species composition of the site's various prairie communities and their general locations. In the mid-1990s, the prairie communities were again surveyed by Lenz (1993) and NPS (1996). The NPS (1996) authored the site's first prairie management plan, which included information on the presence of exotic plants in specific prairie communities. Salas and Pucherelli (2003) completed a vegetation mapping study of KNRI in 2002 and briefly discussed the species composition of each mapping unit. In 2006, KNRI updated its original prairie management plan and resurveyed each prairie community, focusing on the presence of exotic species (DeKeyser and Krabbenhoft 2006). A report from the EPMT (NPS 2011b) provided more recent information on exotic plants at KNRI.

Precipitation data were obtained from several sources: 1971-2000 normals came from NOAA (2002), 1981-2010 normals from NCDC (2012), and 2011 monthly totals from Weather Source (2012).

4.3.5 Current Condition and Trend

Exotic Plant Density

Exotic, invasive plants can have serious and irreversible impacts on plant community structure and function (Mooney and Hobbs 2000, Sakai et al. 2001, as cited by DeKeyser and Krabbenhoft 2006) and are difficult to eradicate once established (DeKeyser and Krabbenhoft 2006, citing Benz et al. 1999, Wilson 2002). As of May 2011, 48 exotic plant species have been documented in KNRI (see Appendix A for a full list) (NPS 2011a). While exotic species have been present in the prairie terrace communities since KNRI's establishment, they seem to have expanded their distribution and cover over the past 25 years. In 1984, Clambey (1985, p. 38) documented smooth brome in Sakakawea pasture, "apparently invading from nearby road ditches", and Kentucky bluegrass at several sites, occasionally reaching 33% in total plant cover. By 1993, Lenz (1993) reported that three of six prairie sites surveyed in KNRI were in fair-to-poor condition, with smooth brome as a dominant grass in Buchfink North Prairie. In 1996, NPS (1996) documented patches of Canada thistle, leafy spurge, Russian thistle (*Salsola tragus*), and other exotic forbs in several sites, along with the continued presence (and perhaps expansion) of smooth brome (Table 17). When these sites were revisited in 2006 (DeKeyser and Krabbenhoft 2006), exotics had become dominant in nearly every location. Exotic grasses had invaded up to 90% of three different sites (Table 17). However, exotic forbs were still only present in small patches (DeKeyser and Krabbenhoft 2006).

Prairie communities were sampled in 2011 as part of the NGPN plant community monitoring program. Exotic species were present in all of the eight plots surveyed, with an average relative percent cover of 62.3% (±30.5%) (Ashton et al. 2012). The only two species found in all the sample plots were Kentucky bluegrass (45.0 ± 29.4% average absolute cover) and smooth brome (53.0 ± 33.1% average absolute cover). Yellow sweetclover, also an exotic species, was the most abundant forb with 13.0% (±17.0%) average absolute cover (Ashton et al. 2012). Two other exotic forbs, Canada thistle and absinth wormwood, were found in the majority of plots sampled.

Table 17. Exotic species observations for six prairie locations within KNRI over time (Lenz 1993, NPS 2006, DeKeyser and Krabbenhoft 2006).

Site	Lenz (1993)	NPS (1996)	DeKeyser and Krabbenhoft (2006)
P1 - Grannis Prairie	fair-poor condition; smooth brome is frequent, crested wheatgrass also present	islands of native species surrounded by smooth brome and other exotics; leafy spurge not established in large amounts	"severely invaded" by smooth brome; exotic grasses make up 60-65% of total cover
P3 - Krieger/Travois Prairie (Big Hidatsa)	good condition	few exotic plants, with the exception of smooth brome and small Canada thistle patches	90% of the unit invaded by smooth brome and Kentucky bluegrass, with patches where these 2 species account for >35% of total plant cover
P4 - Krieger/Upland Prairie (North Prairie)	good condition	Russian thistle on rodent mounds; sweetclover and horseweed becoming established; leafy spurge not established	50% of unit is exotics including smooth brome and Kentucky bluegrass; one small patch of leafy spurge
P5 - Krieger/South Slope Prairie	fair-good condition	small patches of Canada thistle, wormwood, Russian thistle, and one or more exotic grasses	little evidence of invasion, except in draws dominated by Kentucky bluegrass and smooth brome
P7 - Buchfink South Prairie	fair-poor condition; some exotics established	Smooth brome, leafy spurge, and Canada thistle in small to moderate patches; Russian olive and Siberian elm also present	85-90% dominated by smooth brome and Kentucky bluegrass; small patches of leafy spurge and sporadic Canada thistle
P8 - Buchfink North Prairie	fair-poor condition; smooth brome is a dominant grass	Smooth brome in moderate-sized patches; small patches of leafy spurge and Canada thistle	85-90% dominated by smooth brome and Kentucky bluegrass; patches of leafy spurge and Canada thistle

Photo 10. Smooth brome at KNRI (Photo by Barry Drazkowski, SMUMN GSS 2010)

KNRI staff have been treating exotic plants classified as noxious weeds by the state of North Dakota for at least two decades, and continue their efforts today. The EPMT also began treating exotic species in KNRI in 2002, focusing largely on Canada thistle, leafy spurge, and absinth wormwood. The team reports "a remarkable improvement in the size and density of these weed patches, especially in the area of the park known as the North Prairie" (NPS 2011b, p. 6). In 2005, a team of four people spent more than two days in this area treating 5.1 ha (12.5 acres). By 2010, a team of six people surveyed this area in less than two hours, treating only 1.8 ha (4.5 acres). Smooth brome has become a species of focus in recent years, with over 38.8 ha (96 acres) of the exotic grass treated in 2010 (NPS 2011b). A map of KNRI showing areas treated by the EPMT in 2010 is included as Plate 9. Flea beetles (genus *Aphthona*) were also used as a biocontrol agent for leafy spurge from 1995-2011. According to KNRI staff, this biocontrol method worked so well that most of the populations of flea beetles have fallen due to lack of food (i.e., leafy spurge plants).

<u>Precipitation</u>

Snow, spring flooding, and extended drought can impact the species composition of KNRI prairie communities. Some native prairie plants favor mesic conditions while others thrive in drier conditions. Table 18 and Figure 9 show monthly precipitation near KNRI in 2011 in comparison to the 1981-2010 and 1971-2000 precipitation normals. These measurements were taken at the Garrison, ND monitoring station just north of KNRI. A comparison of 1971-2000 and 1981-2010 normals suggest that annual precipitation may have increased in the area. Monthly precipitation normals have also increased, with the exceptions of April, September, and October. Annual precipitation was slightly above normal in 2011, with particularly wet months of March, May, and September. Precipitation in June and July were well below normal, as were the months of November and December.

Table 18. Precipitation normals (cm) from 1971-2000 and 1981-2010 and 2011 monthly precipitation for the KNRI area. Values taken from the Garrison, ND monitoring station (NOAA 2002, NCDC 2012, Weather Source 2012).

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
1971-2000 normals	0.99	0.91	1.60	3.23	5.33	7.92	6.65	4.85	3.66	3.10	1.45	0.99	40.69
1981-2000 normals	1.24	0.97	1.96	3.18	6.40	8.56	6.68	4.93	3.33	2.84	1.78	1.50	43.36
2011	1.52	0.58	4.90	3.56	9.53	6.22	5.36	4.27	5.08	2.77	0.05	0.74	44.58

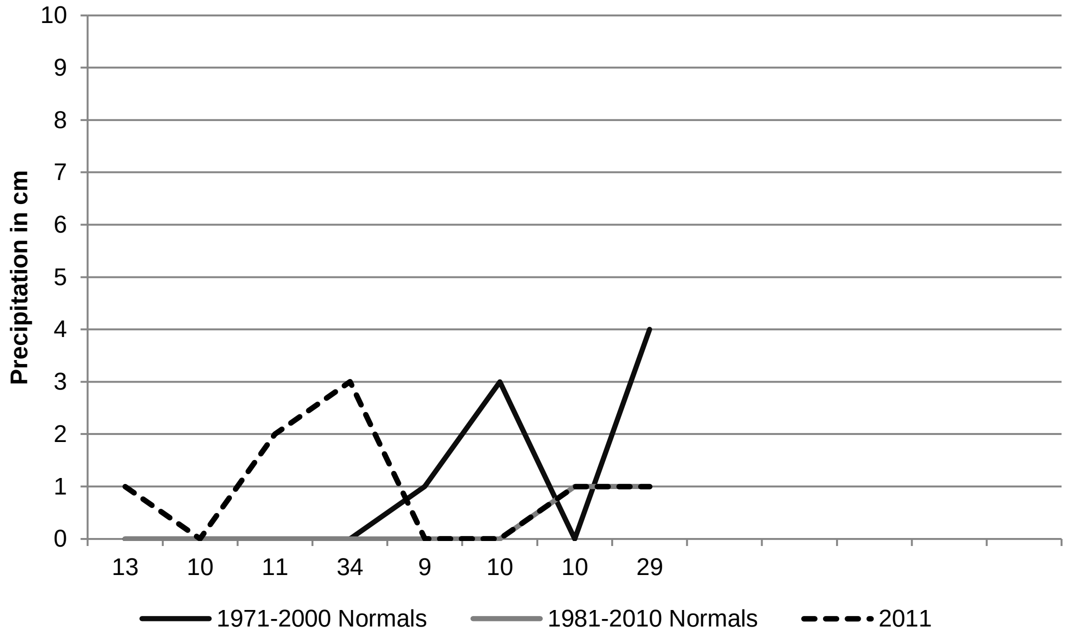


Figure 9. Monthly precipitation near KNRI during 2011 in comparison to 1971-2000 and 1981-2010 monthly precipitation normals (NOAA 2002, NCDC 2012, Weather Source 2012).

Deer Population

White-tailed and mule deer (*Odocoileus hemionus*) both occur in KNRI, although white-tailed deer are more common. Clambey (1985, p. 68) described deer as "abundant in this area." While deer utilize native prairie areas in KNRI, their primary habitats are woodlands and shrubby areas (Moore et al. 1989). Deer browsing can inhibit woody species growth (Clambey 1985), which may actually favor prairie species. However, if present in very high numbers, deer could influence prairie species composition. The KNRI deer population has not been studied in several decades and its current condition is unknown. The effects of deer on the site's prairie communities also have not been studied. Park staff have observed browselines in the park and report that newly planted trees have been browsed and destroyed by deer.

Threats and Stressor Factors

Exotic species have seriously impacted the terrace prairie communities of KNRI, as discussed earlier in this assessment. Smooth brome, which can tolerate a wide range of environmental conditions including flooding and drought, is highly competitive and has become dominant in many prairie areas within KNRI (Plate 8). Leafy spurge, an aggressive forb, can outcompete many native species and often decreases species diversity in areas it invades (Belcher and Wilson 1989, as cited in DeKeyser and Krabbenhoft 2006). Controlling these exotic species is a time-consuming and sometimes expensive process. The staff and budget at KNRI is limited due to its small size, making exotic plant control particularly challenging. KNRI relies on its only dedicated Law Enforcement/Resource Management Park Ranger to work on exotic plant control and management. While maintenance and seasonal bio-technicians provide additional support as time and budget allows, no employees are hired as full-time resource managers. However, if these exotic species are not kept in check or reduced, much of the native plant diversity characteristic of the historic period KNRI was established to preserve will be lost.

Drought may also impact the prairie communities of KNRI. Some native prairie species are more tolerant of dry conditions than others, potentially resulting in a species composition shift during extended drought periods (Gitzen et al. 2010). Drought may also impact the productivity and phenology of grasslands (Jentsch et al. 2009), in turn affecting the wildlife that rely on these communities.

Additional potential threats to prairie communities include management activities (e.g., construction, fence maintenance, mowing) and excessive burrowing mammal activity, as they can create disturbed areas that may be colonized by exotic species. Prescribed burning may also temporarily increase the occurrence of yellow sweet clover, an exotic biennial that appears to be stimulated by fire.

Data Needs/Gaps

While the presence of exotic species within KNRI's prairie communities has been noted in several vegetation surveys, until recently very few surveys have quantified the cover or density of these species. It is important that the NGPN plant community monitoring program continues to provide information on the percent cover of exotics in KNRI, so that trends in exotic species can be followed and the effectiveness of management efforts can be evaluated.

Little seems to be known about how the site's prairie communities interact with other components of the ecosystem, both biotic (e.g., wildlife such as deer) and abiotic (e.g., microclimate, disturbance, nutrients). Research into how these factors relate to each other could help management better understand the prairies and any wildlife that rely on them.

Overall Condition

Exotic Plant Density

The KNRI project team defined the *Significance Level* for exotic plant density as a 3. Exotic species such as smooth brome and Kentucky bluegrass have become dominant in several of KNRI's native prairie communities; densities appear to have increased since previous vegetation surveys in 1985 and 1996. Given the ability of these exotics to reduce overall species diversity, alter community structure, and disrupt natural ecological processes, this is a serious concern for the park. This measure is assigned a *Condition Level* of 3.

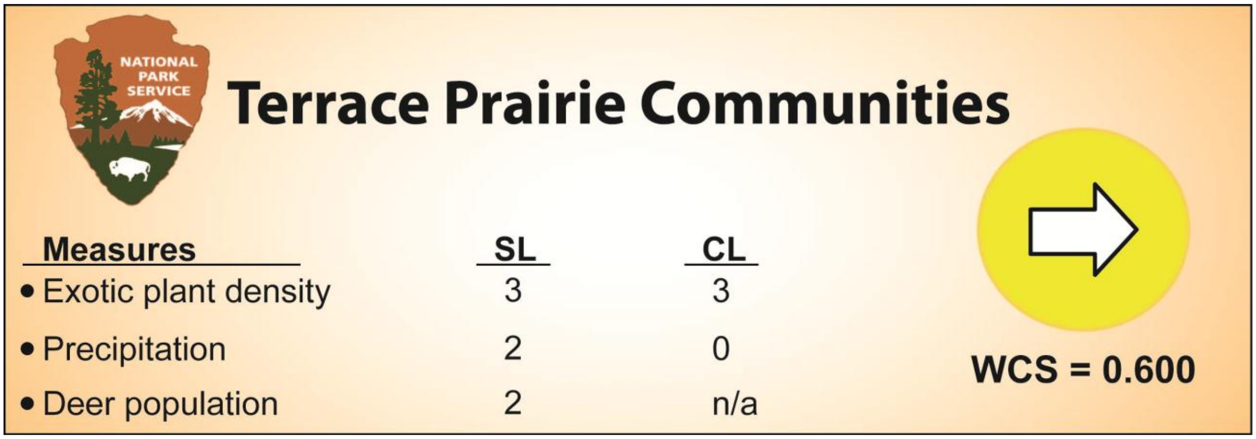
Precipitation

A *Significance Level* of 2 was assigned for the measure of precipitation. A comparison of 1971-2000 and 1981-2010 normals suggests that average precipitation may have increased slightly over the past decade. Monthly precipitation in 2011 was primarily above average, although the summer months were drier than normal. A *Condition Level* of 0, indicating no concern at this time, was assigned.

Deer Population

A *Significance Level* of 2 was assigned for the measure of deer population. The current condition of the KNRI deer population is unknown, and the effects of deer on the site's prairie communities have not been studied. Therefore, a *Condition Level* could not be assigned for this measure.

Weighted Condition Score (WCS)
The *Weighted Condition Score* (WCS) for terrace prairie communities is 0.600, indicating moderate concern, with a stable trend. Exotic plants have widely expanded their distribution and total cover since the 1980s, with exotic grasses such as smooth brome and Kentucky bluegrass becoming dominant in several locations. However, exotic species control and native species restoration efforts have recently started having a positive effect in KNRI, suggesting that the condition of prairie communities is stabilizing and may even improve with continued efforts. NPS managers will need to continue monitoring and treating these species in prairie communities and throughout the site to prevent a loss of native species diversity.



4.3.6 Sources of Expertise
John Moeykens, KNRI Chief of Law Enforcement and Resource Management

Wendy Ross, KNRI Superintendent

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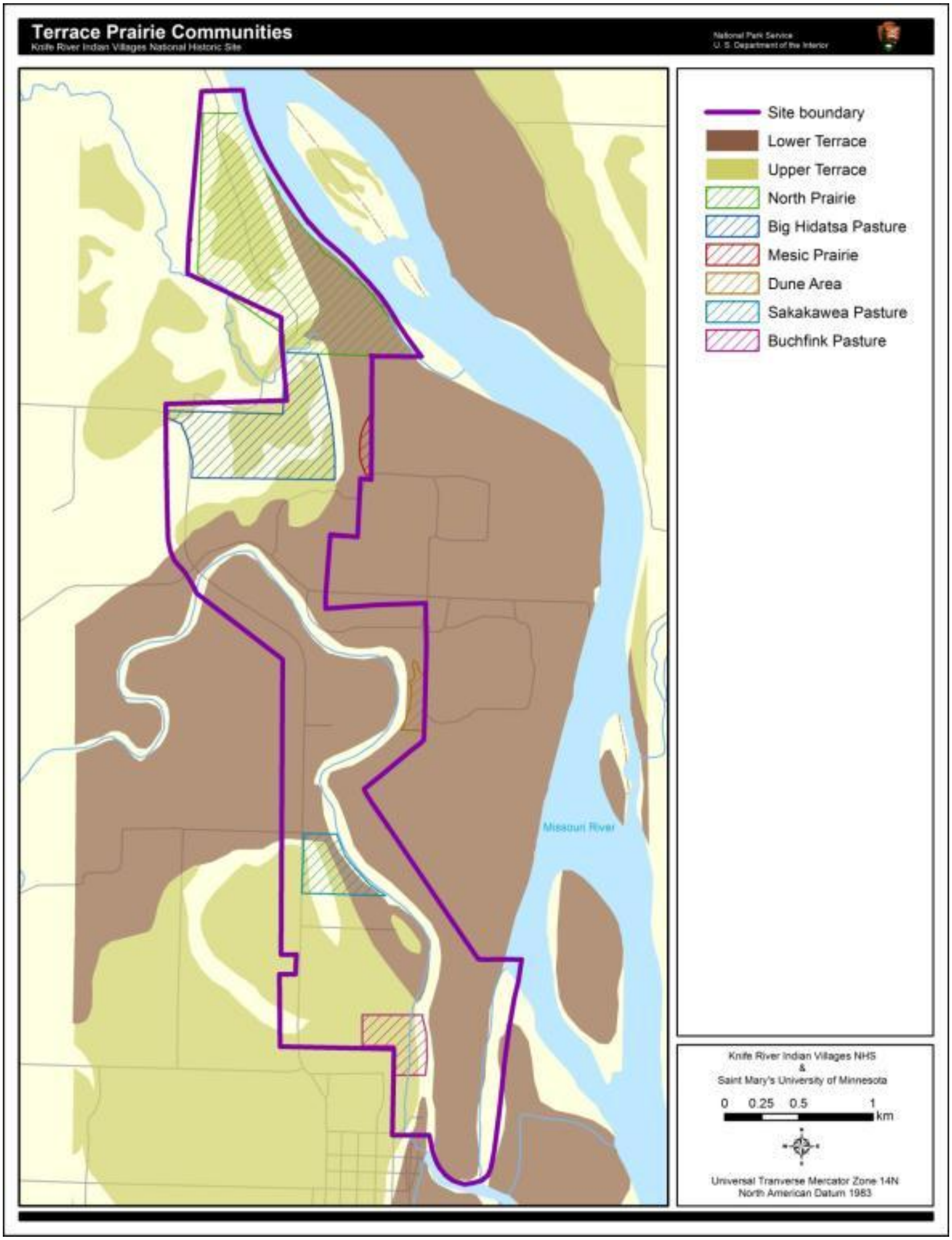


Plate 7. The lower and upper terraces within KNRI and the locations of several prairies within the site.

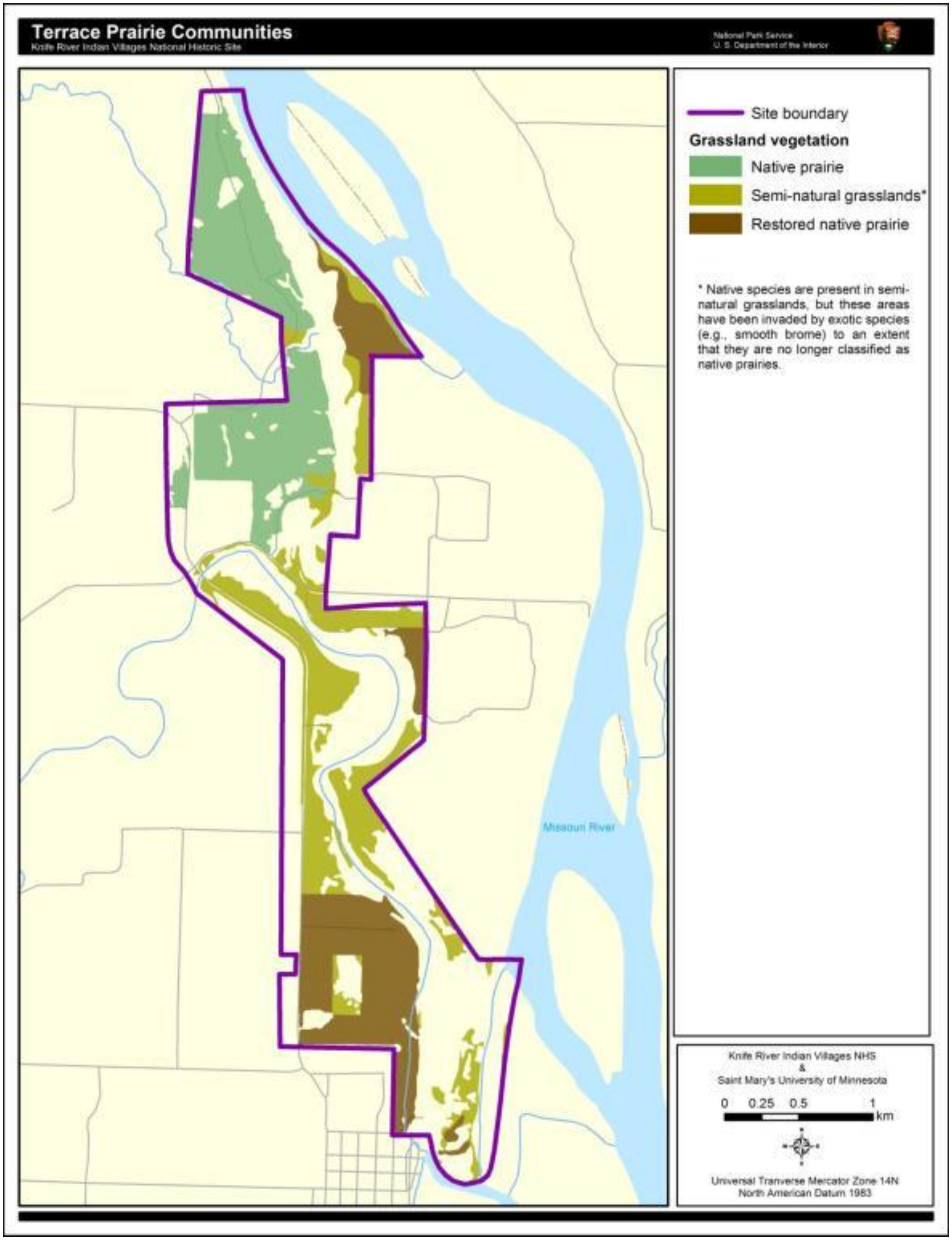


Plate 8. The distribution of remaining native prairie, semi-natural grasslands, and restored prairie in KNRI.

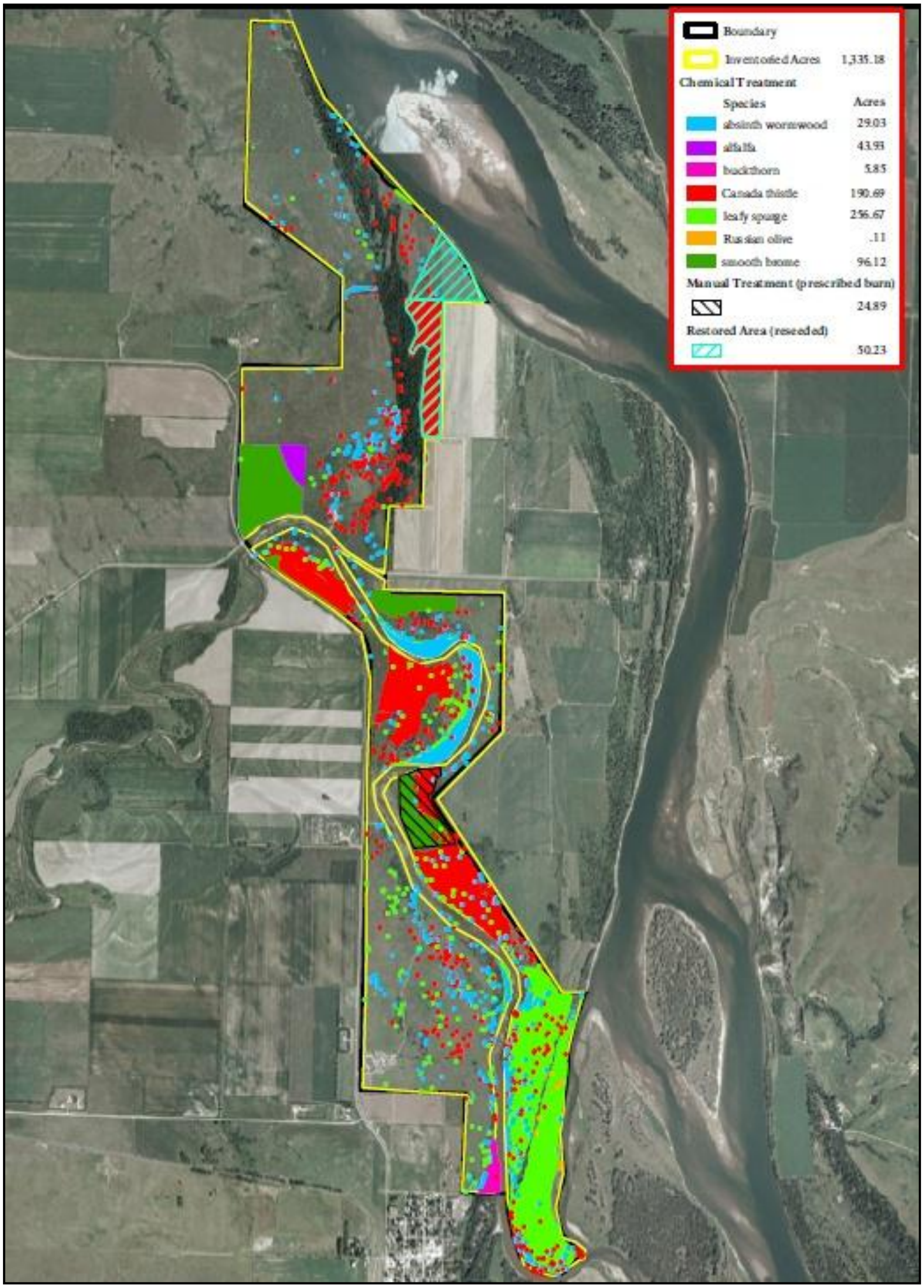


Plate 9. Areas of KNRI surveyed and treated by the EPMT during 2010 (NPS 2011b).

4.4 Raptors

4.4.1 Description

Raptors are top-level predators and are excellent bioindicators of the health of their associated ecosystems (Morrison 1986, Hutto 1998). In the 1940s, raptor populations across North America experienced a population decline due to the use of organophosphates (e.g., dichlorodiphenyltrichloroethane – DDT) as insecticides. Bioaccumulation of these chemicals (particularly DDE, a persistent metabolite of DDT) inhibited calcium metabolism in many raptor species (Fischer 2000). As a result, affected birds laid eggs that were too thin for successful incubation; eggs that did not break during incubation often contained dead embryos, and mortality rates for hatchlings were high (Green 1985, as cited in Fischer 2000).

DDT was banned in the United States in December 1972 and reproductive success rates subsequently increased following this ban (Fischer 2000). Species especially affected by the use of organochlorines, such as the peregrine falcon (*Falco peregrinus*) and bald eagle, experienced a dramatic population recovery following the ban. These species recovered to population levels that allowed for their removal from the Endangered Species List (the peregrine falcon in 1999, and the bald eagle in 2007) (USFWS 2003, 2010).

KNRI has many diverse habitats that can support many different species of birds. The park is able to support a diverse raptor population; commonly observed raptor species in KNRI include northern harriers, red-tailed hawks, American kestrels, and bald eagles (NPS 2006a). Monitoring of the raptor populations may help KNRI managers to better understand the overall condition of the many diverse habitats in the park.

Photo 11. Northern harrier (NPS photo by Sarah Nystrom).

4.4.2 Measures

- Population abundance
- Habitat availability
- Species density

4.4.3 Reference Conditions/Values

Moore et al. (1989) represents one of the first bird inventories in KNRI. The raptor inventory from this survey will serve as the reference condition for this component, and should serve as an appropriate comparison for current conditions of raptors in KNRI.

4.4.4 Data and Methods

From 1986-1987, Moore et al. (1989) established and surveyed 13 bird census plots across different landscapes in KNRI during spring (April/May) and fall (September) migration periods. Two observers stopped at each plot for approximately 10 minutes and recorded all birds seen and heard within the habitat type of the plot.

Moore et al. (1989) also conducted raptor-specific surveys along the northern edge of Big Hidatsa. This route (approximately 2 km) was walked on 21 April 1986, and 14, 16, 17, 19 June

1986. All raptor species that were seen were recorded, and any nesting birds/nest locations were documented. Moore et al. (1989) also conducted acoustical surveys of owls in KNRI on 25 March 1987 and 9 May 1987. These surveys were conducted at night in a vehicle, and were located along the western edge of KNRI and along the interior peninsula. At differing intervals, the vehicle would stop and the surveyors would play tapes of owl calls of species thought to be in the region.

Panjabi (2005), in cooperation with the Rocky Mountain Bird Observatory (RMBO), established two 15-point transects in KNRI from 2002-2004 (Figure 10). Points on the transects were 250 m apart, and each point on the transect was observed for 5 minutes (Panjabi 2005). The two transects were located in different habitats in KNRI; one transect was set in the mostly native mixed-grass prairie, and the other was located in the dense riparian woodlands (the North Woods). The riparian woodland transect was split into two sections, one section with 13 points and the other section with two. This was done to make sure that a similar habitat was sampled throughout the transect.

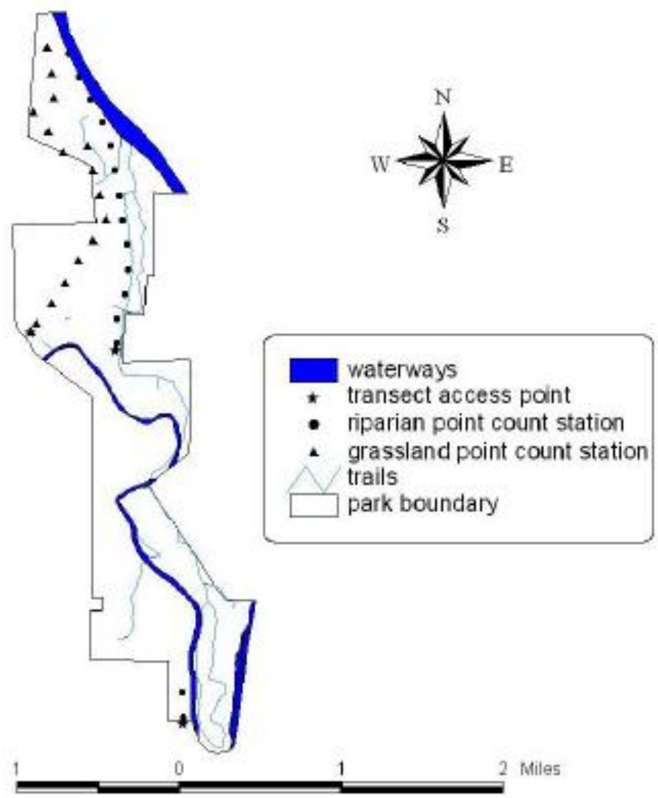


Figure 10. Locations of point transects for bird monitoring in KNRI. These transects were also used for land bird monitoring during the same period. Reproduced from Panjabi (2005).

Data from both the Moore et al. (1989) and Panjabi (2005) surveys were modified to only include raptor species (of the orders Accipitriformes and Strigiformes). SMUMN GSS made no other adjustments to the data.

4.4.5 Current Condition and Trend

Population Abundance and Fluctuation

Moore et al. (1989) surveyed KNRI bird species from 1986-1987. These surveys were not raptor specific, but observers did record raptor observations for the duration of the study (Table 19). The study did not create estimates of population abundance or fluctuation; however, this was the first study that documented the species composition of KNRI's raptor populations.

Table 19. Raptor species observed during Moore et al. (1989) bird surveys. Surveys were conducted from 1986-1987.

Common Name	Scientific Name
Cooper's hawk	*Accipiter cooperii*
northern goshawk	*Accipiter gentilis*
sharp-shinned hawk	*Accipiter striatus*
golden eagle	*Aquila chrysaetos*
red-tailed hawk	*Buteo jamaicensis*
Swainson's hawk	*Buteo swainsoni*
northern harrier	*Circus cyaneus*
bald eagle	*Haliaeetus leucocephalus*
osprey	*Pandion haliaetus*
turkey vulture	*Cathartes aura*
merlin	*Falco columbarius*
prairie falcon	*Falco mexicanus*
American kestrel	*Falco sparverius*
short-eared owl	*Asio flammeus*
long-eared owl	*Asio otus*
snowy owl	*Bubo scandiacus*
great horned owl	*Bubo virginianus*
eastern screech-owl	*Megascopes asio*

The RMBO performed the only estimate of bird species abundance in KNRI to date (Panjabi 2005). RMBO staff observed and recorded all bird species on the established transects from 2002-2004. Table 20 presents only the raptor species observed in Panjabi (2005); Chapter 4.5 presents a table that includes all land bird species abundance estimates from the survey.

Table 20. Abundance of raptor species in riparian woodlands and grasslands at KNRI (Panjabi 2005).

	Grasslands				Riparian Woodland			
Species	**2002**	**2003**	**2004**	**All Years**	**2002**	**2003**	**2004**	**All Years**
bald eagle	0	0	0	0	0	0	1	1
northern harrier	1	0	2	3	0	0	1	1
Cooper's hawk	0	0	1	1	0	0	1	1
broad-winged hawk	0	0	0	0	2	0	0	2
red-tailed hawk	1	1	1	3	2	0	1	3
great horned owl	1	0	1	2	2	0	0	2

The short duration (only 3 years) of the Panjabi (2005) study, combined with the limited observations of raptor species during the study, make assessing the current condition of species abundance and fluctuation impossible at this time. Long-term trend data are needed to accurately assess condition of these measures.

Considering the raptor species present in KNRI on a wider geographic scale, the Intermountain-Rocky Mountain populations of turkey vultures (*Cathartes aura*), ospreys (*Pandion haliaetus*), broad-winged hawks (*Buteo platypterus*), red-tailed hawks, merlins (*Falco columbarius*), and peregrine falcons increased until the late 1990s for diverse reasons (Hoffman and Smith 2003). Drought-related conditions in the late 1990s potentially slowed raptor population growth (Hoffman and Smith 2003). These data are not included in the overall condition assessment of the KNRI raptors, but rather help to provide regional context for the overall health of these migratory species.

Not all raptor populations are increasing in abundance, as migration data collected by Hoffman and Smith (2003) indicate increasing concern for western golden eagles (*Aquila chrysaetos*), and expressed uncertainty regarding the status of northern harriers and American kestrels. Partners in Flight (PIF) currently lists golden eagles and northern harriers as Species of Regional Importance for the KNRI area (Bird Conservation Region [BCR] 17 - Badlands and Prairies) (RMBO 2005).

Habitat Availability

Tapia et al. (2007) define habitat availability for raptor species as the amount of habitat that is exploitable by a raptor within a defined area and time. Raptor species seek out habitats that offer the necessary resources for forage and nesting success. Many of the raptor species in KNRI are tree or cavity nesters (golden eagles and turkey vultures being the notable exceptions). A variety of live trees (used by red-tailed hawk), snags (used by osprey), and cavity-possessing trees (used by American kestrel) are necessary for KNRI to support a diverse nesting population of raptor species. Dramatic changes in habitat composition could result in a reduction of the overall raptor diversity of KNRI.

A major factor influencing the quality of raptor habitats is food availability, defined not only by prey density, but also by various habitat features influencing the accessibility of prey (Widén 1994). Many of the raptors found in KNRI hunt ground-living prey (e.g., red-tailed hawk, American kestrel). In the pursuit of these prey species, raptors will frequently utilize an energy-saving pause-and-travel search tactic; raptors find habitats difficult to exploit if perches to hunt from are absent (even if prey is abundant) (Widén 1994).

No habitat availability studies have been conducted for raptors in KNRI. Because of this, SMUMN GSS cannot assess the condition of habitat availability for raptors at this time.

Threats and Stressor Factors

KNRI staff identified the loss of nesting and perching trees as the biggest threat facing raptor populations in KNRI. The Garrison Dam on the Missouri River upstream of KNRI has almost entirely prevented annual large scale flooding of the Missouri River in KNRI (NPS 2006b). While flooding does still occur in the park, it is not on the same scale or frequency as the historic flood regime, and because of this, regeneration of several tree species, such as cottonwood and willow, is almost completely absent from the area.

Recent flooding events (2009, 2011) resulted in raptor perching/foraging areas being inundated with water from early spring until August. The saturated soils, strong windstorms, prescribed burns, and a monoculture of exotic grasses (e.g., smooth brome) are affecting the availability of roosting and nesting trees for raptor species. North American beaver activity has increased in the park, and has actively removed several old growth cottonwoods from the floodplains.

Cottonwoods along the Missouri River are important nesting/roosting trees for many raptor species. For example, bald eagles along the Missouri River exhibit a preference for nesting and perching in mature cottonwood trees (USACE 2008). As the mature cottonwoods in KNRI approach senescence, the lack of cottonwood regeneration could have dramatic impacts on the raptor species of the park.

Portions of the riparian forest in KNRI have a fungal disease that is killing the mature green ash trees (NPS 2006b). The park actively monitors the fungus, and removes infected trees to allow for the succession of younger, disease-resistant trees (NPS 2006b). The removal of mature trees eliminates many potential perching and nesting sites for raptors. In addition, cavity-nesting raptors (e.g., American kestrel, eastern screech-owl [*Megascopes asio*]) may benefit from dead snags created by the fungus.

Panjabi (2005) identified several management activities (e.g., burning, removal of downed trees, invasion of non-native plant species) that could be detrimental to land bird species (see Chapter 4.5). Such practices would also affect the raptor species, as they depend on riparian forests for both habitat and foraging.

Data Needs/Gaps

Annual monitoring of the raptor populations of KNRI is needed to establish long-term trend data. Trend data is vital to assessing the condition of raptors in the park. Surveys such as Breeding Bird Surveys (BBS) or Christmas Bird Counts (CBC) are two popular surveys that could help increase the understanding of raptor abundance in KNRI. These surveys can be accurate snapshots of raptor population health, as Hoffman and Smith (2003) found that BBS and CBC results corroborated their migration study results in the Intermountain-Rocky Mountain region. A survey of the suitable nesting/perching trees would also be beneficial in understanding the habitat available for raptors in KNRI.

Overall Condition

Population Abundance and Fluctuation
KNRI staff assigned the measure population abundance and fluctuation a *Significance Level* of 2. However, SMUMN GSS did not assign a *Condition Level* for this measure due to insufficient data. Moore et al. (1989) and Panjabi (2005) provide brief glimpses of the raptor population of KNRI, but they do not provide long-term trend data nor do they estimate the condition of raptors in the park.

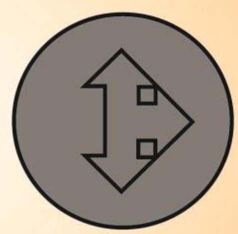
Habitat Availability
KNRI staff also assigned the measure habitat availability a *Significance Level* of 2. SMUMN GSS did not assign a *Condition Level* to this measure due to insufficient data. Habitat monitoring and inventory are necessary in order to assign a condition to this measure.

Species Density
The measure species density was assigned a *Significance Level* of 1 by KNRI staff. Because a *Significance Level* of 1 was assigned, SMUMN GSS does not focus on the measure in the text of this component, but rather briefly discusses the condition level of the component here. However, SMUMN GSS was unable to assign a *Condition Level* to the species density measure due to the lack of available data. Panjabi (2005) provides brief discussions of species density, but raptor species were not abundant enough to generate density estimates. In order for condition to be assigned to this measure, density monitoring is necessary in KNRI.

Weighted Condition Score (WCS)
Because SMUMN GSS could not assign condition levels to the measures of this component, no *Weighted Condition Score* was assigned.

Raptors

Measures	SL	CL
• Population abundance and fluctuation	2	n/a
• Habitat availability	2	n/a
• Species density	1	n/a



WCS = N/A

4.4.6 Sources of Expertise
John Moeykens, KNRI Chief of Law Enforcement and Resource Management

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4.5 Land Birds

4.5.1 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). KNRI is home to many diverse habitats that can sustain high numbers of bird species (Panjabi 2005). The extent and quality of these diverse habitats in KNRI, namely the shrub lands, native grasslands, riparian woodlands, and the Knife and Missouri River systems, enable this relatively small parcel of land to boast a tremendous diversity of land bird species (NPS 2006a). Monitoring avian population health and diversity in these habitats will be important for detecting population and ecosystem changes.

Photo 12. Bobolink (*Dolichonyx oryzivorus*), a common grassland bird in KNRI (USFWS photo).

4.5.2 Measures

- Species observed vs. species expected

- Species abundance

4.5.3 Reference Conditions/Values

At this time, a reference condition for land birds in KNRI does not exist.

4.5.4 Data and Methods

Moore et al. (1989) surveyed the terrestrial vertebrate populations of KNRI from 1986-1987. Included in these surveys were a series of bird observations that spanned the terrestrial landscape of KNRI. Because this survey included all bird species, and not just the land bird species described in Rich et al. (2004), SMUMN GSS adjusted some of the data. These adjustments consisted of updating the observed species list to include only land bird species defined in Rich et al. (2004). No other adjustments were made to the data.

Panjabi (2005), in cooperation with the RMBO, inventoried the KNRI breeding bird population from 2002-2004. Panjabi (2005) also established two 15-point transects in order to obtain density estimates. These transects occurred in two different habitats: one in dense woodlands and the other in a mostly native mixed-grass prairie. Each transect was surveyed in its entirety in 2002, 2003, and 2004.

Similar to Moore et al. (1989), Panjabi (2005) included bird species that Rich et al. (2004) did not list as land birds. Because of this, SMUMN GSS adjusted the observed species lists from this report to include only land birds as defined in Rich et al. (2004). SMUMN GSS used the adjusted species lists to create updated comparisons of observed vs. expected species in KNRI. Abundance estimates of bird species that were not land birds were omitted from this assessment.

This assessment also used the NPS Certified Species List for KNRI. SMUMN GSS adjusted this list to include only land bird species in accordance with Rich et al. (2004). All sources of data included raptors as a land bird species, and while SMUMN GSS did not omit raptors, this assessment does not discuss them specifically. Chapter 4.4 of this document addresses the raptors of KNRI in detail.

4.5.5 Current Condition and Trend

Species Observed vs. Species Expected

Moore et al. (1989) surveyed KNRI bird species from 1986-1987 during spring (April/May) and fall (September) migration periods. In June of 1986 and 1987, Moore et al. (1989) established and surveyed 13 bird census plots across different landscapes in KNRI. Two observers stopped at each plot for approximately 10 minutes and recorded all birds seen and heard within the habitat type of the plot. The Moore et al. (1989) surveys did not compare the number of observed species to the number of expected species, but they did identify and confirm the presence of 108 different species of land birds in KNRI (Appendix B).

The RMBO inventoried the KNRI breeding bird population from 2002-2004 (Panjabi 2005). RMBO visited KNRI three times during the study, 12-15 June 2002, 5-8 June 2003, and 15-17 June 2004. RMBO staff extensively inventoried all reaches of KNRI; the habitats inventoried included:

- the North Woods;
- the grasslands and woody draws north of Big Hidatsa Road;
- the grasslands surrounding the KNRI Visitor Center;
- the riparian woodlands along both sides of the Knife River;
- the riparian woodlands at the confluence of the Knife and Missouri Rivers;
- the sandbars and open water on the Missouri River;
- the riparian woodlands north of Stanton Town Campground.

When the study began in 2002, the NPS certified species list for KNRI had 92 *documented* land bird species and another 19 species listed as *expected* (Panjabi 2005). RMBO staff detected 80 land bird species during the three visits to the park. RMBO confirmed the presence of 68 (73.9%) of the 92 previously *documented* land bird species, and confirmed the presence of seven (36.8%) of the *expected* land bird species (Figure 11) (Panjabi 2005). RMBO also identified five additional species of land birds that the NPS certified species list did not list as *documented* or *expected* (Table 21, Figure 11).

Table 21. Species of land birds detected by Panjabi (2005) that had not previously been identified as *documented* or *expected* in KNRI.

Common Name	Scientific Name
broad-winged hawk	*Buteo platypterus*
common grackle	*Quiscalus quiscula*
sedge wren	*Cistothorus platensis*
alder flycatcher	*Empidonax alnorun*
yellow-bellied sapsucker	*Sphyrapicus varius*

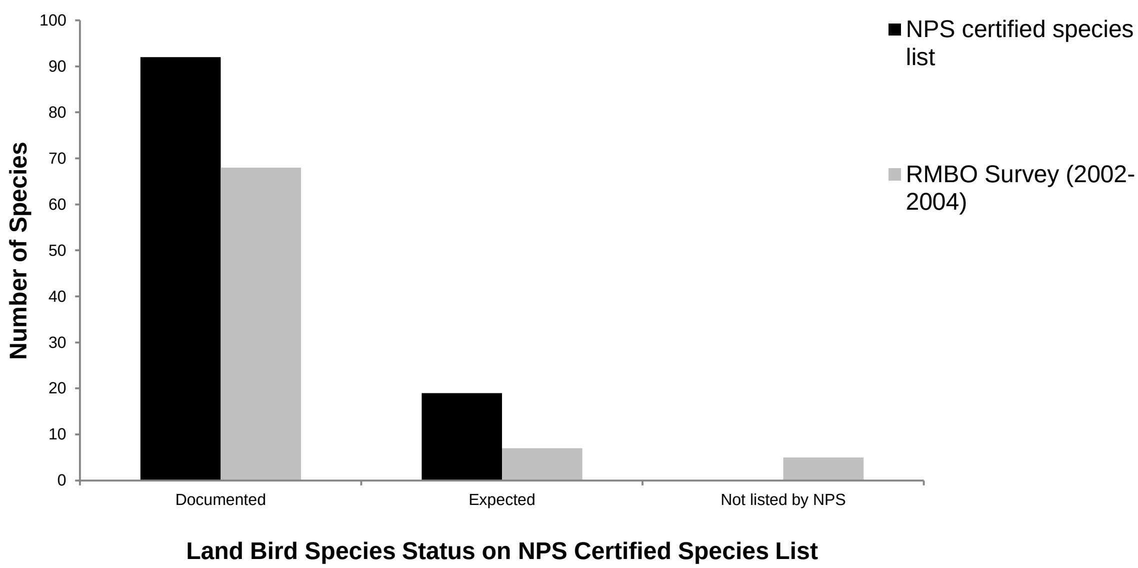


Figure 11. Land bird species observed in the RMBO 2002-2004 survey of KNRI (Panjabi 2005). Observations were compared to the NPS certified species list's documented and expected species.

Appendix B includes a list of all land bird species observed and confirmed in KNRI. This appendix includes the Moore et al. (1989) survey, the Panjabi (2005) inventory, and the current NPS Certified Species List.

Species of Conservation Concern

Four species of land birds that are confirmed on the NPS Certified Species List for KNRI are listed as North Dakota Level I Priority Species (Table 22). A Level I Priority Species is one with

> …a high level of conservation priority because of declining status in either North Dakota or across their range; or a high rate of occurrence in North Dakota constituting the core of the species' breeding range, but are at-risk range wide, and non-SWG [State Wildlife Grants] funding is not readily available to them (Dyke et al. 2004, p. 3).

Table 22. KNRI confirmed bird species that are also designated as bird species of conservation concern.

Common Name	Scientific Name	ND PS[1]	PIF[2]
Swainson's hawk	*Buteo swainsoni*	x	x
black-billed cuckoo	*Coccyzus erythropthalmus*	x	x
grasshopper sparrow	*Ammodramus savannarum*	x	x
lark bunting	*Calamospiza melanocorys*	x	x
golden eagle	*Aquila chrysaetos*		x
northern harrier	*Circus cyaneus*		x
sharp-tailed grouse	*Tympanuchus phasianellus*		x
black-billed magpie	*Pica hudsonia*		x
vesper sparrow	*Pooecetes gramineus*		x
northern rough-winged swallow	*Stelgidopteryx serripennis*		x
western meadowlark	*Sterna neglecta*		x
loggerhead shrike	*Lanius ludovicianus*		x
mountain bluebird	*Sialia currucoides*		x
willow flycatcher	*Empidonas traillii*		x
Say's phoebe	*Sayornis saya*		x
red-headed woodpecker	*Melanerpes erythrocephalus*		x
short-eared owl	*Asio flammeus*		x

[1] ND PS = North Dakota Priority Species (Dyke et al. 2004)
[2] PIF = Partners in Flight Species of Regional Importance (www.rmbo.org)

Photo 13. Say's phoebe (*Sayornis saya*, left, NPS photo by Mary Brazell), lark bunting (*Calamospiza melanocorys*, center, NPS photo by Dan Licht), and sharp-tailed grouse (*Tympanuchus phasianellus,* right*,* USFWS photo).

Beginning in 1991, PIF began assessing species with the intent of providing 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 RMBO maintains PIF assessment data and organizes the species on a geographic scale using BCRs. BCRs are the accepted planning units for updated regional bird conservation assessments under the North American Bird Conservation Initiative (NABCI) (RMBO 2005). KNRI is part of BCR 17 (Badlands and Prairies), and PIF lists 17 land bird species from the KNRI Certified Species List as Species of Regional Importance (Table 22)

Species Abundance

Panjabi (2005) established and surveyed two 15-point transects in KNRI from 2002-2004 (Figure 10). Transect points were 250 m apart, and surveyors recorded observations at each point for 5 minutes (Panjabi 2005). The two transects were located in different habitats in KNRI; one transect was set in the mostly native mixed-grass prairie, while the other transect was located in the dense riparian woodlands (the North Woods). The riparian woodland transect was split into two sections, one section with 13 points and the other section with two. This ensured that a similar habitat was sampled throughout the transect.

Mixed-grass Prairie

From 2002-2004, Panjabi (2005) observed between 171 (2004) and 238 (2003) individual birds of 42 species along the mixed-grass prairie transect (Table 23, Table 24). The variation in observed birds between survey years may be explained partially by the fact that in 2004, part of the grassland habitat was treated with herbicide to remove an invasive smooth brome stand. In 2002 and 2003, this habitat held a dense concentration of bobolinks; Panjabi (2005) reported seeing 20 bobolinks at points in this habitat in 2003, while only seeing one in 2004.

Table 23. Abundance of land bird species in riparian woodlands and grasslands at KNRI (Panjabi 2005).

	Grasslands				Riparian Woodland			
Species	**2002**	**2003**	**2004**	**All Years**	**2002**	**2003**	**2004**	**All Years**
ring-necked pheasant	13	10	11	34	9	10	10	29
wild turkey	0	0	0	0	1	3	0	4
bald eagle	0	0	0	0	0	0	1	1
northern harrier	1	0	2	3	0	0	1	1
Cooper's hawk	0	0	1	1	0	0	1	1
broad-winged hawk	0	0	0	0	2	0	0	2
red-tailed hawk	1	1	1	3	2	0	1	3
mourning dove	7	5	1	13	6	13	8	27
black-billed cuckoo	0	0	0	0	1	0	0	1
great horned owl	1	0	1	2	2	0	0	2
chimney swift	0	0	0	0	2	0	0	2
common nighthawk	2	1	0	3	0	0	0	0
red-headed woodpecker	0	0	0	0	0	1	0	1
hairy woodpecker	0	0	0	0	5	3	1	9
downy woodpecker	0	1	0	1	0	0	0	0
northern flicker	6	2	1	9	2	1	2	5
alder flycatcher	0	0	0	0	0	2	0	2
willow flycatcher	0	0	3	3	0	0	0	0
least flycatcher	3	0	1	4	20	17	14	51
Say's phoebe	0	1	0	1	0	0	1	1
great crested flycatcher	0	0	0	0	4	1	0	5
eastern kingbird	8	6	1	15	2	0	1	3
warbling vireo	0	0	0	0	0	1	0	1
red-eyed vireo	0	0	0	0	35	21	22	78
black-billed magpie	1	1	1	3	0	0	0	0
blue jay	0	0	0	0	1	1	0	2
American crow	1	3	2	6	5	8	2	15
horned lark	0	0	1	1	0	0	1	1
northern rough-winged swallow	0	0	0	0	1	0	0	1
bank swallow	2	0	6	8	6	32	2	40
black-capped chickadee	0	0	0	0	6	3	2	11
white-breasted nuthatch	0	0	0	0	3	2	1	6
house wren	5	3	2	10	29	24	20	73
sedge wren	0	0	1	1	0	0	0	0
Swainson's thrush	0	0	0	0	0	1	0	1
American robin	0	3	0	3	13	7	5	25
gray catbird	2	3	1	6	3	4	1	8
brown thrasher	1	0	1	2	0	3	3	6
cedar waxwing	0	2	0	2	13	3	2	18

Table 24. Abundance of land bird species in riparian woodlands and grasslands at KNRI (cont.) (Panjabi 2005).

	Grasslands				Riparian Woodland			
Species	**2002**	**2003**	**2004**	**All Years**	**2002**	**2003**	**2004**	**All Years**
yellow warbler	4	6	3	13	31	27	30	88
black-and-white warbler	0	0	0	0	10	1	6	17
American redstart	0	0	0	0	32	46	30	108
ovenbird	0	2	0	2	20	17	16	53
common yellowthroat	5	9	6	20	12	18	11	41
yellow-breasted chat	1	0	2	3	6	2	1	9
spotted towhee	5	4	2	11	13	9	9	31
clay-colored sparrow	10	12	8	30	7	9	6	22
field sparrow	8	4	4	16	5	7	7	19
vesper sparrow	0	1	3	4	0	0	0	0
lark sparrow	1	1	0	2	1	0	1	2
grasshopper sparrow	35	32	26	93	0	0	0	0
song sparrow	1	4	1	6	11	10	8	29
black-headed grosbeak	0	1	0	1	7	3	2	12
lazuli bunting	0	0	0	0	1	2	4	7
bobolink	72	75	41	188	1	2	1	4
red-winged blackbird	3	10	3	16	0	9	2	11
western meadowlark	19	25	17	61	5	4	5	14
Brewer's blackbird	3	1	0	4	1	0	0	1
common grackle	0	0	11	11	3	0	3	6
brown-headed cowbird	0	6	6	12	13	14	8	35
American goldfinch	5	3	0	8	8	18	23	49
Total species observed	226	238	171	635	360	359	275	994

Riparian Woodlands

Panjabi (2005) observed between 275 (2004) and 360 (2002) individual birds of 54 species along the riparian woodlands transect (Table 23, Table 24). The riparian woodlands appear to support a higher number of species and individuals than the mixed grass-prairie. However, in 2004 the number of observed individuals (275) was markedly lower than in the previous two survey years (2002: 360 individuals; 2003: 359 individuals). Panjabi (2005) speculates that this is the result of an actual decline in the density of birds breeding in KNRI; however, there is no long-term evidence or ongoing annual surveys that support this claim.

Threats and Stressor Factors

KNRI staff identified forest degradation as perhaps the greatest threat to the land bird population in KNRI. The density of birds in the riparian woodland habitat of KNRI was more than triple that of other parks in the Northern Great Plains surveyed by Panjabi (2005). Protecting this diverse landscape is an important goal for park managers at KNRI.

Several factors are altering the riparian forests of KNRI. First, the installation of the Garrison Dam on the Missouri River upstream of KNRI has largely prevented large-scale flooding of the Missouri River in KNRI (NPS 2006b). Because of this, regeneration of many trees, such as cottonwood and willow, is almost completely absent from the area. A lack of regeneration creates an ecosystem that is a stagnant forest with little to no succession, reminiscent of the historic "Lewis and Clark" forest (NPS 2006b). Many riparian land bird species (e.g., yellow-breasted chat [*Icteria viren*], American redstart [*Setophaga ruticilla*]) are dependent upon early successional species for reproduction and foraging (Brown 1993, Peterson 1995, Hunt 1996); a reduction in this habitat could lead to an overall reduction in bird species abundance and diversity in KNRI.

The presence of non-native, invasive plants in KNRI's forests represents a significant threat to the park's land bird populations. In 2004, Panjabi (2005) noted that Dame's rocket (*Hesperus matronalis*) had taken over the understory in the North Woods and many of the riparian areas. A change in the diversity of the forest understory in this area of high avian use could have dramatic impacts on the land bird population in the area.

Seventy-five percent of KNRI's forests have a fungal disease (NPS 2006b). This disease primarily kills the mature green ash trees of KNRI, but the younger saplings are also affected. The loss of these trees could affect both early- and late-successional land bird species. Because of this, the park continues to monitor the fungus, and remove infected trees in order to allow the succession of younger, disease-resistant trees (NPS 2006b).

Panjabi (2005) raised several concerns regarding management practices (namely prescribed burning and removal of woody debris) in KNRI's forests and the subsequent impacts those actions could have on the park's birds. Panjabi (2005, p. 52) suggested that prescribed burning in the forests of KNRI could have devastating effects on the birds of KNRI, saying that:

> Many trees of other species, including dominant species like peachleaf willow (*Salix amygdaloides*), eastern cottonwood, and green ash, were severely damaged or killed by these prescribed fires and do not show signs of regenerating. This effort to promote regeneration of riparian vegetation through burning has resulted in a net loss of habitat and wildlife, and it likely will have lasting negative consequences for the biodiversity at Knife River.

Contrary to what was reported in Panjabi (2005), the burning and dead tree removal that occurred in the park from 2003-2004 was not done to promote regeneration, but rather to clear a safety zone of approximately 15 m (50 ft) from established trails in the KNRI forest. This process was only done near the trails on the inside loop of the forest trail in KNRI. Panjabi (2005) was likely unaware of the extent of the burning/removal, as many of the survey locations were in very close proximity to these managed trails.

Park staff have observed that dead, down, and dying trees in the North Woods of KNRI have been rapidly increasing due to record flood conditions in 2009 and 2011, and from strong wind storms. While this may not directly represent a threat to bird populations, the downed wood presents human safety issues that will likely be managed by KNRI staff. Any management activities in these high-value forests should take extra precautions to make sure that bird diversity is not negatively impacted by these management activities.

Data Needs/Gaps

There is a need for long-term trend data for land birds in KNRI for continued monitoring of the condition of these birds into the future. Regular monitoring in KNRI would allow for a more accurate assessment of current land birds observed vs. expected species counts, and species abundance. Annual bird surveys, such as the BBS, CBC, or continuation of the Panjabi (2005) survey transects, are a few ways that this monitoring could occur. Without monitoring in the park, these measures cannot be accurately determined. Annual surveys would also help to monitor the current abundance of priority species within park boundaries.

KNRI management has plans in place to continue the mixed-grass prairie transect established by Panjabi (2005). This survey would be part of a larger study that will look at bird density in the park, particularly paying attention to areas of KNRI that are being slowly restored to native prairies by KNRI managers.

Overall Condition

KNRI staff assigned each of the measures (species observed vs. species expected, species abundance) a *Significance Level* of 2.

Species Observed vs. Species Expected

SMUMN GSS did not assign a *Condition Level* for the KNRI's species observed vs. species expected measure due to a lack of information or data to describe the current condition of the component. While Panjabi (2005) performed a species observed vs. species expected analysis, the data are now several years old and researchers have not repeated this analysis since the 2004 survey. The NPS Certified Species List has been updated since Panjabi (2005) conducted the inventory. Most of the updates were inclusions of species that Panjabi (2005) observed but were not in the previous certified species list. A repetition of the Panjabi (2005) inventory is necessary to accurately assign a condition score to this measure.

Species Abundance

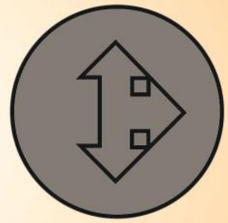
SMUMN GSS did not assign a *Condition Level* for KNRI's species abundance measure for this assessment. Similar to the species observed vs. species expected measure, there are not enough data to assign a current condition to this measure. Long-term trend data are vital in determining the overall condition of land bird species abundance in the park. Panjabi (2005) represents the only estimate of species abundance for KNRI.

Weighted Condition Score (WCS)

Because SMUMN GSS could not assign condition levels to the measures for this component, no *Weighted Condition Score* was assigned.

Land Birds

Measures	SL	CL
• Species observed vs. species expected	2	n/a
• Species abundance	2	n/a



WCS = N/A

4.5.6 Sources of Expertise

John Moeykens, KNRI Chief of Law Enforcement and Resource Management

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4.6 Air Quality

4.6.1 Description

Air pollution can significantly affect natural resources and their associated ecological processes. 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 the CAA's subsequent amendments. The Clean Air Act defines two distinct categories of protection for natural areas, Class I and Class II airsheds. Class I airsheds 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 airshed above baseline levels. For Class II airsheds, the increment ceilings for additional air pollution above baseline levels are slightly greater than for Class I areas and allow for moderate development (EPA 2008a). However, new and modified sources of air pollution must be analyzed for potential impacts to ambient air quality and visibility prior to development. KNRI is a Class II airshed.

Parks designated as Class I and II airsheds typically use the EPA's National Ambient Air Quality Standards (NAAQS) for criteria air pollutants as the ceiling standards for allowable levels of air pollution. The EPA believes these standards, if not exceeded, protect human health and natural resources (EPA 2008a). The CAA also establishes that current visibility impairment in these areas must be remedied and future impairment prevented (EPA 2008a). However, the EPA acknowledges that the NAAQS are not necessarily protective of ecosystems and is currently developing secondary NAAQS for ozone, nitrogen, and sulfur compounds to protect sensitive plants, lakes, streams, and soils (EPA 2010a, 2010b). To comply with CAA and NPS Organic Act mandates, the NPS established a monitoring program that measures air quality trends in many park units for key air quality indicators, including atmospheric deposition, ozone, and visibility (NPS 2008).

NPS (2005) suggests the most abundant pollutant emissions affecting the northern Great Plains include nitrogen oxides, ammonia, and sulfur dioxide. Air quality is primarily affected by area sources (e.g., oil and gas development, agriculture, fires, and road dust), stationary sources (e.g., power plants and industry), and mobile sources (e.g., vehicle emissions) (Peterson et al. 1998, NPS 2005). In addition to concerns about increases in nitrate, sulfate, and ammonium, there is also concern throughout the Great Plains Network about increases in ozone levels (Gitzen et al. 2010). Emissions from coal-fired power plants in western North Dakota also present a concern for increased mercury deposition in the region (Peterson et al. 1998, Gitzen et al. 2010). Likewise, flaring at oil and natural gas wells in the region may contribute emissions that could be carried into on predominant winds.

4.6.2 Measures

- Nitrogen deposition
- Sulfur deposition
- Mercury deposition/concentration
- Ozone concentration

- Concentration of particulate matter (PM 2.5 and 10)
- Visibility

Atmospheric Deposition of Nitrogen and Sulfur

Nitrogen and sulfur oxides are emitted into the atmosphere primarily through the burning of fossil fuels, industrial processes, and agricultural activities (EPA 2008b). While in the atmosphere, these emissions form compounds that may be transported long distances and settle out of the atmosphere in the form of pollutants such as particulate matter (e.g., sulfates, nitrates, ammonium) or gases (e.g., nitrogen dioxide, sulfur dioxide, nitric acid, ammonia) (EPA 2008b, NPS 2008). Atmospheric deposition can be in wet (i.e., pollutants dissolved in atmospheric moisture and deposited in rain, snow, low clouds, or fog) or dry (i.e., particles or gases that settle on dry surfaces as with windblown dusts) form (EPA 2008b). Deposition of sulfur and nitrogen can have significant effects on ecosystems including acidification of water and soils, excess fertilization or increased eutrophication, changes in the chemical and physical characteristics of water and soils, and accumulation of toxins in soils, water, and vegetation (NPS 2008, reviewed in Sullivan et al. 2011a and 2011b). Grassland prairie and meadow communities are sensitive to increased levels of nitrogen and may be impacted by excess nitrogen enrichment via deposition (reviewed in Sullivan 2011b); the predominant landcover in KNRI is grassland and meadow (Sullivan et al. 2011c). On the other hand, many non-natives, such as the invasive cheatgrass (*Bromus tectorum*), prefer nitrogen rich environments and may displace native species as nitrogen deposition increases in these sensitive communities (Sullivan et al. 2011a, 2011b, and 2011c).

Mercury

Sources of atmospheric mercury include fuel combustion and evaporation (especially coal-fired power plants), waste disposal, mining, industrial sources, and natural sources such as volcanoes and evaporation from enriched soils, wetlands, and oceans (EPA 2008b). Mercury deposited into rivers, lakes, and oceans can accumulate in various aquatic species resulting in exposure to wildlife and humans that consume them (EPA 2008b).

Ozone

Ozone occurs naturally in the earth's atmosphere where, in the upper atmosphere, it protects the earth's surface against ultraviolet radiation (EPA 2008b). However, it also occurs at the ground level (i.e., ground-level ozone) where it is created by a chemical reaction between nitrogen oxides and volatile organic compounds (VOCs) in the presence of heat and sunlight (NPS 2008). Ozone is also one of the most widespread pollutants affecting vegetation in the U.S. (NPS 2008). Considered phytotoxic, ozone can cause significant foliar injury and growth effects for sensitive plants in natural ecosystems (EPA 2008a, NPS 2008). Specific effects include reduced photosynthesis, premature leaf loss, and reduced biomass, and prolonged exposure can increase vulnerability to insects and diseases or other environmental stresses (NPS 2008). At high concentrations, ozone can aggravate respiratory and cardiovascular diseases, reduce lung function, cause acute respiratory problems, and increase susceptibility to respiratory infections (EPA 2008b, EPA 2010c); this would be a concern for visitors and staff engaging in aerobic activities in the park, such as hiking.

Particulate Matter (PM) and Visibility

Particulate matter (PM) is a complex mixture of extremely small particles and liquid droplets suspended in the atmosphere. PM is categorized as 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). Particulate matter largely consists of acids (such as nitrates and sulfates), organic chemicals, metals, and soil or dust particles (EPA 2008a, EPA 2009a). Fine particles are a major cause of reduced visibility (haze) in many national parks and wildernesses (EPA 2010b). $PM_{2.5}$ 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 2010d). 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). Particulate matter either absorbs or scatters 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 2010d). PM_{10} and $PM_{2.5}$ are also a concern for human health as these particles can easily pass through the throat and nose and enter the lungs (EPA 2008b, EPA 2009a, EPA 2010d). Short-term exposure to these particles can cause shortness of breath, fatigue, and lung irritation (EPA 2008b, EPS 2009a).

4.6.3 Reference Conditions/Values

The NPS Air Resources Division (ARD) developed an approach for rating air quality conditions in national parks, based on the current NAAQS, ecosystem thresholds, and visibility improvement goals (Table 25) (NPS 2010a). Assessment of current condition of nitrogen and sulfur atmospheric deposition is based on wet (rain and snow) deposition. Ozone condition is based on the NAAQS standard of 75 parts per billion (ppb). Visibility conditions are assessed 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 2010d). 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 2010d). Currently, there is no standard or threshold established for mercury deposition. Finally, NPS ARD recommends the following values for determining air quality condition (Table 25). The "good condition" metrics may be considered the reference condition for KNRI.

Table 25. 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)	Visibility (dv)
Significant Concern	≥76	>3	>8
Moderate Condition	61-75	1-3	2-8
Good Condition	≤60	<1	<2

4.6.4 Data and Methods

NPS Data Resources

Currently, there are no active air quality monitors located in KNRI, so data must be interpolated or estimated from data recorded at regional monitors. NPS ARD provides estimates of ozone, wet deposition of nitrogen and sulfur, and visibility that are based on interpolations of data from all air quality monitoring stations operated by NPS, EPA, various states, and other entities, averaged over five years (2005-2009). These estimates are available from the Explore Air website (NPS 2011) and are used to evaluate air quality conditions. Note that on-site or nearby data are needed for a statistically valid trends analysis, while a five-year average interpolated estimate is preferred for the condition assessment. NPS ARD (2010b) reports on air quality conditions and trends in an annual report for over 200 park units, including KNRI. This report examines trends in ozone, visibility, and deposition data collected from 1999 to 2008.

NPS (2004) reports on the estimated risk of foliar injury from ozone on native vegetation in national parks in the NGPN. Information on ozone sensitive plant species present in the parks, levels of ozone exposure, and relationships between exposure and soil moisture are synthesized into a risk assessment of foliar injury for each park, including KNRI.

Other Air Quality Data Resources

The National Atmospheric Deposition Program–National Trends Network (NADP) database provides access to annual average summary data for nitrogen and sulfur concentration and deposition near KNRI. Data from the nearest monitoring site (ND00) located at Theodore Roosevelt National Park (THRO), approximately 160 km (100 mi) west-southwest of KNRI was used in this analysis.

The Clean Air Status and Trends Network (CASTNet) provides access to summaries of the composition of nitrogen and sulfur deposition in the region around KNRI. Data from the nearest monitoring site (THR422) located at THRO, approximately 160 km (100 mi) west-southwest of KNRI was used in this analysis.

The EPA Air Trends database provides access to annual average summary data for ozone concentrations near KNRI. Monitoring site number 380650002 is located approximately 20 km south of the park.

The Visibility Information Exchange Web System (VIEWS) database provided average annual visibility monitoring data (in deciviews [dv]) and trend graphics for THRO from 2002 through 2008 (VIEWS 2010); the monitoring station at THRO is the nearest station to KNRI for visibility information.

Special Air Quality Studies

NPS (2004) reports on the estimated risk of foliar injury from ozone on native vegetation in national parks in the NGPN. Information on ozone sensitive plant species present in the parks, levels of ozone exposure, and relationships between exposure and soil moisture are synthesized into a risk assessment of foliar injury for each park, including KNRI.

Sullivan et al. (2011a) assessed the relative sensitivity of national parks to the potential effects of acidification caused by acidic atmospheric deposition from nitrogen and sulfur compounds. The relative risk for each park was assessed by examining three variables: the level of exposure to emissions and deposition of nitrogen and sulfur; inherent sensitivity of park ecosystems to acidifying compounds (N and/or S) from deposition; and level of mandated park protection against air pollution degradation (i.e., Wilderness, Class I or II airshed). The outcome was an overall risk assessment that estimates the relative risk of acidification impacts to park resources from atmospheric deposition of nitrogen and sulfur (Sullivan et al. 2011a). Using the same approach, Sullivan et al. (2011b) assessed the sensitivity of national parks to the effects of nutrient enrichment by atmospheric deposition of nitrogen. The outcome was an overall risk assessment that estimates the relative risk to park resources of nutrient enrichment from increased nitrogen deposition.

4.6.5 Current Condition and Trend

Nitrogen and Sulfur Deposition

Five-year interpolated 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 current 5-year average (2005-2009) estimates total wet deposition of nitrogen in KNRI to be 2.69 kg/ha/yr, while the wet deposition of sulfur is 0.98 kg/ha/yr (NPS 2011). Overall, deposition of nitrogen and sulfur appears to be stable. Based on NPS ratings for air quality conditions, the current estimates for nitrogen deposition fall into the *Moderate Concern* category, while the current estimates for sulfur deposition fall into the *Good Condition* category (see Table 25 for ratings values). However, several factors are considered when rating the condition of atmospheric deposition, including effects of deposition on different ecosystems (NPS 2010a). Based on the NPS process for rating air quality conditions, ratings for parks with ecosystems considered potentially sensitive to nitrogen or sulfur deposition are typically adjusted up one condition category. In general, native grassland and meadow ecosystems can be sensitive to increased levels of nitrogen, as acidification and nutrient enrichment can cause shifts in native species composition and encourage encroachment of exotic species and grasses (reviewed in Sullivan et al. 2011a and 2011b). KNRI comprises native grassland/prairie vegetation communities, which may be at risk from increased nitrogen deposition. Thus, the condition for deposition of nitrogen in KNRI is considered to be of *Significant Concern* and *Moderate Concern* for sulfur deposition, based on natural background and current average deposition rates.

Concentrations (mg/L) of nitrogen, sulfur, and ammonium compounds in wet deposition can be used to evaluate trends in deposition of total nitrogen and sulfur. Since atmospheric wet deposition can vary greatly depending on the amount of precipitation that falls in any given year, it can be useful to examine concentrations of pollutants, which factor out the variation introduced by precipitation. The nearest NADP monitoring station to KNRI is located at THRO approximately 160 km west-southwest of KNRI. Figure 12 shows the annual average concentrations of sulfate, nitrate, and ammonium recorded from 2000-2010. Despite a slight increase in concentrations in 2002 and 2006, annual averages indicate that sulfate and nitrate concentrations in KNRI have been decreasing overall, but ammonium deposition appears stable (NADP 2011).

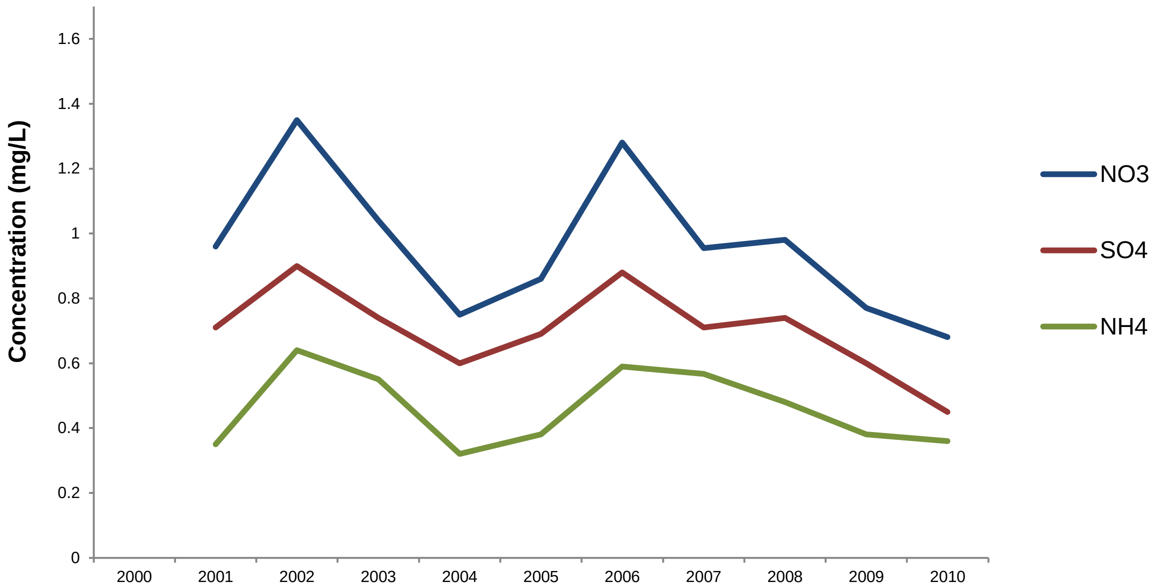


Figure 12. Annual average precipitation-weighted concentrations of nitrate (NO_3), sulfate (SO_4), and ammonium (NH4) (mg/L) near KNRI, 2000-2010 [NADP monitoring site ND00 is located at THRO approximately 160 km (100 mi) west southwest from KNRI] (Source: NADP 2011).

Dry deposition (dust, particles, and aerosols) also contributes significantly to total deposition in the region around KNRI. CASTNet data (collected at THRO) indicate that wet forms contribute about three-fourths (74%) to total deposition of nitrogen, and about 30% to total sulfur deposition (EPA 2012) (see Figure 13 and Figure 14). Figure 13 indicates that reduced forms of nitrogen (i.e., ammonium [NH_4]) contribute approximately 50% of total nitrogen deposition; this is likely an underestimate because ammonia gas is not included in the measurements.

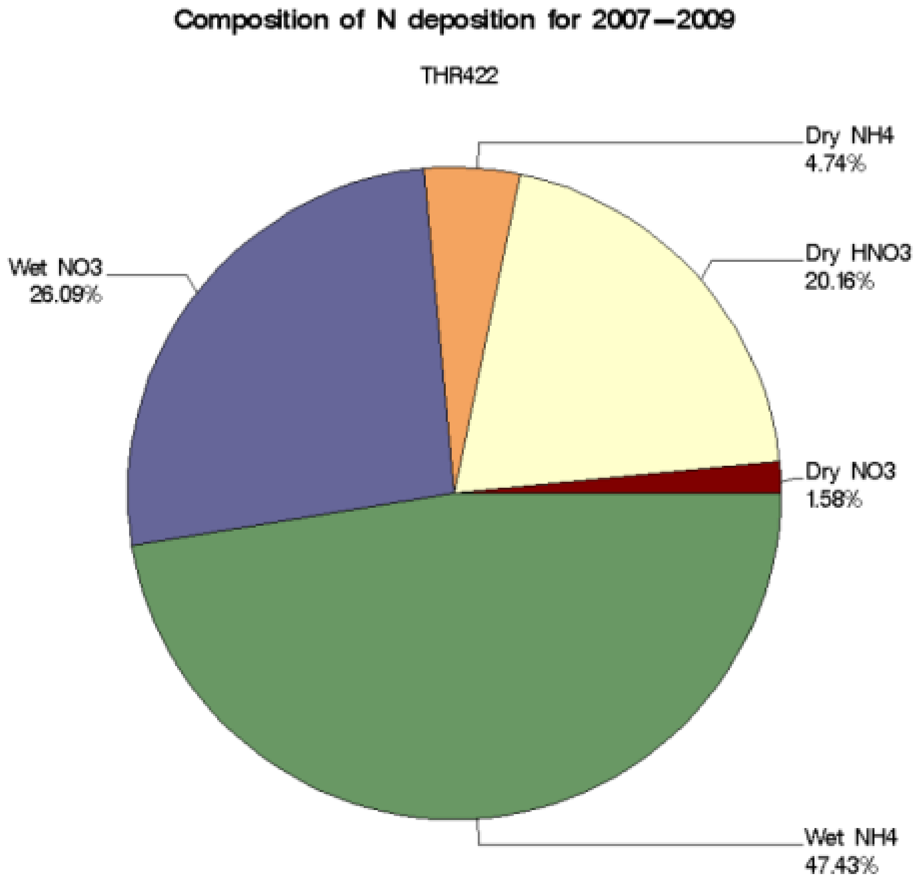


Figure 13. Composition of nitrogen deposition near KNRI, 2007-2009 (EPA 2012). Monitoring station located at THRO, approximately 160 km west-southwest of KNRI (site ID number is THRO422).

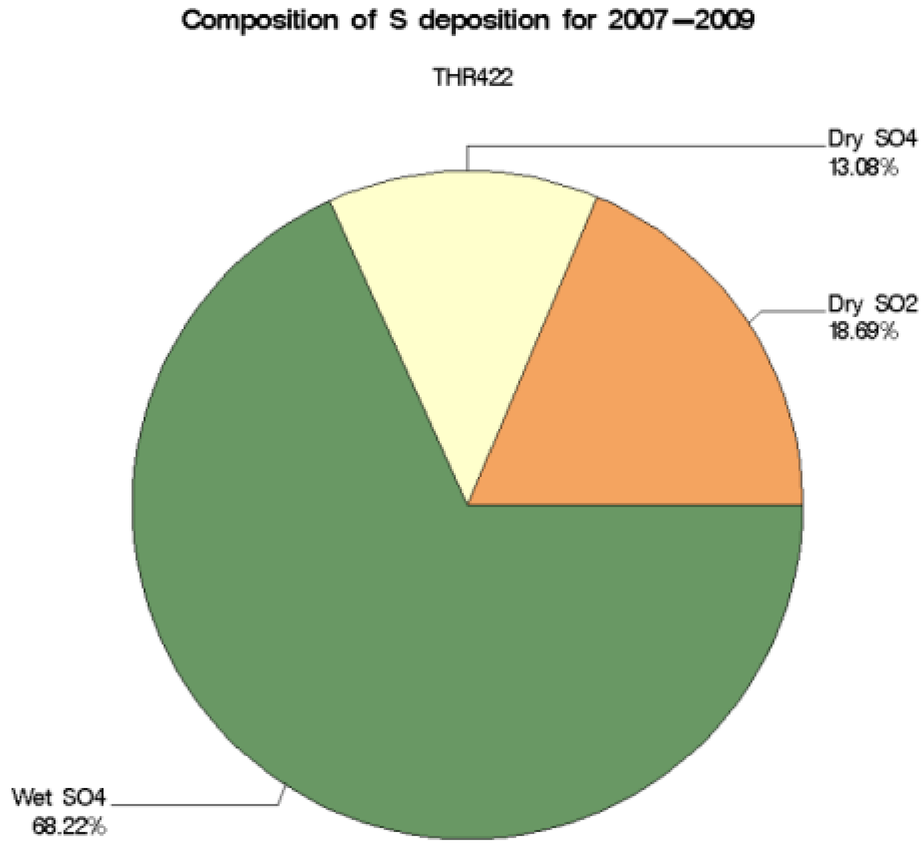


Figure 14. Composition of sulfur deposition near KNRI, 2007-2009 (EPA 2012). Monitoring station located at THRO, approximately 160 km west-southwest of KNRI (site ID number is THRO422).

Sullivan et al. (2011a) ranked KNRI as having moderate acidifying (nitrogen and sulfur) pollutant exposure, very low ecosystem sensitivity to acidification in its grassland ecosystem, and moderate park protection (Class II airshed) against air pollution. The relative ranking of overall risk from acidification due to acid deposition was low relative to other parks (Sullivan et al. 2011a). In a separate examination, Sullivan et al. (2011b) used the same approach to assess the sensitivity of national parks to nutrient enrichment effects from atmospheric nitrogen deposition relative to other parks. Risk relative to other parks was assessed by examining exposure to nitrogen deposition, inherent sensitivity of park ecosystems, and mandates for park protection. KNRI was ranked as being at moderate risk for nitrogen pollutant exposure, moderate ecosystem sensitivity of grasslands and meadows, and moderate park protection mandates (Class II airshed). The ranking of overall risk of effects from nutrient enrichment due to atmospheric nitrogen deposition was determined to be low relative to other parks (Sullivan et al. 2011b).

Mercury Deposition and Concentration

KNRI does not have a monitoring station that records mercury deposition. The nearest monitoring station is located in Eagle Butte, South Dakota. However, it is approximately 322 km (200 mi) south of KNRI and, thus, it is inappropriate to estimate deposition rates in the park from this monitor. For locations in the U.S. that do not have mercury monitoring stations, deposition is interpolated from the nearest sites in areas with sufficient numbers of samplers; this data can be used to estimate conditions in a particular area, but should be used with caution in considering current condition or in determining trends. Figure 15 shows the most recent interpolated average mercury wet deposition for monitoring sites across the U.S (the approximate location of KNRI is marked with a red star). Recent average deposition data indicate wet deposition of mercury in the region of the park is less than or equal to 4 μg/m^2 (NADP 2012).

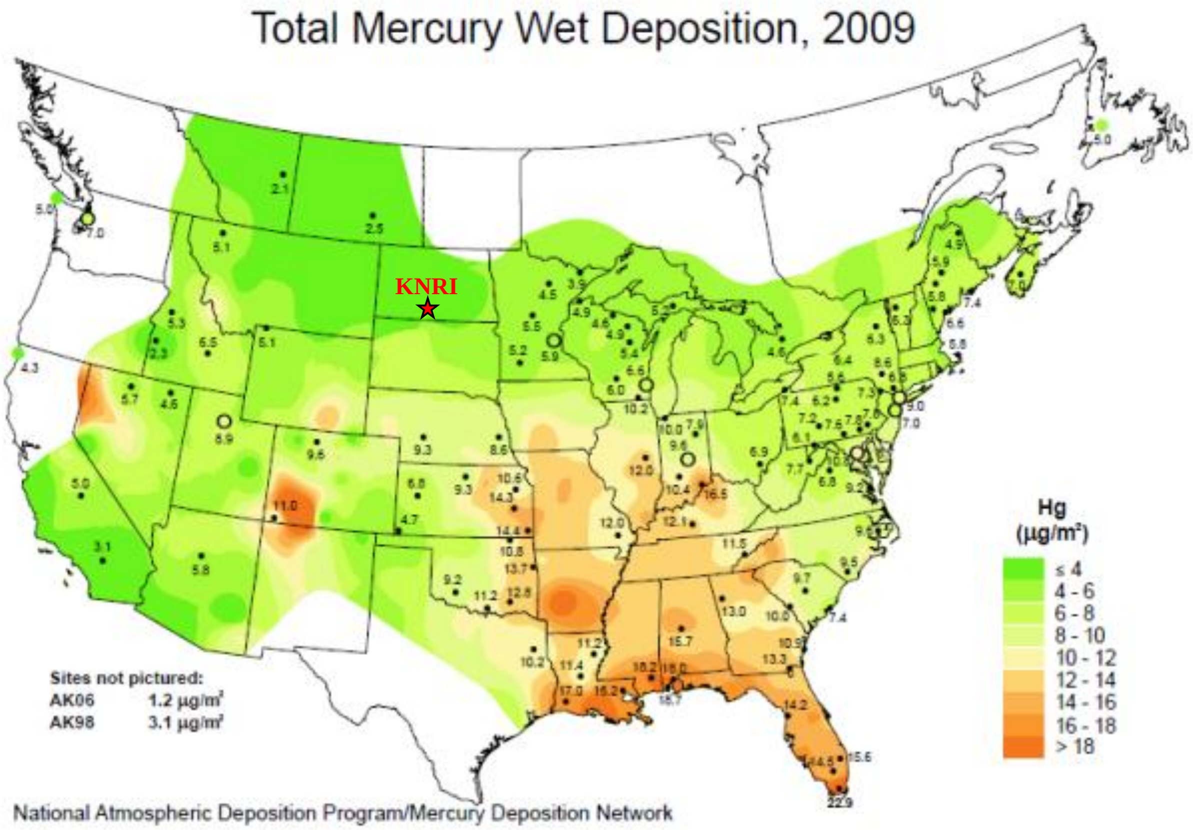


Figure 15. Total mercury deposition near KNRI, 2009 (Source: NADP 2012). Red star indicates the approximate location of KNRI.

Wet deposition of mercury can vary greatly depending on variations in the amount of precipitation that has fallen in an area across a year or several years. Mercury concentrations more accurately reflect patterns in mercury emissions. Figure 16 shows the most recent interpolated average mercury concentrations for monitoring sites across the U.S. (approximate location of KNRI is marked with a red star). Recent average concentration data indicate mercury concentrations in the region of KNRI are approximately 8-10 ng/L (NADP 2012). Reliable data for both concentration and deposition of mercury prior to 2009 are unavailable.

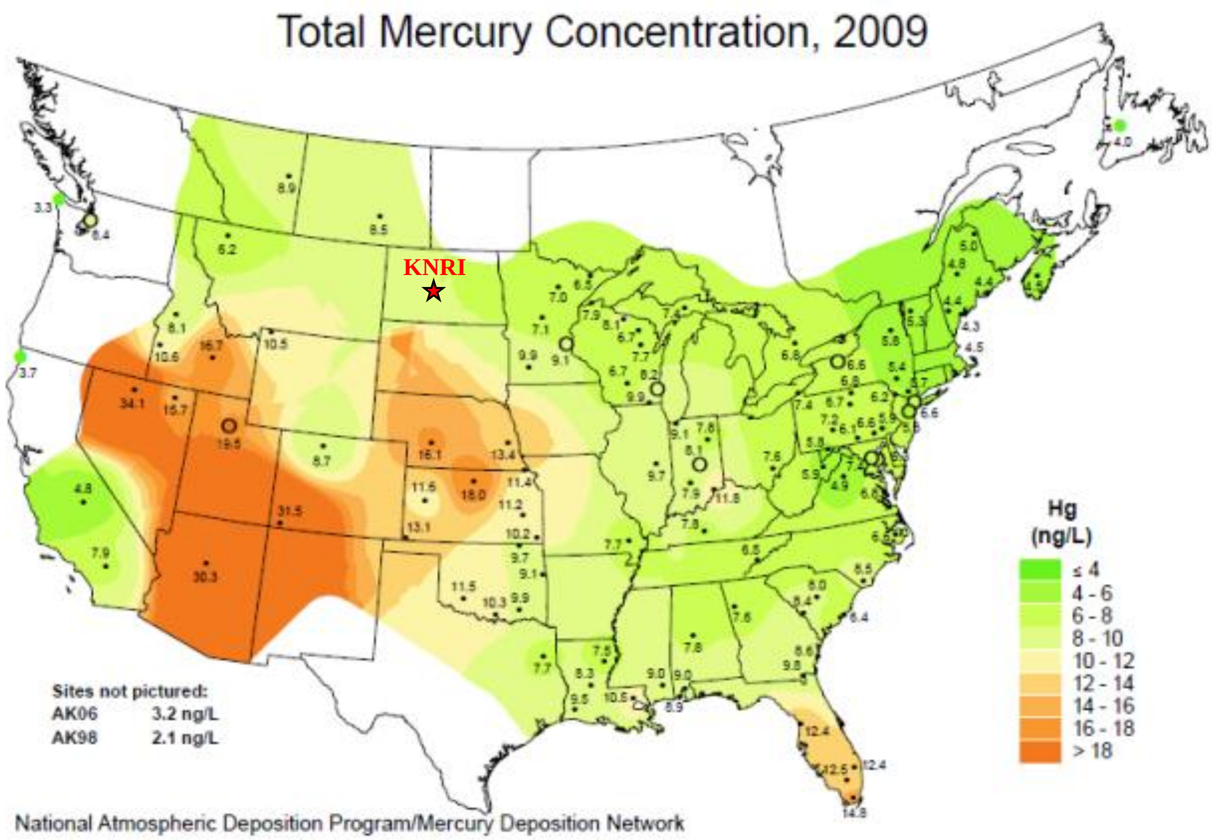


Figure 16. Total mercury concentration near KNRI, 2009 (Source: NADP 2012). Red star indicates the approximate location of KNRI.

Ozone Concentration

The NAAQS standard for ground-level ozone is the benchmark for rating current ozone conditions within park units. The condition of ozone in NPS park units is determined by calculating the 5-year average of the fourth-highest daily maximum of 8-hour average ozone concentrations measured at each monitor within an area over each year (NPS 2010a). The current 5-year average (from 2005-2009) for KNRI indicates an average ground-level ozone concentration of 59.0 ppb (NPS 2011), which falls under the *Good Condition* category based on NPS guidelines. Based on trend analysis of annual average data from 1999-2008, ozone concentrations in KNRI are in good condition with a stable trend (NPS 2010b). Figure 17 shows the trend for average annual ozone concentrations (Note: concentrations are in ppm, while NPS thresholds are in ppb) from 1991 to 2010 with respect to the national standard; data are recorded at a monitoring site approximately 20 km south of KNRI (EPA 2009b). Data suggest ozone concentrations vary slightly but, overall, concentrations appear to be stable and within the EPA national standard.

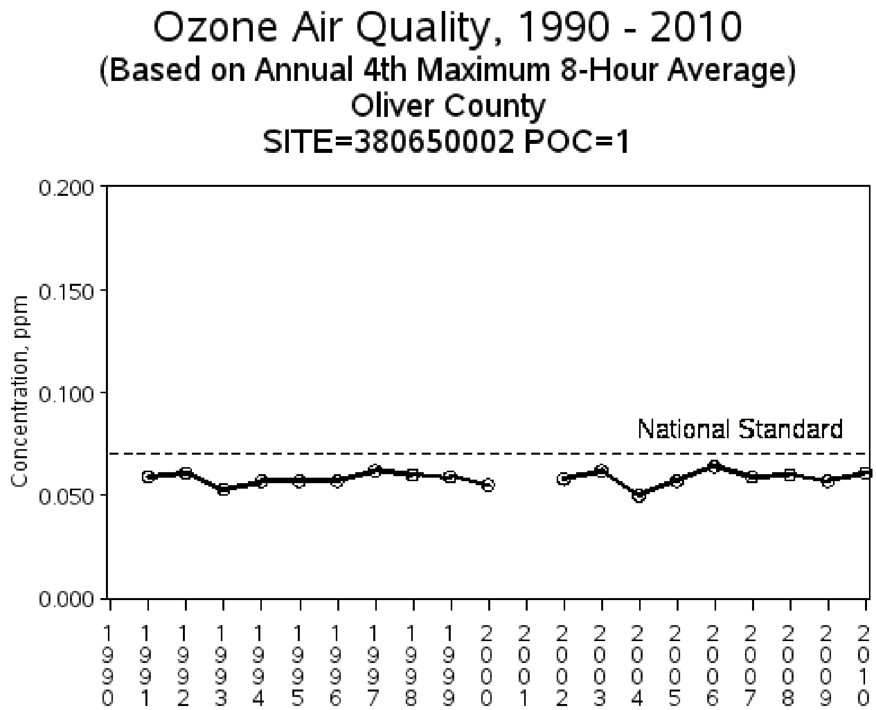


Figure 17. Average annual ozone (O_3) concentration (ppm) for KNRI, 1992-2010 (Source: EPA 2009b). Note: Site 380650002 is the monitor located nearest to KNRI (approximately 20 km south of the park).

NPS (2004) assessed ozone concentrations in the NPGN and the risk of injury to plant species that are sensitive to sustained ozone exposure. Data from 1995-1999 indicate ozone concentrations in KNRI during this time frequently exceeded 60 ppb for a few hours each year but only once exceeded 80 ppb; ozone concentrations never 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) (NPS 2004). Thus, the risk of foliar injury to plants was determined to be low (NPS 2004). However, if ozone concentrations should increase in the future, an on-site monitoring program that assesses foliar injury and growth progress may be necessary (NPS 2004).

Various plant and tree species are monitored to track air pollution impacts. KNRI has eight plant species known to be sensitive to excessive or extended concentrations of ozone, including common milkweed (*Asclepias syriaca*), chokecherry, green ash, Indianhemp (*Apocynum cannabinum*), Saskatoon serviceberry (*Amelanchier alnifolia*), spreading dogbane (*Apocynum androsaemifolium*), quaking aspen (*Populus tremuloides*), and white sagebrush. Specifically, spreading dogbane, common milkweed, and quaking aspen could be used as bioindicator species in the park (NPS 2004, NPS 2006).

Photo 14. Common milkweed (NPS photo).

Concentration of Particulate Matter

Concentrations of particulate matter ($PM_{2.5}$ and PM_{10}) are recorded at a monitoring site in nearby Beulah, North Dakota, approximately 32 km (20 mi) east of KNRI. Measurements recorded at this site represent 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 3 years (EPA 2010d). 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 3 years (EPA 2010d). $PM_{2.5}$ concentrations have remained stable around 5.5-6.5 µg/m^3 since 2006 (Figure 18). Average concentrations of PM_{10} fluctuated between 30-40 µg/m^3, with the exception of a considerable increase in concentration (up to 84 µg/m^3) in 2008. The cause of this increase is unknown; average concentrations decreased again in 2009 and have remained consistent at 30-40 µg/m^3 through 2011. Values for both $PM_{2.5}$ and PM_{10} are well within the EPA standards for levels that are protective of human health and visibility.

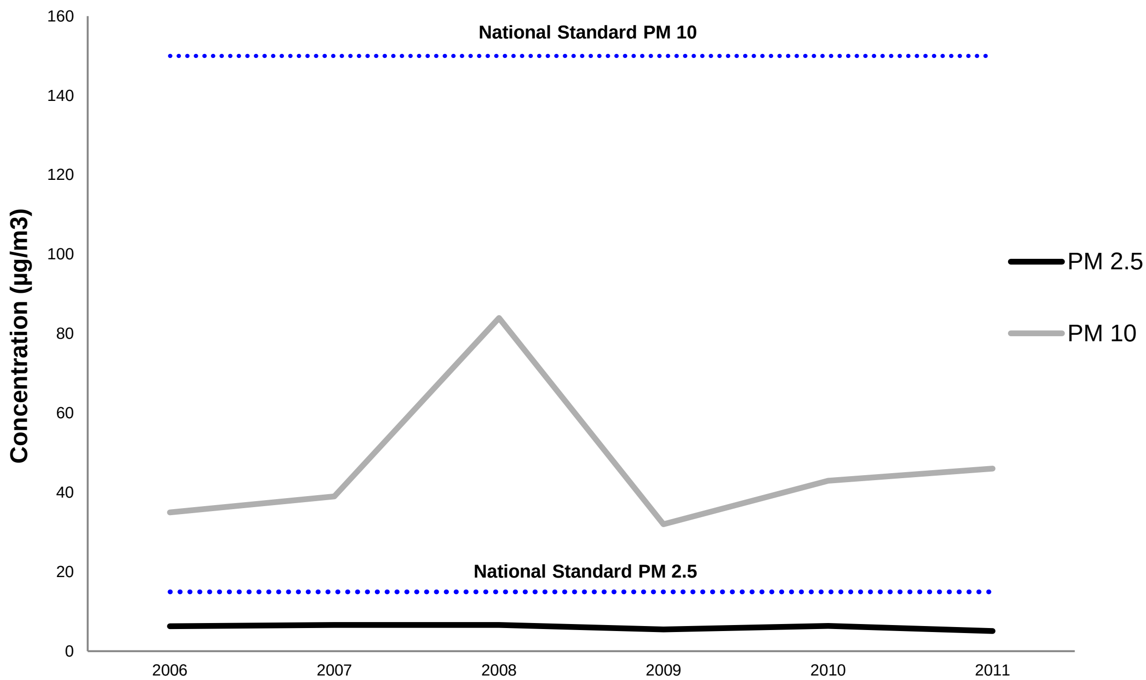


Figure 18. Average annual particulate matter concentration ($PM_{2.5}$ and PM_{10}) near KNRI, 2006-2011 (EPA 2011).

Visibility

Visibility impairment occurs when airborne particles and gases scatter and absorb light; the net effect is called "light extinction," which is a reduction in the amount of light from a view that is returned to an observer (EPA 2003). In response to the mandates of the CAA of 1977, federal and regional organizations established IMPROVE in 1985 to aid in monitoring of visibility conditions in Class I airsheds. The goals of the program are to 1) establish current visibility conditions in Class I airsheds; 2) identify pollutants and emission sources causing the existing visibility problems; and 3) document long-term trends in visibility (NPS 2009a).

The nearest visibility monitoring station is located at THRO, approximately 160 km west-southwest of KNRI. Thus, average visibility conditions at KNRI are estimated using interpolated values from the nearest monitors. The most current 5-year average (2005-2009) estimates visibility in KNRI to be 7.0 dv (this is an estimate above the estimated natural conditions), which falls into the *Moderate Concern* category for NPS air quality condition assessment (NPS 2011). Table 26 presents the estimated interpolated visibility conditions over the last four averaging periods.

Table 26. Estimated average visibility in KNRI since 2001 (NPS 2011).

5-year Period	Estimated Interpolated Visibility (dv)
2001-2005	6.4
2003-2007	7.1
2004-2008	7.12
2005-2009	7

The clearest and haziest 20% of days each year also are examined for parks (NPS 2009). Figure 19 depicts estimated visibility conditions (in Mm^{-1}) for the 20% haziest and 20% clearest days in THRO. Conditions measured near 0 Mm^{-1} are clear and provide excellent visibility, and as Mm^{-1} measurements increase, visibility conditions become hazier. Estimated visibility conditions appear consistent for both the 20% haziest and clearest days over the last five averaging periods.

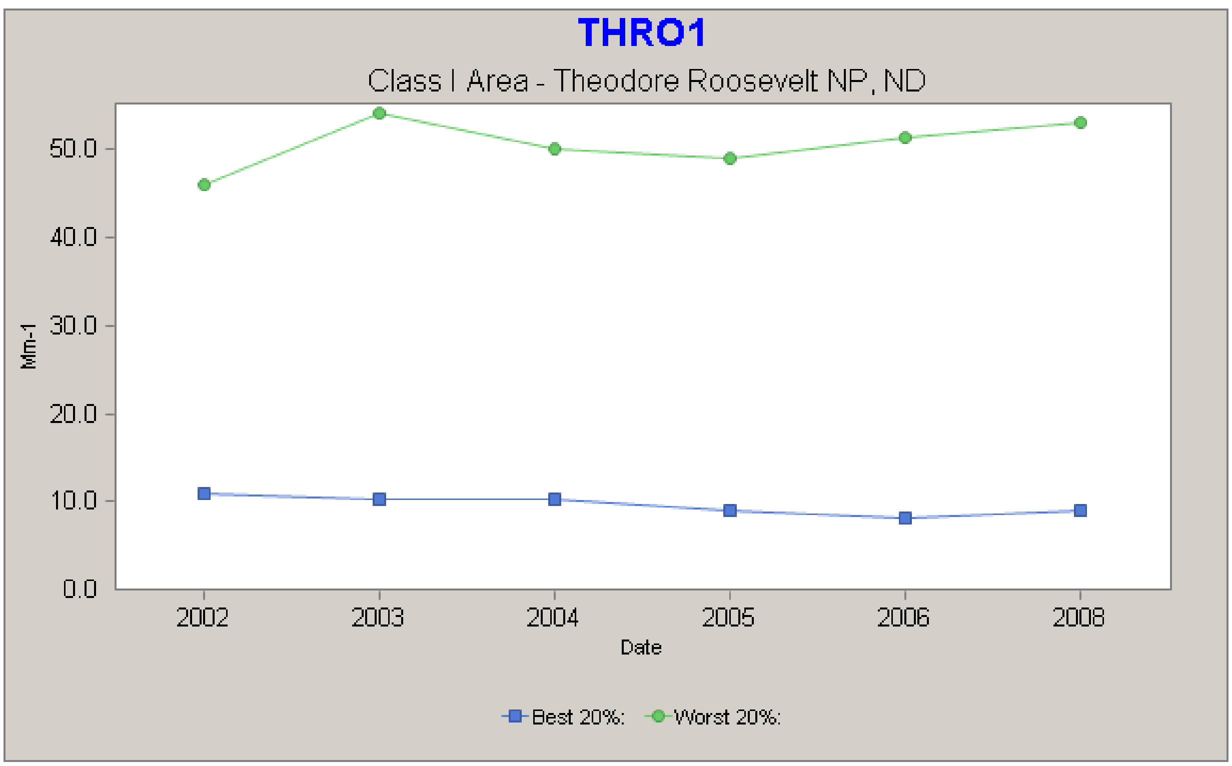


Figure 19. Annual visibility in THRO, 2002-2008 (VIEWS 2010). Note: the IMPROVE monitoring site nearest to KNRI is located at THRO, approximately 160 km west of KNRI.

Threats and Stressor Factors

The most substantial threat to air quality in KNRI is energy development in the region, particularly crude oil and natural gas. Western and central North Dakota have experienced a significant increase in oil and gas development in the last two decades (Peterson et al. 1998). Since the Peterson et al. (1998) assessment, development has increased steadily in the area. The major sources of pollution that could affect protected areas in this region have been associated with oil and gas operations as well as coal-fired power plants; these sources add sulfur dioxide and nitrogen oxides emissions to the air (Peterson et al. 1998). Two power plants, the largest sources of sulfur dioxide emissions in the region, are located directly west of KNRI (Peterson et al. 1998), where predominant winds can carry emissions into the park. Although KNRI is unlikely to be affected by acidification from sulfur dioxide and associated sulfate deposition, these coal-burning power plants also release mercury into the atmosphere that, when transformed to toxic methylmercury in wetlands, can bioaccumulate in fish and wildlife. Nitrogen oxides emissions from oil and gas development may increase nitrogen deposition to KNRI grasslands and wetlands, affecting plant communities and promoting growth of annual grasses and invasive species.

Smoke produced by wildfires or human-caused fires have long been a part of the Great Plains ecosystem. Though fires are not considered a long-term source of pollution in the northern Great Plains (including KNRI), if persistent and substantial in extent, they may result in periods of decreased visibility and increased concentrations of particulate matter (Peterson et al. 1998).

Data Needs/Gaps

There is no monitoring effort in KNRI that currently tracks impacts to species known to be sensitive to increases in various pollutants. Nitrogen and sulfur deposition can affect plant communities (e.g., promoting invasive species, loss of biodiversity, or encouraging transition/succession of plant communities), while ozone can cause foliar injury and inhibit growth. Certain plant and tree species can be used to monitor such air pollution impacts. KNRI has several plant and tree species known to be sensitive to increases in ozone, including common milkweed, chokecherry, green ash, Indianhemp, Saskatoon serviceberry, spreading dogbane, quaking aspen, and white sagebrush (NPS 2006). Such species could be used as bioindicators to track potential increases in ozone, as well as long-term impacts to the health of the ecosystem. Changes to plant communities over time may reflect changes in nitrogen deposition.

Overall Condition

Atmospheric Deposition of Nitrogen

The project team defined the *Significance Level* for atmospheric deposition of nitrogen as a 2. When factoring in the sensitivity of the grassland ecosystem, current 5-year average estimates of nitrogen deposition fall into the significant concern category. These estimates appear to have remained stable in recent years. Concentrations of nitrates near the park appear to be decreasing over the last decade. Therefore, deposition of nitrogen is of significant concern (*Condition Level*=3) with a stable trend.

Atmospheric Deposition of Sulfates

The project team defined the *Significance Level* for atmospheric deposition of sulfates as a 2. When factoring in the sensitivity of the grassland ecosystem, current 5-year average estimates of sulfur deposition fall into the moderate concern category. These estimates also appear to have remained stable in recent years. Concentrations of sulfates near the park appear to be decreasing over the last decade. Therefore, deposition of sulfates is of moderate concern (*Condition Level*=2) with a stable trend.

Deposition/concentration of Mercury

The project team defined the *Significance Level* for mercury concentration as a 2. Current data suggest mercury deposition and concentration in the northern Great Plains are low relative to other regions of the U.S. However, these data are interpolated from monitoring stations some distance from KNRI and serve only as estimates for the region versus data collected in or near to the park. Limited data make it impossible to determine a *Condition Level* for this measure.

Ozone Concentration

The project team defined the *Significance Level* for ozone concentration as a 2. Current average ground-level ozone concentrations fall into the good condition category based on NPS criteria for rating air quality. Both 5-year estimated averages (measured in ppb) and annual averages (measured in ppm) indicate concentrations are stable in the park. Concentrations are well within EPA standards. Therefore, the condition of ozone concentration is of no concern (*Condition Level*=0).

Particulate Matter (PM $_{2.5}$ and PM$_{10}$)

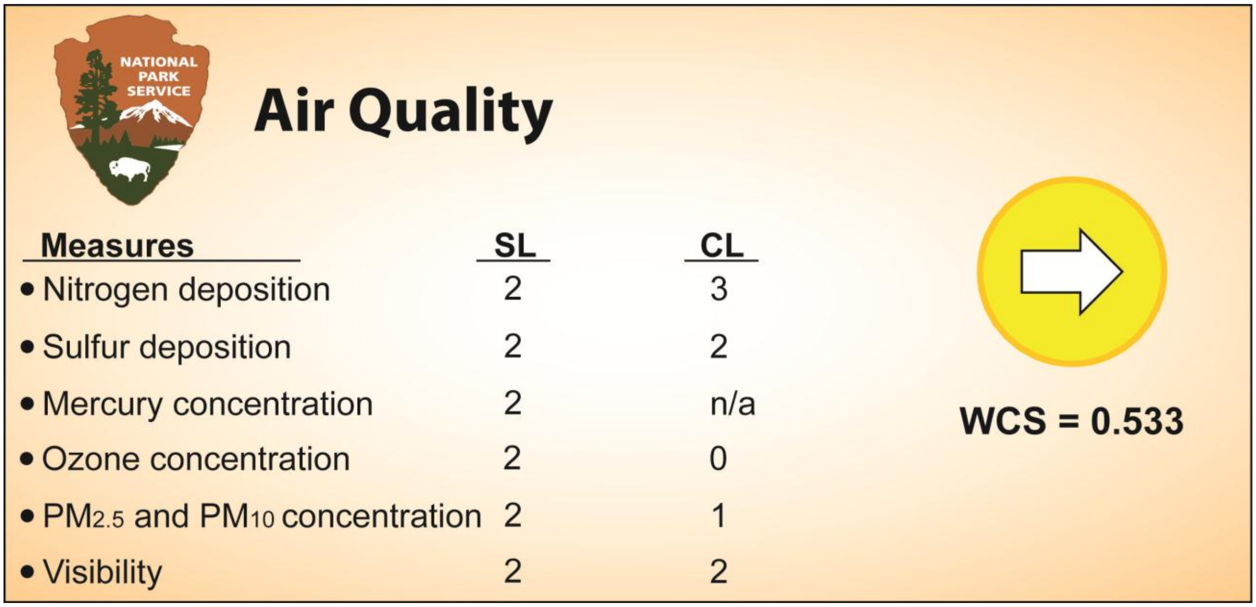
The project team defined the *Significance Level* for concentration of particulate matter ($PM_{2.5}$ and PM_{10}) as a 2. Values for both $PM_{2.5}$ and PM_{10} measured near KNRI are well within the EPA standards for levels that are protective of human health. However, particulate matter concentrations do contribute somewhat to visibility conditions in the park. The *Condition Level* for $PM_{2.5}$ and PM_{10} is of low concern (*Condition Level*=1).

Visibility

The project team defined the *Significance Level* for visibility as a 2. The most current 5-year average estimates for visibility conditions in KNRI fall into the *Moderate Concern* category for NPS air quality condition assessment. However, data suggest the trend in visibility is relatively stable for both the 20% haziest and clearest days. The *Condition Level* for visibility is of moderate concern (*Condition Level*=2).

Weighted Condition Score

The *Weighted Condition Score* (WCS) for the air quality component is 0.444, indicating the condition is of moderate concern with a stable trend.



4.6.6 Sources of Expertise

Ellen Porter, Biologist, NPS, Air Resources Division.

John Moeykens, KNRI Chief of Law Enforcement and Resource Management.

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4.7 Water Quality

4.7.1 Description

Water quality monitoring has been identified as a priority for NGPN parks, including KNRI. Water quality monitoring is important for tracking ecological health in the park, assessing compliance with water quality standards, and detecting threats to human health. The NGPN will monitor a core set of water quality measures, including dissolved oxygen, pH, specific conductivity, water temperature, as well as fecal coliform bacteria as part of their long-term monitoring program (NPS 2012).

KNRI is located on both sides of the Knife River and lies adjacent to the Missouri River near the confluence of the Knife and Missouri Rivers. Its location along both rivers helped to make the villages at KNRI a main trading center in North America in the early part of the 19th century (NPS 2009). Both the Knife and Missouri Rivers provide habitat for a variety of plants and animals that are observed frequently at KNRI. In addition, both rivers provide opportunities to recreate in and near the park. Thus, impaired water quality could substantially affect animals, plants, and people in the park.

Photo 15. The Knife River flowing through KNRI (SMUMN GSS photo, 2010).

4.7.2 Measures

- Temperature
- Dissolved oxygen
- Turbidity
- pH
- Fecal coliform

Temperature

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 2010). All aquatic organisms, from fish to insects to zoo- and phytoplankton, have a preferred or ideal temperature range for existence (USGS 2010). 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, making them more toxic to aquatic life (USGS 2010).

Dissolved Oxygen

Dissolved oxygen (DO) is critical for organisms that live in water. Fish and zooplankton filter out or "breathe" dissolved oxygen from the water to survive (USGS 2010). Oxygen enters water from the atmosphere or through ground water discharge. As the amount of DO drops, it becomes more difficult for water-based organisms to survive (USGS 2010). The concentration of DO in a water body is closely related to water temperature; cold water holds more DO than does warm water (USGS 2010). 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 2010).

Turbidity

Turbidity assesses the amount of fine particle matter (e.g., 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 passing through water (USGS 2010). 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 DO in the water (USGS 2010). The scattering of sunlight by suspended particles decreases photosynthesis by plants and algae, which contributes to decreased DO concentrations in the water (USGS 2010). Suspended particles also irritate and clog the gill structures of many fish or amphibians, making it difficult for the species to thrive (USGS 2010).

pH

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 2010). 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 2010). Chemicals in water can change the pH and harm animals and plants living in the water; thus, monitoring pH can be useful for detecting natural and human-caused changes in water chemistry (USGS 2010).

Fecal Coliform

Fecal coliform bacteria, including *Escherichia coli* (*E. coli*), are accurate indicators of fecal contamination in water from warm-blooded animals or humans. Contamination is tested by counting bacterial colonies that grow on micron filters placed in an incubator for 22-24 hours. High numbers of fecal coliform can be an indicator of harmful bacteria as well as other disease-causing organisms such as viruses and protozoans (USGS 2011).

4.7.3 Reference Conditions/Values

The reference condition for THRO's water quality is the North Dakota Standards of Water Quality for the State for surface waters established by the North Dakota Department of Health (NDDH) (NDDH 2001). The Missouri River is classified as a Class I stream and Knife River is classified as a Class II stream; by these standards this requires that water quality be suitable for propagation or protection, or both, of resident species and other aquatic biota and for swimming, boating, and other water recreation (NDDH 2001). When state standards are unavailable, the EPA's water quality criteria for surface waters were used. The water must be safe for freshwater organisms, for human bathing, and must meet drinking water standards.

Table **27** displays water quality parameter standards set by the state of North Dakota and EPA.

Table 27. North Dakota water quality standards (North Dakota Department of Health 2001, EPA 2012b).

Parameter	North Dakota Water Quality Standard
Temperature	<85°F or 29.4°C (for Class II streams)
Dissolved oxygen	≥5 mg/L
Turbidity	50 NTU (EPA standard)
pH	≥7.0 – ≤9.0 (up to 10% of representative samples collected during any 3-year period may exceed this range provided that lethal conditions are avoided)
Fecal coliform	≤126 CFU/100 mL (for recreational waters from May 1 – September 30)

4.7.4 Data and Methods

In 1997, the NPS published the results of surface-water quality data retrievals for KNRI 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). The retrieval resulted in 352 observations for various parameters at 11 monitoring stations operated by USGS and the EPA from 1975 to 1991 (NPS 1997). Only three of the 11 stations collected the water quality data (temperature, pH, dissolved oxygen). Most of the observations (93%) were reported between 1988 and 1991 by the USGS. All of the monitoring stations were located immediately downstream of KNRI on the Missouri River, outside of the park boundary (NPS 1997).

Rust (2006) collected water quality samples for several parameters on the Little Missouri River in 2004-2005. The objective of the research was to provide baseline descriptions of macroinvertebrate communities in the aquatic systems of national parks in the NGPN (including KNRI), as well as select optimal metrics for use in future monitoring efforts by park resource managers. Chemical, physical, and aquatic habitat parameters were assessed for the Missouri and Knife Rivers during the 2004 and 2005 field summer seasons. Water quality parameters measured in the study included dissolved oxygen, temperature, turbidity, fecal coliform concentration, pH, and diversity and abundance of macroinvertebrate species, as well as other parameters.

A project to monitor macroinvertebrate communities in the Knife River along KNRI is currently underway and led by Dr. Lusha Tronstad, an invertebrate zoologist with the Wyoming Natural Diversity Database (WNDD). In August 2011, Dr. Tronstad collected aquatic invertebrate and water quality samples at three sites along the Knife River at KNRI. Parameters examined include diversity of macroinvertebrate taxa, water temperature, dissolved oxygen, specific conductance, salinity, pH, turbidity, and concentration of coliform bacteria. Preliminary results are available for chemical and physical water quality parameters; analysis of macroinvertebrate taxa is still underway.

4.7.5 Current Condition and Trend

Temperature

The acceptable temperature range for Class I and II rivers and streams in North Dakota is less than 85°F (<29.4°C), with the maximum increase being no greater than five degrees Fahrenheit (2.78°C) above natural background conditions (NDDH 2001). Twenty-two temperature measurements were recorded from three gages on the Missouri River (Class I river) near KNRI between 1975 and 1991. At two of the stations (stations 1 and 7), measurements were collected in a short-term sampling effort in August 1991. Only 15 observations were made, eight at Station 1 and seven at Station 7 (NPS 1997). Station 2 recorded seven temperature measurements between 1975 and 1987 (NPS 1997). All water temperature measurements were within state standards for a Class I river.

Rust (2006) collected temperature samples from one reach on the Knife River and two reaches on the Missouri River. Thirty observations were taken along each reach (three observations per transect with ten transects in each reach) for a total of 90 observations, 30 observations on the Knife River and 60 observations on the Missouri River (Rust 2006). Table 28 shows the mean, median, and range of temperatures observed in each river during sampling. Sampling in August 2011, by Dr. Lusha Tronstad, showed water temperatures ranged from 21.2 to 23.4°C at three sites on the Knife River. All temperature measurements are within the state standard for Class I and II rivers.

Table 28. Water temperature observations (°C) on the Knife and Missouri River near KNRI (Rust 2006).

River	Number of Observations	Mean	Median	Range
Knife River	30	21.7	21.6	16.3-27.9
Missouri River	60	15.4	14.9	11.7-22.4

It is important to note that the section of the Missouri River below the Garrison Dam and adjacent to the park is a tailwater that drains cold water from the bottom of Lake Sakakawea, explaining the lower average temperatures of the Missouri River.

Dissolved Oxygen

NPS (1997) reported that two stations recorded dissolved oxygen levels in the Missouri River near KNRI (Stations 1 and 7). Both stations collected DO data during the same week in August 1991 (8-15 August) to total 15 observations (eight observations from Station 1 and seven observations from Station 7) (NPS 1997). DO measurements ranged from 9.3 to 10.0 mg/L. Median DO concentrations were 9.7 and 9.9 mg/L for Stations 1 and 7 respectively. All measurements are within the state standards for protection of freshwater aquatic life.

In 2004 and 2005 during an inventory of macroinvertebrate communities, Rust (2006) also collected 90 DO samples along three reaches, two of which were located on the Missouri River and one located on the Knife River. Thirty observations were recorded on the Knife River (three samples collected per transect across 10 transects per reach) and sixty were recorded on the Missouri River. DO measurements for the Missouri and Knife River reaches are show in Table 29. Sampling in August 2011, by Dr. Lusha Tronstad, showed DO measurements ranged from

8.6 to 10.9 mg/L at three sites on the Knife River. All measurements are within state standards for protection of freshwater aquatic life.

Table 29. Dissolved oxygen measurements (mg/L) on the Knife and Missouri River near KNRI (Rust 2006).

River	Number of Observations	Mean	Median	Range
Knife River	30	8.4	8.4	6.9-10.8
Missouri River	60	9.8	9.8	8.0-12.3

Turbidity

The EPA considers turbidity levels ≤50 Nephelometric Turbidity Units (NTU) suitable for freshwater aquatic life (NPS 1997). Turbidity varies in different sized streams and rivers, usually increasing as river velocity increases (EPA 2012a). Since the Knife River is a tributary of the Missouri River, its velocity tends to be slower. The average stream velocity of the studied portions of the Knife and Missouri Rivers were 0.07m/s and 0.48 m/s, respectively (Rust 2006).

Rust (2006) collected nine turbidity measurements in total from both the Knife and Missouri Rivers near KNRI. The range of turbidity in the Knife River reach was 5 to 20 NTU, while the turbidity ranged from 3 to 173 NTU in the Missouri River. During the entire study (2004-2005), only one measurement on the Missouri River exceeded EPA criteria for protection of freshwater aquatic life (173 NTU) (Rust 2006).

pH

NPS (1997) reported that pH was measured 21 times at three monitoring stations located on the Missouri River near KNRI from 1977 to 1991. Of these observations, only one measurement was at the maximum extent of the pH range (7.0-9.0) considered to be protective of freshwater aquatic life. pH values on the Missouri River ranged from 7.1 to 9.0; mean and median values were 8.5 and 8.25 respectively.

Rust (2006) collected 90 pH measurements on the Knife and Missouri Rivers near KNRI during the summer months of 2004 and 2005. Thirty observations were recorded on the Knife River and 60 observations were recorded from the Missouri. During this sampling, all values were found to be within the state criteria protective of freshwater aquatic life. Table 30 shows the range, mean, and median values for samples collected during the study. Sampling in August 2011, by Dr. Lusha Tronstad, showed pH measurements ranged from 8.31 to 8.46 at three sites on the Knife River.

Table 30. pH measurements on the Knife and Missouri River near KNRI (Rust 2006).

River	Number of Observations	Mean	Median	Range
Knife River	30	8.2	8.3	7.7-8.5
Missouri River	60	8.1	8.2	7.6-8.3

Fecal Coliform

The reach of the Knife River between the Antelope Creek confluence and the Missouri River confluence is listed by the EPA as an impaired waterway (303d list) for fecal coliform bacteria (EPA 2011). The EPA has listed this stretch of river as impaired in 2004, 2008, and again in 2010 (EPA 2010). According to the EPA (2012b), the three possible sources of the pathogens are animal feeding operations, grazing of livestock in riparian areas, and municipal point source discharges.

Rust (2006) identified the presence of coliform bacteria in both the Missouri and Knife Rivers. However, few fecal coliform samples were able to be analyzed due to problems with overnight shipping. Three samples analyzed revealed fecal coliform concentrations were well within water quality standards for safe bathing water (10, 10, and 90 CFU/ml) (Rust 2006).

Sampling in August 2011, by Dr. Lusha Tronstad, showed fecal coliform concentrations were 2,419 CFU/100mL at three sites on the Knife River. These samples exceeded the maximum concentration for safe bathing.

Threats and Stressor Factors

Pathogens found in the Knife River are a major concern to the park. Fecal coliform or *E. coli* were present in the water, indicating contamination and the possible presence of disease-causing pathogens (USGS 2011). The reach of the Knife River from the Antelope Creek confluence to the Missouri confluence has been declared impaired under 303(d) (EPA 2011). Possible sources affecting the water quality are pesticide use, development, cultivation, and livestock feeding operations from upstream from the park. Recently, a Black Angus ranch was operating along the Knife River a few miles upstream from the park. This operation, among others like it, may be contributing to fecal coliform concentrations.

In addition, recent flooding on the Missouri River in spring 2011 has changed the morphology at the confluence of the Knife and Missouri Rivers. It is unclear how this change in river structure will affect water quality conditions extending upriver from the confluence.

Data Needs/Gaps

Currently, consistent monitoring of the basic water quality parameters does not occur in the Knife and Missouri Rivers adjacent to KNRI. Available data for the Knife and Missouri Rivers near the park is limited, with most data specific to the Missouri River dating back to 1991 or earlier. Data for the Knife River is even more limited, and because the Knife River is free-flowing and much different from the Missouri River, consistent monitoring of water quality parameters on the Knife River is essential for understanding how conditions may be changing. Sporadic studies offer a snapshot of water quality conditions in the Knife and Missouri Rivers adjacent to the park at various time periods; however, these periodic observations of parameters are likely not representative of typical or abnormal conditions of water quality throughout the course of each year. Long-term monitoring of temperature, DO, turbidity, pH, and fecal coliform concentrations is needed to identify possible trends in water quality at KNRI.

In addition, consistent monitoring of aquatic macroinvertebrate populations in the park is lacking. The presence or absence of species that are tolerant and intolerant to pollution can be an indication of the condition of the water body and water quality. To date, Rust (2006) represents the most recent examination of the benthic macroinvertebrate community in the Knife and Missouri Rivers adjacent to KNRI that has been completed. In August 2011, Dr. Lusha Tronstad collected aquatic invertebrate samples at three sites along the Knife River adjacent to the park. Examination of Dr. Tronstad's macroinvertebrate samples is still underway and results should be available in late 2012. Results from these two surveys could be used as baseline information to which the results from future monitoring efforts may be compared.

<u>Overall Condition</u>
The water quality for KNRI is difficult to assess due to sporadic data collection and lack of long-term monitoring. Due to the lack of data, no trends could be determined. Much of the available data is at least 20 years old. The most recent monitoring efforts have occurred in 2004 and 2005 by Rust (2006) and again in 2011 by Dr. Tronstad. However, both Rust (2006) and Dr. Tronstad collected water quality data only during the summer months, which does not capture variation in water quality parameters across an entire year. Due to significant data gaps, *Condition Levels* could not be assigned for the majority of water quality measures.

Temperature
The project team defined the *Significance Level* for temperature as a 2. When examining the data collected from the Knife and Missouri Rivers, all measurements were within the state standards for Class I and II rivers and streams. However, the available data is neither consistent nor is it current. For this reason, a *Condition Level* was not assigned to temperature.

Dissolved Oxygen
The project team defined the *Significance Level* for dissolved oxygen as a 2. Available data indicate that DO levels are well within the state standards for protection of freshwater aquatic organisms. However, data are very limited and outdated, which makes it difficult to determine current conditions in the Knife and Missouri Rivers. Because of this data gap, a *Condition Level* for dissolved oxygen was not assigned.

Turbidity
The project team defined the *Significance Level* for turbidity as a 2. Rust (2006) collected a total of nine observations from both Knife River (3) and the Missouri River (6) reaches near KNRI. Data are limited for the Knife River and consistent, long-term monitoring is required to accurately assess any trends. All but one measurement to date (173 NTU) has met state standards, but more current data are needed for an accurate assessment. For this reason, a *Condition Level* for turbidity was not assigned.

pH
The project team defined the *Significance Level* for pH as a 2. Between Rust (2006) and NPS (1997), there were a total of 111 pH measurements. All measurements are within the state

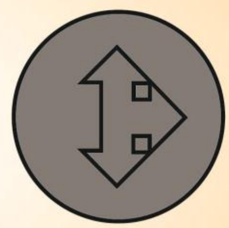
standards considered protective of freshwater aquatic life. Current data and a long-term data study are needed to calculate any current trends. Therefore, a *Condition Level* for pH was not assigned.

Fecal Coliform
The project team defined the *Significance Level* for fecal coliform as a 2. Data are limited for fecal coliform concentrations in the Knife and Missouri Rivers. Observations by Rust (2006) and Dr. Tronstad in 2011 indicate fecal coliform concentrations exceed the state standards for safe bathing. As of 2010, a reach of the Knife River between the Antelope Creek confluence and the Missouri confluence is listed under section 303(d) for pathogens. This same stretch of river also has been listed as impaired in 2004 and 2008. Long-term data are needed to more accurately assess any trends. However, due to a recent history of the Knife River being impaired, a *Condition Level* of 3 is assigned for this measure, indicating significant concern.

Weighted Condition Score
A *Weighted Condition Score* was not calculated for water quality in KNRI because >50% of the measures had unknown *Condition Levels*.

Water Quality

Measures	SL	CL
• Temperature	2	n/a
• Dissolved oxygen	2	n/a
• Turbidity	2	n/a
• pH	2	n/a
• Fecal coliform	2	3



WCS = N/A

4.7.6 Sources of Expertise
John Moeykens, KNRI Chief of Law Enforcement and Resource Management.

Dr. Lusha Tronstad, WNDD Invertebrate Zoologist

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4.8 Soundscape

4.8.1 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 NPS mission is to preserve natural resources, including natural soundscapes associated with the national park units. Intrusive sounds are of concern to park visitors, as they detract from their natural and cultural resource experiences (NPS 2000). According to an NPS survey, many visitors come to National Parks to enjoy, equally, the natural soundscape and natural scenery (NPS 2000).

As described in BridgeNet (2005), different frequencies (A-weighted, B-weighted, and C-weighted) are used to compute sound loudness levels. The most common measurement used is the A-weighted decibel scale (dBA) which approximates the sensitivity to the human ear. In an A-weighted decibel scale, every day sounds range from 30 dBA (very quiet) to 90 dBA (very loud). Table 31 presents examples of human perceived sound levels of comfort expressed in dBA (BridgeNet 2005).

Table 31. Examples of various A-weighted decibel sound environments (BridgeNet 2005).

dBA	Human Sensitivity	Outdoor Example
130		Military Jet Takeoff (130)
120	Uncomfortably Loud	
110		
100		Boeing 747 Takeoff (101)
90	Very Loud	Power Mower (96)
80		
70	Moderately Loud	Passenger Car @ 65 mph (77)
60		Propeller Airplane Takeoff (67)
50	Quiet	Large Transformers (50)
40		Bird Calls (44)

4.8.2 Measures

- Occurrence of human-caused sound
- Natural ambient sound

4.8.3 Reference Conditions/Values

The reference condition for soundscape is a soundscape that is comparable to the period of active Indian villages in the area.

4.8.4 Data and Methods

There are no quantitative data related to the soundscape in KNRI.

4.8.5 Current Condition and Trend

Occurrence of Human-caused Sound

A power plant located approximately 3.2 km (2 mi) south of KNRI produces a constant humming sound which is more pronounced at night. The plant occasionally releases excess steam which adds additional noise.

Threats and Stressor Factors
KNRI staff identified highway and train traffic, future mining, and the power plant as threats to the natural soundscape. There is discussion of establishing a mining operation along the Missouri River adjacent to KNRI, which could have a major impact on the park's soundscape.

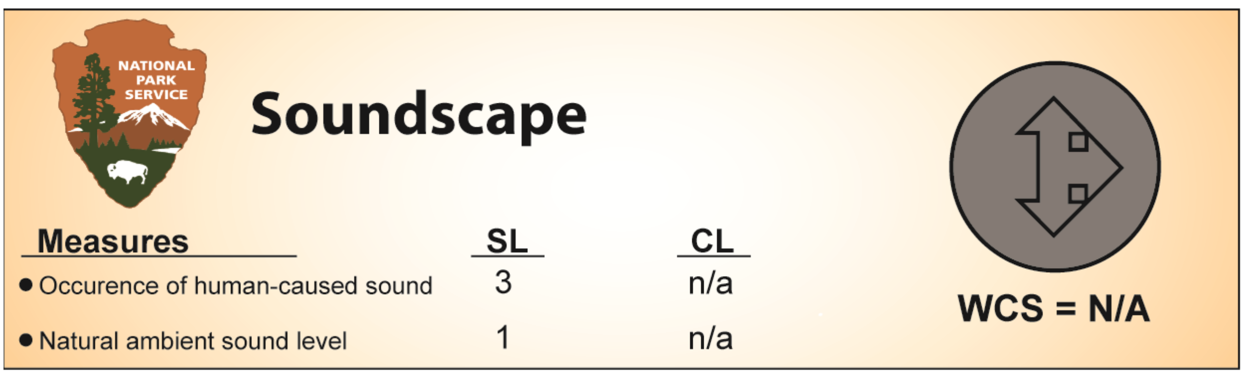
Data Needs/Gaps
Baseline data are needed to determine the natural ambient sound level in KNRI. Noise levels from traffic could be measured as well.

Overall Condition

Occurrence of Human-caused Sound
The KNRI project team defined the *Significance Level* for occurrence of human-caused sound as a 3. A local power plant creates most of the human-caused noise in the soundscape, and there is potential for additional noise if mining operations are established near KNRI. There are no quantitative data on noise levels in KNRI, so a *Condition Level* cannot be assigned.

Natural Ambient Sound Level
A *Significance Level* of 1 was assigned for the measure of natural ambient sound level. There have been no baseline soundscape data collected in KNRI; therefore, a *Condition Level* cannot be assigned.

Weighted Condition Score
A *Weighted Condition Score* (WCS) cannot be assigned for the KNRI soundscape due to a lack of data on component measures.



4.8.6 Sources of Expertise
John Moeykens, KNRI Chief of Law Enforcement and Resource Management

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4.9 Dark Night Skies

4.9.1 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 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 expect skies to be free of light pollution to allow for star observation.

4.9.2 Measures

- Ambient light pollution

4.9.3 Reference Conditions/Values

The reference condition for KNRI is the absence of anthropogenic light pollution, which is in accordance with National Park Service management policies.

4.9.4 Data and Methods

No data have been collected by the NPS in KNRI related to dark night skies.

4.9.5 Current Condition and Trend

<u>Ambient Light Pollution</u>

NPS defines ambient light pollution as “the illumination of the night sky caused by artificial light sources, decreasing the visibility of stars and other natural sky phenomena” (NPS 2007). Unfortunately, levels of ambient light pollution have not been recorded or monitored in KNRI.

The National Park Service 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 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). Night sky assessments have not been completed at KNRI.

<u>Threats and Stressor Factors</u>

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).

Perhaps the most significant of the threats facing KNRI’s dark night skies is the development of nearby wind, power, oil, and gas facilities. KNRI lies within one of the largest structural and sedimentary basins in North America. The basin has been active in oil and gas development since the mid 1970s. In the past 20-30 years, many wells have been developed outside of the park boundaries on public and private lands (NPS 1991). Theodore Roosevelt National Park (THRO) is located 225 km (140 mi) west of KNRI, and in 2008 the National Parks Conservation Association (NPCA) identified THRO as one of ten national parks most threatened by pollution from new coal-fired power plants (NPCA 2008). KNRI has many of the same concerns as THRO, and energy and associated developments within the park's viewshed will continue to be a threat to the park's dark night skies.

Apart from internal sources of light pollution in KNRI (e.g., park facilities, road and train traffic), other potential sources of light pollution come from the nearby city of Stanton, ND, a small city of approximately 350 citizens, located 7 km (4.3 mi) from KNRI; although the southern end of KNRI is in very close proximity to the city boundary. Sources of light pollution in Stanton include automobile lights, overhead streetlights, and residential lights. Park staff believes that the recent construction of industrial facilities in the southwest portion of Stanton, ND will likely contribute to light pollution in the park.

Several wind-powered turbines were installed approximately 14 km (9 mi) south of KNRI. From some locations in the park, these turbines are visible in the daylight. However, at night the turbines have automated, flashing air traffic lights, making them easily discernible from KNRI.

Data Needs/Gaps

There has been no collection of baseline data at KNRI in regards to dark night skies. Without this data an assessment of the condition of the night skies cannot be completed. An investigation conducted by the NPS Night Sky Team is needed to obtain the necessary data to assess the condition of KNRI's dark night skies.

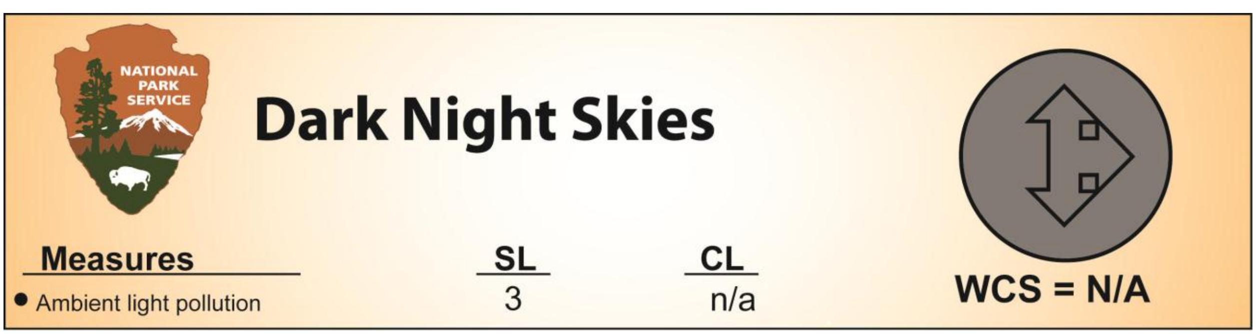
Overall Condition

Ambient Light Pollution

KNRI staff assigned the measure of ambient light pollution a *Significance Level* of 3. However, due to the lack of appropriate data, SMUMN GSS did not assign a *Condition Level* to this measure.

Weighted Condition Score (WCS)

Because SMUMN GSS could not assign a condition level to the measure for this component, no *Weighted Condition Score* was assigned.



4.9.6 Sources of Expertise

John Moeykens, KNRI Chief of Law Enforcement and Resource Management
Wendy Ross, KNRI Superintendent

4.9.7 Literature Cited

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4.10 Knife River Geomorphology/Watershed

4.10.1 Description

The Knife River is a sinuous, meandering river that flows east from the Killdeer Mountains in North Dakota, through KNRI, and into the Missouri River near Stanton, North Dakota. The Knife River is one of the larger tributaries of the Missouri River between the Garrison Dam and Lake Oahe, and measures over 322 km (200 mi) in total length (USGS 2009).

Photo 16. Example of outer bank erosion of the Knife River in KNRI (SMUMN GSS Photo).

The completion of the Garrison Dam in 1955 (approximately 16 km [10 mi] from the Knife River's confluence), and the subsequent regulation of the Missouri River, had extensive effects on the Missouri and Knife Rivers (USACE 2000, Ellis 2005). The Missouri River is regulated by the U.S. Army Corps of Engineers, and a high priority is given to maintaining a navigable waterway. As a result, annual large floods no longer occur at the magnitude, duration, or frequency that they once did (Ellis 2005), and the flood-scale channel has become largely redundant. Furthermore, Garrison Dam impounds the natural sediment load in the Missouri River, which causes the Missouri River system immediately downstream to experience severe degradation (Ellis 2005). The confluence of the Knife River and the Missouri River lies within this degradation zone and, as a result, the Knife River has had to adjust to a lower base-level.

In KNRI, several archeological sites are in close proximity to the Knife River; four Hidatsa village remains (Lower and Big Hidatsa Villages, Awatixa or Sakakawea Village, and Awatixa X'ie Village) are situated on elevated river terraces in the park (Ellis 2005). Archeological features also exist near Elbee Bluff, which is an area in KNRI that experienced over 18 m (59 ft) of lateral erosion from 1982-2004 (Ellis 2005). The archaeological sites within KNRI are vulnerable to the Knife River's meander evolution and high erosion rates (especially in regards to the outer banks of the river) (Ellis 2005), and are undergoing significant degradation due to river bank erosion (Cummings 2011). Monitoring of the Knife River's erosion rates and movement, particularly at the priority river bends in the park, is important to park managers so that the archeological sites are preserved and the cultural landscape is maintained.

4.10.2 Measures

- River bank/bluff erosion
- Movement of the Knife River

4.10.3 Reference Conditions/Values

The reference condition for Knife River geomorphology/watershed is the condition of the area prior to the construction of the Garrison Dam.

4.10.4 Data and Methods

Ellis (2005) looked at the geomorphology at Elbee Bluff on the Knife River in KNRI. Elbee Bluff is an angular meander bend in KNRI near many archaeological features. According to Ellis (2005), the study had several major objectives:

- review of existing reports on the Missouri and Knife Rivers;
- evaluation of potential geomorphological and morphological responses to changes in the hydraulic and sedimentary regimen after the closure of Garrison Dam;
- inspection of the retreating bank to determine the local processes and mechanisms of erosion and the likely future rate of retreat;
- assistance with evaluating the data collection, stream characterization and detailed geomorphological analyses required to address the river bank erosion at the Elbee site;
- development of a river management plan based on the geomorphological assessment;
- identification of potential avenues of funding and/or partnerships to manage bank erosion on the Knife River.

Jalyn Cummings, IMR/MWR Hydrologist, completed a trip report (Cummings 2011) after a visit to KNRI in July 2011. Among the objectives of this visit were to explain ongoing erosion work in the park and to adjust the current erosion monitoring plan so that it better suited the KNRI staff's needs. While this trip report does not address the geomorphology of the Knife River, it does update conditions of the river/river banks witnessed at old sites, adds new sites to the monitoring plan, and documents any decisions made regarding erosion procedures.

Sexton (2012) created a highly accurate and repeatable mapping methodology to determine the extent of contemporary cut bank edge erosion along the Knife River. Complete methodology is available in Sexton (2012). According to Sexton (2012), there were two objectives for this study:

1. Develop and implement a high accuracy mapping methodology used to delineate the current location of cut banks along the Knife River within Knife River Indian Villages National Historic Site.

2. Acquire, process, and analyze historical aerial and high-resolution satellite imagery for use in delineating past locations of Knife River cutbanks albeit at a lower resolution than the high accuracy mapping methods.

4.10.5 Current Condition and Trend

River Bank/Bluff Erosion

With the close proximity of archeological sites to the Knife River, river bank stability and bank/bluff erosion are very important to KNRI staff; with an estimated 1-40 m of lateral river bank lost in the last several years (Cummings 2011), river bank erosion represents the largest threat to KNRI's archaeological resources (Sturdevant 2009).

Many of the banks on the Knife River in KNRI are cutbanks. These cutbanks are near vertical cliffs or bluffs that are found at most of the high priority erosion sites in the park; many of the park sites have been named after these cutbanks (e.g., Elbee Bluff, Taylor Bluff). River bank stability depends on the strength of the bank and the amount of stress acting upon it (Ellis 2005). Bank failure occurs when the base of the bank is eroded to the point that it exceeds its critical value, and gravitational force exceeds the strength of the bank material (Ellis 2005). The stability of these banks is largely dependent upon the degree of bank material saturation, tension cracking, presence of failed material, and the influence of vegetation (Thorne 1982, Ellis 2005); the presence of vegetation can be the most important stabilizing factor for river banks (Thorne and Osman 1988, Thorne 1990, Ellis 2005). However, the degree of saturation can also be crucial, as the additional weight of water can lead to bank failure (Thorne 1982, Ellis 2005). In KNRI, bank erosion and failure most often occurs in response to ice gouging and abrasion of saturated banks during spring thaw, prolonged periods of precipitation, and lateral erosion due to direct river flow (Ellis 2005).

Flood Events

Mass bank failure most frequently occurs after a rapid fall in river stage following a high-magnitude flood (Ellis 2005). However, with the regulation of the nearby Missouri River, high magnitude floods are not as frequent in the lower reaches of the Knife River. A major flood affected the reach of the Knife River as it passes through KNRI in March 1997. This flood occurred due to rapid ice melt and had high levels of sustained flows for several weeks (Ellis 2005), with a short period (3-4 hours) of overbank flooding. Several bends of the river experienced significant soil loss due to erosion as a result of this flood; 26 m (86 ft) of shoreline downstream of the Elbee Bluff site was lost, as was a portion of a KNRI trail running along the river terrace (Ellis 2005). Figure 20 displays the overbank flow line and tension cracks/bank failures from the 1997 flood in relation to the archeological features near Elbee Bluff.

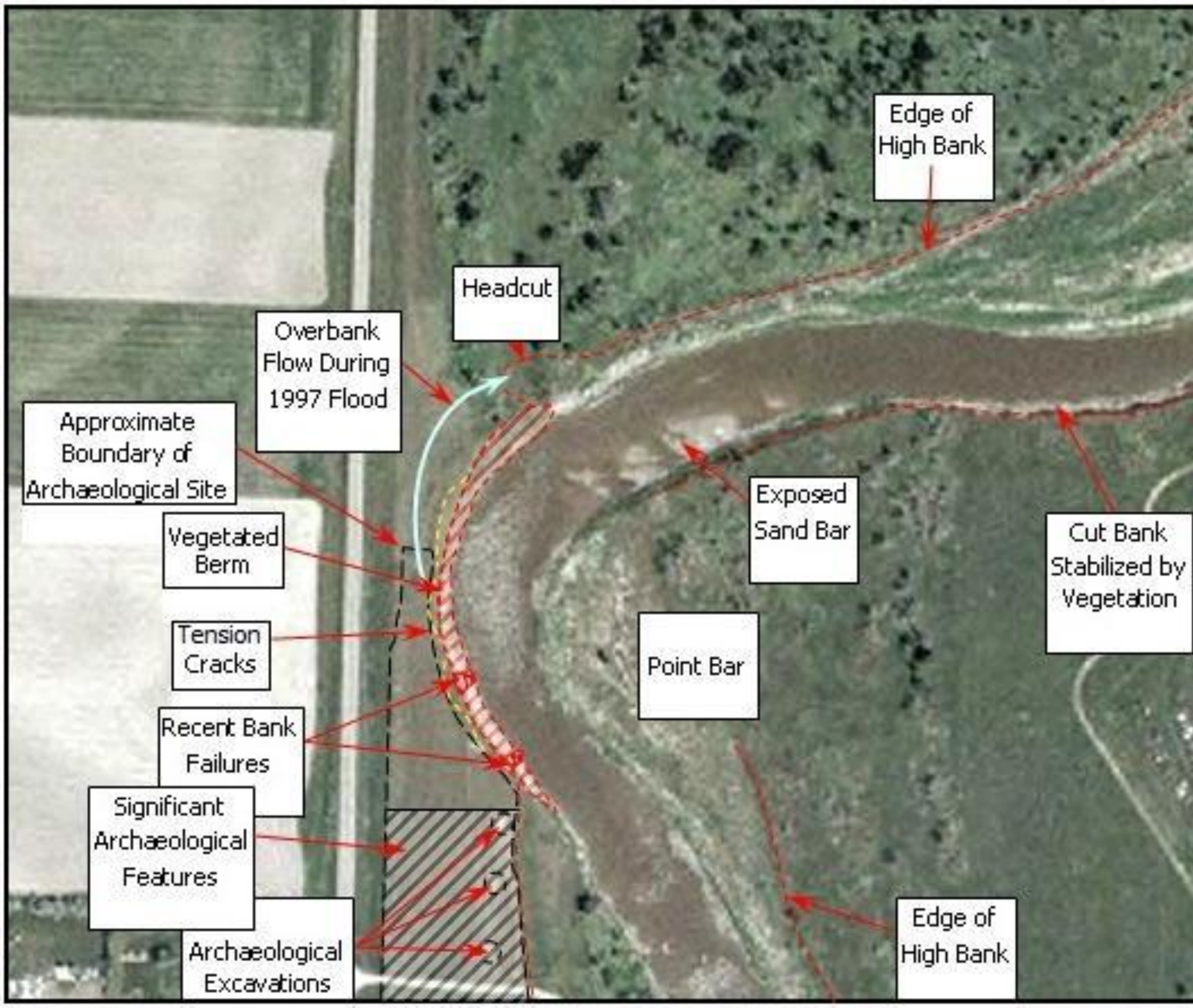


Figure 20. Geomorphology of the Elbee Bluff site along the Knife River, and the location of archaeological features in relation to the 2004 bank line (figure reproduced from Ellis 2005).

The Elbee Bluff site is currently eroding at a rapid pace. Ellis (2005) recorded 50 m (165 ft) of shoreline between the archaeological features and the bank of the Knife River. However, strong storms and elevated river stages in 2009 resulted in further erosion of the Elbee site, and created two headcut channels (Cummings 2011). Archaeological features shown in Figure 20 are now either exposed in the bluff, or are less than 1 m (3.28 ft) from the edge of the river bank (Cummings 2011). Sturdevant (2009) and Cummings (2011) recommend that KNRI develop plans to control bank erosion via bank stabilization and that the park should conduct data recovery excavations of the archaeological sites to prevent the future loss of artifacts. With the rapid loss of soil near these archaeological features (Figure 21), immediate action and excavations may be required.

Figure 21. The Knife River, under flood waters, at the Elbee Bluff site looking downstream. On the left is June 2010, and on the right is July 2011 (Images from Cummings 2011).

Ice Gouging/Ice Jams

River ice is common on the Knife River, usually forming in late December and breaking up by late March (Zabilansky et al. 1999, Ellis 2005). When ice breaks free from the bank and moves downstream, it has the potential to severely gouge out and undercut downstream banks. In addition, ice jams can occur when large amounts of fractured river ice jam on tight meander loops (Ellis 2005). Typically, the magnitude of ice behind the ice jam will build up until the ice jam is pushed through; this process continues downstream until the ice leaves the system or melts (Ellis 2005). The smaller channel size and tight meander bends of the Knife River cause more ice jams to form and break up, often contributing to overbank flow. This process can result in ice settling on the top of the bank; once the ice has melted, the bank becomes saturated, and the extra weight of the ice sheet can cause the bank to exceed its critical value and fail (Ellis 2005). Ice jams generally occur just before meander bends, and can last for 3-38 hours (Ellis 2005).

Ice jams not only encourage bank erosion, but they are also related to flood events. Generally, ice cover acts as an additional restriction to flow, which decreases channel capacity and scours the bottom of the channel, increasing the depth of flow (Ellis 2005). During a 1997 flood, concentration of flow beneath the ice jams resulted in bed scour of over 6 m (19.6 ft) in some areas (Ellis 2005). Overbank floods and extensive bank erosion also occurred as a result of the ice jams (Ellis 2005).

Precipitation
Prolonged periods of high precipitation have caused soil saturation and outer bank failure in KNRI. When banks become saturated after these precipitation events, failure can occur even if there is no direct flow on the bank (Ellis 2005, Cummings 2011). The 30-year (1981-2010) precipitation normals for the KNRI region are reported in Table 32. As the Knife River attempts to reach a dynamic equilibrium, cutbanks will tend to "lay back" in order to achieve this equilibrium (Cummings 2011). However, as precipitation and storm events occur, the runoff water continues to form new cutbanks.

Table 32. Precipitation normals (cm) from 1981-2010 for the KNRI area. Values taken from the Garrison, ND monitoring station (NOAA 2010).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Precipitation	1.24	0.97	1.96	3.18	6.40	8.56	6.68	4.93	3.33	2.84	1.78	1.50	43.36

Several observable features indicate outer bank erosion at the Elbee Bluff study site: vertical eroding banks, tension cracks, vegetated berm at the base of the bank, and recent failure blocks (Ellis 2005). Ellis (2005) noted that past height measurements of the eroding banks in the Elbee Bluff area were 1.8-3.0 m (5.9-9.8 ft) tall, with the main bank material being sand (Ellis 2005). In 2005, Ellis (2005) noticed extensive bank failures and tension cracks, likely due to a prolonged rainfall event in June 2005. Total precipitation in June of 2005 (19.48 cm [7.7 in]) exceeded the 30-year normal for that month by more than 10 cm, and was the second greatest precipitation total for that month in recorded times (Table 32, NCDC 2012). This period of high rainfall resulted in saturated banks, increased pore-water pressures, and a decrease in the overall strength of the river bank material (Ellis 2005). This is a unique phenomenon, because the bank failures and tension cracks were caused by excess rainfall and did not have to do with the Knife River hydrology (flow or undercutting) (Ellis 2005).

Missouri River Backflow
The downstream reach of the Knife River experiences a unique phenomenon near the confluence with the Missouri River, as the Missouri River often backs up into the Knife River and makes it appear as though the Knife River is flowing upstream (Ellis 2005) (Figure 22). This "backflow" is due to the difference in stage between the Missouri and Knife Rivers, which is caused by the Garrison Dam's regulation of the Missouri River. Garrison Dam functions as a hydroelectric dam, and during periods of high consumer demand, the river will experience releases of high flow (Ellis 2005). The Knife River's flow is not regulated, and therefore does not experience these anthropogenic fluctuations in river stage or flow. When these periods of differing flow/stage occur, the Missouri River will back up into the Knife River. As was mentioned previously, the Missouri River experienced severe degradation immediately downstream of the Garrison Dam. As a result of this degradation and base-level lowering of the Missouri River, the Knife River (at its confluence) experiences higher levels of erosion, has a deeper and narrower channel, has a more rapid flow, and has less deposition compared to the river's upstream reaches (Ellis 2005).

Figure 22. An example of the backwater effect at the Elbee Bluff site due to elevated flow release from the Garrison Dam. Figure reproduced from Ellis (2005).

<u>Movement of Knife River</u>

The planform of the Knife River today is sinuous with a meandering channel between high banks (Ellis 2005). The channel of the Knife River is largely shaped by the magnitude and frequency of the floods the river experiences, and the tendency of the floods to erode, deposit, and transport sediment through the river (Cummings 2011). Meander migration has occurred in much of the Knife River due to upstream outer bank erosion and changes in morphology (Ellis 2005). As sediment is eroded from the outer bank of a bend, it is carried downstream by the river and deposited on the next point bar the flow encounters (Hey and Thorne 1975, Ellis 2005). The result of this erosion and deposition is a change in the position and geometry of the eroded bend as the river moves toward dynamic equilibrium (Ferguson 1977, Ellis 2005). These changes are largely natural, and most of the Knife River is natural and free flowing. Garrison Dam indirectly affects only the lower reaches of the Knife River (where KNRI is situated). Figure 23 illustrates the change in the Knife River's channel position at the Ellis (2005) Elbee Bluff study site between 1995 and 2004.

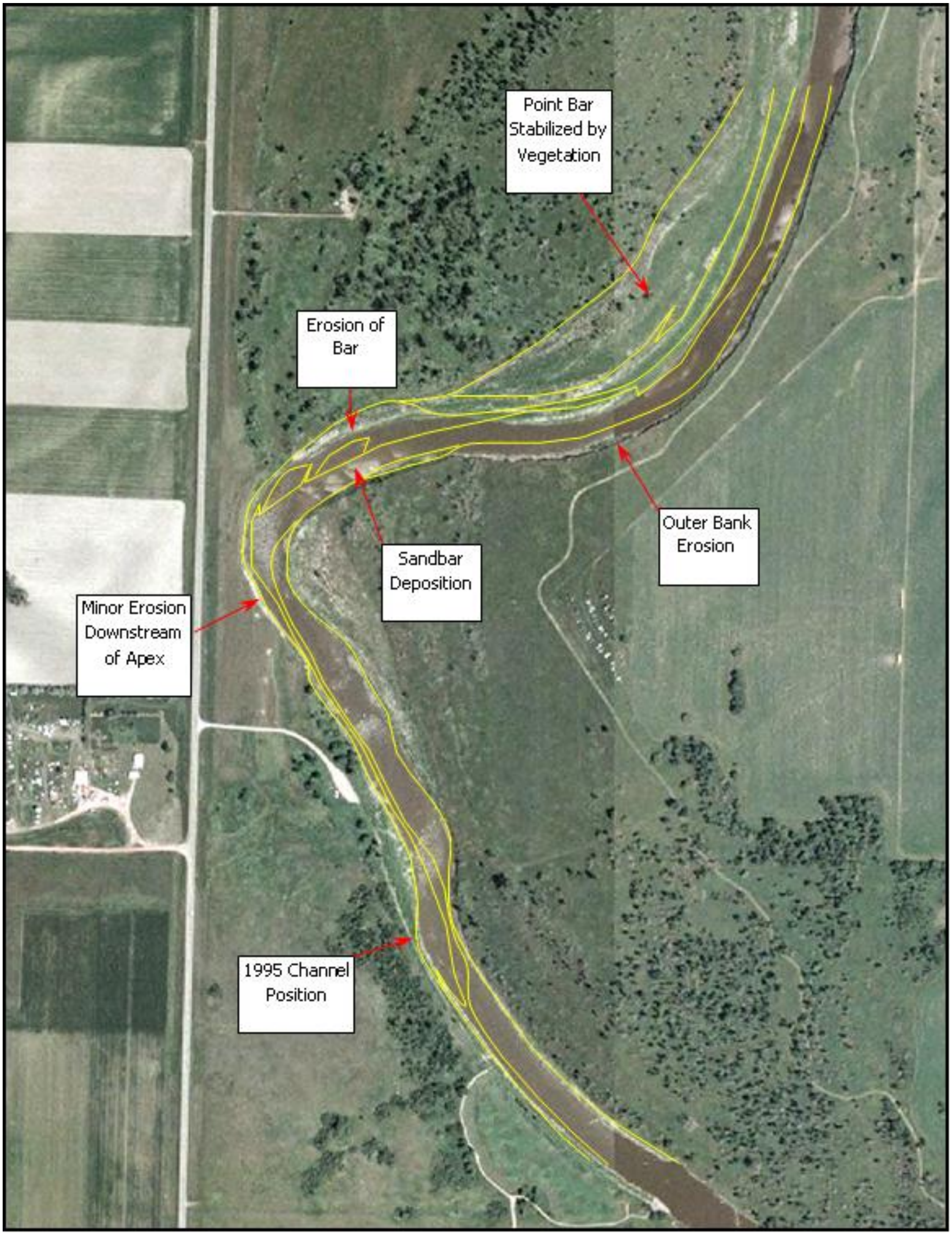


Figure 23. Knife River channel change at the Elbee Bluff study site from 1995 to 2004. The yellow line represents the Knife River's channel position in 1995. Figure reproduced from Ellis (2005).

The movement of the Knife River near the confluence of the Missouri River has changed since the construction of the Garrison Dam (Ellis 2005). The Knife River has a high sediment load; when the sediment reaches the Missouri River, the transport capacity of the Missouri River is too low and the sediment is deposited (Ellis 2005). This deposition has resulted in the formation of a semi-permanent island at the confluence, thus largely separating the Knife and Missouri Rivers (Ellis 2005). The two rivers are now connected only by a narrow anabranch that flows around the semi-permanent island (Ellis 2005).

Movement of the Knife River and River Bank Monitoring (Sexton 2012)
In 2011, Chad Sexton, THRO GIS Analyst, created a highly accurate, repeatable mapping methodology to determine the extent of the contemporary cut bank edges on the Knife River (Sexton 2012). Control points were installed at 10 locations in the park that were suitable for current and future monitoring efforts. Sexton (2012) also utilized aerial photography in bank delineation and movement analyses for the river. Photography from 1965-2010 was used to analyze the amount of river movement. Sexton (2012) outlines the full methodology of the project.

Sexton (2012) completed bank movement measurements and analyses on five priority river bends on the Knife River in KNRI: Taylor Bend, Unnamed Bend, Noname Bend, Elbee Bend, and Loop Bend (Plate 10). A sixth bend (Peninsula Bend) was scheduled to be monitored, but high floodwaters in 2011 prevented sampling at this site. Bank movement and erosional rates are not constant and are 3-dimensional; because of this, specific measurement procedures are needed to accurately monitor this attribute. Sexton (2012) utilized several tools and analyses, including a weighted linear regression model. Complete methodology can be found in Sexton (2012, p. 14).

Taylor Bend is located near the Taylor Bluff archaeological site at the northern most reach of the Knife River in the park. This is a high priority site due to its close proximity to the Taylor Bluff archaeological site, its history of major erosional events (most recently during a 2009 flood), and its close proximity to Mercer County Road 16, which lies adjacent to the bend (Plate 11). Bank stabilization has been attempted at this site using both recontouring and rip-rap (Sexton 2012). Since 1965, the mean distance of bank movement at Taylor Bend is 14.7 m (48.3 ft); the mean rate of movement at the site was 0.3 m/yr (0.9 ft/yr) (Sexton 2012) (Table 33).

Table 33. Total bank movement and rate of bank movement of five priority bends along the Knife River in KNRI. Data summarized from Sexton (2012).

Bend Name		Bank Movement (ft)	Bank Movement (m)	Rate of Movement (ft/year)	Rate of Movement (m/year)
Taylor Bend	Maximum	78.8	24.0	2.0	0.6
	Minimum	13.9	4.2	0.3	0.1
	Mean	48.3	14.7	0.9	0.3
Unnamed Bend	Maximum	328.1	100.0	6.5	2.0
	Minimum	40.0	12.2	0.8	0.2
	Mean	236.4	72.1	3.9	1.2
Noname Bend	Maximum	410.7	125.2	7.4	2.3
	Minimum	64.2	19.6	1.4	0.4
	Mean	253.1	77.1	4.9	1.5
Elbee Bend	Maximum	179.5	54.7	3.1	0.9
	Minimum	69.8	21.3	1.1	0.3
	Mean	137.8	42.0	2.2	0.7
Loop Bend	Maximum	293.1	89.3	7.4	2.3
	Minimum	56.7	17.3	1.0	0.3
	Mean	186.4	56.8	4.2	1.3

Unnamed Bend is located just downstream of Taylor Bend (Plate 10). From 1965-2010, Unnamed Bend had a mean distance of bank movement of 72.1 m (236.4 ft), and a mean rate of movement of 1.2 m/yr (3.9 ft/yr) (Sexton 2012) (Table 33). The relative channel position at Taylor Bend in 1965 compared to 2011 is displayed in Plate 12.

Noname Bend poses a concern for KNRI managers, as it is moving eastward towards the park's administrative boundary. With this movement also comes the potential that KNRI would lose access to the "peninsula" portion of the park (Sexton 2012). Sexton (2012) found that the mean distance of bank movement at Noname Bend from 1965-2010 was 77.1 m (253.1 ft), and that the mean rate of bank movement was 1.5 m/yr (4.9 ft/yr) (Table 33, Plate 13, Plate 14).

As has been mentioned previously, Elbee Bend is in close proximity to the Elbee Bluff archaeological site (Figure 20) and has a high risk of losing cultural artifacts due to cut bank erosion (Ellis 2005, Sexton 2012). From 1965-2010, Elbee Bluff experienced a mean distance of bank movement of 42.0 m (137.8 ft), and a mean rate of bank movement of 0.7 m/yr (2.2 ft/yr) (Table 33, Plate 15) (Sexton 2012).

The last bend studied in Sexton (2012) was Loop Bend, which is located downstream of Elbee Bend and the Sakakawea Village archaeological site (Plate 10). Recently, erosion in the vicinity of this site has required park staff to reroute the nearby Two Rivers hiking trail (Sexton 2012). Sexton (2012) found that the mean distance of bank movement from 1965-2010 at this site was 56.8 m (186.4 ft), and that the mean rate of bank movement was 1.3 m/yr (4.2 ft/yr) (Table 33, Plate 16)

Threats and Stressor Factors

The primary effect of flow regulation from the Garrison Dam is changes in the hydrologic regime, causing the flood peaks to become non-synchronous between the Knife and Missouri Rivers (Ellis 2005). The severe reduction in magnitude, frequency, and timing of large floods in the Missouri River is causing backing up of floodwaters into the Knife River (Ellis 2005). These backups could affect upstream morphology of the Knife River (Ellis 2005). However, the Knife River is largely in a natural state, so only the lower reaches are likely to experience habitat and morphological alterations due to the Garrison Dam (Ellis 2005).

An increase in the frequency of high precipitation events could correlate to an increase in bank erosion along the Knife River. While erosion and deposition of sediment are natural processes along the river, an increase in precipitation or groundwater seepage could accelerate the process. Ice jams, while natural, result in bank gouging and an acceleration of bank erosion rates. An increase in the frequency of major ice jams and floods could result in a dynamic shift in the erosion rates of the river and could accelerate the natural meander process of the river. Furthermore, the size and duration of these ice jams has increased the erosion rates near several archeological sites; examples of severe ice jams are seen in Photo 17, Photo 18, and Photo 19.

Photo 17. Ice jam on the Knife River. Photo taken by John Moeykens, NPS.

Photo 18. Ice jam along a bend of the Knife River. Photo taken by John Moeykens, NPS.

Photo 19. Ice jam along a bend of the Knife River; evidence of ice build up along the shoreline is clearly visible. Photo taken by John Moeykens, NPS.

Data Needs/Gaps

The park would benefit from the development of a management plan for the Knife River and a better understanding of how the river interacts with the park's cultural and archaeological resources. The completion of an EIS for Knife River bank erosion would direct NPS managers with what needs to be done on the river. Also, the completion of a River Management Plan for the Knife River could lay out a framework for making river-related decisions (Cummings 2011). This plan could also help NPS managers plan the best ways to manage and protect the high-risk archaeological sites near the Knife River. Monitoring should continue along the bluffs and river banks of the Knife River, prioritizing areas near archaeological sites.

In 2011, the Missouri River experienced a prolonged, record-breaking flood. During this flood, output from Garrison Dam was the highest ever recorded. Analysis of this flood and its impact on geomorphology and erosion in KNRI will be very important for park managers.

Overall Condition

River Bank/Bluff Erosion

The project team defined the *Significance Level* for river bank/bluff erosion as a 3. Erosion is largely a natural river process; however, there are several factors that have elevated the rate of erosion in KNRI. The base-level lowering of the Knife River in its lower reaches has resulted in a deeper channel with more flow, and the lower reach of the Knife River has experienced more rapid erosion as a result. Several bends along the Knife River are also experiencing rapid rates of bank erosion (most notably the Elbee Bluff site); nearby archaeological sites are in danger of being eroded away.

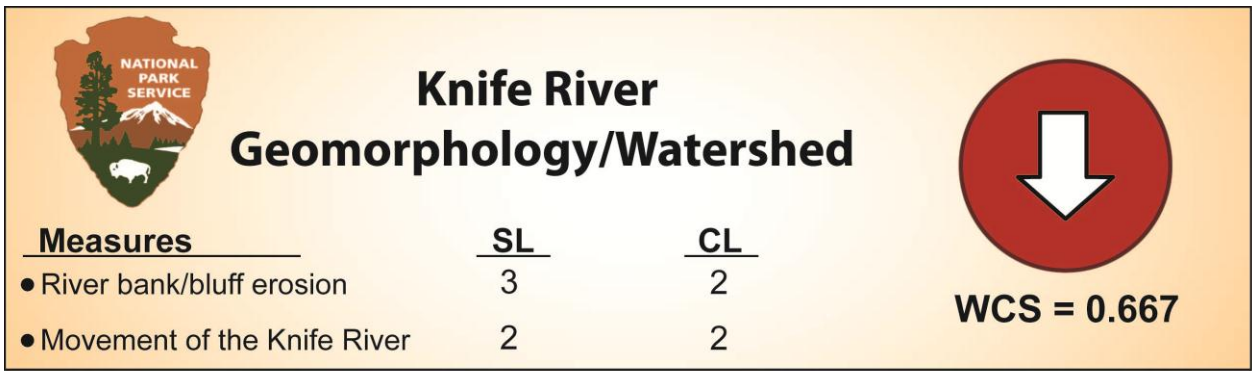
Ellis (2005) identified elevated precipitation levels as a potential cause of tension cracks and bank failures in KNRI. Furthermore, recent floods have accelerated the erosion process in the river, and ice jams frequently gouge the narrow bends of the Knife River. While pre-dam erosion rates are unknown, erosion is a significant issue facing KNRI managers. Because of the erosion rates the park has experienced in recent years, and because of the threat of losing cultural artifacts due to erosion, the *Condition Level* for this measure is a 2.

Movement of the Knife River

The project team defined the *Significance Level* for movement of the Knife River as a 2. The Garrison Dam has had significant implications on the movement of the Missouri River, with effects on the Knife River occurring only on the lower reaches; when the water levels of the Missouri River are too low, the sediment from the Knife River is deposited at the confluence, resulting in a semi-permanent island between the two rivers. However, anthropogenic changes in the hydrologic regime of the Knife River are concentrated near the confluence, leaving most of the river in a natural state. River meander is a natural process, and while recent erosion and outer bank erosion have slightly accelerated the Knife River's movement, the pattern of movement is not unusual for a meandering river such as the Knife River. Sexton (2012) displayed the movement of the Knife River's outer cut banks from 1965-2011 (Plate 11-Plate 16). However, it is unknown whether the bank movements are occurring at a natural pace, or if the erosion rates have accelerated since the installation of the Garrison Dam. The major concern for this measure is that the movement of the river in some locations of the park could result in the washing away of cultural artifacts, and that the river could meander outside of park boundaries (especially near

Noname Bend). Subsequently, the project team defined the *Condition Level* for movement of the Knife River as a 2.

Weighted Condition Score
The *Weighted Condition Score* for the Knife River geomorphology and watershed component is 0.667 (significant concern). While the Garrison Dam's construction on the Missouri River has played a role in the Knife River's evolution, the major factor affecting the river in KNRI is the current levels of bank erosion. Erosion is a largely natural process, but in KNRI it is of particular concern because of the threat it poses to the cultural artifacts in the park; several of the cultural sites in KNRI are in danger of being eroded/washed away by the river. Due to the recent erosion rates, and due to the increasing threat of losing cultural sites, the trend graphic for this component is a decreasing trend.



4.10.6 Sources of Expertise
John Moeykens, KNRI Chief of Law Enforcement and Resource Management

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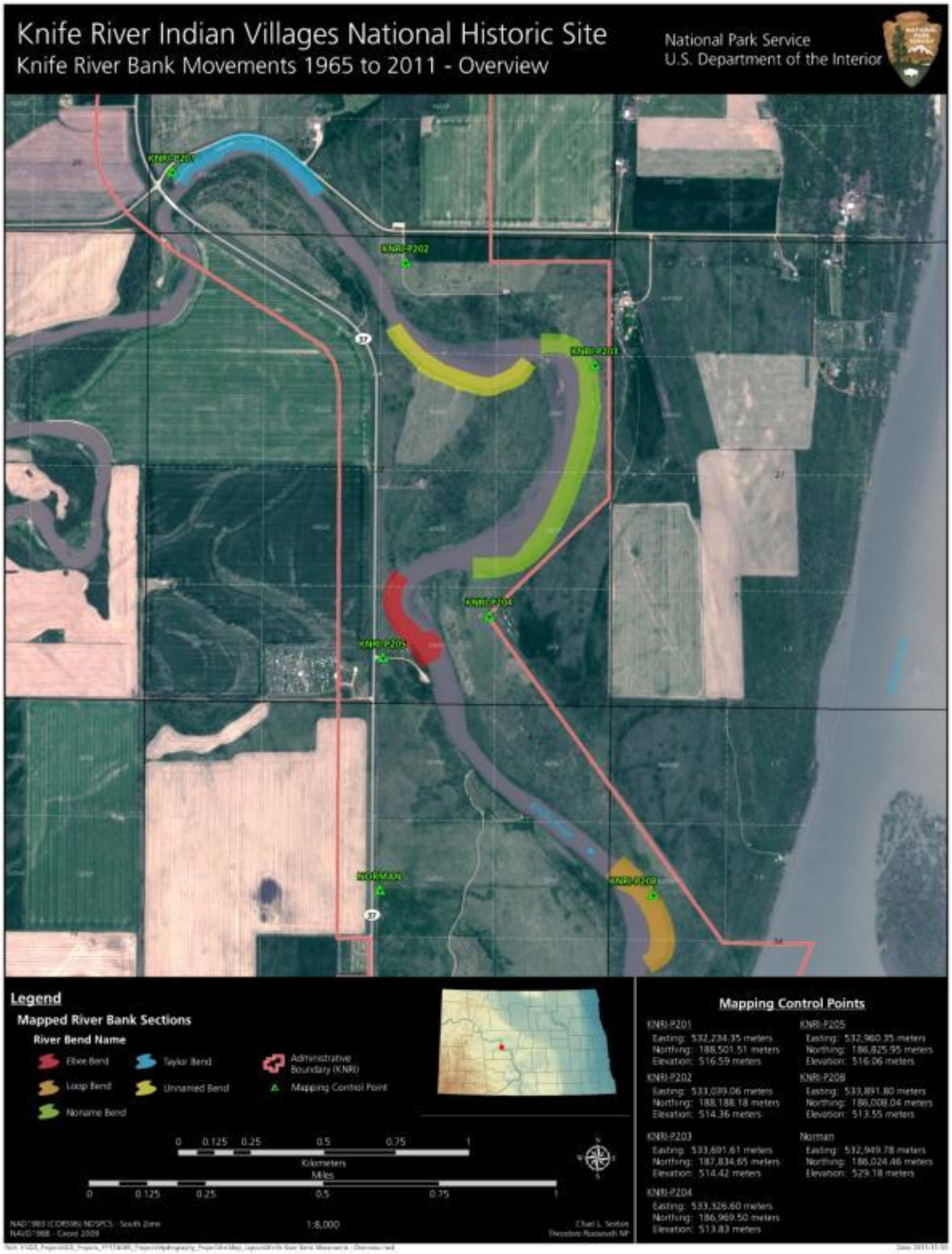


Plate 10. Knife River bend locations analyzed in Sexton (2012). Plate produced by Chad Sexton, THRO GIS Analyst.

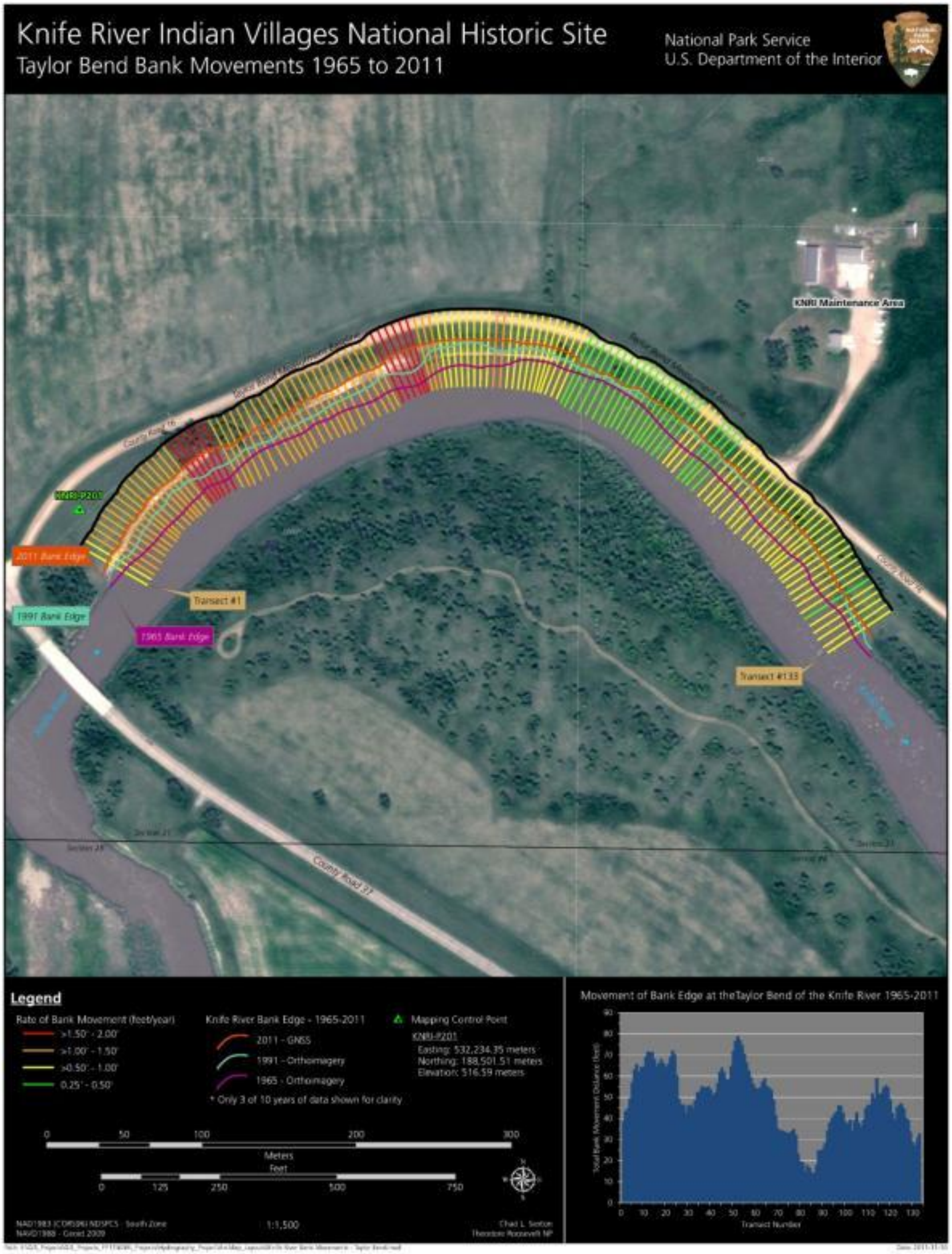


Plate 11. Taylor Bend bank movement from 1965-2011. Plate created by Chad Sexton, THRO GIS Analyst.

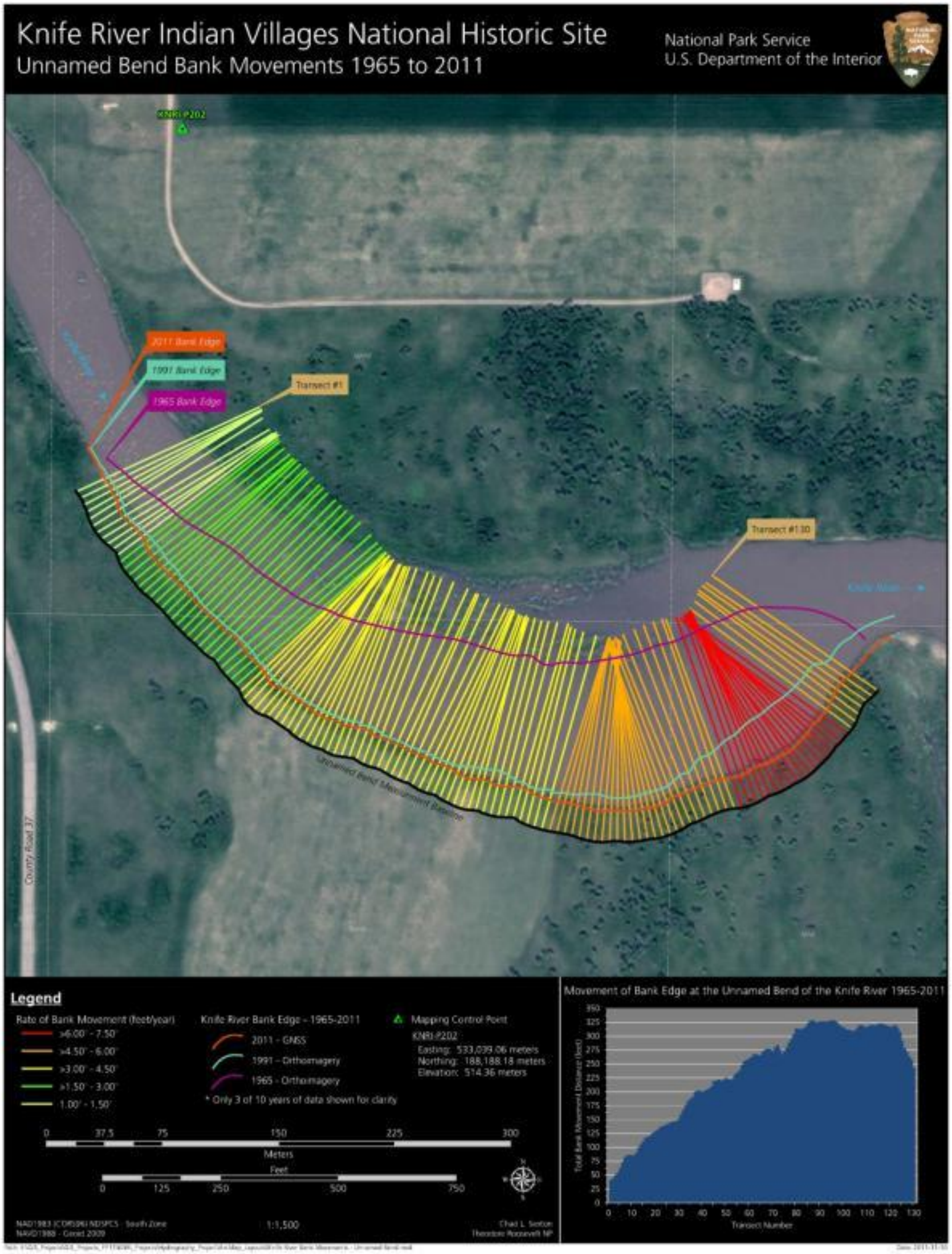


Plate 12. Unnamed Bend bank movements from 1965-2011. Plate created by Chad Sexton, THRO GIS Analyst.

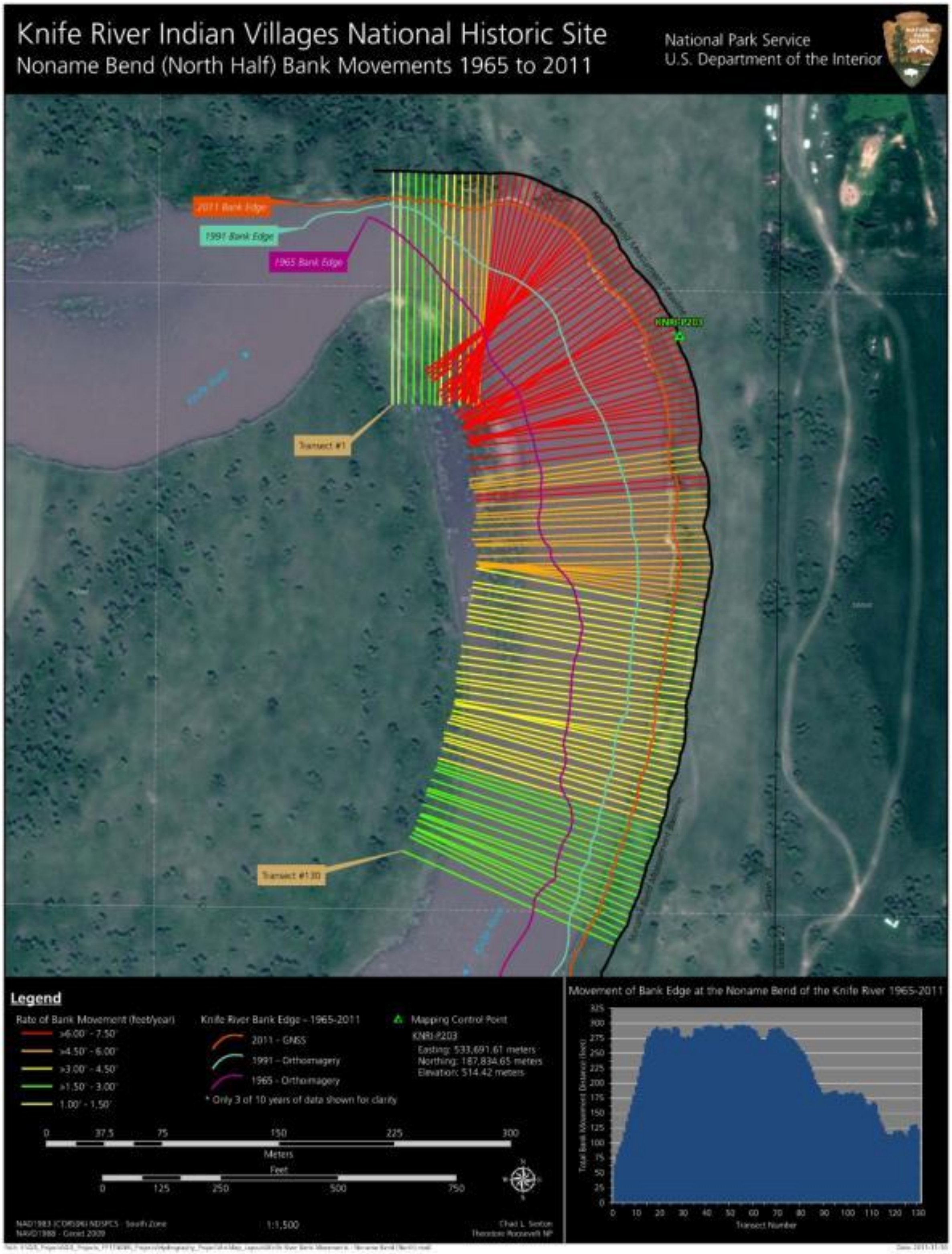


Plate 13. Noname Bend (north half) bank movements from 1965-2011. Plate created by Chad Sexton, THRO GIS Analyst.

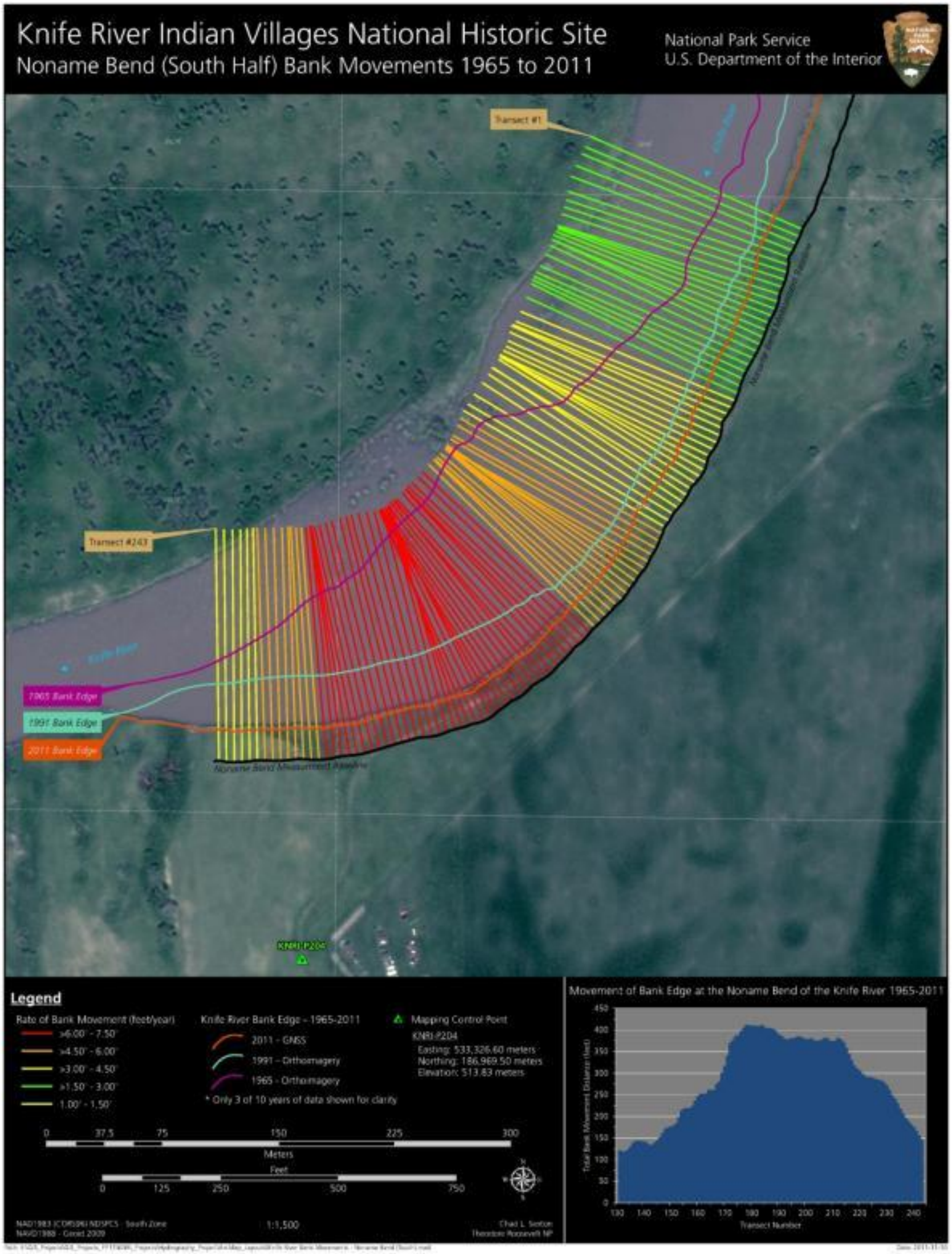


Plate 14. Noname Bend (south half) bank movements from 1965-2011. Plate created by Chad Sexton, THRO GIS Analyst.

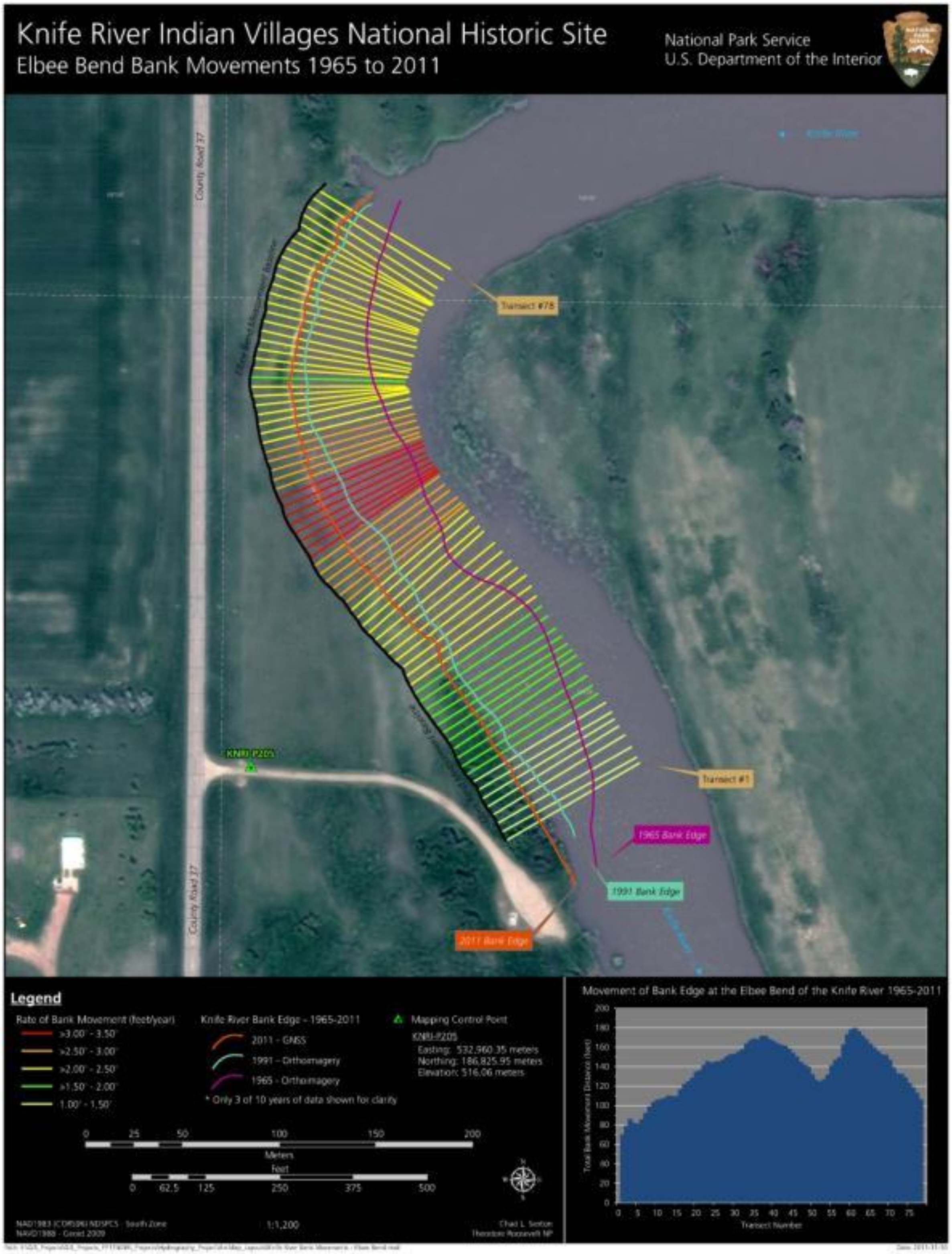


Plate 15. Elbee Bend bank movements from 1965-2011. Plate created by Chad Sexton, THRO GIS Analyst.

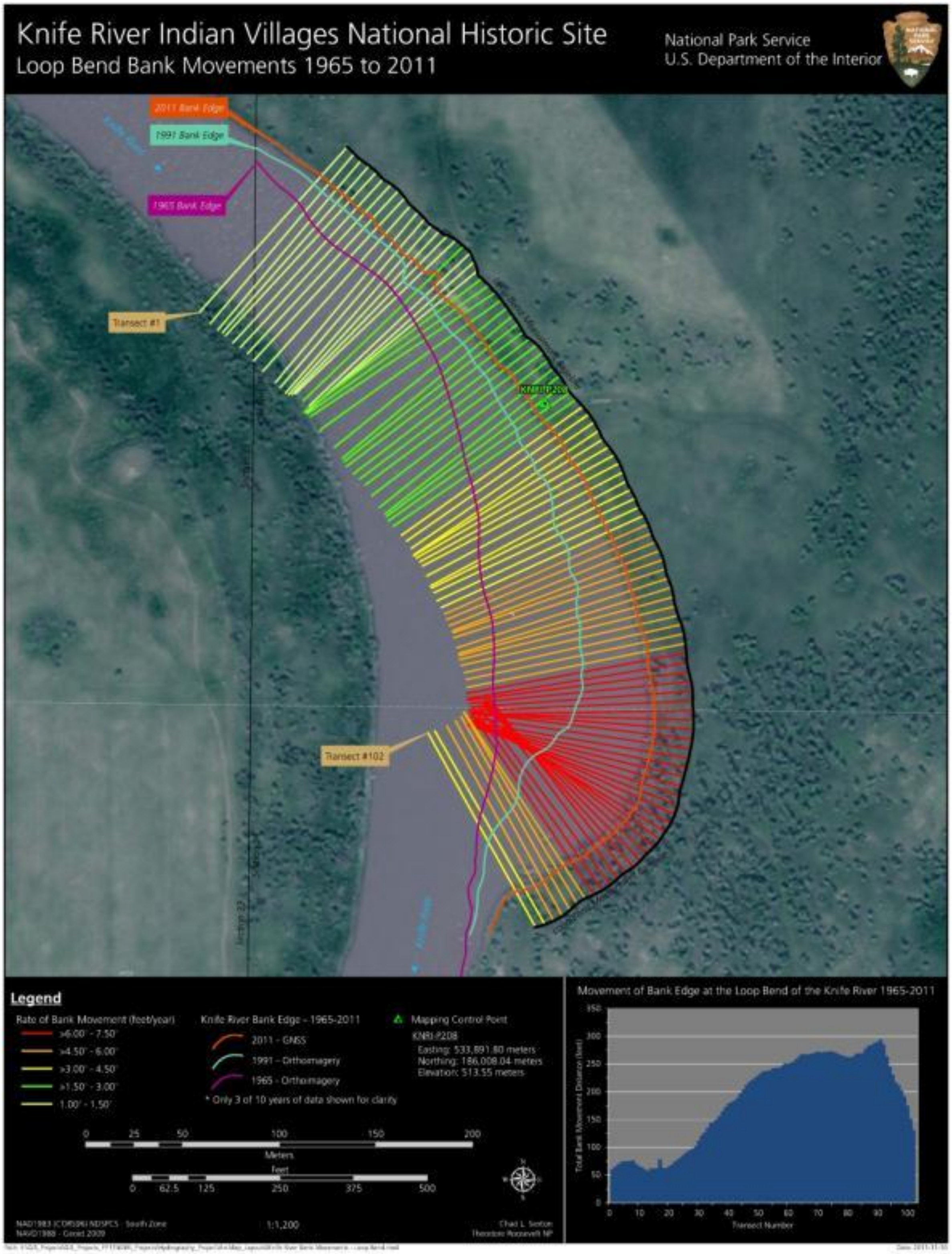


Plate 16. Loop Bend bank movements from 1965-2011. Plate created by Chad Sexton, THRO GIS Analyst.

Chapter 5 Discussion

Chapter 5 provides an opportunity to summarize the assessment findings and discuss the overarching themes and common threads that have emerged for the featured components. Specifically, the data gaps and needs identified for each component are summarized and the role these play in the designation of current condition is discussed. Also discussed is how condition analysis relates to the overall natural resource management issues of the park.

5.1 Component Data Gaps

The identification of key data and information gaps is an important objective of NRCAs. Data gaps or needs are those pieces of information that are currently unavailable, but are needed to help inform the status or overall condition of a key resource component in the park. Data gaps and needs exist for most key resource components assessed in this NRCA. Table 34 provides a detailed list of the key data gaps by component. Each data gap and need is discussed in detail in the individual component assessments in Chapter 4.

Table 34. Identified data gaps or needs for the featured components in KNRI.

Component	Data Gaps/Needs
Landcover	➢ Historic remotely sensed images could be used to map historic land cover conditions and changes between photo dates ➢ An update of the Salas and Pucherelli (2003) vegetation map
Riparian forest community	➢ An investigative study regarding the age class structure of the riparian forests in KNRI ➢ Current and sustained monitoring of the riparian forest community
Terrace prairie communities	➢ Few studies or surveys have quantified the cover or density of exotic species. This information would be valuable to managers ➢ Continuation of the NGPN plant community monitoring data regarding the percent cover of exotics in KNRI is needed so that trends in exotic species can be followed and the effectiveness of management efforts can be evaluated ➢ Research regarding how KNRI's prairies interact with other components of the ecosystem (both biotic and abiotic)
Raptors	➢ Annual monitoring of the raptor population in KNRI ➢ An investigation into the availability of perching and nesting trees in the park would be beneficial.
Land Birds	➢ Long term trend data is needed for land birds in KNRI. At minimum, this could be done by creating an annual survey such as a BBS or CBC in or near the park. ➢ Continuation of the Panjabi (2005) mixed-grass prairie bird transect; park staff have indicated future plans to carry this out
Air quality	➢ No monitoring of air quality exists in KNRI, and the establishment of an air quality monitoring program is needed. Alternatively, certain tree and plant species could be used as indicator species and could aid in monitoring air pollution impacts
Water quality	➢ More recent data for water quality in KNRI, as the most recent data for the park come from 2004-2005 ➢ Long term monitoring of temperature, DO, turbidity, pH, and fecal coliform are needed to detect any possible trends in water quality in KNRI
Soundscape	➢ Baseline data are needed to determine the natural ambient sound level in KNRI. Baseline levels could also be established for current threats such as traffic and oil/gas developments
Dark night skies	➢ No data regarding dark night skies exists in KNRI, and an evaluation of current dark night sky condition is needed. This would most likely be an evaluation that would be coordinated with the NPS's Dark Night Sky Team
Knife River geomorphology/watershed	➢ The park would greatly benefit from the development of a management plan for the Knife River. Furthermore, the completion of an EIS for the Knife River's bank erosion would aid in directing park managers ➢ An analysis of the impacts of the prolonged flood events in 2009 and 2011 will be very important to park managers as they manage the continued erosion along both the Knife and Missouri Rivers

Land cover is a component of unique importance in KNRI. In order to visualize some of the land cover changes over the past centuries, historic, remotely sensed imagery should be used to map the historic land cover of the area. Also, an update to the vegetation map of KNRI is needed. The last update was provided in Salas and Pucherelli (2003), and several management activities have likely changed the vegetative communities of the park (i.e., the removal of stands of non-native species by the EPMT).

For all KNRI vegetation communities, carrying out updated surveys of species composition, capturing the extent/distribution of the communities, and assessing the prevalence of non-native species presence in these communities would help to fill data gaps and provide a more complete understanding of the current condition of each community. The riparian forest community is also in need of an age class analysis; the absence of a consistent flood regime in the park has limited regeneration and many trees in the park may be approaching senescence. The many terraces of the park result in very unique prairie species composition on each level of the terraces. A better understanding of how these terrace prairie communities interact with both the abiotic and biotic communities of the park is needed. Filling in data gaps for each of these vegetation communities would better help managers determine an accurate current condition of these communities, as well as provide insight into how the health and diversity of these vegetative systems affect the organisms that depend on them for habitat.

Two of the biotic communities dependent upon the plant communities of KNRI are land birds and raptors. Both of these components lack annual monitoring, although Panjabi (2005) indicated that the bird density in the park was among the highest in the northern Great Plains. Annual monitoring of these communities is needed in order to identify long-term trends in abundance. In addition, an investigation into the connectivity between bird species and their plant community habitats would likely benefit managers.

The chemical and physical components in KNRI, including water quality and air quality, represent significant data gaps for KNRI. No monitoring of air quality exists in KNRI; creation of an air quality monitoring station or program is needed, especially with the increase in oil and gas development in the area. The water quality data for KNRI is limited, despite the fact that KNRI has two major waterways (the Knife and Missouri Rivers). Data that do exist are out of date and long-term monitoring of temperature, DO, turbidity, pH, and fecal coliform is needed.

Soundscape and dark night skies are components commonly thought of as "goods and services" for visitors; however, quantitative data related to these in KNRI are very limited. National programs and sampling standard have been developed by NPS in order to monitor soundscape and dark night skies conditions in all parks. Currently, baseline data do not exist for dark night skies conditions, and no monitoring of the natural ambient sound level has been conducted. Implementing the NPS protocol for these resources would provide a better understanding of the components' conditions.

The geomorphology and watershed of the Knife River is a component that is of high concern for park managers. The park needs more information regarding the current condition and trend of this component, and is in particular need of a management plan for the Knife River. This, along with the completion of an EIS for the Knife River's bank erosion would greatly aid park staff in managing this complicated park attribute. The recent flood events (2009, 2011) on both the Knife and Missouri Rivers likely accelerated the erosion rates along the bank lines and altered the geomorphology of the area, and further analysis of these events is needed.

5.2 Component Condition Designations

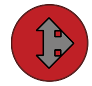
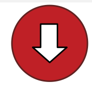
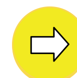
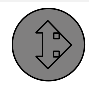
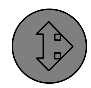
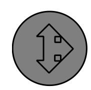
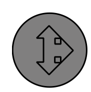
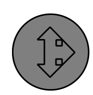
Table 35 displays the conditions assigned to each resource component presented in Chapter 4 (definitions of condition graphics are located in Figure 24 following Table 35). It is important to remember that the graphics are simple symbols for the overall condition and trend assigned to each component. Because the assigned condition of a component (as represented by the symbols used in Table 35) is based on a number of factors and an assessment of multiple literature and data sources, it is strongly recommended that the reader refer back to each specific component assessment in Chapter 4 for a detailed explanation and justification of the assigned condition. Condition designations for some components are supported by existing or long-term datasets and monitoring information and expertise by NPS and other non-NPS scientists, while other components lack historic data, a clear understanding of reference conditions (i.e., what is considered desirable or natural), or even current information.

Data are unavailable or insufficient for many of the measures of the featured components and, thus, it is not possible to define current condition. In other instances, reference condition data were limited or unavailable for components, making comparisons inappropriate or invalid. Current condition was not able to be determined for five of the 10 components (50%) due to these significant data gaps.

For featured components with available data and fewer data gaps, assigned conditions varied. For some components, enough data exist to determine a trend in condition over time; however, for others the lack of available data prevented the determination of trends. Two components were determined to be of moderate concern to park managers: air quality and terrace prairie communities. The current trend for air quality was determined to be stable, meaning that the condition is not believed to be degrading or improving compared to past conditions. The current trend for terrace prairie communities was stable, indicating that current conditions have not improved or degraded compared to conditions in the past.

Three components (landcover, riparian forest community and Knife River geomorphology/watershed) were determined to be of significant concern. These components have been significantly affected by the Garrison Dam’s regulation of the Missouri River, and because of this, the current trend was identified as declining when compared to historic reference conditions (landcover was not assessed a current trend). A discussion of all of these designations is presented in the following section.

Table 35. Summary of current condition and condition trend for featured NRCA components.

Component		WCS	Condition
Ecosystem Extent and Function			
Landcover			
	Landcover	N/A	
Biological Composition			
Ecological communities			
	Riparian Forest Community	0.800	
	Terrace Prairie Communities	0.600	
Birds			
	Raptors	N/A	
	Land Birds	N/A	
Environmental Quality			
	Air quality	0.444	
	Water quality	N/A	
	Soundscape	N/A	
	Dark Night Skies	N/A	
Physical Characteristics			
Geologic & Hydrologic			
	Knife River Geomorphology/Watershed	0.667	

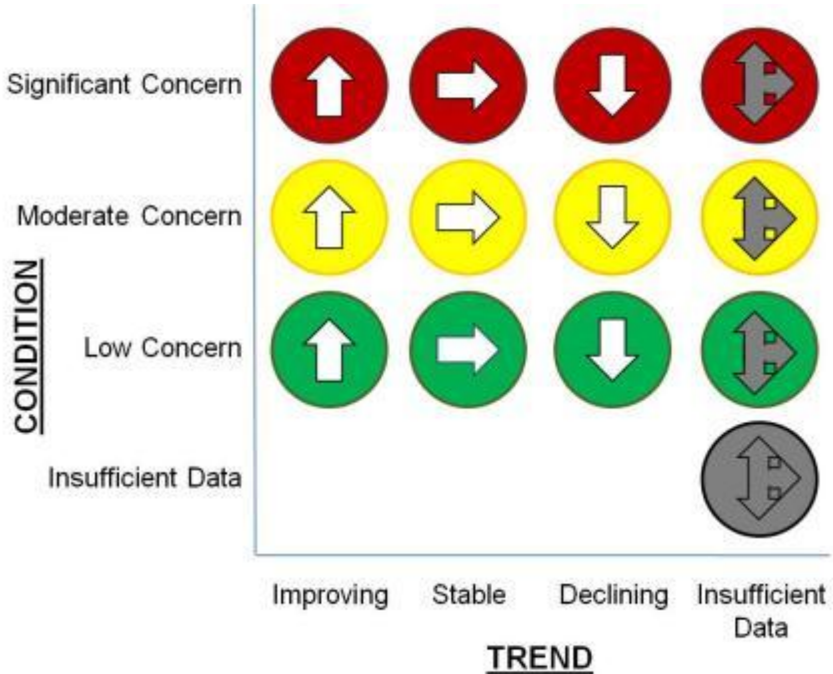


Figure 24. Symbols used for individual component assessments with condition or concern designations along the vertical axis and trend designations along the horizontal.

5.3 Park-wide Condition Observations

KNRI is home to dynamic, diverse, and complex ecosystems that have been influenced by anthropogenic factors, the most significant of these factors likely being the regulation of the Missouri River by the Garrison Dam. This dam has altered the hydrologic regime of the area, and consequently has changed the composition and succession patterns of both the plant and animal communities of the park. As a result, a number of the components featured in this NRCA are interrelated, with the condition of many being dependent on the condition and healthy functioning of others. In particular, the geomorphology/watershed, land cover, and riparian forest communities in KNRI are all closely tied to the historic fluctuations in the Missouri and Knife Rivers.

5.3.1 Ecological Communities

Data gaps exist for both of the identified plant communities in the NRCA. The alteration of the Missouri River's flood regime greatly affected the riparian forest community, as cottonwood regeneration in the remaining stands in the park is largely non-existent. The age class of the trees that remain in the riparian forests is unknown, and mature trees are likely approaching senescence. Further degrading the condition of these communities is the presence of non-native species (notably smooth brome). These non-natives are dominating the understory of the riparian forests and are out-competing many native species in the area. In the terrace prairie communities, few studies have quantified the cover or density of non-native species, although the EPMT has been actively removing these species from the area in an effort to maintain natural diversity. Without continued monitoring in these ecological communities, it will become difficult to assess the current condition and trend. Establishing monitoring in these areas will be important, as several other biotic species (most notably the bird communities) are dependent upon these vital areas.

5.3.2 Bird Community

The bird community in KNRI has only had one major survey, and the results of this survey are now almost 10 years old. Because of the lack of long term and contemporary data, both the land bird and raptor components were not assigned a current condition or a trend. While no condition or trend were assigned in this NRCA, past work by Panjabi (2005) indicated that KNRI had one of the highest densities of land birds in the northern Great Plains. The establishment of a monitoring program is needed to further validate this conclusion.

The bird communities are likely very closely tied to the prairie and forest communities of the park; Panjabi (2005) indicated that the habitat found in the forests (particularly the understory) was excellent breeding bird habitat. These forests also provide foraging habitat, and nesting/perching trees. The prairie communities are also likely to support a unique collection of breeding bird species, and provide a foraging area for the raptor populations of the park.

5.3.3 Environmental Quality

Environmental quality is important in maintaining healthy, functioning ecosystems. The health of terrestrial and aquatic organisms in parks can be substantially affected by the condition of air and water quality. There are no air quality monitoring stations located in KNRI, and data are interpolated and estimated from data recorded at regional monitors. Current data suggest that air quality in KNRI is of moderate concern with a stable trend. One of the measures of particular concern for air quality in the park is the atmospheric deposition of nitrogen. This measure was assigned a condition level of 3, and is of high importance when factoring in the sensitivity of the native grasslands in the park.

Water quality was not assigned a current condition or trend due to a lack of available data. Only a few sporadic, short-term sampling studies have been conducted throughout the years, with the most recent survey occurring from 2004-2005; consistent monitoring of basic water quality parameters is not performed within park boundaries. To understand the state of water quality in the park, managers must rely on monitoring stations established and maintained by other agencies, and most of the water quality data that exists comes from the Missouri River. Park managers are particularly concerned about the water quality of the Knife River, as a reach of the waterway has previously been classified as impaired due to pathogens (primarily fecal coliform).

5.3.4 Geomorphology/Hydrology

The geomorphology and hydrology of the Knife River represents a dynamic resource that is closely linked to many aspects of the KNRI ecosystems. The installation of the Garrison Dam resulted in changes to the flood regime for both the Knife and Missouri Rivers, and greatly affected the health of several components in KNRI (particularly the riparian forest community). The floods of 2009 and 2011 have had significant impacts on the geomorphology and hydrology of both rivers, and many of these effects are currently unknown. One of the major changes that resulted from these floods was that the Missouri River byway filled in with sand and silt and caused the Knife River to run longer (0.8 km [0.5 mi]) to reach the Missouri River. Another threat facing this component is accelerated erosion rates, particularly along the priority bends in the Knife River (as identified in Sexton 2012). Erosion affects not only the morphology of the river, but it is also affecting several archaeological sites that are situated near the Knife River.

Currently, the condition of the Knife River's geomorphology/hydrology is of significant concern and has a declining trend. Continued monitoring and management of the archaeological sites is needed, as is an EIS for the Knife River's erosion patterns and a Knife River management plan. These documents, combined with active management and monitoring, may help to stabilize the condition of this component.

5.3.5 Park-wide Threats and Stressors

Several park-wide threats and stressors exist that will continue to influence the condition of resources in KNRI. Those of primary concern include establishment of non-native species, elevated erosion rates along the Knife River (particularly when in close proximity to archaeological sites), increased oil and gas industry development, and air pollution (especially increased emissions from nearby oil, gas, and power plant development).

The presence of exotic species, especially plants, poses a significant threat for the native vegetation communities in KNRI. Exotic plants such as Kentucky bluegrass and smooth brome have become the dominant species in many prairie and riparian habitats. Major changes in vegetation communities, from native to more exotic species, could have a significant impact on the animal species that use these communities for habitat. The bird community of KNRI would likely be greatly affected by such a change. A more complete understanding of the prevalence of exotic species in the different vegetation communities throughout the park would help managers strategize about potential management actions.

Land development around KNRI is mainly associated with the growth and expansion of the oil and gas industry. This development has increased in western North Dakota and around KNRI over the last decade. Such development affects different aspects of park resources including impacts on the park's dark night skies with increased lighting around newly established developments, impacts to soundscapes with increased industrial activity and vehicle traffic at development sites, and greater stresses to air quality from increased vehicle and industrial emissions.

5.3.6 Overall Conclusions

This assessment serves as a review and summary of available data and literature for featured components in the park. The information presented here may serve as a baseline against which any changes in condition of components in coming years may be compared. Establishing a number of monitoring programs would begin to fill in data gaps for the resources viewed as important by KNRI managers and would help managers better understand the current state of these resources throughout the park. Of those components that had sufficient available information, current condition was determined to be of either moderate or high concern; trends indicated either stable or decreasing levels of condition. Understanding the condition of these resources can help managers prioritize management objectives and better focus conservation strategies to maintain the health and integrity of these ecosystems.

Appendix A: Exotic plant species documented in KNRI

Appendix A. Exotic plant species documented in KNRI through May 2011. Several additional species are classified as "unconfirmed" or "encroaching" and are therefore not listed here. The full list can be found at http://science.nature.nps.gov/im/units/ngpn/monitor/exoticplant/docs/KNRI_Park_Exotics.pdf. Approximately 90% of these species were already present at KNRI during Clambey's (1985) 1984 field survey.

Scientific Name	Common Name	Life cycle[1]	Growth form[2]	High priority?
Agropyron cristatum	crested wheatgrass	P	G	x
Arctium minus	common burdock	B	F	
Artemisia absinthium	absinth wormwood	P	F-SS	x
Asparagus officinalis	garden asparagus	P	F	
Avena fatua	wild oat	A	G	
Bromus inermis	smooth brome	P	G	x
Bromus arvensis	field brome	A	G	
Bromus tectorum	cheatgrass	A	G	
Camelina microcarpa	littlepod false flax	A-B	F	
Chenopodium album	lambsquarters	A	F	
Cirsium arvense	Canada thistle	P	F	x
Convolvulus arvensis	field bindweed	P	F-V	
Descurainia sophia	flixweed	A-B	F	
Echinochloa crus-galli	barnyard grass	A	G	
Elaeagnus angustifolia	Russian olive	P	S-T	x
Elymus caninus	bearded wheatgrass	P	G	
Erysimum cheiranthoides	wormseed wallflower	A-B	F	
Euphorbia agraria	urban spurge	P	F	
Euphorbia esula	leafy spurge	P	F	x
Hesperis matronalis	dames rocket	B-P	F	
Kochia scoparia	kochia	A	F	
Lactuca serriola	prickly lettuce	A-B	F	
Leonurus cardiaca	common motherwort	P	F	
Lonicera tatarica	Tatarian honeysuckle	P	S	
Malva rotundifolia	low mallow	A-B	F	
Medicago lupulina	black medick	A-P	F	
Medicago sativa	alfalfa	A-P	F	
Melilotus alba	white sweetclover	A-B-P	F	
Melilotus officinalis	yellow sweetclover	A-B-P	F	
Nepeta cataria	catnip	P	F	
Pastinaca sativa	wild parsnip	B-P	F	
Pennisetum glaucum	pearl millet	A-P	G	
Poa pratensis	Kentucky bluegrass	P	G	x
Polygonum convolvulus	black bindweed	A	F-V	
Polypogon monspeliensis	annual rabbitsfoot grass	A	G	
Rhamnus cathartica	European buckthorn	P	S-T	x
Rumex crispus	curly dock	P	F	
Salsola tragus	prickly Russian thistle	A	F	
Sinapis arvensis	wild mustard	A	F	
Sisymbrium altissimum	tumbling mustard	A-B	F	
Sonchus arvensis	perennial sowthistle	P	F	
Taraxacum officinale	common dandelion	P	F	
Thinopyrum intermedium	intermediate wheatgrass	P	G	

Scientific Name	Common Name	Life cycle[1]	Growth form[2]	High priority?
Thlaspi arvense	field pennycress	A	F	
Tragopogon dubius	yellow salsify	A-B	F	
Trifolium pratense	red clover	B-P	F	
Typha angustifolia	narrowleaf cattail	P	F	
Ulmus pumila	Siberian elm	P	S-T	

[1] A = Annual, B = Biennial, P = Perennial
[2] F = Forb, G = Graminoid, S = Shrub, SS = Subshrub, T = Tree, V = Vine

Appendix B. Land bird species detected in KNRI

Appendix B. Species of land birds that have been detected in KNRI. Lists used include the NPS Certified Species List, RMBO Confirmed (Panjabi 2005), and Moore et al. (1989).

Common Name	Scientific Name	NPS Confirmed	RMBO Confirmed	Moore et al. 1989
chimney swift	*Chaetura pelagica*	X	X	
Cooper's hawk	*Accipiter cooperii*	X	X	X
northern goshawk	*Accipiter gentilis*	X		X
sharp-shinned hawk	*Accipiter striatus*	X		X
golden eagle	*Aquila chrysaetos*	X		X
red-tailed hawk	*Buteo jamaicensis*	X	X	X
broad-winged hawk	*Buteo platypterus*	X	X	
Swainson's hawk	*Buteo swainsoni*	X		X
northern harrier	*Circus cyaneus*	X	X	X
bald eagle	*Haliaeetus leucocephalus*	X	X	X
osprey	*Pandion haliaetus*	X		X
turkey vulture	*Cathartes aura*	X	X	X
merlin	*Falco columbarius*	X		X
prairie falcon	*Falco mexicanus*	X		X
American kestrel	*Falco sparverius*	X	X	X
rock pigeon	*Columba livia*	X	X	X
mourning dove	*Zenaida macroura*	X	X	X
belted kingfisher	*Ceryle alcyon*	X	X	
black-billed cuckoo	*Coccyzus erythropthalmus*	X	X	X
wild turkey	*Meleagris gallopavo*	X	X	X
gray partridge	*Perdix perdix*	X		X
ring-necked pheasant	*Phasianus colchicus*	X	X	
sharp-tailed grouse	*Tympanuchus phasianellus*	X		
horned lark	*Eremophila alpestris*	X	X	X
cedar waxwing	*Bombycilla cedrorum*	X	X	X
bohemian waxwing	*Bombycilla garrulus*	X		X
lazuli bunting	*Passerina amoena*	X	X	X
indigo bunting	*Passerina cyanea*	X	X	
rose-breasted grosbeak	*Pheucticus ludovicianus*	X	X	
black-headed grosbeak	*Pheucticus melanocephalus*	X	X	X
brown creeper	*Certhia americana*	X		X
American crow	*Corvus brachyrhynchos*	X	X	X
blue jay	*Cyanocitta cristata*	X	X	X
black-billed magpie	*Pica hudsonia*	X	X	X
grasshopper sparrow	*Ammodramus savannarum*	X	X	X
lark sparrow	*Chondestes grammacus*	X	X	X

Common Name	Scientific Name	NPS Confirmed	RMBO Confirmed	Moore et al. 1989
dark-eyed junco	*Junco hyemalis*	X		X
Lincoln's sparrow	*Melospiza lincolnii*	X		X
song sparrow	*Melospiza melodia*	X	X	X
savannah sparrow	*Passerculus sandwichensis*	X	X	X
spotted towhee	*Pipilo maculatus*	X	X	X
snow bunting	*Plectrophenax nivalis*	X		X
vesper sparrow	*Pooecetes gramineus*	X	X	X
American tree sparrow	*Spizella arborea*	X		X
clay-colored sparrow	*Spizella pallida*	X	X	X
chipping sparrow	*Spizella passerina*	X	X	X
field sparrow	*Spizella pusilla*	X	X	X
white-crowned sparrow	*Zonotrichia leucophrys*	X		X
Harris' sparrow	*Zonotrichia querula*	X		X
lark bunting	*Calamospiza melanocorys*	X		X
common redpoll	*Carduelis flammea*	X		X
hoary redpoll	*Carduelis hornemanni*	X		X
pine siskin	*Carduelis pinus*	X		X
American goldfinch	*Carduelis tristis*	X	X	X
purple finch	*Carpodacus purpureus*	X		X
evening grosbeak	*Coccothraustes vespertinus*	X		X
red crossbill	*Loxia curvirostra*	X		X
pine grosbeak	*Pinicola enucleator*	X		X
barn swallow	*Hirundo rustica*	X	X	X
cliff swallow	*Petrochelidon pyrrhonota*	X	X	X
purple martin	*Progne subis*	X		X
bank swallow	*Riparia riparia*	X	X	X
northern rough-winged swallow	*Stelgidopteryx serripennis*	X	X	X
tree swallow	*Tachycineta bicolor*	X	X	X
red-winged blackbird	*Agelaius phoeniceus*	X	X	X
bobolink	*Dolichonyx oryzivorus*	X	X	X
Brewer's blackbird	*Euphagus cyanocephalus*	X	X	X
Baltimore oriole	*Icterus galbula*	X	X	X
orchard oriole	*Icterus spurius*	X	X	X
brown-headed cowbird	*Molothrus ater*	X	X	X
common grackle	*Quiscalus quiscula*	X	X	X
western meadowlark	*Sterna neglecta*	X	X	X
northern shrike	*Lanius excubitor*	X		X
loggerhead shrike	*Lanius ludovicianus*	X	X	
gray catbird	*Dumetella carolinensis*	X	X	X
brown thrasher	*Toxostoma rufum*	X	X	X

Common Name	Scientific Name	NPS Confirmed	RMBO Confirmed	Moore et al. 1989
black-capped chickadee	*Poecile atricapillus*	X	X	X
yellow-rumped warbler	*Dendroica coronata*	X		X
palm warbler	*Dendroica palmarum*	X		X
yellow warbler	*Dendroica petechia*	X	X	X
blackpoll warbler	*Dendroica striata*	X		
common yellowthroat	*Geothlypis trichas*	X	X	X
yellow-breasted chat	*Icteria virens*	X	X	X
black-and-white warbler	*Mniotilta varia*	X	X	X
ovenbird	*Seiurus aurocapilla*	X	X	X
American redstart	*Setophaga ruticilla*	X	X	X
orange-crowned warbler	*Vermivora celata*	X		X
house sparrow	*Passer domesticus*			X
ruby-crowned kinglet	*Regulus calendula*	X		X
red-breasted nuthatch	*Sitta canadensis*	X		X
white-breasted nuthatch	*Sitta carolinensis*	X	X	X
European starling	*Sturnus vulgaris*	X	X	X
sedge wren	*Cistothorus platensis*	X	X	
house wren	*Troglodytes aedon*	X	X	X
hermit thrush	*Catharus guttatus*	X		X
Swainson's thrush	*Catharus ustulatus*	X	X	X
mountain bluebird	*Sialia currucoides*	X		X
eastern bluebird	*Sialia sialis*	X	X	X
American robin	*Turdus migratorius*	X	X	X
olive-sided flycatcher	*Contopus cooperi*	X		X
eastern wood-pewee	*Contopus virens*	X	X	
alder flycatcher	*Empidonax alnorun*	X	X	
least flycatcher	*Empidonax minimus*	X	X	X
willow flycatcher	*Empidonas traillii*	X	X	X
great crested flycatcher	*Myiarchus crinitus*	X	X	X
Say's phoebe	*Sayornis saya*	X	X	X
eastern kingbird	*Tyrannus tyrannus*	X	X	X
western kingbird	*Tyrannus verticalis*	X	X	X
warbling vireo	*Vireo gilvus*	X	X	X
red-eyed vireo	*Vireo olivaceus*	X	X	X
northern flicker	*Colaptes auratus*	X	X	X
red-headed woodpecker	*Melanerpes erythrocephalus*	X	X	X
downy woodpecker	*Picoides pubescens*	X	X	X
hairy woodpecker	*Picoides villosus*	X	X	X
yellow-bellied sapsucker	*Sphyrapicus varius*	X	X	
common nighthawk	*Chordeiles minor*	X	X	X
short-eared owl	*Asio flammeus*	X		X
long-eared owl	*Asio otus*	X		X

Common Name	Scientific Name	NPS Confirmed	RMBO Confirmed	Moore et al. 1989
snowy owl	*Bubo scandiacus*	X		X
great horned owl	*Bubo virginianus*	X	X	X
eastern screech-owl	*Megascopes asio*	X	X	X

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