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Technical Report NPS/NRWRD/NRTR-2005/326

MISSOURI NATIONAL RECREATIONAL RIVER

NEBRASKA – SOUTH DAKOTA

WATER RESOURCES INFORMATION AND ISSUES OVERVIEW REPORT

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Missouri National Recreational River

Nebraska – South Dakota

Water Resources Information and Issues Overview Report

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Technical Report NPS/NRWRD/NRTR- 2005/326

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WATER RESOURCES DIVISION

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The Missouri National Recreational River (MNRR) is complicated from both a natural resources and management perspective. To capture the current understanding and appropriate management direction for water resources at the MNRR, one must understand the complex history of this first great water highway to the American West. To accomplish this within a limited timeframe requires strong cooperation, and as such, there are many who contributed to this product.

This report represents a cooperative effort between the Water Resources Division (WRD) and NPS Geological Resources Division (GRD) of the National Park Service (NPS) Natural Resources Program Center. The report satisfies an element of the 2003 technical assistance request by the MNRR to prepare a Water Resources Information and Issues Overview Report and conduct a River Morphology training workshop for park staff and local agencies.

Information contained within this report was derived from numerous sources including; a review of existing information pertaining to past and present water resource conditions; a water resources scoping session with participants from the MNRR, WRD, NPS Intermountain/Midwest Region, and Nebraska Game and Parks Commission (NGPC) (June 2004); field trips and site visits; and discussions with subject-matter experts familiar with the water resources and aquatic biological resources of the MNRR. Also in June 2004, as part of the MNRR technical assistance request, a River Morphology workshop conducted by Hal Pranger (GRD), with assistance by Rick Inglis (WRD), was attended by the NPS and local agencies (NGPC, U.S. Army Corps of Engineers, and U.S. Fish & Wildlife Service). The workshop provided an understanding of basic principles on the hydrology and fluvial geomorphology of the Missouri River, which is captured in this report.

Park staff were integral to this final product, providing the authors with technical literature on MNRR's water resources, organizing and participating in the scoping meeting and river morphology workshop, and supervision of two field trips on the Missouri River (59-Mile District and 39-Mile District). A special thanks to the MNRR Resource Management Specialist, Wayne Werkmeister, for organizing and supervising the informative field trips, and to the MNRR Superintendent, Paul Hedren, for providing valuable insight on management histories and current management issues at MNRR.

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EXECUTIVE SUMMARY

> *This Water Resources Information and Issues Overview Report is one of several planning products offered by the NPS Water Resources Division that assist national park units with achieving or maintaining water resource integrity.*

The primary objectives of this report include; 1) identifying laws, policies, regulations, and park-specific mandates as they relate to the Missouri National Recreational River's (MNRR) water resources, 2) summarizing historic management practices on the Missouri River and resulting environmental consequences, 3) identification and analysis of those aspects of water resources (physical, chemical, and biological) that warrant consideration in park planning and management, and 4) identifying MNRR's major water-related issues and presenting relevant information and current management considerations to better position NPS managers with meeting the legislated objectives at MNRR.

The report is divided into six major parts. The first part, *Legislative Background*, includes a description of the legislative background for the Missouri River, including applicable State and Federal legislation that provides the foundation for management decisions related to water resources at MNRR.

The second part, *Regional Setting – Missouri River Ecosystem*, contains a description of the MNRR's regional setting, both pre-regulation and post-regulation, with emphasis on water resources. This section provides the reader with an overview of the past manipulation of the river and surrounding floodplain, including; snag removal, dam installation, and floodplain development.

The third part, *Water Resources and Use*, provides an overview of the MNRR's water resources and their use, including background information on hydrology, water quality, floodplains, biological resources, and visitor use.

The fourth part, *Unifying Concepts in Large River Ecology and the Missouri River*, was added to provide an informative overview on large river ecology, looking at some of the latest concepts and their application to the Missouri River.

The fifth section, *Water Resource Issues*, identifies the significant water-related issues captured in the 2004 scoping meeting that pertain to MNRR's water resources and begins to identify some of the current management strategies that will better assist the NPS in providing a greater level of water resource protection. Specific issues discussed in this section include:

- Dam Operation
    - Altered hydrograph
    - Loss of floodplain habitat
    - Loss of sediment transport

- Altered water temperature

- Stream Bank Stabilization
- Water Quality Monitoring
- Threatened and Endangered Species Management
- Coordination

The sixth and final section, *Considerations for Future Action*, provides the following consolidated list of strategies captured in this report as a recommended starting point for protecting and preserving MNRR's water resources:

- MNRR is encouraged to develop, in cooperation with stakeholders, a set of clear "desired future conditions" related to water resources. A desired future condition is a planning goal that describes the resource conditions managers are attempting to obtain over a specified period of time. When a desired future condition agrees with current conditions, future management efforts should naturally focus upon maintaining those conditions. If the desired future condition differs from current resource conditions, then management actions will need to focus on moving away from current resource conditions and towards the desired condition. Future NPS General Management Plans are now required to have a list of desired future conditions for the critical natural resources the park unit is to protect and preserve (NPS Park Planning Program Standards).

- Adaptive management is the recommended approach for the Missouri River. This "trial and error" approach emphasizes the use of carefully designed and monitored projects, based on input from scientists, managers, and citizens, as opportunities to maintain or restore natural systems and to learn more about ecosystems. These actions are monitored for scientific findings to improve understanding of how policy decisions affect ecosystems. Findings from ecosystem monitoring are then to be used to appropriately adjust management policies.

  One of the most significant scientific unknowns in the Missouri River ecosystem is how the Missouri River ecosystem will respond to management actions designed to improve ecological conditions. Ecosystem monitoring programs need to be designed specifically to produce results that serve as input into river ecosystem recovery programs. Adaptive management requires that clear goals and desired outcomes be established so that progress toward desired future conditions can be assured.

- We agree with the perspectives of Bayley (1995) and Ligon *et al.* (1995) – for the Missouri River, we cannot gain more useful information without first attempting to restore or at least emulate the natural hydrological regime. Funding for experimental restoration and evaluation should take priority over ecological research.

- Reservoir operations (Lake Francis Case and Lewis and Clark Lake) should be modified to more closely approximate the 1929-1948 flow regime of the Missouri River to establish a simulated natural riverine ecosystem. Ecological structure and function of the inter-reservoir and upper channelized river sections would benefit by controlled flooding through managed reservoir releases during June and July of some years, as well as by increasing the frequency and duration of annual high-flow pulses, and the annual rate of hydrograph rises and falls. All of the regulated Missouri River would receive ecological benefits from reducing reservoir discharges in most, if not all, years from August through February, modifying the timing of releases and reducing the annual number of hydrograph reversals. Assessment of geomorphic and ecological responses to a re-regulation of river flows that more closely approximates the natural flow regime should then be used in an adaptive fashion to further adjust reservoir operations.

  It should be noted that the water in a more natural flow regime for the Missouri River would still be 'hungry' for sediment. Each reservoir has a predicted storage life. If entrapped sediment could somehow be moved from each reservoir into both segments of MNRR, the storage life of each reservoir would be extended. More importantly, it could add to the sediment load being carried by the river below the dams. This, in turn could reduce the amount of degradation in the free-flowing reaches and contribute organic matter to downstream habitats. A reduction in the amount of degradation would increase the backwater and subsidiary channel habitats that were lost due to degradation. Such habitats are believed to be an important source of autochthonous primary and secondary production for these river segments.

  Strategies that ultimately remove the sediments that continue to accumulate behind the Ft. Randall and Gavins Point dams should be developed and implemented. Delaying this action will increase the complexity of this growing maintenance need.

- Since the net navigation benefits are relatively small in total and because waterway traffic volumes decrease moving upstream, an incremental analysis of the economics of retaining segments for the navigable waterway is recommended. MNRR should support efforts that work toward this objective.

- In order to improve the state of the MNRR ecosystem, some degree of Missouri River meandering must be restored. This would require a much wider channel corridor in some areas than currently exists.

- Each bank stabilization project should be evaluated in detail. Bank stabilization measures that would reduce the channel width should be carefully considered to minimize impacts to sand bar and island development. If the channel width is near the threshold range, below which the persistence of bars are unlikely (e.g., 500 m (1640 ft) for the 59-Mile District), then the reach might be considered very sensitive to relative small width changes with respect to the channel width. The overall stability of the reach is another factor that should be considered when evaluating a bank stabilization project. Response to a reduction in sediment supply from the banks may be different in an aggradational reach than in a degradational reach. If the reach is already degradational, then the reduction in sediment supply from a stabilization project would simply compound the degradational trends.

- For managing the Missouri River floodplain, greater emphasis should be focused on non-structural solutions, including the acquisition and restoration of wetlands. Avoid inappropriate use of floodplains, minimizing vulnerability to damage through both structural and non-structural means. Flood damage could be reduced significantly by allowing the river to wander in selected parts of the original floodplain, thereby releasing its force and spreading itself at flood stage. Public education will be an important component, defining the river and floodplain function needs for adequately managing the Missouri River.

- A number of agencies have monitored or are monitoring water quality within the MNRR. Compiling a complete updated inventory of water monitoring stations located in MNRR is needed, building from the National Park Service (1998) report, *Baseline Water Quality Data Inventory and Analysis* report for MNRR, located online at http://www.nature.nps.gov/water/horizon.htm. Current information about monitoring sites with MNRR can be found online at the websites provided in Table 3 of this report. From this exercise, MNRR can begin the steps for implementing its current proposal, "Assessment of Surface Water Quality of the MNRR" (PMIS 74282). The objective of this proposal is for the U.S. Geological Survey to develop a surface water quality data set of the MNRR for the NPS.

  In general, the availability of data to define spatial and temporal patterns in water quality throughout the 59-mile segment is lacking. The Corps of Engineers recommends a 2-3 year monitoring project that would collect monthly water samples from April through October of each year at five locations within the 59-Mile District. This monitoring project is still inadequate for characterizing spatial and temporal variations in the 59-Mile District.

- The NPS should be active in the Missouri River Natural Resources Committee (MRNRC) that promotes dialogue on Missouri River management issues. The inability of basin stakeholders to reach consensus has made it difficult to arrive at an approach to river operations that will meet future needs in the basin. This matter must be addressed in order to preserve the Missouri River ecosystem and to produce a broader range of ecosystem benefits formerly provided by the river. Missouri River management actions should be set by a formal multiple-stakeholder group that includes, but not necessarily limited to, the U.S. Army Corps of Engineers, the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. National Park Service, Native American tribes, the Missouri River basin states, floodplain farmers, navigation groups, municipalities, and environmental and recreational groups.

- Studies have tended to focus on specific species or portions of the river, but have not been integrated to address complex ecosystem management issues, making decisions more difficult. Poff *et al.* (2003) suggest new techniques (Hobbs *et al*., 2002; Reckhow, 1999) that hold promise for integrating disconnected studies to guide ecosystem management. More large-scale studies on the Missouri River are needed, which view the river as a single system that considers biological and physical linkages. The MNRR should support efforts such as the MRNRC's cooperative partnership, *Missouri River Environmental Assessment Program*, to identify cost-effective approaches to conserving and restoring the Missouri River's fish and wildlife populations, while maintaining current benefits provided to residents of the Missouri River basin. The MRNRC has undertaken a project to assess conditions of the Missouri River through biomonitoring. MNRR supports this effort (PMIS 75503), which includes fishery, invertebrate and water quality sampling, along with some physical parameter sampling, within the boundaries of MNRR.

- It is reasonable to believe that natural carbon and nutrient cycling in the Missouri River system have been changed enough to limit production of fish biomass, and to have contributed to dramatic declines in the abundance of native species. The best alternative for restoration of organic matter dynamics is recovery of a semblance of the natural hydrograph. An interim solution might be to utilize supplies of large trees, grass and leaves collected from urban environments as a supplement to the river. If selected, this interim solution should be carefully administered to minimize potential water quality impacts. Grass and plant material from urban environments are often treated with fertilizers and pesticides, thus the potential to introduce toxic substances into the aquatic environment might exist. A proposal, unfunded, that fits an adaptive management program, would be the snag and organic matter enrichment project proposed by River Ecosystems, Inc. in the mid-1990s. This proposal offers the opportunity to explore solutions to the past removal of large woody debris and the reduction in carbon cycling.

- A legal opinion on the interpretation of the MNRR legislation is needed. Basin stakeholders, including the National Park Service, then need to acknowledge specific roles and responsibilities.

INTRODUCTION

The Missouri National Recreational River (MNRR) requested assistance in 2003 from the NPS Water Resources Division (WRD) and Geological Resources Division (GRD) to prepare this Water Resources Information and Issues Overview Report for MNRR and to conduct a River Morphology training workshop for park staff and other local agencies.

To initiate this effort, WRD and GRD staff traveled to MNRR in June 2004 to: 1) meet the park's Superintendent and natural resource staff; 2) experience, first hand, the water resources of the park; 3) review park files; 4) facilitate a water resource issues scoping workshop with park staff and invited participants; and 5) conduct a one-day River Morphology training workshop for MNRR staff and regional stakeholders. The park requested the training workshop and this report to better position its staff in the assessment of technical issues and the management of the Missouri River. The park has relied on outside expertise in evaluating water-related projects and believed that some basics in hydrology and fluvial geomorphology would improve understanding and communication about these projects.

During the issues overview workshop, participants identified numerous water-related issues at MNRR, which are summarized in Appendix A. Many of these issues are further expanded upon in this report.

The River Morphology workshop began with an overview presentation that included: 1) an introduction to fluvial geomorphology; 2) general principles of fluvial geomorphology; and 3) impacts of dams on Missouri River morphology. Subsequently, this information was applied to actual issues in MNRR: 1) hydrologic impacts of dams; 2) channel geometry changes; 3) net erosion and sediment impacts of dams; 4) impacts on vegetation and large woody debris; and 5) channel evolution, river adjustment and dynamic equilibrium. The workshop wrapped up with components of adaptive management and discussions on the desired future conditions of the river. The information presented during the training workshop is captured in this report.

In 1999, with sponsorship of the U.S. Environmental Protection Agency and the Corps of Engineers, the Water Science and Technology Board of the National Research Council formed a committee of experts to help provide a better scientific basis for river management decisions in the Missouri River basin. The committee began a two-year study to meet three objectives:

1. Characterize the historical and current ecological status of the Missouri River and floodplain ecosystem.
2. Identify and describe the general state of existing scientific information on the Missouri River and floodplain ecosystem.
3. Recommend policies and institutional arrangements for improving Missouri River and floodplain ecosystem monitoring and research, and emphasize those that could promote an adaptive management approach to Missouri River and floodplain ecosystem management.

The resulting report (National Research Council, 2002), communicates the current scientific understanding of the Missouri River issues, including appropriate management direction and strategies for the MNRR. The contents of this Water Resources Information and Issues Overview Report draws heavily from the 2002 report, as it supports the numerous legislative mandates summarized in the *Legislative Background* section. The authors recommend reading the National Research Council (2002) report for details that extend beyond the scope of this product.

Park Location and Description

The Missouri River begins at the juncture of three tributaries at Three Forks, Montana, and flows southeast for 2,300 miles (3,701 km) before joining the Mississippi River a few miles north of St. Louis, Missouri. The Missouri River flows through several different landscapes and physical regions on its path from the Rocky Mountains to the Mississippi River.

The MNRR comprises two remnant free-flowing reaches of the Missouri River, separated by Lewis and Clark Lake, along the Nebraska-South Dakota boundary (Figure 1). The eastern portion (59-Mile District) starts immediately downstream from Gavins Point Dam (1957) and continues downriver to Ponca, Nebraska (Figure 1). The western portion (39-Mile District) starts immediately downstream from Fort Randall Dam (1954) and continues downriver to Running Water, South Dakota (Figure 1). At the same time the 39-Mile reach was established, the lower 20 miles (32 km) of the Niobrara River and the lower 8 miles (13 km) of Verdigre Creek were also designated as recreational rivers (the Niobrara National Recreational River and Verdigre Creek Recreational River) and are collectively known as the 1991-designated Missouri National Recreational Rivers (National Park Service, 1997). Both Districts were designated as a National Recreational River under the Wild and Scenic River Act because of the significant natural, recreational, and cultural qualities that warrant preservation.

Both the 59-Mile and 39-Mile districts are influenced by controlled dam releases. The MNRR is bordered by a mosaic of private homes, communities, tribal lands, federal, state and community parklands and recreational facilities. The river currently supports irrigation, hydroelectric power production, flood control, and water supply throughout the basin; angling and recreation at the reservoirs and on the river; water for cattle; navigation from Sioux City to St. Louis; habitat management for fish and wildlife and their endangered species; and protection of Wild and Scenic reaches. Managing for one use, like flood control, can lead to impacts on other uses such as habitat preservation (U.S. Environmental Protection Agency, 2002).

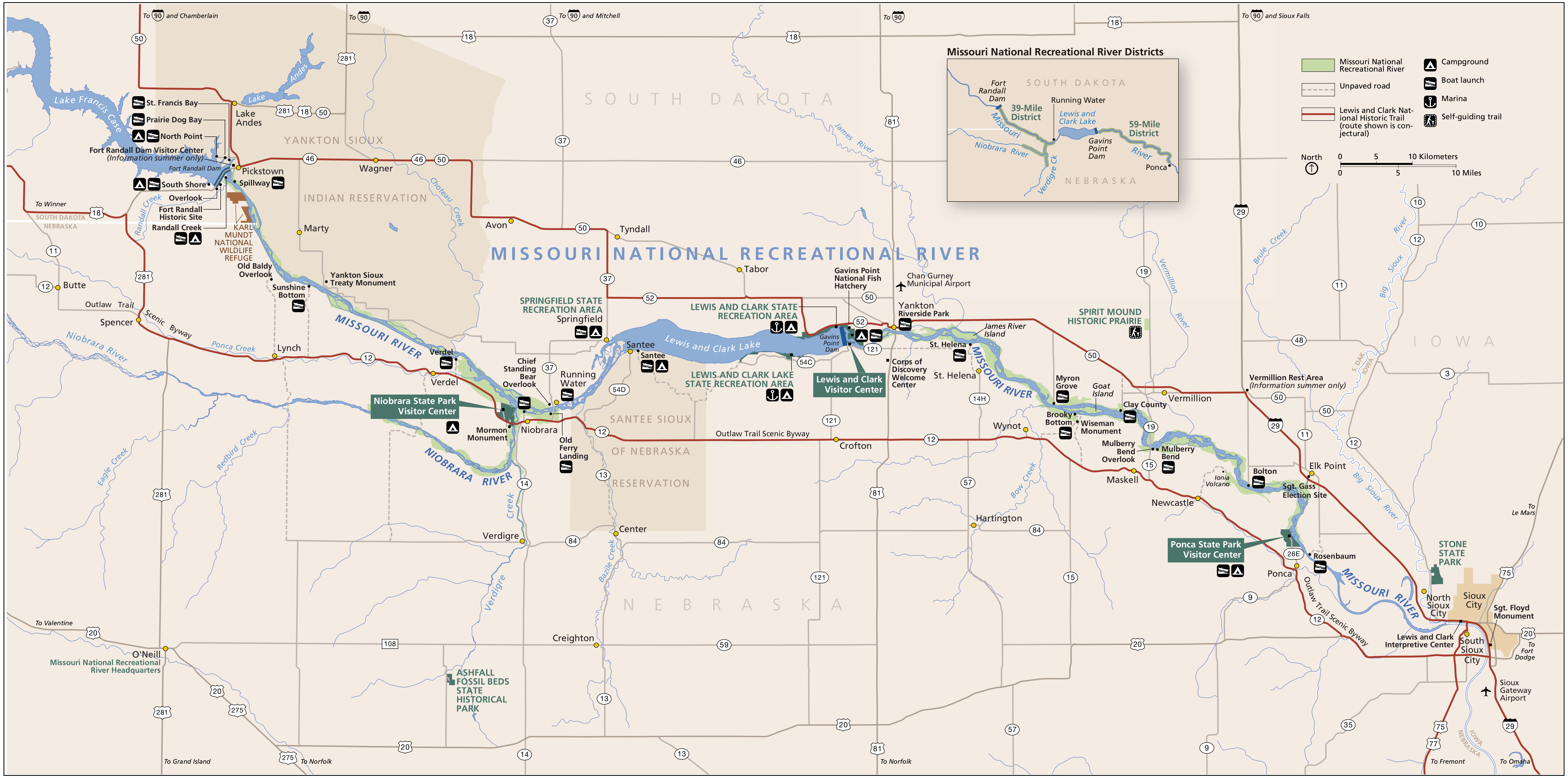

Figure 1. Missouri National Recreational River

LEGISLATIVE BACKGROUND

MNRR Enabling Legislation. The MNRR (both the 59-mile and 39-mile segments) was established under the authority of the *Wild and Scenic Rivers Act* (October 2, 1968; 82 Stat. 906). The 59-mile segment was established in 1978 by P.L. 95-625 (92 Stat. 3529), which amended Section 3(a) of the Wild and Scenic Rivers Act by adding, "…Such segment shall be administered as a recreational river by the Secretary (DOI). The Secretary shall enter into a written cooperative agreement with the Secretary of the Army (acting through the Chief of Engineers) for construction and maintenance of bank stabilization work and appropriate recreational development."

The 39-mile segment was established in 1991 by P.L. 102-50, which amended Section 3(a) of the Wild and Scenic Rivers act by adding, "…The 39-mile segment of the headwater of Lewis and Clark Lake to Ft. Randall Dam, to be administered by the Secretary of the Interior as a recreational river". Section 6(c) states that the "Secretary (DOI) shall permit the use of erosion control techniques, including the use of rocks from the area for streambank stabilization purposes, subject to such conditions as the Secretary may prescribe…"

The NPS is designated the overall administrator of MNRR. In 1999, the Corps and NPS jointly finalized an updated version of the General Management Plan (GMP) for MNRR. The existing GMP, developed in 1980, was outdated because of the identification of additional federally designated threatened and endangered species that inhabit MNRR, among other reasons. The new GMP provides a management strategy to protect and enhance the values for which MNRR was designated as a recreational river, which includes fish and wildlife values. The NPS and Corps manage the MNRR through a cooperative agreement that has the NPS generally administering land-related resources and the Corps generally managing water-related resources

Pick-Sloan Plan. The most important and lasting alteration of the Missouri River ecosystem resulted from the 1944 Pick-Sloan Plan. Pick-Sloan was the product both of the Great Depression and the progressive conservation movement's belief that multiple-purpose water projects would stimulate growth in the arid West (Hays, 1999). The Pick-Sloan Plan was the result of merging two development plans prepared by the Bureau of Reclamation and the U.S. Army Corps of Engineers. The Corps of Engineers proceeded with plans for flood-control and navigation-enhancement dams and reservoirs under the supervision of Colonel Lewis Pick. The Bureau of Reclamation proceeded with plans for irrigation development and hydroelectric generation under the management of William Glenn Sloan. Both the Pick Plan and Sloan Plan were presented to Congress at the same time Congress was considering legislation to create a Missouri River Authority that would promote and coordinate comprehensive development. There was considerable pressure to create a single plan, and in 1944 the two agencies reconciled the differences between the two plans and combined them into one unified plan, Pick-Sloan Plan. The separate plans were coordinated in Senate Document 247, which was part of the Flood Control Act passed by congress in 1944. The final paragraph of S.D. 247 states that the plan, "will secure the maximum benefits for flood control, irrigation, navigation, power, domestic, industrial and sanitary water supply, wildlife, and recreation." It should be noted that support for the plan was not unanimous and American Indians were particularly opposed to it.

Wild and Scenic Rivers Act. The 1968 Wild and Scenic Rivers Act (WSRA) states that "It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess, outstandingly remarkable scenic, recreational, geologic, fish, and wildlife, historic, cultural, or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations." The WSRA defines "*free-flowing*" as: *existing or flowing in natural condition without impoundment, diversion, straightening, rip-rapping, or other modification of the waterway*. The existence, however, of low dams, diversion works, and other minor structures at the time any river is proposed for inclusion in the national wild and scenic rivers system shall not automatically bar its consideration for such inclusion: provided, that this shall not be construed to authorize, intend, or encourage future construction of such structures within components of the national and wild scenic rivers system."

Section 7(a) of the WSRA restricts the Federal Power Commission from licensing "the construction of any dam, water conduit, reservoir, powerhouse, transmission line, or other project works under the Federal Power Act (16 U.S.C. 791a et seq.), on or directly affecting any river which is designated in section 3 of this Act as a component of the national wild and scenic rivers system….and no department or agency of the United States shall assist by loan, grant, license, or otherwise in the construction of any water resources project that would have a direct and adverse effect on the values of which such river was established, as determined by the Secretary charged with this administration. Nothing contained in the foregoing sentence, however, shall preclude licensing of, or assistance to, developments below or above a wild, scenic or recreational river area or on any stream tributary thereto which will not invade the area or unreasonably diminish the scenic, recreational, and fish and wildlife values present in the area on the date of approval of this Act. *No department or agency of the United States shall recommend authorization of any water resources project that would have a direct and adverse effect on the values for which such river was established, as determined by the Secretary charged with its administration, or request appropriations to begin construction of any project, whether heretofore or hereafter authorized, without advising the Secretary of the Interior*…in writing of its intention so to do at least sixty days in advance, and without specifically reporting to the Congress in writing at the time it makes its recommendation or request in what respect construction of such project would be in conflict with the purposes of this Act and would affect the component and the values to be protected by it under this Act."

Water Resources Development Act (1976) – Section 32 Projects: Congress authorized and directed the Corps of Engineers to establish and conduct for a period of five years a national streambank erosion prevention and control demonstration program that included the Missouri River. The program consisted of (1) an evaluation of the extent of streambank erosion on navigable rivers and their tributaries; (2) development of new methods and techniques for bank protection, research on soil stability, and identification of the causes of erosion; (3) a report to the Congress on the results of such studies and the recommendations of the Secretary of the Army on means for the prevention and correction of streambank erosion; and (4) demonstration projects, including bank protection works. Demonstration projects were conducted at multiple sites that included the reach of the Missouri River between Fort Randall Dam, South Dakota, and Sioux City, Iowa. As required, a final report was submitted to Congress in 1981. Two projects on the "39-mile" stretch were described and nine on the "59-mile" stretch. The projects consist of rock revetments, tiebacks and hardpoint structures. As stipulated in the statute, the completed projects were turned over to local sponsors, and the Corps was not, at that stage, obligated to maintain the Section 32 structures. In 1981, a Missouri River Bank Stabilization Association testified successfully before Congress for funding to maintain Section 32 projects. This funding was added to the Corps' operation and maintenance budget for use in the "59-mile" stretch during fiscal year 1982. Since that time, maintenance has occurred almost annually due to funding expressly added to the Corps' budget. Thus, the Section 32 demonstration program, which was originally limited to a five-year period, is still active within the 59-Mile District as a result of specific appropriations. While the Corps has proceeded independently under its Water Resources Development Act (WRDA) authority, the NPS has sought repeatedly to gain access to the decision-making process through WSRA, without observable result (Davidson, 2004).

Davidson (2004) looks in depth at WSRA and WRDA and the associated management implications for MNRR. According to Davidson, the National Park Service has on paper a substantive authority to protect the Missouri River, but has no means of procedural implementation. Without a means of enforcement, the Wild and Scenic River Act will yield to the greater political weight of the WRDA. If the WSRA is to play a durable role in river protection, Congress must create a procedural device, which provides the management agency with enforceable authority.

Beginning in 1969, Congress began to enact a series of environmental protection laws that imposed new duties on federal water resource management agencies. Three key laws summarized below, require the incorporation of environmental values into dam and reservoir operations.

1. Congress passed the *National Environmental Policy Act* (NEPA) in 1969, which requires that federal actions which may have significant environmental impacts shall: "utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision making which may have an impact on man's environment." This approach is referred to as an Environmental Impact Statement (EIS).
2. The 1972 *Federal Water Pollution Control Act*, more commonly known as the *Clean Water Act*, was designed to restore and maintain the integrity of the nation's waters. States implement the protection of water quality under the

authority granted by the Clean Water Act through best management practices and through water quality standards. Section 404 of the act requires that a permit be issued for discharge of dredged or fill materials in waters of the United States, including wetlands. The U.S. Army Corps of Engineers administers the Section 404 permit program. Section 402 of the act requires that a National Pollutant Discharge Elimination System (NPDES) permit be obtained for the discharge of pollutants from any point source into the waters of the United States. In general, all discharges and storm water runoff from major industrial and transportation activities, municipalities, and certain construction activities must be permitted by the NPDES program. The U.S. Environmental Protection Agency usually delegates NPDES permitting authority to the state.

3. The *Endangered Species Act* of 1973 creates the potential to mandate changes in dam and reservoir operations. Unlike NEPA, the mandates of the statue are substantive rather than procedural. Among implications for the NPS, the act requires the NPS to identify and promote the conservation of all federally listed endangered, threatened, or candidate species within any park unit boundary. This act requires all entities using federal funding to consult with the Secretary of Interior on activities that potentially impact endangered flora and fauna. It requires agencies to protect endangered and threatened species, as well as designated critical habitats. While not required by legislation, it is NPS policy to also identify state and locally listed species of concern and support the preservation and restoration of those species and their habitats. If the U.S. Fish and Wildlife Service decides a federal action is likely to jeopardize the continued existence of the listed species, it will prepare a biological opinion, which documents the likely impacts of the action and suggests reasonable and prudent alternatives and possible mitigations measures.

Some additional legislation and executive orders that help guide management of MNRR's aquatic resources include:

The *National Park Service Organic Act* of 1916 established the NPS and mandated that it "shall promote and regulate the use of the federal areas known as national parks, monuments, and reservations by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of future generations."

The *General Authorities Act* of 1970 reinforced the 1916 *Organic Act* – all park lands are united by a common preservation purpose, regardless of title or designation. Hence, federal law protects all water resources in the national park system equally, and it is the fundamental duty of the NPS to protect those resources unless otherwise indicated by Congress.

The *Redwood National Park Act* (1978) amended the *General Authorities Act* of 1970 to mandate that all park system units be managed and protected "in light of the high public value and integrity of the national park system." Furthermore, no activities should be undertaken "in derogation of the values and purposes for which these various areas have been established", except where specifically authorized by law or as may have been or shall be directly and specifically provided for by Congress.

The *National Parks Omnibus Management Act* of 1998 attempts to improve the ability of the NPS to provide state-of-the-art management, protection, and interpretation of and research on the resources of the national park system by:

- Assuring that management of units of the national park system is enhanced by the availability and utilization of a broad program of the highest quality science and information;
- Authorizing the establishment of cooperative agreements with colleges and universities, including but not limited to land grant schools, in partnership with other Federal and State agencies, to establish cooperative study units to conduct multi-disciplinary research and develop integrated information products on the resources of the national park system, or of the larger region of which parks are a part;
- Undertaking a program of inventory and monitoring of national park system resources to establish baseline information and to provide information on the long-term trends in the condition of national park system resources, and;
- Taking such measures as are necessary to assure the full and proper utilization of the results of scientific study for park management decisions. In each case in which an action undertaken by the NPS may cause a significant adverse effect on a park resource, the administrative record shall reflect the manner in which unit resource studies have been considered. The trend in the condition of resources of the national park system shall be a significant factor in the annual performance.

The *Clean Air Act* of 1970 (as amended) regulates airborne emissions of a variety of pollutants from area, stationary, and mobile sources. The 1990 amendments to this act were intended primarily to fill the gaps in the earlier regulations, such as acid rain, ground level ozone, stratospheric ozone depletion and air toxics. The amendments identify a list of 189 hazardous air pollutants. The U.S. Environmental Protection Agency must study these chemicals, identify their sources, determine if emissions standards are warranted, and promulgate appropriate regulations.

Executive Order 11990: *Wetlands Protection* directs the NPS to 1) provide leadership and to take action to minimize the destruction, loss, or degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) to avoid direct or indirect support of new construction in wetlands unless there are no practicable alternative to such construction and the proposed action includes all practicable measures to minimize harm to wetlands.

Executive Order 11988: *Floodplain Management.* The objective of the E.O. is, "…to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practicable alternative." For non-repetitive actions, the E.O. states that all proposed facilities must be located outside the limits of the 100-year floodplain. If there were no practicable alternative to construction within the floodplain, adverse impacts would be minimized during the design of the project.

Water Rights

Settlement of the Missouri River basin's arid areas required states to adjust their water laws to unfamiliar climatic conditions. The Dakotas initially adopted the common law of riparian rights and subsequently followed dual appropriative-riparian systems until the 1950s and 1960s when riparian rights were extinguished. Nebraska went through a similar transition.

The Reclamation Act of 1902 established federal support of irrigation in the western United States as a national policy and created the Reclamation Service, later renamed the Bureau of Reclamation. Missouri River basin residents were quick to recognize the potential for securing water resources development (National Research Council, 2002). By 1904, irrigation projects were under way in the Missouri River basin at several locations. By the 1930s, most of the Missouri's tributaries had one or more dams, diversion structures, or pump stations to store water or to shift it from the rivers and streams to cultivated lands.

A summary of water rights in the Missouri River Basin is presented below (National Research Council, 2002):

State Use Entitlements

Each riparian state is entitled to an equitable share of the river, but the right must be based on prior or reasonably anticipated use. The rights can be firmed by Supreme Court decree, interstate compact, or congressional apportionment. The states have explored these options, but none have been implemented.

Individual Use Rights

Colorado, Montana, North Dakota, South Dakota, and Wyoming follow prior appropriation and allow an individual to perfect a right based on diversion and application to beneficial use. Riparian rights exist by virtue of ownership of land adjacent to a stream and do not depend on actual use. Nebraska is a dual state and recognizes both riparian and appropriation rights.

Rights of Indian Tribes

Indian tribes may claim group rights that have both riparian and appropriative characteristics. Based on the Winters Doctrine of 1908, federal reserved water rights arise by virtue of the creation of a reservation. These rights date from the date of the creation of the reservation and do not depend on the application of water to beneficial use. However, the rights have been primarily recognized for irrigation and have not been of great benefit to the Missouri River tribes.

Regulatory Rights

The federal government can mandate flows for environmental protection purposes. These flows supercede state-created water rights.

Navigation Rights

The "navigation servitude" posits that no individual may assert a property right to the flow of a navigable stream below the stream's high water mark. The assumption has long been that the government may enhance or destroy the navigable capacity of a stream. In 1988, the Supreme Court gave the Corps of Engineers great discretion to make decisions about Missouri River flow management (ESTI Pipeline Project v. Missouri 848 U.S. 495, 1988). However, the status of navigation is complicated by the O'Mahoney-Millikin compromise, which the upper basin states argue subordinates navigation to irrigation and precludes the recognition of any vested rights for a navigation channel depth.

Flood Protection Rights

The federal government is not liable for "acts of God" and is immune from all liability arising from the operation of flood-control reservoirs (33 U.S.C. Section 702c). There are not any cases alleging that the federal government is liable for flood damage when it subordinates flood control to environmental protection objectives. The assumption is that if the government inundates land above the high-water mark in connection with a flood-control project, the government must compensate the landowner. The Supreme Court limited the federal government's immunity for flood damage. Immunity is now based on the function of the release that did the damage rather than on the source of the release. This decision opens the possibility that land owners injured by reservoir releases unrelated to any flood-control objective may recover damages from the federal government.

REGIONAL SETTING – MISSOURI RIVER ECOSYSTEM

Most large rivers in developed countries have been severely influenced by human alteration. The Missouri River is no exception. In 1804, Lewis and Clark were commissioned by the Federal government to find a road to the west for economic development. Subsequently, the Missouri River became the first great highway for exploitation and settlement of the American West (Galat *et al*., 1996).

<u>Pre-Regulation (before 1950s)</u>

The Missouri River flowed unaltered for 2,555 mi (4104 km) and its drainage basin encompassed 338.5 million acres of which 87% was originally prairie (Hesse and Schmulback, 1991; U.S. Fish and Wildlife Service, 2003). The geology within the MNRR is comprised of sedimentary formations (Petsch, 1946). During the Cretaceous period, the Western Interior Seaway infiltrated the center of the U.S., including Nebraska and South Dakota, depositing marine sediments consisting of chalks, clays and sandstones. In the final stage of deposition, glacial advances brought in gravels, sand, and unconsolidated erratics. The river has cut a valley through these easily erodable deposits, nearly 100 feet deep (30.5 m) (Whitely and Campbell, 1974).

The alluvial plain or floodplain of the Missouri River and most of the tributary valleys were a mixture of grasslands, deciduous forests and wetlands. Bragg and Tatschl (1977) determined that 76% of the presettlement floodplain vegetation in Missouri was forest. Late 19th century survey maps still show extensive stands of floodplain forest throughout the basin (Missouri River Commission, 1898). Although wetlands probably never occupied more than 10% of the surface area between the normal high water marks of the river, their small size belied their importance to the entire system since they were often home to more than 90% of the river's fish community (Hesse and Schmulback, 1991). Additionally, Volesky (1969) found that more than 50% of the total weight of aquatic bottom organisms found in the Missouri River resided in cattail marshes that were still fairly common during the 1960s.

The river earned the nickname 'Big Muddy' because it carried high sediment and nutrient/organic loads from frequent over bank flooding onto the erodable alluvial plain. Galat *et al.* (1996) determined that the average annual suspended sediment load in the pre-regulation river ranged from 125 million metric tons at Yankton, SD to 318 million tons at Boonville, MO. The suspended sediment load of today has decreased by 69% to 99% (Galat *et al.,* 1996).

As is naturally found in rivers with broad floodplains and heavy sediment loads, the river was braided to highly sinuous. The Missouri River wandered ceaselessly throughout its floodplain. The river was characterized by logjams, snags, whirlpools, chutes, bars, cut-off channels and secondary channels around bars. These riverine and floodplain habitats were created and maintained by continuous bank erosion and deposition that reshaped the channel and floodplain, and created unvegetated sandbars and islands (U.S. Fish and Wildlife Service, 2003). The width of the river was variable -- 1000 feet to 10,000 feet

(305 – 3050 m) wide during normal flow to 25,000 to 35,000 feet (7,620 – 10,668 m) wide during floods (Schneiders, 1999). As late as 1923, high bank channel widths ranged from 1500 to 6500 feet (457 – 1981 m) with frequent meandering (Johnson *et al.*, 1976). The main channel typically had a deep thalweg (deepest part of the river) that contained the faster moving flow and a shallower section(s) on one or both sides of the channel (Hesse, 1993). In cross-section the distributions of depth and velocity, functions of both flow patterns and channel shape were quite different than in today's altered channels. For example, Latka *et al.* (1993) found that historically in late summer and fall, 98% of the Missouri River main channel was less than 10 feet (3 m) deep with frequent velocities ranging from 1 to 2.5 ft/s (0.3 – 0.7 m/s).

Generally, average water years in the pre-dam era produced a hydrologic pattern characterized by a peak in March/April from snowmelt in the plains and ice melt on the river and tributaries, a decline in May, a higher peak in June from snowmelt in the Rocky Mountains and basin rainfall, and declining flows throughout the summer and fall (Hesse *et al.*, 1989; Galat and Lipkin, 1999). Although this was the natural hydrographic pattern, the magnitude of the highs and lows varied considerably (U.S. Fish and Wildlife Service, 2003).

Dominant discharge (bankfull) flows or flushing flows occurred approximately every 1.5 years (Hesse and Mestl, 1993) and maintained the dynamic processes of the pre-regulation channel and floodplain characteristics. Hesse and Mestl (1993) estimated the pre-regulation dominant discharge to be 100,000 cfs at Omaha, NE. This discharge was exceeded in 15 of 24 years between 1929 and 1952, but only 2 of 33 years after the main stem dams were completed (1954).

It was the timing, variability, and amplitude of the natural hydrograph and the structural and functional connection between the river and its floodplain that shaped the river and floodplain habitat, biodiversity, and the health of the Missouri River ecosystem (U.S. Fish and Wildlife Service, 2000). The natural hydrograph provided the side-boards within which pre-regulation channel morphology and floodplain characteristics of the Missouri River were established. These defined the biological potential to support a diverse flora and fauna.

Approximately 160 species of wildlife were resident or migrant visitors to the Missouri River ecosystem, and 156 native fish species lived in the main stem and tributaries (Hesse *et al.*, 1988; Hesse *et al.*, 1989). Reliable historic data on the composition and abundance of the pre-regulation fish community are not available, but reports of early settlers and commercial fishing records (Funk and Robinson, 1974) suggest an immense and productive fish community in the main stem river.

In 1927, Congress authorized the development of a six-foot deep navigation channel on the Missouri River from Sioux City, Iowa to St. Louis, Missouri and authorized a feasibility study of a nine-foot-deep channel from Kansas City to St. Louis. With funding secured, the Corps launched a program combining bank stabilization with dike construction and strategic dredging designed to narrow the river and eliminate meandering. Wide bends were eliminated, the channel was narrowed and the river's velocity increased. The result was a self-scouring channel that reduced the amount of dredging required. In 1945, Congress extended the authorization for a nine-foot-deep navigation channel on the Missouri River from Kansas City to Sioux City.

Snag removal from the Missouri River began in 1838 in the first few hundred kilometers upstream from St. Louis, MO and remained somewhat random until 1885 although the number and tonnage of snags was enormous (Hesse *et al.*, 1993). Snagging intensified and became methodical after 1885. Snag boats removed 17,676 snags, 69 drift piles, and 6,073 overhanging trees in 538 miles (866 km) of river in 1901 (Funk and Robinson, 1974). The 1950s saw the end of snag removal on the Missouri River. Since that time few snags have been introduced to the river because large floods have been greatly reduced and banks have been stabilized (Hesse *et al.*, 1993).

Snags and other large woody debris play an important role in river ecology (Bilby and Ward (1991). Snags alter channel morphology by influencing sediment routing, thus creating pools, gravel bars and depositional areas. These habitats reduce the rate of downstream transport of particulate material. A large part of riverine organic matter is associated with woody debris. Invertebrate diversity, biomass and production were found to be higher on snag habitat in the Satilla River, Georgia, than in sandy or muddy habitats (Benke et al. 1985). Snag habitat contained 60% of the biomass per unit length of the river, even though snags composed only 4% of the available habitat.

<u>Post-Regulation (after 1963)</u>

In 1927, Congress passed the River and Harbor Act authorizing the Corps of Engineers to conduct surveys to formulate comprehensive water development plans in several river basins. In examining the Missouri River basin's flood-control and navigation needs, the Corps identified several major projects intended to assist in flood damage reduction and the development of the basin (National Research Council, 2002). Widespread flooding from 1942-1944 was the impetus for passage of the 1944 Flood Control Act to construct a six-dam system of flood control on the mainstream Missouri River (Keenlyne, 1988). The last project, Big Bend, was completed in 1963, yielding a total storage capacity for the six reservoirs of 91.5 km^3, the largest of any system in the United States (Table 1).

This multiple dam system affects the geomorphological, ecological, social, cultural and economic conditions along the Missouri River (U.S. Army Corps of Engineers, 2004). The flood control capacity provided by the lakes greatly reduces the potential for the devastating floods that have historically occurred along the river. Releases from water stored in the lakes and the confining effect of the river structures below Sioux City, IA provide for commercial barge navigation. Storage and release of water provide a water supply for tribal water rights; thermal power plant cooling; and municipal, industrial, and agricultural uses. Hydroelectric power plants at each dam provide large amounts of hydropower to meet a significant portion of the electricity demands of the region. The reservoirs and river reaches provide for millions of visitor days of recreational use each year. The local and regional economies benefit from dollars generated by the infrastructure and activities associated with the system.

Table 1. Characteristics of main stem Missouri River reservoirs (after Galat *et al.*, 1996).

Dam	Year closed	River kilometer[a]	Reservoir	Length (km)	Total volume (km^3)	Annual discharge (km^3/yr)	Mean drainage area (10^3 km^2)	Annual energy output (10^6 Kwhrs)
Fort Peck	1937	2851	Fort Peck	216	23.30	7.8	148.9	1,043
Garrison	1953	2237	Sakakawea	286	29.50	21.3	320.9	2,354
Oahe	1958	1725	Oahe	372	28.80	22.8	160.8	2,694
Big Bend	1963	1588	Sharpe	129	2.34	19.4	13.2	1,001
Fort Randall	1954	1416	Francis Case	172	6.90	13.8	36.8	1,745
Gavins Point	1957	1305	Lewis and Clark	40	0.62	15.6	41.4	700

[a] Distance upstream from convergence of Missouri and Mississippi rivers.

The social, cultural and economic benefits notwithstanding, there have been devastating ecological costs associated with the development and operation of this system. The Missouri River of today is divided into three approximately equal lengths: 1/3 is channelized, 1/3 impounded and the remaining 1/3 consists of remnant free-flowing reaches that are regulated by main stem dam releases (Hesse and Schmulback, 1991). In actuality, only one percent of the entire river's length, the 25 miles upstream of Canyon Ferry Reservoir in Montana, has truly uncontrolled natural flow.

The reservoirs have eliminated many miles of riparian forests and effectively stopped meander and periodic flooding along the upper reaches of the river. Construction of the reservoir system alone was responsible for the flooding or elimination of what was once a rich, abundant ecosystem. For example, main stem reservoirs in South Dakota and Nebraska inundated approximately 171,536 acres (69,417 ha) of grassland, 3,032 acres (1,227 ha) of marsh, 116,611 acres (47,190 ha) of bottomland timber and brush, 9,536 acres (3,859 ha) of sandbar and 84,195 acres (34,072 ha) of free-flowing river (US Fish and Wildlife Service, 1984).

The reservoirs have also served as sinks, preventing downstream movement of organic constituents and sediment. Sediment-free water leaving the reservoirs once again seeks a load to carry, and the result is channel bed deepening, severe bank erosion and drainage of remnant backwaters. Prior to regulation, the amount of sediment transported past Omaha ranged from 39,909,297 metric tons in 1931 to 228,570,000 metric tons in 1944. From 1940-52 (period of dam closure) the average annual sediment load transported past Omaha was 148,930,000 metric tons. After 1954, the average sediment load was reduced to 29,487,600 metric tons (Slizeski *et al.*, 1982). Thus, the Missouri River is no longer the 'Big Muddy'. Erosion is not now a function of meander but of channel bed deepening, therefore, the line of erosion does not rapidly advance landward. The eroding bank instead appears to become higher each year. This problem is dealt with through the strategic placement of rock, broken concrete slabs and in some cases car bodies, an unsightly, ineffective and temporary solution at best (see Figure 2).

Figure 2. Examples of streambank stabilization efforts along the Missouri National Recreational River (Hal Pranger, 2004)

The erodable soils of the basin were developed under prairie conditions and contained much organic material in various stages of decay. The Missouri River carried an annual organic carbon load of 725,000 tons to the Mississippi River (Malcolm and Durum, 1976 as cited in Schmulback *et al*., 1992).   This load constitutes 33% of the organic carbon carried by the Mississippi River even though the Missouri River accounts for only 10% of the Mississippi's volume. However, the carbon load now carried by the Missouri River is less than 20% of the amount carried prior to dam/reservoir construction (Hesse *et al*., 1988).

Channelization along with flood control provided by main stem and tributary reservoirs has fostered agricultural, urban, and industrial encroachment on 95% of the floodplain. This development has dramatically changed the composition of the natural plant communities, reduced available supplies of organic material by at least 65% and interrupted vital life processes for nearly all of the native resident and migratory fauna that depended upon habitat along the Missouri River corridor (Hesse *et al.*, 1988). Native vegetation has been replaced with row-crop agriculture, which in turn has necessitated the construction of thousands of small and moderate-sized dams to abate the downstream movement of soils (sediment) from the basin. Flood control measures coupled with loss of native vegetative cover have interrupted the essential movement of dissolved and suspended organic matter, which forms the basis of ecosystem productivity.

Water quality effects (most significantly cold water releases from middle and or bottom levels of reservoirs) are also most pronounced immediately below dams and diminish as one moves downstream. Biological implications from temperature pollution are discussed later in the report.

Loss of periodic flooding has reduced the productivity of the remaining forest lands in the Missouri River floodplain. In North Dakota, coring data for the major floodplain tree species showed a decrease in post-dam growth when compared to the pre-dam period. This decreased productivity was attributed to the absence of continuous soil saturation, lack of deposition of nutrient-rich silt and water management practices that lower the water table in spring to reduce downstream flooding at the time when these trees have a high water demand (Reiley and Johnson, 1982). Moreover, the reduced post-regulation peaks in Missouri River discharge have been insufficient to cause lateral meandering of the channel that is needed if recruitment sites for pioneer forest communities dominated by cottonwoods and willow are to be created.

As a result of these changes, the production and the diversity of the ecosystem have both markedly declined. Symptomatic of the changes are three federally listed threatened and endangered species – least tern (*Sterna antillarum*), piping plover (*Charadrius melodus*), and pallid sturgeon (*Scaphirhynchus albus*).

Hesse and Schmulback (1991) adequately summarized the post-regulation conditions that biota and humans must adapt to:

1) Altered river flows cause a reversal of the natural hydrograph (lower river elevations and flows) during the spring and summer months. This reversal of the natural hydrology has affected the life cycles of plants, nesting birds, aquatic insects and fish. Most riverine fishes require high spring flows for reproduction.

2) Power-peaking caused daily water-level fluctuations during critical spring and summer months which cause desiccation of fish eggs, larvae, and macroinvertebrates.

3) Main stem dams are complete barriers to fish migration.

4) Elimination of the flood pulse, reduction in scouring flows, and reduction in the meandering rate of the river channel in the unchannelized reaches of the river have accelerated the conversion of barren sandbar habitat to permanently vegetated sandbars.

5) Main stem reservoirs have altered the natural energy cycling in the river's downstream reaches. Organic matter leached from basin soils and eroded from floodplain banks is now buried in reservoir bottoms and no longer available to provide nutrition to aquatic organisms in the river.

6) Unnatural erosion which causes degradation occurs in remnant free-flowing river reaches (39-mile and 59-mile segments) downstream of Fort Randall and Gavins Point dams. Clear water leaving the dams is ‘hungry’ for sediment. It acquires its sediment load now primarily from the channel bottom since stream banks have been armored with rock and other materials in many places.

WATER RESOURCES AND USE

Hydrology and Geomorphology

Due to the installation and operation of several water-control structures, the amplitude and frequency of the Missouri River's natural peak flows have been sharply reduced. Flow regulation and channelization substantially changed the Missouri river's historic hydrologic and geomorphic processes – processes essential to maintaining ecological integrity. The primary change was that the extreme high flows (spring and summer floods) and extreme low flows were lost from the hydrograph downstream of each main stem dam. This dampening effect below Gavins Point Dam extends downstream to near Nebraska City (Hesse, 1994), where tributary influences partially restore pre-regulation flows to the river.

Erosion or deposition in a river can occur with a change in the delicate balance between water discharge, channel bed slope, sediment discharge and sediment size (Lane, 1955). If the river channel slope, sediment discharge and size remains unchanged but the flow is increased, one would expect the channel to scour, or erode. Local river bed erosion reduces the channel slope, which would then tend to lead to sediment deposition. Similarly, if flow remains steady but sediment discharge increases, deposition would be expected to occur, again reducing the channel slope. The constantly fluctuating flow, sediment discharge and local channel slope in natural river systems result in an ever-changing but "adjusted" balance of erosion and deposition that has been widely described as "dynamic equilibrium."

There are predictable general trends in channels that have minor, moderate or extreme disturbances in the water, sediment and bed slope balance. Relatively minor adjustments to an alluvial river channel can occur when minor intrinsic channel slope thresholds are reached or during moderate flooding conditions. Usually the adjustments to minor perturbations result in minor channel incision and partial channel aggradation over relatively short time periods and has been termed a "complex response" (Schumm, 1977). If the perturbation to the flow, sediment and/or channel slope is more severe but the channel is still able to recover in a relatively short time period to an "equilibrium" condition, the channel quite often goes through a predictable "channel evolution." This "moderate" channel evolution response includes not only channel incision and partial infilling, but an intervening step of channel widening. The channel widening creates a new floodplain at a lower elevation (Schumm *et al.,* 1984). If the perturbation is extreme, due to, for example, exceedence of major intrinsic geomorphic thresholds or system-wide major hydrologic or sedimentologic alterations, a channel can adjust its geometry in a more drastic series of long-term "episodic erosion" or "episodic deposition" events in order to achieve a new dynamic equilibrium condition (Schumm, 1977). A river with drastically altered flow and sediment discharge conditions will ultimately adjust its geometry to accommodate the changed conditions. The precise degree and period of adjustment, and mode of adjustment (channel evolution or long-term episodic erosion/deposition), will depend on the severity of the impact.

The Fort Randall Dam influences the hydrology of MNRR's 39-Mile District and the Gavins Point Dam influences the hydrology of MNRR's 59-Mile District. Bed material in both reaches is predominately sand with occasional outcrops of gravel. The channel is essentially straight with sinuosity ranging from about 1.0 to 1.02 in the 39-Mile District and 1.0 to 1.25 in the 59-Mile District. Most reaches exhibit a moderate to high degree of braiding with numerous bars and islands. Channel widths range from 984 feet (300 m) to 7447 feet (2,270 m) in the 39-Mile District and range from 607 feet (185 m) to 5249 feet (1,600 m) in the 59-Mile District (Biedenharn *et al.*, 2001). The largest tributary in the 39-Mile District is the Niobrara River, located at Niobrara, Nebraska. Biedenharn *et al.* (2001) found local channel geometry, and in particular channel width of the Missouri River, one of the dominate factors that affects bar and island morphology. A threshold value of 1640 feet (500 m) for channel width was established for the 59-Mile District, below which the persistence of bars is unlikely. Because of the highly braided nature of the 39-Mile District, no threshold value could be established.

The hydrology of MNRR was characterized recently (U.S Army Corps of Engineers, 2004) as follows:

- Releases from Fort Randall Dam vary considerably during the year. Maximum hourly releases for hydropower generation are 45,000 cfs. The minimum hourly release is 0 cfs, except during the spring game fish spawning season, when the desired minimum hourly release is 15,000 to 20,000 cfs. During the navigation season, spring through fall monthly average releases are usually 20,000 – 36,000 cfs to meet navigation targets downstream. During extended droughts, spring through fall, monthly average releases typically drop to 3,000 – 15,000 cfs, even in years when navigation is supported. Winter releases are generally in the 8,000 – 17,000 cfs range to meet non-navigation service levels downstream.
- Releases from Gavins Point Dam follow the same pattern as those for Fort Randall Dam. These releases generally fall into three categories: navigation, flood evacuation, and non-navigation releases. In the navigation season, dam releases are generally 25,000 – 35,000 cfs. In the winter, releases are in the 10,000 – 20,000 cfs range. In wet years with above-normal inflows, releases are higher to evacuate flood control storage in upstream reservoirs. In recent years, winter releases have averaged 25,000 – 30,000 cfs for flood storage evacuation.

Morphometrically, the Missouri River has lost nearly all sandbars, sloughs, chutes, backwaters, oxbow lakes, and even tributary streams since these have also been channelized and/or dammed (Hesse, 1987). Reprinted maps of the first Missouri River survey, completed between 1892 and 1895, show the braided channel and vegetated floodplain before controls were in place. Nearly all this habitat is gone.

The isolation of the Missouri River from its floodplain caused by river regulation structures has in many stretches largely eliminated the flood pulse and its ecological functions and services. Degradation (approximately 6 feet (1.8 m) of eroded bed immediately downstream Fort Randall Dam and 10 feet (3 m) downstream of Gavins Point Dam) of the river channel disconnects the river channel from its floodplain.

Because the water table is hydrologically connected to the river channel itself, there is a consequent lowering of this aquifer in association with the incision of the river channel. This lowering of the water table effectively drains water from oxbow lakes and wetlands. Moreover, in highly-regulated reaches reduced fluctuations in river stage have resulted in reduced fluctuations in the floodplain water table. These fluctuations are important to maintaining biotic richness in the floodplain as some species will benefit from a raised water table, while others will benefit from the lowering of the water table.

As channel degradation continues to entrench the stream, there are fewer overbank flows than there were prior to degradation, thus reducing interaction between the flow in the channel and the floodplain. Rates of channel migration also have decreased. Lateral migration of river channels can occur in areas below dams; however, meandering rates have been markedly reduced downstream of the Missouri River main stem dams because of sharp reductions in peak flows and the armoring of stream banks. Johnson (1992) found that channel erosion and deposition rates (both indicators of meandering rates) are only 25 and 1 percent of pre-regulation values, respectively, downstream of Garrison Dam.

Water Quality

States adopt water quality standards pursuant to the Clean Water Act. Standards are to designate beneficial uses for all surface waters and to establish water quality criteria (numeric or narrative) to protect and maintain the identified designated uses. Designated uses for the South Dakota portion of the Missouri River in MNRR include: warmwater fishery; drinking water; recreation; and livestock and wildlife watering. Designated uses for the Nebraska portion of the Missouri River in MNRR are defined for each segment. For the 39-mile segment the designated uses are High Quality/State Resource Water; aesthetics; warmwater fishery; recreation; and agriculture. The designated uses for the 59-mile segment include that for the 39-mile segment plus drinking water. In cases such as these with multiple use designations, water quality criteria for all the uses apply.

Both segments of MNRR are designated by the State of Nebraska as a State Resource Water – Class A in its water quality standards. A Class A State Resource Water constitutes an outstanding State or National resource, such as waters within national or state parks and waters of exceptional recreational or ecological significance. These include waters that provide for unique habitat for federally designated endangered or threatened species and rivers designated under the Wild and Scenic Rivers Act. A Class A designation identifies a waterbody for the greatest protection under the state's antidegradation policy – existing water quality must be maintained and protected.

States and Tribes must identify surface waters that do not meet EPA-approved water quality standards. Under Section 303(d) of the Clean Water Act, States must report these impaired waters to the EPA as a List of Impaired Waterbodies. The State of Nebraska lists the 109.2 mile section of the Missouri River (Waterbody ID: MT2-1000) from the Niobrara River to Big Sioux River as impaired because of the presence of pathogens from municipal point sources, agriculture, and urban runoff/storm sewers. This listing includes a portion of the 39-mile segment and all of the 59-mile segment.

A review of water quality monitoring activities along the 59-mile segment found limited historic and ongoing water quality sampling (U.S. Army Corps of Engineers, 2002). The Corps of Engineers consistently monitors the Gavins Point Dam discharge; however, that monitoring is limited to the following parameters: water temperature, dissolved oxygen, pH, and conductivity. The State of Nebraska periodically samples the Missouri River at Ponca State Park as part of its river basin monitoring network. The State of Nebraska's 2000 305(b) report labels the water quality in the 59-mile segment as relatively good based on the 1995 sampling at Ponca State Park. The city of Yankton uses the Missouri River as a drinking water source and regularly monitors the quality of river water. In general, the availability of data to define spatial and temporal patterns in water quality throughout the 59-mile segment is lacking (U.S. Army Corps of Engineers, 2002).

In an effort to establish baseline water quality conditions for the 59-mile segment, the Corps of Engineers (2002) monitored 16 parameters weekly over a 6-week period (August through September 2001) at eight locations on the Missouri, James and Vermillion rivers. Parameters included: water temperature; dissolved oxygen; pH; conductivity; Secchi depth; turbidity; total suspended solids; total organic carbon; total phosphorus; total Kjeldahl nitrogen; total ammonia as N; nitrate-nitrite as N; chlorophyll *a*; and three herbicides (atrazine; alachlor; and metholachlor). The eight sample locations allowed for a limited assessment of the longitudinal variation in parameters along the entire 59 miles (95 km) of the segment. Some sites had multiple, within site samples – the objectives were to assess horizontal (i.e., main channel versus backwater) and vertical (i.e., near-surface versus near-bottom) variability in water quality parameters.

Based on the Corps of Engineers limited sampling period, the water quality in the 59-mile segment appears to be good. All water quality parameters met the appropriate state water quality standards. Conductivity, dissolved oxygen, Secchi depth, turbidity, total suspended solids and total phosphorus exhibited significant longitudinal variability. With the lone exception of dissolved oxygen, the longitudinal variability appears to be attributable to the inflows of the James and Vermillion rivers. There were no significant differences between near-surface and near-bottom water quality conditions and main channel and backwater conditions. Recognizing the limitations of its study, the Corps (U.S. Army Corps of Engineers, 2002) recommended a 2-3 year monitoring project that would collect monthly water samples from April through October of each year at five locations (i.e. three Missouri River sites that represent upriver, middle and downriver conditions in the 59-mile segment, and sites on the James and Vermillion rivers near their mouths).

In 1998, the NPS Water Resources Division completed a comprehensive summary of existing surface-water quality data for MNRR, the *Baseline Water Quality Inventory and Analysis, Missouri National Recreational River* (National Park Service, 1998). This document presents the results of surface-water-quality data retrievals for MNRR from six of the United States Environmental Protection Agency's (EPA) national databases: (1)

Storage and Retrieval (STORET) water quality database management system; (2) River Reach File (RF3); (3) Industrial Facilities Discharge (IFD); (4) Drinking Water Supplies (DRINKS); (5) Water Gages (GAGES); and (6) Water Impoundments (DAMS).

The stations yielding the longest-term records within the park boundaries are: (1) Lake Francis Case Releases (MNRR 0103); (2) Missouri River at Yankton, SD (MNRR 0029); (3) Lake Francis Case near Dam (MNRR 0109); (4) Missouri River at Yankton, SD (MNRR 0026); (5) Monitor at Fort Randall Power House (MNRR 0108); (6) Niobrara River near Verdel, NE (MNRR 0086); and (7) Missouri River at Fort Randall Dam (MNRR 0107). The stations yielding the longest-term records immediately outside of the park boundaries, are: (1) Vermillion River near Vermillion, SD (MNRR 0012); (2) Lewis and Clark Lake Releases (MNRR 0040); (3) Niobrara River at Niobrara (MNRR 0072); (4) Lewis and Clark Lake near Dam (MNRR 0048); (5) Lake Yankton Deep (MNRR 0025); (6) Lake Yankton Shallow (MNRR 0042); and (7) Lewis and Clark Lake near Springfield, SD (MNRR 0055)

Screening criteria consisting of published EPA water-quality criteria and instantaneous concentration values were used to identify potential water quality problems within the study area. In contrast to the Corps of Engineers findings, the results of the MNRR water quality criteria screen from the National Park Service (1998) document found 21 groups of parameters exceeded screening criteria at least once within the study area. Dissolved oxygen, pH, chlorine, antimony, cadmium, copper, lead, mercury, selenium, zinc, and heptachlor epoxide exceeded their respective EPA criteria for the protection of freshwater aquatic life. Fluoride, sulfate, nitrate, nitrite, nitrite plus nitrate, antimony, cadmium, lead, mercury, thallium, carbon chloroform, and heptachlor epoxide exceeded their respective EPA drinking water criteria. Fecal-indicator bacteria concentrations (total coliform and fecal coliform) and turbidity exceeded the WRD screening limits for freshwater bathing and aquatic life, respectively.

Wetlands, Floodplains, and Riparian Zones

Riparian ecosystems occupy the transition zones (ecotone) between upland and aquatic realms. More precisely, the riparian ecosystem can be defined as the stream channel between the low- and high-water marks plus the terrestrial landscape above the high-water mark, where vegetation may be influenced by elevated water tables or extreme flooding and by the ability of the soils to hold water (Naiman *et al.*, 1993). Under current conditions of flow regulation, the Missouri River riparian zone undoubtedly has less area when compared to historic (pre-regulation) conditions. Under historic conditions, the above definition would then have encompassed much of the floodplain or alluvial plain in the middle Missouri River.

Riparian areas are particularly sensitive to variation in the hydrological cycle and serve as good indicators of the environmental change caused by flow regulation. Moreover, riparian processes have a central ecological role in most landscapes. They provide organic input to streams and are largely responsible for primary productivity in some systems. Riparian ecosystems offer habitats for many species, such as amphibian and reptiles and several bird species that require both healthy aquatic and terrestrial environments. They also function as filters between land and water, and serve as pathways for dispersing and migrating organisms (Naiman and Decamps, 1997). Riparian ecosystems also have many economic and recreational values. These qualities make them key ecosystems for preserving biodiversity (Naiman *et al*., 1993) and for understanding how environmental change may affect interactions between adjacent landscape elements (Decamps, 1993).

In addition, riparian zones provide woody debris to river systems. Woody debris piles dissipate energy, trap moving materials, and create habitat (Naiman and Decamps, 1997). Depending upon size, position in the channel and geometry, woody debris can resist and redirect water currents, causing a mosaic of erosional and depositional patches in the riparian corridor (Montgomery *et al.*, 1995).

Wetlands are also lands that are transitional between terrestrial and aquatic systems, and they may be considered collectively as a component of the broader riparian zone/floodplain in the Missouri River. Cowardin *et al.* (1979) developed a wetland classification system that is the standard of the NPS. Wetlands must have one or more of the following attributes: 1) at least periodically, the land supports predominantly hydrophytes (water-loving plants); 2) the substrate is predominantly undrained hydric soil; and 3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. Wetlands have many of the characteristics/benefits associated with the riparian zone.

Flood control has reduced wetland habitat. Backwater chutes, pools, and lakes were a normal part of the braided river channel created by erosion and sedimentation. Wetlands, created by a shift in channel conformation, were often maintained by periodic flooding. Wetlands maintained by groundwater have slowly disappeared as the channelized river degraded. Many wetlands were drained and converted to fertile cropland. Those wetlands that were historically maintained by occasional floods, but that are now isolated and converted to cropland will ultimately lose much of their productive potential due to the loss of nutrient input from the river.

The Corps of Engineers (2004) determined that wetland classes along the Missouri River fall into four major groups, each based on dominant vegetation structure:1) emergent—dominated by perennial or persistent herbaceous plants; 2) scrub-shrub—dominated by woody vegetation less than 20 feet (6 m) tall; 3) forested—dominated by woody vegetation greater than 20 feet (6 m) tall; and 4) exposed shore—less than 30 percent cover of trees, shrubs, or persistent emergents and associated with rivers, reservoirs, or lakes. Riparian classes along the Missouri River are also defined by dominant vegetation structure: (1) grassland; (2) shrub; and (3) forest.

The Corps of Engineers mapped and classified wetlands (according to Cowardin *et al.*, 1979) and riparian resources in MNRR in 1991 (Table 2; U.S. Army Corps of Engineers 2004). In the 39-mile segment riparian vegetation constitutes about 33%, water about 46% and wetlands about 19%. Nearly 30% of the wetlands are forested; most of the remainder is emergent (56%). The forested wetlands are characterized by a mix of peachleaf willow (*Salix amygdaloides*) and cottonwood (*Populus deltoides*), with some sandbar willow (*Salix exigua*). Emergent wetlands generally support the typical mix of reed canary grass (*Phalaris arundinacea L.*) and common reed (*Phragmites australis Cav.*). Expansive areas of cattail (*Typhra sp.*), often mixed with softstem bulrush (*Scirpus sp.*), have developed in old channels and backwaters.

Table 2. Wetland and riparian acreages for both segments of the Missouri National Recreational River from 1991 (after U.S. Army Corps of Engineers, 2004).

WETLAND/RIPARIAN TYPE	**39-mile segment (acres)**	**59-mile segment (acres)**
Emergent	1682	2461
Scrub Shrub	454	2517
Forested	889	187
Exposed shore	297	545
Riparian Forest	4536	3949
Riparian Shrub	196	874
Riparian Grass	564	1595
Total Acres	***16,073***	***27,599***

Nearly all of the riparian vegetation in the 39-mile segment is forested with cottonwood (*Populus deltoides*) as the dominant species, mixed with green ash (*Fraxinus pennsylvanica*), Russian olive (*Elaeagnus angustifolia*), slippery elm (*Ulmus rubra*), and box elder (*Acer negundo*). The sparse understory typical of mature stands contains Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), scouring rush (*Equisetum arvense*), eastern red cedar (*Juniperus virginiana*), and roughleaf dogwood (*Cornus drummondii*). Open areas are usually grazed or farmed.

The 59-mile segment resembles the pre-dam natural river more than any other reach of the Missouri River and displays the greatest density of wetlands, about 90 acres per mile (U.S. Army Corps of Engineers, 2004). Wetland acreage has, however, greatly declined as a result of channel degradation. Water constitutes about 56%, riparian vegetation about 23%, and wetlands about 19%.

Wetlands in the 59-mile segment are composed of an even mix of emergent (48%) and scrub shrub (49 %). Scrub-shrub wetlands typically occur as dense stands of young sandbar willow (*Salix hindsiana*), but less frequently inundated areas also include peachleaf willow (*Salix amygdaloides*) and cottonwood (*Populus deltoids*). Most emergent wetlands consist of reed canary grass (*Phalaris arundinacea*) or a mix of hydric and mesic species. Cattails (*Typhra sp.*) occur in old channels, backwaters, and near islands. Areas of exposed shore are not common but occur along the entire Gavins Point reach and are associated with sandbars, eroding banks, developing islands, and areas exposed as a result of degradation of the riverbed.

Riparian vegetation in the 59-mile segment has been severely reduced by agricultural clearing. Over one-half of that remaining is forested and dominated by cottonwood (*Populus deltoides*) with lower densities of green ash (*Fraxinus pennsylvanica*), slippery elm (*Ulmus rubra*), red cedar (*Juniperus virginiana*), Russian olive (*Elaeagnus angustifolia*), mulberry (*Morus* spp.), and box elder (*Acer negundo*). The typically sparse herbaceous layer beneath mature cottonwood consists mostly of scouring rush (*Equisetum variegatum*), Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromus inermis*), and switchgrass (*Panicum virgatum*). Riparian grasslands are dominated by Kentucky bluegrass, smooth brome, and other invasive grasses and weeds.

The regeneration of cottonwood forests is restricted because this species requires a moist, bare substrate for establishment (Reily and Johnson, 1982). Cottonwood forest regeneration currently appears largely restricted to narrow shoreline zones or the upstream end of deltas. The decreased frequency of over bank flooding, perhaps compounded by lowered water tables, is probably causing the reduced vigor and high mortality observed in mature riparian forests of this area.

<u>Biological Resources</u>

Aquatic Biological Resources

As part of a larger study of the Missouri River main stem (Berry and Young, 2001; Pegg and Pierce, 2002), Berry and Young (2004) collected fish from 1996 to 1998 from the MNRR. In an effort to maximize sampling by using a variety of methods in different habitats, they collected 5,209 fish representing 45 species from the 39-mile segment and 16,490 fish representing 53 species from the 59-mile segment. The 59-mile segment had a higher number of species because it is open to fish migration from downstream. The 59-mile segment also had greater numbers of large river species than did the 39-mile segment.

Berry and Young (2004) further combined their data with past studies and agency surveys as well as angler catches to produce a list of 92 fish species known from these two segments; 72 are native. Despite efforts to maximize sampling, they collected only 49% (39-mile) to 58% (59-mile) of the known number of fish species, assuming species documented in earlier studies still exist.

Twenty species (22%) are considered exotic or introduced (Berry and Young, 2004); a similar percentage was found for the entire main stem (Berry *et al*., 2003). Exotic species are not endemic to North America, whereas introduced species are from North America but outside of their native range. Berry and Young (2004) found more introduced than imperiled or extirpated species; thus, nonnative species tend to artificially increase total species richness. In such cases throughout North America, imperiled species are at greatest risk because of the non-native species, and ecological function may be compromised.

Funk and Robinson (1974) conservatively estimated that the collective fish density in the Missouri River declined by 80% between 1947 and 1963, based on commercial fishing reports and major reductions in benthic and aufwuch invertebrate production since 1963. System-wide lost fish production may exceed 400 million pounds (181,440,000 kg) annually since flow regulating structures were completed along the river (Hesse and Schmulback, 1991). Hesse and Sheets (1993), based on the above decline, estimated that pre-regulation fish standing stock may have exceeded 196 lb/acre (220 kg/ha).

Sauger (*Sander canadensis*), a species widely adapted to the pre-regulation turbid environment of the Missouri River, was common prior to flow regulation and channelization. This species comprised between 10% and 65% of the main channel large-river fish assemblage. They have declined by as much as 98% in some locations in the river. Sauger was an important sport fish and recreational anglers fished for sauger prior to regulation. They are closely related to the walleye (*Sander vitreus*) except they were widely adapted to the turbid environment of the Missouri River and they were much more numerous than walleye before regulation.

Hesse et al. (1988) noted the differences in aquatic macroinvertebrate habitat between the 59-mile and 39-mile segments. The 59-mile segment has more stable summer flows because of the need to provide for a nearly constant stage for downstream navigation. Severe degradation has eliminated habitat types such as backwaters and chutes – colonizing areas for macroinvertebrates. The 39-mile segment has suffered less degradation and several large off-channel areas remain. However, this reach is subjected to severe stage fluctuations due to power peaking discharges from March through August and to dewaterings because of flood control activities.

What is known about the aquatic insect community and its habitat types in the middle Missouri River appears to reside in a number of MS theses (e.g., Langemeier, 1965; Namminga, 1969; Volesky, 1969; Nord, 1971; Gould, 1975; and Dixon, 1986 [as cited in Mestl and Hesse, 1993]). Mestl and Hesse (1993) combined their results on secondary production (amount of biomass produced over time) of aquatic insects with the results of these previous studies to examine changes in secondary production over time. They found secondary production in what is now the 59-mile segment of MNRR declined 61% between 1963 and 1980, and the source of the production also changed. Clear water released by the dams has caused severe channel bed degradation, which subsequently drained many backwaters due to lowered water table elevations. In 1963, chute and backwater habitat contributed 37% of the secondary production; this dropped to only 19% by 1980. This habitat apparently contributed more to secondary production than would be expected, given the aerial extent of backwaters. Moreover, the actual biomass of insects produced in chute and backwater habitats dropped 80% from 1963-1980. The loss of backwater habitat and its aquatic insect productivity is important because native fish populations have been declining in the Missouri River. Mestl and Hesse (1993) concluded that the availability of aquatic insects has contributed to the decline in fish abundance.

In the pre-regulation Missouri River, channel meandering caused trees and root masses of the riparian zone to fall into the river, providing high quality habitat for the attachment of plants and animals (collectively called aufwuchs), particularly aquatic insects. Snag removal combined with the loss of channel meandering virtually eliminated this source of aufwuchs habitat. Remnant aufwuchs habitat has been reduced through a combination of stabilized backlines and channel bed degradation. Main channel and chute border aufwuchs habitat contributed a disproportionate 73% of the secondary production in the 59-mile segment of MNRR (Mestl and Hesse 1994). Morris *et al.* (1968) and Namminga (1969) noted the almost complete dissimilarity between the drift and benthic communities of the Missouri River. In both studies, the drift was primarily composed of insects that colonized aufwuchs habitat versus bottom habitat strongly suggesting that aufwuchs habitat is essential for the development of the Missouri River aquatic insect community. Additionally, Morris *et al.* determined that 1159 lbs (525.7 kg) of organisms drifted past a site in the unchannelized Missouri River in 24 hours in 1963. By 1984, this drift biomass had dropped to 0.27 lbs (125.3 g) in 24 hours!

Just over 25 years ago, Hoke (1983) determined the existence of 13 mussel species in the Missouri River along Nebraska, including 10 species from two sites in the 59-mile segment of MNRR below Gavins Point Dam. More recently, Perkins and Backlund (2000) sampled 47 sites from the 59-mile segment and identified eight mussel species from live specimens; 16 species were identified from dead specimens. The mouth of the James River had the highest number of species; total abundance was highest just below Gavins Point Dam. Six species appear to be thriving: *Lasmigona complanata*, *Leptodea fragilis*, *Potamilus alatus*, *P. ohiensis*, *Pyganodon grandis*, and *Truncilla truncata*.

The NPS has determined that the expected number of species of amphibians and reptiles in the MNRR is 27. Preliminary sampling from Fogell (2003) resulted in 18 species (67%) – six frogs, eight snakes, and four turtles.

A 5-year biomonitoring and assessment project (fishes, invertebrates, water quality and physical parameters) for the Middle Missouri that includes MNRR began in July 2001. The project is receiving funding from the states of South Dakota, Nebraska, Iowa and Missouri, USFWS, NPS, American Rivers, Rivers Corportation, and the Missouri River Natural Resources Committee. This project will continue biomonitoring started by the four states in 1996, and will complete detailed statistical analysis of the long-term database to examine flow/fish abundance relationships.

Rare, Threatened and Endangered Species

The pallid sturgeon, *Scaphirhynchus albus*, is the only federally listed endangered fish in the Missouri River, and it is also listed as endangered by South Dakota and Nebraska. This species is native to the Missouri River and therefore adapted to the pre-regulation conditions that existed in this river – large, free-flowing, warm and turbid water in a diverse assemblage of habitat types in a constant state of flux (Dryer and Sandvol, 1993). According to the Recovery Plan for pallid sturgeon, modification of the natural hydrograph, habitat loss, migration blockage, pollution, hybridization and overharvesting are probably all responsible for its decline (Dryer and Sandvol, 1993). The Recovery Plan identified six recovery-priority management areas that will receive priority for implementation of appropriate recovery tasks – both segments of MNRR are included.

Seventeen pallid sturgeon were caught in Lewis and Clark Lake in 1995, and one was found in the 39-mile section in 1976 (Berry and Young 2004). Pallid sturgeon were not caught in the 3-year study by Berry and Young (2004), but the species is sometimes reported in state agency surveys. The Gavins Point National Fish Hatchery transferred over 20,000 pallid sturgeon fry from the hatchery in 2003 for stocking purposes or to other rearing facilities (http://www.mountain-prairie.fws.gov/moriver). Juvenile pallid sturgeons, some tagged, were stocked at two sites in MNRR below Gavins Point Dam for the first time in 2002, and are being monitored to learn more about their ecology (Berry and Young 2004).

The paddlefish, *Polyodon spathula*, is not federally or state listed but may be considered a species of special concern. However, the harvest of paddlefish is routinely monitored and artificial propagation and successful stocking have reduced fears that it was a threatened resources (Berry and Young, 2004). This species is one of the largest, native, freshwater fishes in North America, attaining lengths in access of 6 feet (1.8 m) and weights of more than 100 lbs (45 kg). The paddlefish is found in the Missouri River in both segments of MNRR. Historically, paddlefish were free to move great distances – now many paddlefish populations are isolated between dams. Adult paddlefish trapped between the Missouri River dams did not spawn and populations began to decline because of overfishing. However, today successful reproduction has been documented in both the 39- and 59-mile segments of MNRR. The recreation harvest in the 59-mile segment is limited to about 3000 fish during a 30-day season. In the 39-mile, segment migrating adults are captured for spawning, and fingerlings are reared in captivity for stocking back into the Missouri River system. Over their 3-year sampling period, Berry and Young (2004) captured one paddlefish in the 39-mile segment and two in the 59-mile segment.

The sicklefin chub, *Macrhybopsis meeki*, is listed by South Dakota as threatened and the sturgeon chub, *M. gelida*, is listed by South Dakota as threatened and by Nebraska as endangered; both species have been suggested for federal listing. Bailey and Allum (1962) found these species somewhat common at sites now within the segments of MNRR. Berry and Young (2004) found no sturgeon chubs and only one sicklefin chub in MNRR. Hesse *et al.* (1993) previously warned that these and other species of river chubs were declining. Additionally, Nebraska lists the lake sturgeon, *Acipenser fluvescens*, as threatened, and both states list the scaleshell (a mussel), *Leptodea leptodon*, as endangered.

Berry and Young (2004) determined that all main stem fish species that were found in earlier surveys have persisted, but with reduced or declining populations. Their results corroborate earlier studies that have determined that species of special concern in MNRR are the sturgeon chub (*M. gelida*), sicklefin chub (*M. meeki*), flathead chub (*Platygobio placitus*), silver chub (*M. storeriana*), speckled chub (*M. aestivalis*), plains minnow

(*Hybognathus placitus*), western slivery minnow (*H. argyritus*) and pallid sturgeon (*Scaphirhynchus albus)*.

The bald eagle, *Haliaeetus leucocephalus*, is listed as a federally threatened species. In addition, the bald eagle is listed as threatened by both South Dakota and Nebraska. For many years the bald eagle was considered only an occasional visitor to the Middle Missouri. Today, the species is considered a year-round resident. Nests are generally built in the largest tree in the area (primarily cottonwoods) with a clear flight path to water. In 2004, South Dakota Game, Fish and Parks worked with Nebraska Game and Parks, the U.S. Fish and Wildlife Service, and the National Park Service to perform aerial surveys for all active bald eagle nests in South Dakota and Nebraska. Thirty-two active bald eagle nests are extant on the South Dakota or Nebraska side of the Missouri River (http://www.sdgfp.info/Wildlife/WildlifePlans/BEIndex.htm), with nine active and two inactive nests in MNRR. However; perching, roosting and nesting habitats continue to decline due to the loss of mature cottonwoods along the river. Agricultural conversion of riparian and wetland habitat is also affecting bald eagle habitats.

In winter, bald eagles congregate in areas where water remains ice-free and food is abundant, often in the tailrace areas below dams (http://www.sdgfp.info/Wildlife/WildlifePlans/BEIndex.htm). Stands of mature trees are important for wintering bald eagles because they spend much of the day perched in branches overhanging water waiting for an opportunity to feed. At night eagles may roost communally in one or two large trees that provide some protection from the elements. The 39-segment of MNRR is an active wintering area for bald eagles particularly in the Karl Mundt National Wildlife Reserve (U.S. Army Corps of Engineers, 2004).

The ephemeral sandbars of the 39- and 59-mile segments below Fort Randall and Gavins Point dams serve as nesting habitat for the least tern, *Sterna antillarum*, and piping plover, *Charadrius melodus*, avian species now classified as federally endangered and threatened, respectively. These species are similarly listed by South Dakota and Nebraska. The least tern is North America's smallest tern. Least terns usually arrive in early May and select barren beaches along sandy or gravelly river shorelines or islands. Their small nesting colonies are close to feeding areas and may include the piping plover.

The alteration of the Missouri River led to a loss of nesting habitat. Nesting habitat was historically created by high flows that scoured vegetation from islands and redeposited sediments to create new sandbars. The dams and storage reservoirs have reduced peak flows and sediment loadings, allowing vegetation to encroach on islands and reducing the creation of new sandbars.

The widespread loss of nesting habitat coupled with a loss of wintering habitat elsewhere led to the 1985 listing of the interior population of the least tern as endangered. In the 39-mile segment of MNRR, from 1989-2000, least terns ranged from a high of 124 adults in 1999 to zero terns in 1988 and 1997 with an annual average of only 33 adults (U.S. Army Corps of Engineers, 2004). In the 59-mile segment over the same timeframe, adult least terns ranged from 272 in 1993 to 82 in 1996 with an annual average of 172 adult birds. The habitat of the 59-mile segment has the highest number of least terns along the Missouri River (U.S. Army Corps of Engineers, 2004).

Piping plovers are a type of shorebird related to killdeer and avocets. Piping plovers breed in parts of the prairie, along major rivers of the northern Great Plains. Piping plovers usually arrive to the MNRR in mid-May. They favor open, sparsely vegetated areas with a sand or gravel surface and near water, hence their proclivity for sandbars. This species like the least tern has suffered from drastic changes to the Missouri River caused by flow regulation. For a 12-year period (1989-2000) adult piping plovers in the 39-mile segment ranged from a high of 62 in 2000 to zero in 1988-1989, 1995, and 1997 with an annual average of 17 adults (U.S. Army Corps of Engineers 2004). The long-term reduction of water-borne sediments has reduced sandbar habitat for least tern and piping plover nesting. Cold hypolimnetic water may also reduce tern and plover use of this reach. In the 59-mile segment, adult piping plovers, over the same timeframe, ranged from 211 in 1998 to a low of 22 from 1996-1997 with an annual average of 109 adults.

The Corps of Engineers and the U.S. Fish and Wildlife Service have been creating additional habitat on several reaches of the Missouri River by removing vegetation from islands and by installing fences in shallow water to trap sediment. As part of the U.S. Fish and Wildlife Service's 2003 amended Biological Opinion, dredged sand from the creation of an enhanced backwater development at Ponca State Park was used to create new sandbar habitat for the least tern and piping plover.

Exotic and Introduced Species

Asian carp populations – bighead carp (*Hypophthalmichthys nobilis*), silver carp (*Hypophthalmichthys molitrix*), and grass carp (*Ctenopharyngodon idella*) – have increased in the Missouri and Mississippi river systems. Bighead and silver carp escaped from fish culture operations in the 1990s and have already become the most abundant large fish in portions of the Lower Missouri River (U.S. Fish and Wildlife Service, 2003). The abundance of these fish coupled with their large-volume, plankton feeding ability and ability to feed opportunistically on detritus presents a risk to the productivity of the Missouri River food web. This could occur to such a degree that obligate plankton feeders, like the pallid sturgeon (*Scaphirhynchus albus*) and most other native fishes that consume zooplankton in at least a part of their life cycles, will be negatively impacted. Berry and Young (2004) did not sample any bighead carp although previous surveys noted its presence. Silver carp have been discovered in the 59-Mile District.

Grass carp is a large generalist herbivore that preferentially consumes aquatic macrophytes and as such have been used as a biological control agent for "pondweeds". However, there are few aquatic macrophytes in the Missouri River. Berry and Young (2004) recorded six grass carp from the 59-mile segment and none from the 39-mile segment. Previous surveys have also noted the presence of grass carp (Barry and Young, 2004). Gavins Point Dam has prevented the invasion of this and the above Asian carp species into the upper Missouri River (U.S. Fish and Wildlife Service, 2003).

Introduced fishes include those species stocked during the 1950s in the reservoirs and tail waters of the impounded Missouri River that would enhance recreational fishing. Berry and Young (2004) identified 15 introduced species in MNRR. Many of these species are considered predators that have been associated with the decline of native, turbid-river cyprinids (Berry and Young, 2004).

The zebra mussel, *Dreissena polymorpha*, is an exotic invertebrate species from Europe. It was first discovered in North America in 1988. By 1990, this species was found in all of the Great Lakes. In 1991, zebra mussels escaped the Great Lakes basin and found their way into the Illinois and Hudson rivers. By 1992, they were found in the major river systems of the Arkansas, Cumberland, Mississippi, Ohio and Tennessee. They were first discovered in the Missouri River basin in 1999 (http://nas.er.usgs.gov/zebra.mussel/docs/sp_account.html). This species spreads either as veligers (larval stage) transported in water or as adults attached to boat hulls, engines, aquatic macrophytes, or other surfaces. This pernicious species is notorious for its biofouling capabilities. In addition, it appears to have an impact on native mussels by interfering with their feeding, growth, locomotion, respiration and reproduction by their proclivity for attaching to live mussels rather than to dead ones or rocks. Hesse (2003) found no adult zebra mussels in 2003 in the Missouri River along Nebraska, South Dakota and Iowa; however, veligers were sampled in both MNRR districts.

Visitor Use and Recreation

Summer use of cabins and trailers along the MNRR is high. Recreational developments along the Missouri River include permanent and seasonal residences. Traditional recreational uses of the MNRR include power boating, fishing, camping, hunting, trapping, and watching wildlife throughout the year. More riverfront land each year is converted to recreational cabin development, with most of the development located in the 39-Mile District on the Nebraska shore. Development in the 59-Mile District occurs on both South Dakota and Nebraska shores. Currently, individual owners plan and manage without zoning or guidelines (National Park Service, 1997).

Degradation of natural systems such as the Missouri River, extend beyond the obvious loss of habitat and the flora and fauna that occupy these habitats. The values of visitor use and recreation must also be included in the "loss" equation. As the natural resources deteriorate, so does interest by the public to spend time in these impacted areas. The value of visitor use historically has not been considered or, at best, undervalued. But there is a growing recognition that the replacement costs would be very high (National Research Council, 2002).

From April through September 1994 and May through September 1995, anglers spent 34,840 and 56,340 days respectively, fishing the Missouri River from Ft. Randall Dam downstream to Lewis and Clark Lake (Wikstrom, 1995; 1996). During these same time periods, anglers spent 27,880 and 32,900 days, respectively, fishing the Gavins Point Dam tailwater. The combined value of these fisheries was estimated to be worth between $2,700,000 and $4,600,000 in direct benefits to the local economy (Mestl *et al*., 2001).

Large, regional water projects no longer enjoy the widespread political support they once did. The economic rationale for these projects has eroded and there is today more concern over these projects' environmental and social costs. As a result, the Corps of Engineers' traditional roles have been expanded by Congress to include environmental restoration and programs that address environmental problems associated with existing projects (National Research Council, 2002).

UNIFYING CONCEPTS IN LARGE RIVER ECOLOGY AND THE MISSOURI RIVER

Despite the importance of large rivers, understanding of how they function and how human activities influence river processes is limited (Johnson *et al.*, 1995). Large rivers have not received the attention that small streams have with regard to ecological studies. As a consequence, river ecologists, until recently, perceived river courses as stable, single-thread channels with virtually no consideration of floodplains or adjacent ground water aquifers (Ward and Tockner, 2001). This lack of study may have resulted, in part, from the difficulty in sampling large rivers versus small streams. In addition, there was no clear foundation for how large river ecosystems operated (Johnson *et al.*, 1995).

Given that unidirectional flow is the defining feature of rivers, downstream changes in the structure of biological communities from headwaters to the lower reaches has been a dominant theme in running water ecology (Hawkes, 1975). The European perspective on this topic has been zonal, i.e. delineating more-or-less discrete communities separated by transitional boundaries (Illies and Botosaneanu, 1963). In North America, the River Continuum Concept (RCC:Vannote *et al.*, 1980) posits that river systems have a longitudinal structure that results from a gradient of physical forces along which the biota are predictably structured, thereby approaching longitudinal changes from a clinal rather than a zonal perspective. According to the model, biodiversity should have maximum values in the middle reaches (stream order 4 to 7) with lower biodiversity both in the headwaters (stream order 1 to 3) and in the lower reaches (stream order > 7). Low biodiversity in the headwaters is attributed to low light, low nutrients and a less variable temperature regime. In the lower reaches biodiversity is constrained by a shifting and homogeneous substrate, high turbidity, and oxygen deficits. In contrast, the middle reaches have adequate light and nutrient levels, high water clarity, and a more diverse and patchy substrate. Also, the middle reaches show the highest variability in temperature regime. Under the RCC, it was believed that large rivers received the majority of their primary energy needs (from particulate organic matter) from upstream processing of dead leaves and woody tissue.

Subsequently, two additional concepts, nutrient spiraling (Newbold *et al.*, 1981, 1982) and the serial discontinuity concept (Ward and Stanford, 1983), were developed that are corollaries of the River Continuum Concept. Nutrient cycling in running waters must take into account downstream transport – the passage of an element as dissolved in the water column is transported some distance as a solute, then becomes incorporated into the biota and eventually is returned to the water column in dissolved form. A spiral best describes this cycle of downstream transport. Smaller streams favor nutrient retention and uptake because they have a lower flow, higher streambed areas to channel volume, and more permeable substrates. In contrast, the throughflow of stored materials is favored by the opposite conditions that exist in larger rivers. Under nutrient spiraling, one would then expect decreasing retentiveness along a continuum from small stream to large river (Allan, 1995) – some results appear to support this expectation (Minshall *et al.*, 1983; Naiman *et al.*, 1987).

The serial discontinuity concept (Ward and Sandford, 1983) is a model for rivers whose natural dynamics have been suppressed by flow regulation via dams. This regulation induces major discontinuities to longitudinal resource gradients. Biodiversity patterns along regulated rivers are characterized by major declines at riverine sites immediately downstream from dams, followed by relatively rapid increases concomitant with the recovery of environmental conditions (Ward *et al*., 2002). Stream regulation alters virtually all environmental variables downstream; the sublethal effects of modified flow and temperature regimes are paramount in structuring biotic communities below many dams.

The River Continuum Concept and its corollaries lacked a floodplain perspective, i.e. the interactions between the river channel and its floodplain (Ward and Tockner, 2001; Ward, 1998). Also, the River Continuum Concept was postulated for streams from the deciduous forest biomes of the Pacific Northwest, which is decidedly different than prairie river systems of the Great Plains. It was the study of tropical rivers (e.g., Junk *et al*., 1989) coupled with historical investigations of temperate rivers (e.g., Sedell and Frogatt, 1984) that allowed river ecologists to recognize the importance of the floodplains in large river ecology (Ward and Tockner, 2001). With this in mind, Ward and Stanford (1995) revised their serial discontinuity concept to include alluvial floodplains. With this revision the River Continuum Concept now linked the biota in the river to the floodplain. They postulated a three-reach model (canyon-constrained headwater, braided, and meandering). The meandering reach is expected to have the highest biodiversity. Different types of water bodies, indeed different successional stages within them, contribute to biodiversity as the biota exploit the spatial and temporal variability (Ward, 1998).

However, Junk *et al.* (1989) were the first to incorporate floodplain dynamics by formulating the Flood-Pulse Concept. The Concept is perhaps the major unifying descriptive model that links, hydrology, biogeochemistry, and the ecology of riverine organisms in large rivers with extensive floodplains. It proposes that the pulse of river discharge (seasonal flooding) is the major controlling factor in river-floodplain-biota interactions. The concept emphasizes the importance of alternating dry and wet phases in enhancing biodiversity and productivity as well as the dynamic edge effect created by the 'moving littoral'. The moving littoral is the river water's edge with the land as it moves across the floodplain during flooding and its recession.

Central to the Flood Pulse Concept is: 1) the hydrological linkage or connectivity (both surface and ground water) between the floodplain (a source of organic energy, nutrients and habitat) and the river channel (primarily an avenue to feeding, nursery, spawning areas and refugia); and 2) flooding as part of the natural hydrologic regime. The latter is not a disturbance, rather it is the prevention of floods in a floodplain river that constitutes a disturbance (Sparks, 1995). In the former, rising flood waters inundate formerly distinct aquatic habitats (maximum connectivity). As the flood waters recede, the different types of habitats slowly recover their distinctive properties (including habitat features and biota (Ward and Tockner, 2001). The balance between wet and dry phases of the floodplain sustains a diversity of successional stages and high biological productivity (Bayley, 1995). Each of these stages contains distinctive biota that increases biodiversity. In contrast river regulation reduces the wet phase, i.e. the floodplain is isolated from the river; this lost connectivity arrests the formation of new floodplain aquatic habitats and upsets the balance such that the system experiences reduced biodiversity (low serial diversity; Ward and Tockner, 2001). With the loss of lateral dimension, large regulated rivers may function in a fashion more closely described by the RCC, especially in source and transfer of energy. Natural disturbance induced by flooding enhances ecological connectivity – the transfer of energy and matter – and biodiversity. The latter is recognition that the flow regime is the grand structuring factor in rivers and that such aspects of the regime's frequency, duration, magnitude and timing, in combination, controls biotic associations along rivers and influences the riverine food web (Poff *et al*. 1997; Richter *et al*., 1997; Ward, 1998)

Early on, researchers and managers recognized the applicability of the Flood-Pulse Concept to the Missouri River (Hesse and Schmulback, 1991; Hesse and Sheets, 1993), and recently, an acclaimed publication further promoted it as the unifying concept for the Missouri River (National Research Council, 2002). But what has this recognition and understanding of the Concept done for the management of the Missouri River? Essentially, it has provided us with a conceptual understanding of what has been or continues to be lost from the Missouri River ecosystem. Apart from this, there may be little else to gain in testing the tenets of this Concept on the Missouri River. The Missouri River may be so adversely affected by flow regulation that this has mostly destroyed our ability to study its natural ecology. In cases such as this, Bayley (1995) believes that we cannot gain more useful information without first attempting to restore or at least emulate the natural hydrological regimes. He suggests that funding for experimental restoration and evaluation should take priority over ecological research on severely impaired river-floodplain systems.

Ligon *et al.* (1995) appear to concur with Bayley (1995), albeit from a different perspective. In their case geomorphologic changes are the key to understanding the ecological consequences of dams. Their premise: "… by minimizing the alteration of the physical dynamics and morphology of rivers, many complex species interactions and physical requirements can be maintained without scientists' understanding or even acknowledging their importance. If the physical foundation of the stream ecosystem is pulled out from under the biota, even the most insightful biological research program will fail to preserve ecological integrity. Minimizing or mitigating the physical geomorphic changes may often be crucial to protecting the biological integrity of a river." The conclusions and recommendations of the National Research Council (2002) are also along a similar line of reasoning.

WATER RESOURCE ISSUES

The National Research Council (2002) identified the following changes in the Missouri River ecosystem, which jeopardize its fundamental natural processes: 1) the loss of natural flood pulses; 2) the loss of natural low flows; 3) straightening of stream meanders and the elimination of cut-and-fill alleviation; 4) losses of natural riparian vegetation; 5) reductions in water temperature variation; 6) introduction of nonnative species; and 7) extensive bank stabilization and stream channelization.

No Missouri River management issue has polarized the river's stakeholders as much as the debate over how the provision of flows and channel depths for navigation has affected the Corps' ability and willingness to meet ecosystem needs. Improved navigation was a major feature of the mid-twentieth century vision of the 1944 Pick-Sloan Plan, as navigation's future economic benefits were assumed to be substantial. However, the 1950 projections for commercial waterway traffic were overly optimistic; commercial towboat traffic on the Missouri River peaked in 1977 (below projected levels) and has fallen slowly and steadily since then (National Research Council, 2002). The current dam and reservoir operation schedules reduce the river's natural hydrologic variability in order to provide a steady and reliable nine-foot deep navigation channel. Such operations run counter to established river science, in which a large degree of natural hydrological variability is essential to biological productivity and species richness of large floodplain rivers (National Research Council, 2002).

Because net navigation benefits are relatively small in total, and because waterway traffic volumes decrease moving upstream, an incremental analysis of the economics of retaining segments of the navigable waterway has been recommended by the National Research Council (2002). In proceeding segment by segment, the analysis should discover the point at which it is beneficial to retain navigation to the mouth of the river.

In order to improve the state of the MNRR ecosystem, some degree of Missouri River meandering must needs to be returned to the Missouri River in order to improve the state of the MNRR ecosystem (National Research Council, 2002). This would require a much wider channel corridor in some areas than currently exists, impacting many who live and work along the river.

Dam Operation

The Corps of Engineers constructed and operates six of the seven mainstem dams on the Missouri River; the U.S. Bureau of Reclamation operates the seventh, Canyon Ferry Dam, east of Helena, Montana. Dams in the Missouri River basin have the capacity to hold roughly 106 million acre-feet of water, with the six Corps of Engineers Missouri mainstem reservoirs having a combined capacity of roughly 73.4 million acre feet, making it North America's largest reservoir system (U.S. Army Corps of Engineers, 2001).

Operations of the dams maintained by the Corps of Engineers are guided by the Corps' 1979 Missouri River Main Stem Reservoir System Reservoir Regulation Manual, usually referred to as the "Master Manual". When the Corps of Engineers constructed five of the Missouri River mainstem dams in the 1950s and 1960s after passage of the Pick-Sloan Plan, goals for dam and reservoir operations were to reduce flood damages, enhance navigation, generate hydroelectric power, and store water for irrigation. But changes in social preferences have resulted in a new mix of uses and stakeholders on the Missouri River today. Many of the new uses revolve around recreational and environmental considerations, such as boating and sport fishing (National Research Council, 2002).

The drought of the 1980s stretched the Corps' ability to meet the variety of mainstem water demands, and the Corps ultimately decided to review the Master Manual. At the same time, the Missouri River basin states expressed concerns over priorities being assigned by the Corps to various water uses. Recreation and fish and wildlife interests argued that priority in water use for a dwindling navigation program was at their expense. The U.S. Fish and Wildlife Service asked the Corps to more carefully consider threatened and endangered species in its operations. As a result, the Corps in 1989 announced that it would conduct a major review of the Master Manual. The U.S. Fish and Wildlife Service issued jeopardy opinions (which state that a proposed action will jeopardize the existence of a threatened or endangered species) regarding operation of the Missouri River dams and the threat to federally listed species. This followed the Corps of Engineers issuance of the Master Manual Draft Environmental Impact Statement, which recommended changes in the management of the dams and reservoirs. The Corps of Engineers conducted public hearings on this draft document. These hearings revealed controversies surrounding the river's many uses. A consensus emerged that recognized the need for improved ecological monitoring and scientific knowledge to improve river management. Nevertheless, the National Environmental Policy Act environmental impact statement process, initiated by the Corps of Engineers began revisions to its Master Manual in 1989, and a final revision of the Corps' Master Manual was completed in 2004.

The reservoirs created by dams along the Missouri River have the following authorized purposes (National Research Council, 2002):

- *Flood Damage Reduction* – The high-risk season for flooding in the Missouri River basin, March until mid-summer, coincides with the potential occurrence of snowmelt, ice jams, or heavy rainstorms. The Corps divides the storage capacity of each reservoir into zones or pools, and reserves space in each reservoir for flood control.
- *Water Supply and Irrigation* – One of the authorized purposes of the mainstem reservoir system is to supply water for municipalities, industries, and irrigation throughout the basin. Irrigation was an integral component of the original system planning and design, pumps, diversions, and other water distribution facilities were planned and constructed to move water to farms in the basin.
- *Navigation* – The Missouri River navigation channel extends 735 miles (1,183 km) upstream from the river's mouth at St. Louis, Missouri to

Sioux City, Iowa, immediately downstream of MNRR. Shipping is seasonal, and typically extends from late March until late November or mid-December. The multiple use zones in the reservoirs store water from year to year to support navigation when water in the annual operating zone is exhausted.

- *Hydropower* – All reservoirs have facilities for hydropower generation, and the sale of the energy is a major revenue-producing system purpose. The Western Area Power Administration markets and transmits the power generated by the Missouri River reservoir system.
- *Fish and Wildlife* – The Master Manual requires that, "…the reservoirs will be operated for maximum benefit to recreation, fish and wildlife" to the extent possible, without interference with other project purposes. The manual acknowledges that fish production and development are affected by reservoir levels and releases and makes provisions for operation of selected reservoirs to improve fishery resources. Similarly, the Master Manual acknowledges a need to operate the reservoirs for improving migratory waterfowl habitat.
- *Recreation* – Public Law 78-534 and Public Law 99-662 authorize operation of the mainstem reservoirs for recreation. Recreation use is particularly important in the MNRR and at the reservoirs immediately upstream from the MNRR's 39-mile District (Lake Francis Case) and 59-mile District (Lewis and Clark Lake).

The value of dams today is questioned by segments of society that value environmental preservation and enjoyment. Some smaller U.S. dams have been breached or removed (e.g., Edwards Dam on the Kennebec River in Maine was breached in 1999), and others are scheduled to be removed (e.g., Elwha Dam in the state of Washington).

Altered Hydrograph

Restoring the ecological integrity of the Missouri River necessitates characterizing the "natural" flow regime. Historical flow data often provide the only opportunity to estimate natural or reference conditions because few naturally-flowing large rivers exist. Galat and Lipkin (1999) assessed the natural range of variation of the Missouri River's flow regime at 11 locations before (1929-1948) and after (1967-1996) mainstream impoundment. Mean annual discharge for all stations ranged from 8% to 42% higher, inter-annual flow variability was lower, and flow predictability was higher in the post-regulation period. Flow regulation was associated with a reduction in magnitude and duration of the annual flood pulse, increase in magnitude and duration of annual discharge minima, reduction in frequency of annual low-flow pulses, earlier timing of March-October low-flow pulses, and a general increase in frequency of flow reversals with a reduction in the rate of change in river flows.

According to Galat and Lipkin (1999), reservoir operations could be modified to more closely approximate the 1929-1948 flow regime of the Missouri River if a management goal is to establish a simulated natural riverine ecosystem. Ecological structure and function of the inter-reservoir and upper channelized river sections would benefit by controlled flooding through managed reservoir releases during June and July of some years, as well as by increasing the frequency and duration of annual high-flow pulses, and the annual rate of hydrograph rises and falls. All of the regulated Missouri River would receive ecological benefits from reducing reservoir discharges in most, if not all, years from August through February, modifying the timing of releases and reducing the annual number of hydrograph reversals. Assessment of ecological responses to a re-regulation of river flows that more closely approximates the natural flow regime should then be used in an adaptive fashion to further adjust reservoir operations.

Aspects of these ecologically based flow-management guidelines conflict with contemporary Missouri River management objectives of maximizing mid-summer power production and providing summer-autumn flow releases for navigation in the channelized river.

Loss of Floodplain Habitat

The Missouri River had a wide floodplain, part of which was inundated each year (Galat *et al*., 1996). Before the construction of the dams along the Missouri River, downstream lands were subject to annual flooding and were a natural part of the river's floodplain. After the closing of the dams, the vast lands were cleared for agricultural production. Thus, the landowners have enjoyed an enormous return on these fertile lands at public expense. As timed passed, the idea that these lands were flood-free caused developers to move-in, thus supplementing the demands for bank stabilization projects.

The biological impact from loss of floodplains is well documented. Karr and Schlosser (1978) suggested that standing stock of fish may decline by as much as 98 percent when the lateral linkage between floodplain and channel is severed. Morris *et al.* (1968) determined that, as channelization occurred on the Missouri River, 67 percent of the off-channel benthic insect production was lost in direct proportion to lost off-channel habitat.

A major consequence of lost habitat is a reduction in the secondary production or simply put, production of aquatic insects, a major component in the aquatic food web. Production for the 59-mile segment of MNRR declined 61% between 1963 and 1980 (Mestl and Hesse, 1993). For example in 1963, chute and backwater habitat contributed 37% of the secondary production; this dropped to only 19% by 1980. More importantly, the actual biomass of insects produced in chute and backwater habitats dropped 80% from 1963-1980. Additionally, the removal of snags has also affected the production of aquatic insects. In 1963, approximately 70% of all secondary production in the 59-mile segment of MNRR was from snag habitat; in 1980, snag production dropped to about 50% of total production. This loss of backwater habitats and their aquatic insect communities is important because native fish use these areas as feeding sites.

In 1993, unprecedented rains caused floods in the upper Mississippi River basin and the lower Missouri River basin. In the aftermath of the great flood, the President established an Interagency Floodplain Management Review Committee to describe and examine the consequences of the flood, to evaluate the performance of existing floodplain management and related watershed management programs, and to make recommendation for changes in current federal policies and programs that would achieve risk reduction, economic efficiency, and environmental enhancement in the floodplain and related watersheds. The Committee's 1994 report, "Sharing the Challenge: Floodplain Management into the 21st Century" (*Galloway Report*), was the outcome of this effort and is regarded as "essential reading" on floodplain management. The Galloway Report called for greater emphasis on non-structural solutions, including the acquisition and restoration of wetlands. The report supports a floodplain management strategy of, sequentially, avoiding inappropriate use of floodplains, minimizing vulnerability to damage through both structural and non-structural means, and mitigating flood damages when they occur. According to the Galloway Report, flood damage could be reduced significantly by allowing the river to wander in selected parts of the original floodplain, thereby releasing its force and spreading itself at flood stage (Davidson, 2004).

Loss of Sediment Transport

With the presence of Fort Randall Dam and Gavins Point Dam, much of the sediment that would have been entering the MNRR now deposits in the reservoirs immediately upstream from these two structures, Lake Francis Case and Lewis and Clark Lake, respectively. "Sediment hungry" water is discharged into MNRR from these water control structures, increasing river bank and riverbed erosion. Erosion rates for MNRR's 39-Mile and 59-Mile districts average 14,455 m^3/yr/km and 28,000 m^3/yr/km, respectively (Biedenharn *et al*., 2001).

Sediment transport and deposition are critical to maintaining the river system's form and dynamics. The predominate trend for island and bar density in MNRR between 1976 and 1994 was a decrease in density due to this "sediment-starved" system. The three primary factors necessary for the formation and persistence of bars are a supply of suitable sized sediment, local channel geometry and a stability status that allows and promotes bar existence (Biedenharn *et al*., 2001).

The influences of the waters backed up by Gavins Point Dam (Lewis and Clark Lake and the Niobrara River) have degraded the habitat at the mouth of the Niobrara River where it joins the Missouri River. The sediment-rich waters of the Niobrara River deposit suspended sediments into the Missouri River, where the energy to transport sediments has been greatly reduced due to the influence of waters backed up by Gavins Point Dam. Groundwater elevations in the area have increased due to this rapid aggrading system, resulting in the relocation of the town of Niobrara, Nebraska due to basement flooding in homes. The higher ground water table also appears to be related to the loss of cottonwood trees in the area. According to the U.S. Army Corps of Engineers (1994), "continued sedimentation in the headwaters of Lewis and Clark Lake and aggradation of the Missouri River above its confluence with the Niobrara River would result in several potential economic problems. These include the loss of project benefits at Fort Randall Dam and Gavins Point Dam, increased flood damage on tributary streams, damage to the water intake at Springfield, South Dakota, and ground water or flooding impacts to additional land in the Missouri River floodplain above the Niobrara River."

Each year more sediment accumulates in the reservoirs that feed MNRR, Lake Francis Case and Lewis and Clark Lake. A sustainable way of transporting this sediment around the dams is needed to minimize sediment accumulation and benefit downstream ecosystems. Waiting will only compound the inevitable task of sediment removal.

Altered Water Temperature

The productivity of the Missouri River ecosystem and reproductive success of riverine organisms depends not only on the hydrograph and appropriate habitat, but also suitable water temperatures. Even if flow regime and physical habitat requirements are met, suitable water temperatures must exist for successful fish reproduction and production of periphyton, plankton, aquatic invertebrates and other aquatic and wetland organisms vital to the food and energy supply of the riverine system.

The largest dams on the main stem of the Missouri River release water from a depth of 42 meters (Ft. Randall Dam) to 59 meters (Oahe Dam) (U.S. Army Corps of Engineers, 1985). Release of the colder waters from the bottom of the reservoirs has reduced downstream water temperature by as much as 10ºC on any given day (Hesse *et al*., 1993). The mean number of miles of warm river aquatic habitat during April - August below Fort Randall is 16.6 miles (26.7 km) (31%) (U.S. Fish and Wildlife Service, 2000).

Cold water pollution from dam releases has long been recognized by aquatic professionals as having a detrimental affect on aquatic species within the influence of the release. Native fishes such as the sauger, sturgeon, and blue sucker spawn in response to water temperature and runoff cues (Hesse, 1996). Obviously, modifications to the natural temperature and discharge disrupt these spawning cycles. Temperature reductions can affect aquatic insects by altering emergence cues, egg hatching, diapause and maturation (Petts, 1984).

Stream Bank Stabilization

Stream bank stabilization practices can alter the hydrologic balance of a river reach in several ways. Examples include: (1) increased storage by changing the resistance characteristics of each reach or by altering the channel geometry (slope or cross section); (2) modifying surface/subsurface water exchange by creating a barrier to flow; and (3) modifying the hydrodynamic character by altering flow fields or through the creation of backwater conditions (Fischenich, 2003). Stabilization structures impact sedimentation processes. They reduce or eliminate sediment yield and tend to generate local scour, usually at the toe or immediately downstream. Local habitat conditions are also affected by stabilization measures. Riprap provides a substrate that generally differs from the parent material of the channel boundary, producing a different habitat condition. In addition, the stabilization structure may alter the channel geometry, flow field, riparian vegetation conditions, or a host of other habitat elements (Fischenich, 2003). Stream channels and their associated riparian zones help maintain soil and water quality and support important chemical processes and nutrient cycles necessary to perpetuate the long-term health of physical and biological properties of these areas. Stabilization measures generally affect these functions indirectly (Fischenich, 2003).

The 1990's had three unusually high water years resulting in increased runoff and dam discharges, with resultant increased erosion. Concern about erosion of cottonwood forests was expressed by the public during 1999 meetings held by the National Park Service and the Corps of Engineers. The Corps of Engineers was tasked by the National Park Service to determine if erosion protection measures were needed to prevent further decline in cottonwood forest within the MNRR. After site visits and analysis of erosion rates, the Corps recommended erosion protection at five sites (three sites are private lands, two sites are state-owned lands). Construction of permanent projects using quarry stone was recommended as the most cost-effective solution (U.S. Army Corps of Engineers, 2000). The NPS rejected rock and encouraged environmentally friendly alternatives. To date, no work has been undertaken.

Most streambank stabilization efforts are intended to protect infrastructure or other important investments. There is a false impression that ecologically healthy streams and riparian corridors are stable. In truth, dynamic processes such as erosion, deposition, flooding, and drought occur in healthy streams. Even in pristine systems, it is common to find that 10 to 50 percent of the banks are actively eroding, and the process of erosion is important to the ecological health of most systems (Fischenich, 2003).

Bank stabilization projects should be evaluated very carefully. The hardening of streambanks with various materials (quarry stone, broken concrete slabs, car bodies, etc.) and often a narrow objective of protecting immediate property from erosion, is rarely the best solution. According to Biedenharn *et al.* (2001), any stabilization measures that would reduce the channel width should be carefully considered to minimize impacts to sand bar and island development. If the channel width is near the threshold range, below which the persistence of bars are unlikely (e.g., 500 m (1640 ft) for the 59-Mile District), then the reach might be considered very sensitive to relatively small channel width changes. Bank stabilization projects can also reduce local sediment supply for bar and island development. As a result of reducing the supply of bed material sized sediment from the banks, the channel will attempt to acquire additional sediment from the bed, bars, islands or remaining unprotected banks (Biedenharn *et al*., 2001). Another factor that should be considered when evaluating a potential bank stabilization project is the overall stability of the reach. Response to a reduction in sediment supply from the banks may be different in an aggradational reach than in a degradational reach. If bed material supply is reduced in an aggradational reach, the response may simply be a decrease or elimination of aggradation in the reach depending upon the magnitude of reduction. If the reach is already degradational, then the reduction in supply of sediment would simply compound the degradational trends (Biedenharn *et al*., 2001).

One of the more persistent oppositions to bank stabilization on the Missouri River is the impact stabilization products have on fish and wildlife. A free-flowing river characterized by islands, back-water areas, and braided channels, provide the biological diversity needed for native fish and wildlife. Hardening of the banks, reduces this diversity, degrading important habitat.

Water Quality Monitoring

A number of agencies have monitored or are monitoring water quality within the MNRR. A list of these agencies and the contact information for them can be found in Table 3. Other local or private organizations might also monitor water within the park, yet their information could be difficult to retrieve since it may not be reported to a public database such as STORET. Compiling a complete updated inventory of water monitoring stations located in the park extends beyond the scope of this report, but is needed. Fortunately a comprehensive list of the monitoring sites located in the park already exists (National Park Service, 1998), though it is somewhat dated. The list includes information on the operating agency of the station, location of the site, type of data collected, and the status of the site. This information can be found in the *Baseline Water Quality Data Inventory and Analysis* report for Missouri National Recreation River (National Park Service, 1998), located online at http://www.nature.nps.gov/water/horizon.htm. Current information about monitoring sites within the park and vicinity can be found online at the websites provided in Table 3. The data for a large number of the water quality monitoring sites found in the park is reported to www.epa.gov/storet or http://water.usgs.gov/data.html; however, to properly identify monitoring stations within the park, one must be acquainted with either the geographic characteristics of the area such as dams or stream intersections, the coordinates for the area, or the stations identification number as these are the ways the locations of the sites are recorded in the mentioned online sources.

Table 3. Agency contact information for water quality monitoring within the Missouri National Recreational River.

Primary Contact Name	Organization	Phone Number	Home Page	Water data Web Page
Ihrie, Dave	Nebraska Dept Env Quality	(402)471-0283	http://www.deq.state.ne.us	Must navigate to water data page from home page
Bartholomay, Roy	US Geologic Survey South Dakota	(605)352-4241 ext. 204	http://www.usgs.gov	http://water.usgs.gov/data.html
Wilson, Richard	US Geologic Survey Nebraska	(402)437-5115	http://www.usgs.gov	http://water.usgs.gov/data.html
Cropp, Trevor	Corps of Engineers	(816)842-6039	http://www.usace.army.mil	http://www.nwd.usace.army.mil/wm
Kindt, Trish	SD Dept Water & Nat Res	(605)773-4055	At the time of initial data entry into the STORET program this agency existed individually, it has since been added to SD Dept Env & Nat Res, thus all contact information is the same.	
Kindt, Trish	SD Dept Env & Nat Res	(605)773-4055	http://www.state.sd.us/denr/denr.html	http://www.state.sd.us/denr/DES/Surfacewater/watermonitoring.htm
Tucker, Dean	National Park Service	(970)225-3516	http://www.nps.gov	http://www.nature.nps.gov/water/horizon.htm
Generaux, Jack	USEPA Region 7	(913)551-7690	http://www.epa.gov/region7	http://www.epa.gov/region7/water/index.htm
Berkley, Jim	USEPA Region 8	(303)312-7102	http://www.epa.gov/region8	http://www.epa.gov/region8/water
STORET user assistance	USEPA HQ	(800)424-9067	http://www.epa.gov	http://www.epa.gov/storet

Using the updated inventory of existing water monitoring stations, MNRR can then begin the steps for implementing its current proposal, "Assess the Surface Water Quality of the MNRR" (PMIS 74282). The objective of this proposal is for the U.S. Geological Survey to develop a surface water quality data set of the MNRR for the NPS.

Threatened and Endangered Species Management

The Corps of Engineers constructed a side-channel backwater within the 59-mile District in 2004. Construction of backwaters and chutes has become a popular means of rehabilitating habitat in the lower Missouri River. These structures provide increased areas of sandbars and shallow, slow water-habitats substantially diminished in the modern Missouri River today. Jacobson *et al*. (2004) studied various aspects of hydrology, hydraulics, and geomorphology of four side-channel chutes on the Missouri River to document a range of existing conditions: Cranberry Bend, Lisbon Bottom, Hamburg Bend and North Overton Bottoms. Each of the side-channel chutes shows evidence of erosion and deposition. The Cranberry Bend side-channel chute has existed for 40+ years and continues to maintain natural form and process. The Lisbon side-channel chute was created by extreme floods (1993-1996) and was allowed to evolve with minimal engineering. This young chute appears to have achieved equilibrium width with slight aggradation as it adjusts to altered hydrology and sediment availability. The Hamburg chute, constructed in 1996, shows evidence of lateral movement and construction of a floodplain. The North Overton Bottoms chute is the newest and appears to be extremely stable after two floods and the accumulation of potentially destabilizing large woody debris jams (Jacobson *et al*., 2004).

After over a decade of consultation, the U.S. Fish and Wildlife Service concluded in a 2000 Biological Opinion that the Corp's current operations of the Missouri River Main Stem Reservoir System and the operation and maintenance of the Missouri River Bank Stabilization and Navigation Project jeopardized the continued existence of the pallid sturgeon, least tern, and piping plover. To offset jeopardy, the Biological Opinion identified five reasonable and prudent alternatives: flow enhancement from Gavins Point and Fort Peck dams; habitat restoration/creation/enhancement of shallow water habitat and emergent sandbar habitat; unbalanced system regulation of Fort Peck Lake, Lake Sakakawea, and Lake Oahe; adaptive management/monitoring; and propagation/augmentation of pallid sturgeon through fish culture and stocking.

The Corps requested reinitiation of formal consultation under section 7 of the Endangered Species Act and provided a Biological Assessment in support of that request. The Biological Assessment emphasized that the Corps accepted approximately 95% of the 2000 Biological Opinion. However, the Corps proposed to substitute some specific elements for those in the 2000 Biological Opinion. For example, it proposed to remove the requirements for a spring water rise and low summer habitat flows from Gavins Point Dam. In their place it proposed several actions to minimize impacts to the listed species, including a modified drought conservation plan; a Gavins Point Dam summer release flow test; accelerated construction of shallow water habitat; pallid sturgeon hatchery improvements; accelerated pallid sturgeon brood stock collection; and an adaptive management framework.

In 2003, the U.S. Fish and Wildlife Service (FWS) rendered an amended Biological Opinion for operation of the Missouri River main stem reservoirs. The 2003 amended Biological Opinion took into consideration the 2000 Biological Opinion together with the Corps' proposals and concluded no jeopardy for the least tern and piping plover, but not for the pallid sturgeon. The amended Biological Opinion retained the majority of the measures included in the 2000 Biological Opinion, but incorporated a performance-based approach that allowed the Corps greater flexibility in reaching targeted goals. Among other things, the 2003 Biological Opinion proposed habitat creation and restoration, test rises along the river, and an adaptive management and monitoring programs. Specific measures are included that address spawning cues and habitat improvement for the sturgeon. Additionally, the 2003 Biological Opinion accepted the Corps' rationale behind the lack of Gavins Point Dam flow modifications, and proposed to meet the habitat goals specified in the 2000 Biological Opinion through mechanical creation of sandbars (2,324 acres of emergent sandbar habitat within the 59-Mile District of the MNRR by 2005 and 4,648 acres by 2015) and restoration of existing sandbars through vegetation removal. If the Corps does not implement measures to provide adequate flows and habitat for the three species, the Biological Opinion provides for a specific flow regime.

The Corps of Engineers has started a project that will create two island complexes utilizing hydraulic dredging in the 59-Mile District of the MNRR by July 2005 (Figure 3). The NPS has conveyed to the Corps of Engineers concerns for potential disturbances to the river's values, including free-flowing condition, fish and wildlife, and recreational potential associated with construction activities. The total proposed development of emergent sandbar habitat has the potential to result in active construction (dredging and contour bulldozing) in the MNRR over the next 10 years.

The Corps of Engineers finalized its Environmental Assessment (EA) for the emergent sandbar habitat in July, 2004. The EA did not provide a complete assessment of the cumulative impacts associated with the proposal. Because the two island construction project would be the first of its kind, the Corps of Engineers has indicated it would not be able to predict cumulative impacts associated with the emergent sandbar habitat creation until something had actually been built. However, little baseline inventory of existing conditions or monitoring during or after construction is proposed, except for terns and plovers, but not for aquatic resources, geomorphology, or hydrology. The cumulative effects of multiple and successive dredging/construction projects proposed within a National Wild and Scenic River are of great concern. The Corps of Engineers completion of the EA triggers the NPS to prepare a Section 7(a) determination, pursuant to the Wild and Scenic Rivers Act. The NPS is continuing to work with the Corps of Engineers and FWS to identify solutions that protect the resources under the Department's care, which are compatible with existing laws and policies.

Figure 3. U.S. Army Corps of Engineers sandbar island construction project, Ponca State Park, Missouri National Recreational River, 59-Mile District (Hal Pranger, 2004).

Coordination

The Missouri Basin Inter-Agency Committee (MBIAC) was formed in 1945 as a basinwide governance organization, consisting of representatives from several federal agencies and five governors. The MBIAC was hampered by the lack of a clear legal mandate and it was terminated in the early 1970s. Pursuant to Title II of the 1965 Water Resources Planning Act, the Missouri River Basin Commission (MRBC) was established in 1972 and assumed responsibilities of the former MBIAC. The MRBC developed a management plan, published numerous reports, and established a hydrology model that supported water use monitoring and accounting within the basin and, most importantly, provided a forum for communication and information sharing. Unfortunately, the MRBC was seen as ineffective and terminated in 1981, eliminating one of the important forums for frequent discussions and cooperative activities on Missouri River water management issues.

The Missouri Basin states immediately formed the Missouri Basin States Association (MBSA), which was dissolved in 1988 when the basin states concluded it was not effective in resolving basin conflicts or was peripheral to their interests. The MBSA was reconstituted in 1990 with a new name, Missouri River Basin Association (MRBA), and its membership was expanded to include tribal representation. Eight basin states are currently members of the association (Colorado and Minnesota currently do not participate).

The Missouri River Natural Resources Committee (MRNRC), formed in 1987, is another organization that promotes dialogue on Missouri River management issues. The U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and the U.S. Department of Energy's Western Power Administration are ex officio, non-voting members, and the U.S. Geological Survey, Bureau of Reclamation, and National Park Service are cooperating members.

Federal agencies with Missouri River management and science responsibilities currently meet each year on Missouri River issues under the auspices of a Missouri River Roundtable (see Table 4 for a list of these agencies and responsibilities). Roundtable members have mutually agreed to avoid areas of conflict and focus on areas of cooperation (National Research Council, 2002).

Table 4. U.S. Water Resources Management and Science organization in the Missouri River Basin (modified from National Research Council, 2002).

U.S. Army Corps of Engineers	Responsible for flood-damage reduction activities and navigation-enhancement activities; also involved in ecosystem restoration activities. The Corps constructed and operates six mainstem dams on the Missouri River.
U.S. Bureau of Reclamation	Responsible of water resources development and management activities in 17 western U.S. states. The Bureau constructed and operates the Canyon Ferry Dam on the Missouri River.
U.S. Environmental Protection Agency	Water-related responsibilities include establishing drinking water standards, wastewater management, and wetlands and watersheds. EPA jointly administers (with the COE) the Clean Water Act's Section 404 program. EPA also monitors progress of national programs for total maximum daily load pollutants and for reducing nonpoint source pollution.
Federal Emergency Management Agency	Administers the National Flood Insurance Program, which provides flood insurance to communities that agree to assure that future floodplain structures meet safe standards. FEMA also conducts other flood hazard mitigation, response, and recovery activities.
Federal Energy Regulatory Commission	Responsible for reviewing, relicensing, and decommissioning federally licensed hydroelectric power dams.
U.S. Fish and Wildlife Service	Major responsibilities involve migratory birds, endangered species, freshwater and anadromous fish. A major function is the identification and recovery of endangered species. The Service consults with other federal agencies and renders "biological opinions" on the effects of proposed federal projects on endangered species.
U.S. Forest Service	Manages federal "Wild and Scenic rivers" and manages national forest lands to promote watershed protection.
U.S. Geological Survey	Conducts scientific programs in several areas of water resources, including streamflow gauging, groundwater monitoring, water quality assessments and ecosystem monitoring through its Biological Resources Division.
U.S. National Park Service	Has regulatory and planning responsibilities on National Park Lands, including the Missouri National Recreational River.
U.S. Natural Resources Conservation Service	Promotes land-use management practices aimed toward reducing erosion and promoting conservation. The Service seeks to reduce floods and droughts in the nation's watersheds.
Tribal Governments	Native American tribes have federal public trust rights and responsibilities on their reservations. The Mni Sose organization represents 28 of the Missouri Basin's Native American tribes in basinwide water policy discussions and formulation.
Western Area Power Authority	Markets and delivers hydroelectric power and related services within a 15-state region of the central and western U.S., including most of the Missouri River basin. WAPA markets electricity from Bureau of Reclamation and Corps of Engineers hydropower dams.

Due to the inability of the states and federal government to develop an effective basinwide governance structure, management of the Missouri River is almost exclusively by the U.S. Army Corps of Engineers. Since the Pick-Sloan Plan, the Corps of Engineers has emerged as the Missouri River water master, although the river must be managed in the context of a larger suite of federal, state, and tribal laws. The lack of well-structured, flexible, and updated mechanism for coordinating the current interests of the Missouri River basin states, tribes, federal and state agencies, and nongovernmental parties with stakes in dam and reservoir operations represents a barrier to resolving differences and improving environmental and operational conditions. The inability of basin stakeholders to reach consensus has made it difficult to arrive at an approach to river operations that will meet future needs in the basin. This matter must be addressed in order to restore the Missouri River ecosystem and to produce a broader range of ecosystem benefits formerly provided by the river (National Research Council, 2002).

The National Research Council (2002) states: "Although knowledge of the ecological intricacies within a system as large as the Missouri River ecosystem will always be limited by scientific uncertainties, the system's broad ecological parameters and patterns are currently well understood. Nonetheless, existing studies are only a starting point for future management choices because this extensive body of research has not been adequately synthesized. Further, studies have tended to focus on specific species or portions of the river. Only a few studies of Missouri River ecology view the river as a single system from headwater to mouth, or as a single system that considers biological and physical linkages. *The lack of synthesis and utilization of these scientific data may be as much a function of institutional and political barriers as it is to the limitations of the scientific information itself.* Neither discrete scientific disciplines nor mission agencies have been provided with sufficient incentives to conduct this synthesis and integration. Without this fundamental information, truly comprehensive assessments of the ecological state of the Missouri River are not possible."

According to the National Research Council (2002), the most significant scientific unknowns in the Missouri River ecosystem are how the ecosystem will respond to management actions designed to improve ecological conditions. It is important that ecosystem monitoring programs be designed specifically to produce results that serve as input into river ecosystem recovery programs.

Determining specific goals and objectives for Missouri River management that meet the legislative mandates established by Congress for the MNRR require participation from a wide spectrum of groups with stakes in Missouri River management. Missouri River management actions should be set by a formal multiple-stakeholder group that includes, but not necessarily limited to, the U.S. Army Corps of Engineers, the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. National Park Service, Indian tribes, the Missouri River basin states, floodplain farmers, navigation groups, municipalities, and environmental and recreational groups (National Research Council, 2002).

Adaptive management is a recommended approach for the Missouri River (National Research Council, 2002). Proven in many ecosystem restoration efforts around the country (i.e., Florida Everglades, Columbia River, Colorado River), adaptive management recognizes that scientific uncertainties and unforeseen environmental changes are inevitable. This "trial and error" approach emphasizes the use of carefully designed and monitored projects, based on input from scientists, managers, and citizens, as opportunities to maintain or restore natural systems and to learn more about ecosystems. These actions are monitored for scientific findings to improve understanding of how policy decisions affect ecosystems. An example is found in bank stabilization projects. Each potential bank stabilization project should be evaluated with respect to channel width, reduction in sediment supply from the banks, and the existing stability of the reach (Biedenharn, *et al*., 2001). Due to the data gaps and the stochastic nature of alluvial processes associated with a complex river system such as the Missouri River, a considerable amount of uncertainty is included in any study results. Therefore, the integration process must be accomplished by scientists and others whose knowledge of the system will allow them to temper the results with their experiences in order to develop rational solutions (Biedenharn *et al*., 2001). Findings from ecosystem monitoring are then to be used to appropriately adjust management policies. Adaptive management requires that clear goals and desired outcomes be established so that progress toward desired future conditions can be assured (National Research Council, 2002). One of the major advantages of adaptive management is that it allows managers, with input from science advisors, to implement changes in strategies as we learn over relatively short time periods, rather than having to wait for results from long-term monitoring efforts that can take several years to provide adequate information on trends in a system.

CONSIDERATIONS FOR FUTURE ACTIONS

Given the size and complexity of the Missouri River ecosystem, it is not clear where the point of irrepairable environmental change lies, or how close the Missouri River ecosystem, including MNRR, might be to passing that point (National Research Council, 2002). Strategies for improving ecological conditions in large river systems are relatively new and a clear vision of the future Missouri River basin remains elusive. One thing is clear…degradation of the natural Missouri River ecosystem continues. What does this mean for the National Park Service? The following provides a consolidated list of strategies presented in this report that is a start in the right direction for protecting and preserving MNRR's water resources.

- MNRR is encouraged to develop, in cooperation with stakeholders, a set of clear "desired future conditions" related to water resources. A desired future condition is a planning goal that describes the resource conditions managers are attempting to obtain over a specified period of time. When a desired future condition agrees with current conditions, future management efforts should naturally focus upon maintaining those conditions. If the desired future condition differs from current resource conditions, then management actions will need to focus on moving away from current resource conditions and towards the desired condition. Future NPS General Management Plans are now required to have a list of desired future conditions for the critical natural resources the park unit is to protect and preserve (NPS Park Planning Program Standards).

- Adaptive management is the recommended approach for the Missouri River. This "trial and error" approach emphasizes the use of carefully designed and monitored projects, based on input from scientists, managers, and citizens, as opportunities to maintain or restore natural systems and to learn more about ecosystems. These actions are monitored for scientific findings to improve understanding of how policy decisions affect ecosystems. Findings from ecosystem monitoring are then to be used to appropriately adjust management policies.

  One of the most significant scientific unknowns in the Missouri River ecosystem is how the Missouri River ecosystem will respond to management actions designed to improve ecological conditions. Ecosystem monitoring programs need to be designed specifically to produce results that serve as input into river ecosystem recovery programs. Adaptive management requires that clear goals and desired outcomes be established so that progress toward desired future conditions can be assured.

- We agree with the perspectives of Bayley (1995) and Ligon *et al.* (1995) – for the Missouri River, we cannot gain more useful information without first attempting to restore or at least emulate the natural hydrological regime. Funding for experimental restoration and evaluation should take priority over ecological research.

- Reservoir operations (Lake Francis Case and Lewis and Clark Lake) should be modified to more closely approximate the 1929-1948 flow regime of the Missouri River to establish a simulated natural riverine ecosystem. Ecological structure and function of the inter-reservoir and upper channelized river sections would benefit by controlled flooding through managed reservoir releases during June and July of some years, as well as by increasing the frequency and duration of annual high-flow pulses, and the annual rate of hydrograph rises and falls. All of the regulated Missouri River would receive ecological benefits from reducing reservoir discharges in most, if not all, years from August through February, modifying the timing of releases and reducing the annual number of hydrograph reversals. Assessment of geomorphic and ecological responses to a re-regulation of river flows that more closely approximates the natural flow regime should then be used in an adaptive fashion to further adjust reservoir operations.

  It should be noted that the water in a more natural flow regime for the Missouri River would still be 'hungry' for sediment. Each reservoir has a predicted storage life. If entrapped sediment could somehow be moved from each reservoir into both segments of MNRR, the storage life of each reservoir would be extended. More importantly, it could add to the sediment load being carried by the river below the dams. This, in turn could reduce the amount of degradation in the free-flowing reaches and contribute organic matter to downstream habitats. A reduction in the amount of degradation would increase the backwater and subsidiary channel habitats that were lost due to degradation. Such habitats are believed to be an important source of autochthonous primary and secondary production for these river segments.

  Strategies that ultimately remove the sediments that continue to accumulate behind the Ft. Randall and Gavins Point dams should be developed and implemented. Delaying this action will increase the complexity of this growing maintenance need.

- Since the net navigation benefits are relatively small in total and because waterway traffic volumes decrease moving upstream, an incremental analysis of the economics of retaining segments for the navigable waterway is recommended. MNRR should support efforts that work toward this objective.

- In order to improve the state of the MNRR ecosystem, some degree of Missouri River meandering must be restored. This would require a much wider channel corridor in some areas than currently exists.

- Each bank stabilization project should be evaluated in detail. Bank stabilization measures that would reduce the channel width should be carefully considered to minimize impacts to sand bar and island development. If the channel width is near the threshold range, below which the persistence of bars are unlikely (e.g., 500 m (1640 ft) for the 59-Mile District), then the reach might be considered very sensitive to relative small width changes with respect to the channel width. The overall stability of the reach is another factor that should be considered when evaluating a bank stabilization project. Response to a reduction in sediment supply from the banks may be different in an aggradational reach than in a degradational reach. If the reach is already degradational, then the reduction in sediment supply from a stabilization project would simply compound the degradational trends.

- For managing the Missouri River floodplain, greater emphasis should be focused on non-structural solutions, including the acquisition and restoration of wetlands. Avoid inappropriate use of floodplains, minimizing vulnerability to damage through both structural and non-structural means. Flood damage could be reduced significantly by allowing the river to wander in selected parts of the original floodplain, thereby releasing its force and spreading itself at flood stage. Public education will be an important component, defining the river and floodplain function needs for adequately managing the Missouri River.

- A number of agencies have monitored or are monitoring water quality within the MNRR. Compiling a complete updated inventory of water monitoring stations located in MNRR is needed, building from the National Park Service (1998) report, *Baseline Water Quality Data Inventory and Analysis* report for MNRR, located online at http://www.nature.nps.gov/water/horizon.htm. Current information about monitoring sites with MNRR can be found online at the websites provided in Table 3 of this report. From this exercise, MNRR can begin the steps for implementing its current proposal, "Assessment of Surface Water Quality of the MNRR" (PMIS 74282). The objective of this proposal is for the U.S. Geological Survey to develop a surface water quality data set of the MNRR for the NPS.

  In general, the availability of data to define spatial and temporal patterns in water quality throughout the 59-mile segment is lacking. The Corps of Engineers recommends a 2-3 year monitoring project that would collect monthly water samples from April through October of each year at five locations within the 59-Mile District. This monitoring project is still inadequate for characterizing spatial and temporal variations in the 59-Mile District.

- The NPS should be active in the Missouri River Natural Resources Committee (MRNRC) that promotes dialogue on Missouri River management issues. The inability of basin stakeholders to reach consensus has made it difficult to arrive at an approach to river operations that will meet future needs in the basin. This matter must be addressed in order to preserve the Missouri River ecosystem and to produce a broader range of ecosystem benefits formerly provided by the river. Missouri River management actions should be set by a formal multiple-stakeholder group that includes, but not necessarily limited to, the U.S. Army Corps of Engineers, the U.S. Department of Energy, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. National Park Service, Native American tribes, the Missouri River basin states, floodplain farmers, navigation groups, municipalities, and environmental and recreational groups.

- Studies have tended to focus on specific species or portions of the river, but have not been integrated to address complex ecosystem management issues, making decisions more difficult. Poff *et al.* (2003) suggest new techniques (Hobbs *et al*., 2002; Reckhow, 1999) that hold promise for integrating disconnected studies to guide ecosystem management. More large-scale studies on the Missouri River are needed, which view the river as a single system that considers biological and physical linkages. The MNRR should support efforts such as the MRNRC's cooperative partnership, *Missouri River Environmental Assessment Program*, to identify cost-effective approaches to conserving and restoring the Missouri River's fish and wildlife populations, while maintaining current benefits provided to residents of the Missouri River basin. The MRNRC has undertaken a project to assess conditions of the Missouri River through biomonitoring. MNRR supports this effort (PMIS 75503), which includes fishery, invertebrate and water quality sampling, along with some physical parameter sampling, within the boundaries of MNRR.

- It is reasonable to believe that natural carbon and nutrient cycling in the Missouri River system have been changed enough to limit production of fish biomass, and to have contributed to dramatic declines in the abundance of native species. The best alternative for restoration of organic matter dynamics is recovery of a semblance of the natural hydrograph. An interim solution might be to utilize supplies of large trees, grass and leaves collected from urban environments as a supplement to the river. If selected, this interim solution should be carefully administered to minimize potential water quality impacts. Grass and plant material from urban environments are often treated with fertilizers and pesticides, thus the potential to introduce toxic substances into the aquatic environment might exist. A proposal, unfunded, that fits an adaptive management program, would be the snag and organic matter enrichment project proposed by River Ecosystems, Inc. in the mid-1990s. This proposal offers the opportunity to explore solutions to the past removal of large woody debris and the reduction in carbon cycling.

- A legal opinion on the interpretation of the MNRR legislation is needed. Basin stakeholders, including the National Park Service, then need to acknowledge specific roles and responsibilities.

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APPENDIX A

WATER RESOURCE ISSUES SCOPING WORKSHOP SUMMARY
June 14, 2004
1:00 pm - 5:00 pm

Participants: George Berndt (MNRR), Sue Braumiller (NPS-IMRO/MWRO), Paul Hedren (MNRR), Dugan Smith (MNRR), Dave Tunink (NGPC), David Vana-Miller (NPS-WRD), Don Weeks (NPS-WRD), Wayne Werkmeister (MNRR), and Gene Zuerlein (NGPC)

Summary of Issues, listed by common themes, generated during the workshop

1. Floodplains/Riparian

- Encroachment by humans into the floodplain and riparian (agriculture, permanent and seasonal homes)

- Degradation of Missouri River. 59-mile section of river has dropped up to 14 feet since dam built. 39-mile section is aggrading at Niobrara.

- Sedimentation. Dam restricts sediment budget. USCOE says that 55% of sediment in 39-mile section comes from Niobrara River.

  Senator Nelson's office studying flushing as a possible solution.

  USGS studying geomorphology and looking at floodplains and riparian environments along the Missouri River.

  Terns and plovers require sediment budget to maintain river island habitat…current flows restrict island building. Continued stabilization puts sediment budgets into question..

- Unnatural hydrograph. Gavins Point Dam: primarily, navigation drives the dam releases…removal of peak discharges that penetrate floodplains..

  Ft. Randall has more peaks that are demand driven.

  NPS need to address the rivers needs in a way that allows NPS to weigh more heavily in management of Missouri River.

- Restore sinuosity to tributaries as they enter Missouri River…several straighten in the past.

- Restoration. Nearly all ownership in NPS boundary is private which is a big obstacle to restoration. Private ownership almost 100%.

- Exotic species: purple loosestrife, salt cedar, leafy spurge, Russian olive, thistles.

- WSRA only gives authority for what's in boundary so for watershed impacts/restoration need to broaden cooperation/communication.

- Bank stabilization (rock, junk cars, concrete, wood) impacting riparian zone.

- ❖ Changes in water table due to aggradation and degradation of riverbed possible contribution to problem.

  Cottonwood regeneration problem on floodplain.

  Changing dynamics of vegetation communities in floodplain (i.e., invasion of red cedars)

- ❖ Windbreaks (bring in non-native species).

- ❖ Education: Impacts from nitrates and phosphates, herbicides. Impacts downstream, especially nitrates and phosphates to the Gulf of Mexico.

2. **Water Quality**

- ❖ Agricultural runoff (sedimentation and chemicals)…nitrogen big problem in Verdigris -- has 20 ppm NO_3.

- ❖ Dam influences.
  Water temperature influences from dam releases.
  Lack of sedimentation (turbidity)

- ❖ Water quality monitoring

  Nebraska vs South Dakota in water quality standards.
  USCOE monitors at dam.
  USGS has water quality monitoring stations.
  Nebraska does not monitor Missouri River, but South Dakota may monitor.
  No coordination of water quality monitoring along Missouri River.

- ❖ Do cities along the river backflush sewer systems with chlorine? Niobrara and Yankton release treated sewage into Missouri River.

- ❖ Sediment toxicity monitoring proposed.

- ❖ Development: Septic tanks from individual properties...is this a water quality problem in high density development areas?

- ❖ Tributaries: Feed lots may contribute to water quality problems.

- ❖ Reduction in buffer strips (natural riparian areas) may increase water quality problems in the Missouri River.

3. Water Rights

- ❖ Irrigation water rights

- ❖ American Indians have not yet quantified their water rights.

- ❖ USFWS hatchery with water use.

- ❖ Yankton et al.-- drinking water source is the Missouri River.

- ❖ South Dakota and Nebraska differ on ownership of riverbed: Nebraska - adjacent landowner for accretion lands. South Dakota – is state-owned.

- Nebraska is changing laws (water rights): Bill LB962-DNR.

4. Visitor Use and Recreation

- Visitor Use Surveys

  2004: 59-mile reach survey (included in larger study from Gavins Point to St. Louis).

  NPS/Nebraska cooperative visitor use survey 3 years ago

- Loss economy due to loss of multiple uses (i.e., loss of fish habitat).

- Public needs education on the effects of different water flows.

- Fishing: sauger walleye, channel/blue/flathead cat, northern, crappie, carp, buffalo, sturgeon, suckers, etc. – some reaches smallmouth/largemouth bass

  Paddlefish (59-mile reach): 1 month (Oct) snag season, 3 weeks (July) archery season…know that spawning occurs in mouth of Niobrara.

  Invasives = Asian Carp (grass, bighead, silver)

  Commercial fishing below Gavins Point (59-mile reach)

- Hunting: duck blinds left year round, placing loosestrife on boats for blinds, hunting on sandbars.

- Lewis & Clark 200 year anniversary…big visitor use event.

- Boy Scouts base camp: national advertisement to come to the Missouri River

- Commercial fishing below Gavins Point (59-mile reach).

- State Parks within boundary: Ponca and Niobrara in Nebraska and Randall Creek in South Dakota

5. Groundwater

- Lower 39-mile reach: dam backed sediment (large input from Niobrara River) and raised water table. Evidence of dead cottonwood trees in area.

- Accumulative impacts of groundwater withdrawal…inventory.

6. T&E Species

- Pallid sturgeon – present in both MNRR sections…Gavins Point hatchery raises pallid sturgeons.

  Recovery plan
  Monitoring plan
  USCOE contact: Mark Droubish
  Park contact: Stephen K. Wilson

- State Threatened Species

  Lake Sturgeon

Sticklefin and Sturgeon chubs
LARS – 10 years old
Need to check South Dakota for state threatened species.

- Check GMP for sensitive mollusks.
- Terns, plovers and eagles.
- Need to review 2000 Biological Opinion and 2003 Amendment to Biological Opinion.
- Loss of bird habitat in both MNRR sections (lack of natural hydrograph). Vegetation is encroaching in sandy reproductive habitat.
- Birds and bird habitat on Niobrara
- Eagles nest on old cottonwoods, which are dying out. What will they nest on in the future? Riverside park…fireworks may disturb eagles before fledging.
- Macroinvertebrates: not much development due to riverbed dynamics.
  Becky Latka (USCOE) – see about macroinvertebrate studies (check COE website).
- Fish in 39-mile section seem to have health issues.
- Just talking about bioassessments in water quality.
- MRNRC – Bibliographies
- Lack of organic matter entering Missouri River due to regulated flows (no flooding of floodplains)

7. **Exotics**

- Asian Carp in 59-mile section (silver and bighead). Young of year not observed for this species.
- Rainbow and Brown trout stocked in tailwaters of Ft. Randall Dam.
- Zebra mussels (2003) in both sections – veliger only so far.

8. **Spill Management**

- NPS not connected to a spill management plan for the area.

9. **Coordination**

- Missouri River NR Committee
- Missouri River Basin Association
- Missouri River Bank Stabilization Association
- ACT (Fed Agency re: endangered species input for Master Plan).
- USCOE, USFWS, USEPA, DEQ, DNR, NRD, USGS, Congressionals, RC&D
- 2 states (Nebraska/South Dakota), 13 counties

- Santee Reservation: they own paddlefish permits for Missouri River but do not communicate with state (issue: potential overexploitation).

10. **Wetlands**

    - Need diversity in specific areas

    - Wetlands inventory

    - Degradation of wetlands in specific areas

11. **Niobrara River**

    - Dam removal. (Spencer)

    - Water quality monitoring need to evaluate sluicing operations at dam.

Note: Wild and Scenic Rivers Act - define at beginning of report.

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

MNRR D-20, March 2005