US Army Corps of Engineers

Northwestern Division
Missouri River Basin
Water Management Division

Missouri River Mainstem Reservoir System

System Description and Regulation

November 2007

MISSOURI RIVER MAINSTEM RESERVOIR SYSTEM

System Description and Regulation

TABLES

FIGURES

PLATES

ABBREVIATIONS

AOP	-	annual operating plan
ACHP	-	Advisory Council on Historic Preservation
BiOp	-	Biological Opinion
cfs	-	cubic feet per second
Corps	-	Corps of Engineers
CY	-	calendar year (January 1 to December 31)
elev	-	elevation
ESA	-	Endangered Species Act
ft msl	-	feet above mean sea level
FTT	-	Flow-to-Target
FY	-	fiscal year (October 1 to September 30)
KAF	-	1,000 acre-feet
kcfs	-	1,000 cubic feet per second
kW	-	kilowatt
kWh	-	kilowatt hour
Master Manual	-	Missouri River Mainstem Reservoir System Master Water Control Manual
MAF	-	million acre-feet
MRBWMD	-	Missouri River Basin Water Management Division
MRNRC	-	Missouri River Natural Resources Committee
msl	-	mean sea level
MW	-	megawatt
MWh	-	megawatt hour
NPDES	-	National Pollutant Discharge Elimination System
plover	-	piping plover
ppm	-	parts per million
PA	-	Programmatic Agreement
P-S MBP	-	Pick-Sloan Missouri Basin Program
RCC	-	Reservoir Control Center
RPA	-	Reasonable and Prudent Alternative
System	-	Missouri River Mainstem Reservoir System
SHPO	-	State Historic Preservation Officers
SR	-	Steady Release
SR-FTT	-	Steady Release – Flow-to-Target
tern	-	interior least tern
T&E	-	Threatened and Endangered
THPO	-	Tribal Historic Preservation Officers
TLR	-	Transmission Loading Relief
USBR	-	United States Bureau of Reclamation
USFWS	-	United States Fish and Wildlife Service
USGS	-	United States Geological Survey
WAPA	-	Western Area Power Administration

DEFINITION OF TERMS

Acre-foot (AF, ac-ft) is the quantity of water required to cover 1 acre to a depth of 1 foot and is equivalent to 43,560 cubic feet or 325,850 gallons.

Cubic foot per second (cfs) is the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and is equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute. The volume of water represented by a flow of 1 cubic foot per second for 24 hours is equivalent to 86,400 cubic feet, approximately 1.983 acre-feet, or 646,272 gallons.

Discharge is the volume of water (or more broadly, volume of fluid plus suspended sediment) that passes a given point within a given period of time.

Drainage area of a stream at a specific location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the river above the specified point. Figures of drainage area given herein include all closed basins, or noncontributing areas, within the area unless otherwise noted.

Drainage basin is a part of the surface of the earth that is occupied by drainage system, which consists of a surface stream or body of impounded surface water together with all tributary surface streams and bodies of impounded water.

Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.

Runoff in inches shows the depth to which the drainage area would be covered if all the runoff for a given time period were uniformly distributed on it.

Streamflow is the discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Storage is the amount of water stored in the System or in any individual reservoir project at a given time.

Storage capacity is the volume of water that can be stored in the System or any individual reservoir project.

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MISSOURI RIVER MAINSTEM RESERVOIR SYSTEM

System Description and Regulation

I. FOREWORD

This report presents a summary of pertinent data and a description of the Missouri River Mainstem Reservoir System (System) and discusses the regulation of the System to serve the Congressionally authorized project purposes. The Missouri River Basin Water Management Division (MRBWMD), located in Omaha, Nebraska, directs the regulation of the System to serve the Congressionally authorized project purposes of flood control, navigation, hydropower generation, irrigation, water supply, water quality control, recreation, and fish and wildlife. The combined storage capacity of the six mainstem dams, 73.3 million acre-feet (MAF), makes it the largest reservoir system in North America. The System is regulated using guidelines published in the Missouri River Mainstem Reservoir System Master Water Control Manual (Master Manual). The Master Manual presents a highly technical description of the water control plan and operational objectives for the integrated regulation of the System. The purpose of this document is to provide a less technical discussion of the regulation of the System under the Master Manual guidelines. In the event substantive differences exist between this document and the Master Manual, the Master Manual takes precedence unless specifically noted.

The Master Manual, which was first published in 1960 and subsequently revised during the 1970's, was revised in March 2004 to include more stringent drought conservation measures and again in March 2006 to include technical criteria for a spring pulse from Gavins Point Dam to benefit endangered species. The System is currently regulated for three species protected under the Endangered Species Act (ESA): the endangered interior least tern, the threatened piping plover, and the endangered pallid sturgeon. The 2004 revision of the Master Manual represented the culmination of a review that began in 1989 during the first major drought the Missouri River basin experienced since the System first filled in 1967. The purpose of the study was to identify a water control plan that would serve the Congressionally authorized project purposes, comply with current environmental laws, and meet the Corps' trust and treaty obligations to the Federally recognized Tribes. The 2006 revision of the Master Manual was a result of the U.S. Fish and Wildlife Service's (USFWS) 2003 Amendment to the 2000 Biological Opinion on the Operation of the Missouri River Main Stem Reservoir System, Bank Stabilization and Navigation Project, and the Kansas River Reservoir System (2003 Amended BiOp). The 2003 Amended BiOp presented the USFWS's opinion that the regulation of the System would jeopardize the continued existence of the endangered pallid sturgeon. The 2003 Amended BiOp provided, among other things, a Reasonable and Prudent Alternative (RPA) to jeopardy that included a provision for the Corps to develop a bimodal "spring pulse" from Gavins Point Dam. In March 2006, the Master Manual was revised to include technical criteria for a bimodal spring pulse from Gavins Point Dam.

An Annual Operating Plan (AOP) is developed each year that presents forecasts of the System regulation for the upcoming year to serve the authorized purposes under varying hydrologic conditions. A draft AOP is prepared by the Reservoir Control Center (RCC), part of the MRBWMD, and circulated for public review by October of each year. Public meetings are generally held in October, and, after consideration of Tribal and public comments, a final AOP is published in the December-January timeframe. Spring public meetings are conducted to provide an update on the current hydrologic conditions and projected System regulation for the remainder of the year as it relates to implementing the Final AOP.

Regulation plans developed in the AOP may require adjustments to respond to substantial departures from expected runoff occur; to meet emergencies including short-term intrasystem adjustments to protect human health and safety; to prevent loss of historic and cultural properties; or to meet the provisions of applicable laws, including the ESA. These adjustments would be made to the extent possible after evaluating impacts to other System uses, would generally be short-term in nature, and would continue only until the issue is resolved.

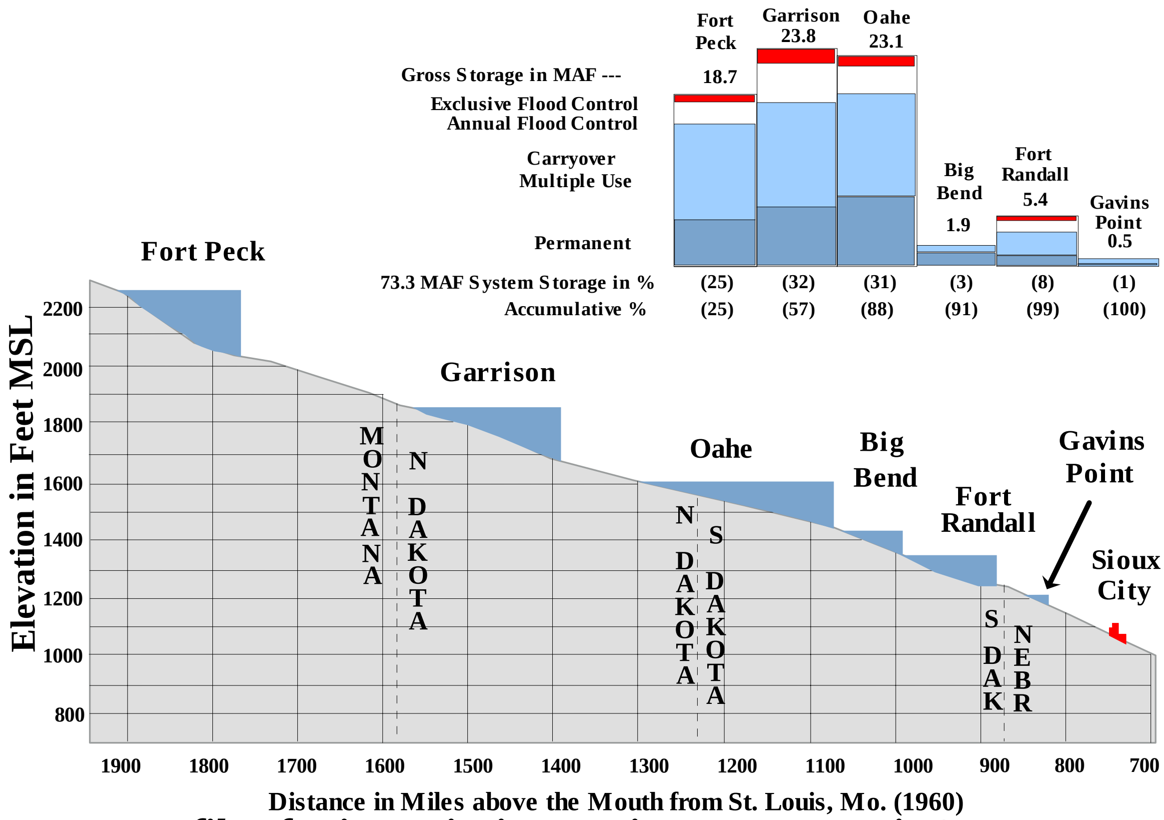
Under the terms of Stipulation 18 of the March 2004 "Programmatic Agreement for the Operation and Management of the Missouri River Main Stem System for Compliance with the National Historic Preservation Act, as amended" (PA), the Corps has agreed to consult/meet with the affected Tribes and Tribal Historic Preservation Officers (THPO's), State Historic Preservation Officers (SHPO's), the Advisory Council on Historic Preservation (ACHP), and other parties regarding the draft AOP. The purpose of this consultation/meeting is to determine whether operational changes are likely to cause changes to the nature, location, or severity of adverse effects to historic properties or to the types of historic properties affected and whether amendments to the Corps' Cultural Resources Management Plans and Five-Year Plan are warranted in order to better address such effects to historic properties.

II. DESCRIPTION OF MISSOURI RIVER BASIN AND MISSOURI RIVER

A. Basin Geography.

The Missouri River basin has an area of 529,000 square miles, including about 9,700 square miles located in Canada. The basin spans 10 states, including all of Nebraska; most of Montana, Wyoming, North Dakota, and South Dakota; about half of Kansas and Missouri; and smaller parts of Iowa, Colorado, and Minnesota. The Missouri River is the longest river in North America extending 2,321 miles from Three Forks, Montana to the mouth near St. Louis, Missouri, and 2,619 miles from the utmost source to the mouth. A map of the Missouri River basin identifying the major mainstem and tributary Corps civil works projects and certain Bureau of Reclamation projects is shown on **Plate 1**. A summary of engineering data for the six mainstem projects is shown on **Plate 2**. **Figure 1** shows a profile of the mainstem projects, including the elevations of the projects and locations in river miles above the mouth of the Missouri River near St. Louis. **Figure 1** also displays the relative proportion of storage capacity in each of the projects.

Figure 1
Profile of Mainstem System and Storage Capacities



Profile of Missouri River Mainstem Reservoir System

Basin topography varies from the 56,000 square-mile Rocky Mountain area in the West where many peaks exceed 14,000 feet in elevation, to the approximately 370,000 square-mile Great Plains area in the heartland of the basin, to the 90,000 square-mile Central Lowlands in the lower basin where the elevation is 450 feet above mean sea level (feet msl) near the mouth at St. Louis, Missouri. The Black Hills in South Dakota and the Ozarks in Missouri are isolated domelike uplifts that have been eroded into a hilly and mountainous topography. Stream slopes vary from about 200 feet per mile in the Rockies to an average of a foot per mile along the Missouri River as it flows through the Great Plains and Central Lowlands.

Several major Missouri River tributaries are shown on **Plate 1**. They are the Yellowstone River, which drains an area of over 70,000 square miles, and joins the Missouri River near the Montana-North Dakota boundary; the Platte River, with a 90,000 square-mile drainage area entering the Missouri River in eastern Nebraska; and the Kansas River, which empties into the Missouri River in eastern Kansas and drains an area of approximately 60,000 square miles. A prominent feature in the drainage pattern of the upper portion of the basin is that every major tributary, with the exception of the Milk River, is a right bank tributary flowing to the east or to the northeast. Only in the extreme lower basin below the mouth of the Kansas River, is a fair balance reached between left and right bank major tributaries. The direction of flow of the major tributaries is of particular importance from the standpoint of potential concentration of flows from storms that typically move across the basin in an easterly direction. It is also important in another respect on the Yellowstone River, since early spring temperatures in the headwaters of the Yellowstone and its tributaries are normally from 8 to 12 degrees Fahrenheit higher than along the northern most reach of the Missouri near the Yellowstone confluence. This ordinarily results in ice breakup on the Yellowstone prior to the time the ice goes out of the Missouri River, thereby contributing to ice jam floods along the Missouri River downstream from its confluence to near Williston, North Dakota.

B. Climatology.

The Missouri River basin's broad range in latitude, longitude, and elevation and its location near the geographical center of the North American continent result in a wide variation in climatic conditions. The climate of the basin is produced largely by interactions of three great air masses that have their origins over the Gulf of Mexico, the northern Pacific Ocean, and the northern polar regions. These air masses regularly invade and pass over the basin throughout the year, with the Gulf air tending to dominate the weather in summer and the polar air dominating in winter. This seasonal domination by the air masses and the frontal activity caused by their collisions produce the general weather regimens found within the basin. As is typical of a continental-interior plains area, the variations from normal climatic conditions from season to season and from year to year are extreme. The outstanding climatic rarity in the basin was the severe drought of the 1930's, when excessive summer temperatures and below-normal precipitation continued for more than a decade.

Average annual precipitation ranges from as low as 8 inches just east of the Rocky Mountains to about 40 inches in the southeastern part of the basin and in parts of the Rocky Mountains at higher elevations. Prolonged droughts of several years' duration and frequent shorter periods of deficient moisture, interspersed with periods of abundant precipitation, are characteristic of the plains area. The normal seasonal maximum precipitation is observed throughout the basin during the spring and early summer months. Precipitation during the late summer and fall months is usually from short-duration thunderstorms with small centers of high intensity, although widespread general rains do occasionally occur, especially in the lower basin. Winter precipitation generally occurs in the form of snow in the northern and central portions of the basin, and as rain or snow or a mixture of both in the lower basin states. Average annual snowfall ranges from 20 inches in the lower basin to 30 inches in the eastern Dakotas to near 50 inches in the high plains areas in the West. High elevation stations in the Black Hills and in the Rockies along the western edge of the basin receive in excess of 100 inches of snowfall. Following the winter season, snow depths of up to 6 feet with a water equivalent of 2 feet are not uncommon at mountain locations. Snow does not usually progressively accumulate over the plains but is melted by intervening thaws. However, there have been exceptions over the northern plains when snow that accumulated on the ground throughout the winter had a water equivalent of 6 inches or more.

Due to its mid-continent location, the basin experiences temperatures noted for wide fluctuations and extremes. Winters are relatively long and cold over much of the basin, while summers vary from mild to hot. Spring is normally cool, humid, and windy; autumn is normally cool, dry, and fair. The basin experiences temperatures above 100 degrees Fahrenheit in summer and below -20 degrees Fahrenheit in winter.

C. **Water Supply.**

Records of monthly flows and their distribution above Sioux City, Iowa are available for the period 1898 to date. During this period, there has been a substantial growth in the development of water related resources in the Missouri River basin. Because this growth is expected to continue, it is necessary to adjust flows to a common development level for comparative purposes. While selection of a particular level of depletion is rather arbitrary, computations are facilitated by selection of a base level that is relatively recent yet prior to major development. This allows the effects of the development on resultant stream flows to be readily quantifiable on an annual and monthly basis. The base level of 1949 meets these criteria because it represents a base prior to the accelerated water resource development that occurred in the basin during the 1950's. Therefore, records accumulated prior to and since 1949 have been adjusted to the 1949 level of depletion for comparative purposes. Required flow adjustments to reflect this base level are discussed later in this section.

1. Runoff. On average 23 percent of the annual water supply above Sioux City, Iowa is received in the months of March and April as a result of plains snowmelt augmented by early spring rains. Roughly 48 percent of the annual runoff comes in the months of May, June, and July as a result of the melt of the mountain snowpack augmented by late spring and summer rains. Runoff varies widely from year to year but averages 25.2 million acre-feet (MAF) annually above Sioux City. Records dating back to 1898 indicate runoff has varied from a high of 49.0 MAF in 1997 to a low of 10.7 MAF in 1931. In this 109-plus year period, the basin has experienced four periods of significant drought, including the record 12-year drought from 1930 to 1941, the 8-year drought from 1954 to 1961, the 6-year drought that began in 1987 and ended abruptly with the flood of 1993, and the more recent drought that began in 2000 and is ongoing, making it the longest drought since the System first filled in 1967.

The draft AOP is developed each year in August using August 1st as the initial conditions. Runoff into the six System reservoirs is typically low and relatively stable during the period from August to February. Therefore, the August runoff forecast, covering the period from August 1st to the end of February, is used as input to the "Basic" reservoir regulation simulation. Two other runoff scenarios based on the August runoff forecast are developed for the same period. These are the 80 percent and 120 percent of the August runoff forecast, which are input to the 80 percent and 120 percent of Basic reservoir regulation simulations.

For the following runoff year, March 1st to the end of February, the regulation studies use five statistically derived inflow scenarios based on an analysis of historic water supply records from 1898 to 1997. This approach provides a good range of simulation for dry, average, and wet conditions, and eliminates the need to forecast future precipitation.

The five statistically derived inflows are identified as the Upper Decile, Upper Quartile, Median, Lower Quartile and Lower Decile runoff conditions. Upper Decile runoff (34.5 MAF) has a 1 in 10 chance of being exceeded, Upper Quartile (30.6 MAF) has a 1 in 4 chance of being exceeded, and Median (24.6 MAF) has a 1 in 2 chance of being exceeded. Lower Quartile runoff (19.5 MAF) has a 1 in 4 chance of the occurrence of less runoff, and Lower Decile (15.5 MAF) has a 1 in 10 chance of the occurrence of less runoff. There is still a 20 percent chance that a runoff condition may occur that has not been simulated; i.e., a 10 percent chance that actual runoff could be lower than Lower Decile, and a 10 percent chance that actual runoff could be greater than Upper Decile.

The Upper Decile and Upper Quartile simulations extend from the end of the 120 percent of Basic simulation. Likewise, the Median simulation extends from the end of the Basic simulation, and the Lower Quartile and Lower Decile simulations extend from the end of the 80 percent of Basic simulation.

2. Upstream Effects. Not all of the runoff from the drainage basin is available for storage in the reservoirs or release for downstream purposes. Some is lost by evaporation, some is intercepted and depleted for agricultural, municipal or industrial uses, and some runoff is regulated by upstream reservoirs.

a. Evaporation Losses. The System reservoir evaporation losses vary in magnitude and are calculated as the net losses that occur when precipitation on the reservoir surface is considered. Since there is a great variation in precipitation from year to year and the surface area of a particular project at its maximum operating level can be more than double the surface area at minimum pool levels, these losses may vary widely from day to day and year to year. In general, the sum of evaporation losses at the six projects has averaged approximately 2 MAF per year. In accounting for past regulation, evaporation losses are based on observed conditions at the projects and are dependent on the actual surface area of the reservoirs and prevailing weather conditions. The amount of evaporation used for forecasted regulation of the System is based on average meteorological conditions and the forecasted variations in surface area of the reservoirs.

b. Depletions. As mentioned previously, the year 1949 is the base level of development against which changes from the natural water supply are estimated. In comprehensive basin planning studies, the U.S. Bureau of Reclamation (USBR), in cooperation with other interested Federal and state agencies in the basin, has made detailed investigations of the various developments that affect the natural streamflow within the basin. Some of these developments deplete water, others accrete water, while others merely rearrange the natural supply. These developments include surface water irrigation, ground water irrigation and its effects on surface water supplies, municipal and industrial supplies, watershed treatment, rural domestic and livestock uses, tributary reservoirs, recreation lakes and stock ponds, evaporation from man-made ponds and reservoirs, and forestry practices. These studies indicate that the depletions above Sioux City, Iowa resulting from all developments and water uses at the 1949 level averaged about 3.8 MAF annually. Developments since 1949 have resulted in additional depletions currently averaging approximately 1.2 MAF annually, exclusive of mainstem reservoir evaporation, for a total of 5 MAF.

c. Upstream Reservoirs. Regulation of the streamflow by the upstream tributary reservoirs affects the regulation of the System. The most significant upstream projects are the USBR's Clark Canyon, Canyon Ferry, and Tiber reservoirs above Fort Peck, and Boysen and Yellowtail reservoirs above Garrison. Their regulation may increase or decrease inflows to the downstream System reservoirs over an extended period. The influence of these projects on the System during the year ahead is estimated from forecasts provided by the USBR. The extent of tributary reservoir impacts depends on current System storage and the magnitude of the water supply.

D. Mainstem and Tributary Streamflow Characteristics.

Streams having their source in the Rocky Mountains are fed by snowmelt. They are clear flowing and have steep gradients with cobble-lined channels. Stream valleys often are narrow in the mountain areas and widen out as they emerge from the mountains onto the outwash plains. Flood flows in this area are generally associated with the snowmelt runoff period occurring in May and June. Occasionally, summer rainfall floods with high, sharp peaks occur in the lower mountainous areas, such as the Big Thompson River flood in July 1976 and the Rapid City (Rapid Creek) flood in June 1972.

Streams flowing across the plains area of Montana, Wyoming, and Colorado have variable characteristics. The larger streams with tributaries originating in the mountain areas carry sustained spring and summer flows from mountain snowmelt, and they have moderately broad alluvial valleys. Streams originating locally often are wide, sandy-bottomed, intermittent, and subject to high peak rainfall floods.

Streams in the plains region of North and South Dakota, Kansas, and Nebraska, with the exception of the Sandhills area, generally have flat gradients and broad valleys. Except for the Platte River, most of the streams originate in the plains area and are fed by snowmelt in the early spring and rainfall runoff throughout the warm season. Streamflow is erratic. Stream channels are small for the size of the drainage areas, and flood potentials are high. When major rainstorms occur in the tributary area, streams are forced out of their banks onto the broad flood plains.

Streams in the regions east of the Missouri River have variable characteristics. Those in the Dakotas, such as the Big Sioux and James Rivers, are meandering streams with extremely flat gradients and very small channel capacities in relation to their drainage areas. These areas are generally covered with glacial drift and contain many pothole lakes and marshes. Rainfall in the spring often combines with the plains snowmelt to produce floods that exceed channel capacities and spread onto the broad flood plains.

Streams in the Ozark Highlands of Missouri resemble mountain streams with their clear, dependable base flows. Much of the area is underlain by limestone, and there are cavernous underground springs. The hilly terrain produces high peak runoff, which contributes to frequent floods with large volumes due to this area's higher annual rainfall.

Regulation provided by the System reservoirs and by upstream tributary reservoirs has greatly reduced flood flows on the Missouri River from Fort Peck Dam downstream to the mouth of the Platte River below Omaha, Nebraska. Critical stages can be reached for a short time below the upper three System reservoirs during the winter freeze-up of the Missouri River. During this period, key locations are frequently monitored so that reservoirs can be regulated to prevent localized flooding. From Sioux City to the mouth of the Platte River, damaging floods are still possible, but their frequency of occurrence has been greatly reduced by the System. Below the Platte River to the mouth near St. Louis, the incremental drainage area is of sufficient size that above-bankfull stages can be expected to occur frequently as a result of flood runoff from major storms over the tributary areas, although significant stage reductions due to System regulation will usually occur.

III. MAINSTEM RESERVOIR SYSTEM

A. System Description.

The six Corps dams spanning the Missouri River control runoff from approximately half of the basin. Those six dams, from the upper three giants of Fort Peck in eastern Montana, Garrison in central North Dakota and Oahe in central South Dakota, to the lower three smaller reservoirs of Big Bend and Fort Randall in South Dakota, and Gavins Point along the Nebraska-South Dakota border, comprise the largest system of reservoirs in the United States. Four of the System reservoirs were named by the Congress: Lake Sakakawea (Garrison Dam); Lake Sharpe (Big Bend Dam); Lake Francis Case (Fort Randall Dam); and Lewis and Clark Lake (Gavins Point Dam).

The combined storage capacity of all six System reservoirs is 73.3 MAF, about three times the annual runoff into the System above Sioux City. This high ratio of storage capacity to runoff lends an unusual degree of flexibility to the regulation of the multipurpose reservoir system. In contrast, the ratio of reservoir storage capacity to annual runoff in the Columbia and Ohio River basins is 1:5, approximately one acre-foot of storage for each five acre-feet of annual runoff.

The storage capacity of the six individual reservoirs ranges from over 23 MAF at Garrison and Oahe, to less than 0.5 MAF at Gavins Point as shown in **Table 1**. The System is also unique in the fact that 88 percent of the combined storage capacity is in the upper three reservoirs of Fort Peck, Garrison, and Oahe. As a result, these three projects experience the bulk of the impacts during periods of very high runoff or extended drought. The lower three projects, Big Bend, Fort Randall, and Gavins Point, are regulated in much the same manner year after year regardless of the runoff conditions.

Table 1
Reservoir Storage Capacities
(MAF)

Project	Storage Capacity
Fort Peck	18.688
Garrison	23.821
Oahe	23.137
Big Bend	1.798
Fort Randall	5.418
Gavins Point	0.470
Total System	73.332

The System storage capacity is divided into four unique storage zones for regulation purposes, as shown in **Figure 2**. Information on the unique storage zones for each of the six individual reservoirs is provided on **Table 2**. Other pertinent data for all projects are presented in the Summary of Engineering Data shown on **Plate 2**. The bottom 25 percent of the total System storage capacity comprises the permanent pool designed for sediment storage, minimum fisheries, and minimum hydropower heads. The largest zone, comprising 53 percent of the total storage capacity, is the carryover-multiple use zone which is designed to serve all project purposes, though at reduced levels, through a severe drought like that of the 1930's.

The annual flood control and multiple use zone, occupying 16 percent of the total storage capacity, is the desired operating zone of the System. Ideally the System is at the base of this zone at the start of the spring runoff season. Spring and summer runoff is captured in this zone and then metered out throughout the remainder of the year to serve the other project purposes, returning the reservoirs to the base of this zone by the start of the next runoff season.

The top 6 percent of the System storage capacity is the exclusive flood control zone. This zone is used only during extreme floods, and evacuation is initiated as soon as downstream conditions permit.

Figure 2
System Storage Zones

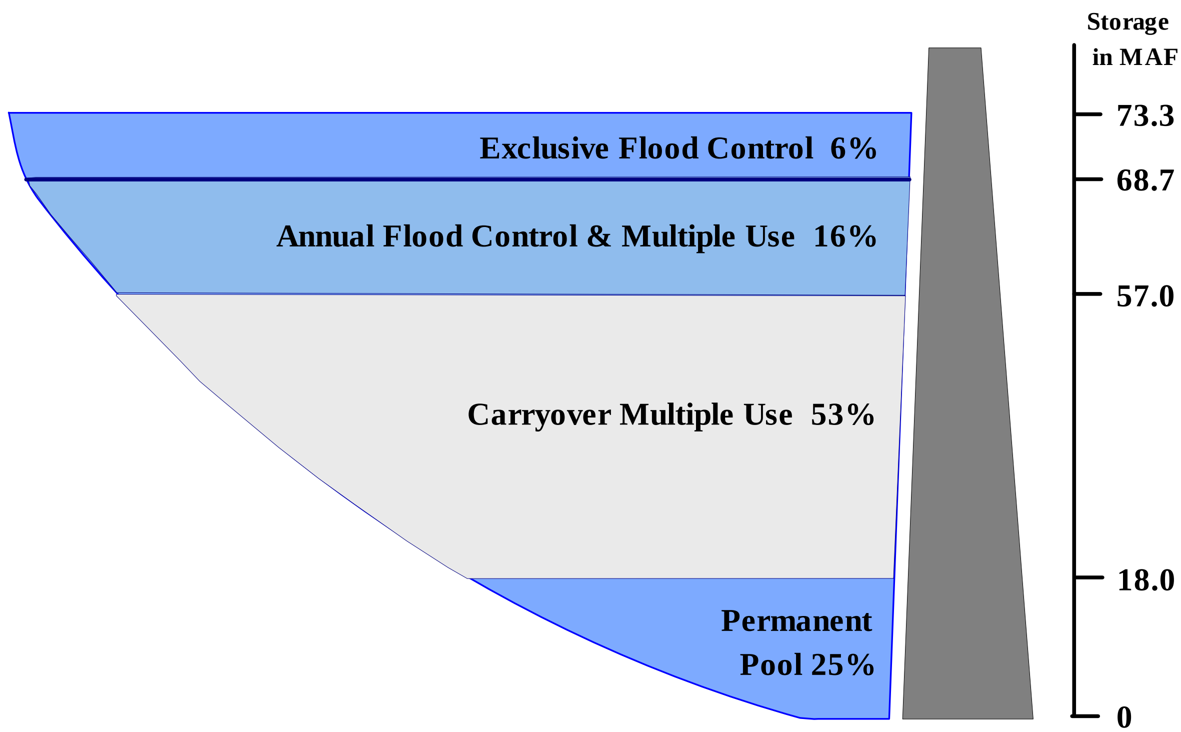


Table 2
Reservoir Storage Zones

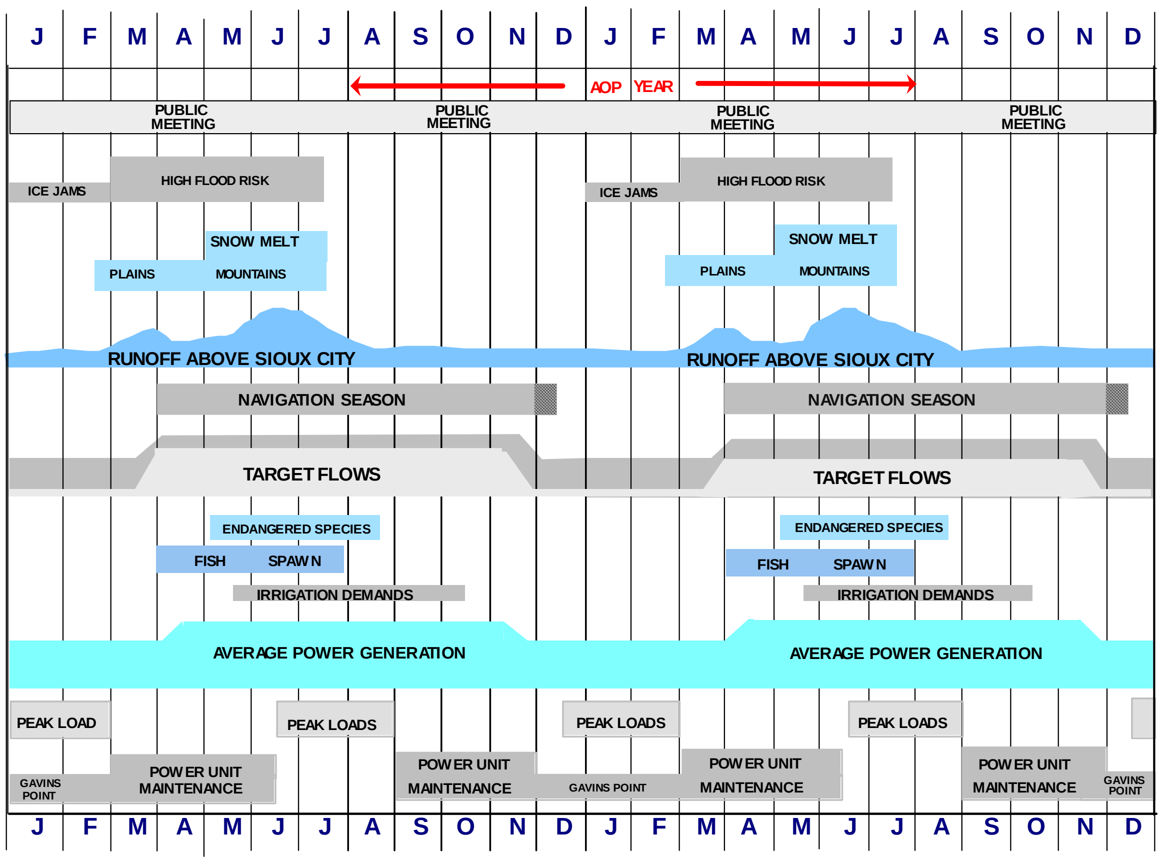
Project	Top of Permanent Storage (MAF)	Top of Permanent Elev. (ft msl)	Top of Carryover Multiple Use Storage (MAF)	Top of Carryover Multiple Use Elev. (ft msl)	Top of Flood Control & Multiple Use Storage (MAF)	Top of Flood Control & Multiple Use Elev. (ft msl)	Top of Exclusive Flood Control Storage (MAF)	Top of Exclusive Flood Control Elev. (ft msl)
Fort Peck	4.2	2160.0	15.0	2234.0	17.7	2246.0	18.7	2250.0
Garrison	5.0	1775.0	18.1	1837.5	22.3	1850.0	23.8	1854.0
Oahe	5.4	1540.0	18.8	1607.5	22.0	1617.0	23.1	1620.0
Big Bend	1.6	1420.0	1.6	1420.0	1.7	1422.0	1.8	1423.0
Randall	1.5	1320.0	3.1	1350.0	4.4	1365.0	5.4	1375.0
Gavins Point	0.3	1204.5	0.3	1204.5	0.4	1208.0	0.5	1210.0
Total System	18.0		57.0		68.7		73.3	

B. System Regulation.

1. Overview. The System is regulated to serve the Congressionally authorized purposes of flood control, navigation, hydropower, irrigation, water supply, water quality control, recreation, and fish and wildlife. Overall System regulation follows the "water control plan" presented in the Master Manual. Each of the six System dams also has an individual water control manual that presents more detailed information on its regulation. System regulation is in many ways a repetitive annual cycle. Most of the year's water supply is produced by runoff from winter snows and spring and summer rains which increase System storage. After reaching a peak, usually during July, System storage declines until late in the winter when the cycle begins anew. A similar pattern may be found in releases from the System, with the higher releases from mid-March to late-November, followed by low rates of winter discharge from late-November until mid-March, after which the cycle repeats.

The Water Control Calendar of Events, shown on **Figure 3**, displays the time sequence of many of these cyclic events. The water control plan is designed to achieve the multipurpose objectives of the System given these cyclical events. The two primary high-risk flood seasons shown are the plains snowmelt season, which extends from late February through April, and the mountain snowmelt period, which extends from May through July. Runoff during both of these periods may be augmented by rainfall. The winter ice-jam flood period extends from mid-December through February. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The major maintenance periods for the System hydropower facilities extend from March through mid-May and September through November, which normally are the lower demand and off-peak energy periods. The exception is Gavins Point where maintenance is performed after the end of the navigation season when all three generation units are not normally required to provide downstream flow support. The normal 8-month navigation season extends from April 1st through November 30th during which time System releases are scheduled, in combination with downstream tributary flows, to meet downstream target flows. Winter releases after the close of navigation season are much lower, and vary depending on the need to conserve or evacuate System storage while managing downstream river stages for water supply given ice conditions. Minimum release restrictions and pool fluctuations for fish spawning management generally occur from April through June. Gavins Point spring pulses, which are designed to cue spawning of the endangered pallid sturgeon, are provided in March and May with the flow magnitude, duration, and timing based on System storage, runoff forecast, and other criteria. Nesting of the two Federally protected bird species, the endangered interior least tern and the threatened piping plover, occurs from early May through mid-August.

Figure 3
Water Control Calendar of Events



2. **Intrasystem Regulation - General.** Much of the flexibility of the System is derived from intrasystem regulation, or the transfer of water from one reservoir to another. This is due to the fact that System releases necessary to support downstream water requirements are defined within a relatively narrow range and inflow to the System is subject to only very minor regulatory control by upstream tributary reservoirs.

Intrasystem regulation is an important tool in the management of water in the System to meet the authorized purposes. It is used to regulate individual reservoir levels in the System to balance or unbalance the water in storage at each project, to smooth the annual System regulation by anticipating unusual snowmelt runoff, to maintain the seasonal capability of the hydropower system, and to improve conditions for the reservoir fish spawn and recruitment. It also can be used to maintain stages on the open river reaches between projects at desirable levels. Intrasystem adjustments may also be used to meet emergencies, including the protection of human health and safety, protection of significant historic and cultural properties, or to meet the provisions of applicable laws including the Endangered Species Act. These adjustments are made to the extent reasonably possible after evaluating impacts to other System uses, are generally short term in nature, and continue only until the issue is resolved.

The presence of large reservoirs in the System increases intrasystem regulation flexibility. A small reservoir such as Gavins Point with storage of less than one-half million acre-feet can only tolerate a large difference between inflow and release for less than a day. Big Bend is in this category as well. To a lesser extent, so is Fort Randall, although its carryover-multiple use and annual flood control and multiple use storage of nearly 3 MAF make possible significant storage transfers and flow differentials extending a month or more. But it is the upper three large reservoirs of Fort Peck, Garrison, and Oahe, with their combined 37.4 MAF of carryover multiple-use storage plus an additional 10.1 MAF of annual flood control multiple-use storage, that provide the flexibility to adjust intrasystem regulation to better serve authorized purposes.

3. Seasonal Intrasystem Regulation Patterns. Factors that influence intrasystem regulation may vary widely from year to year; however, regulation of the System generally follows a regular seasonal pattern. Some of these factors, such as the amount of System storage and the magnitude and distribution of inflow received during the year, can affect the timing and magnitude of individual System project releases. The levels of each of the six System reservoirs are checked on a daily basis and compared to the water control plan and the AOP. Adjustments to the amount of water transferred between reservoirs are made when necessary to achieve the desired volume of water in each project and to maximize power generation.

a. Summer Release Patterns. Intrasystem regulation to meet the needs of power generation follows a regular seasonal cycle. Releases from Gavins Point are generally at their highest during the navigation season when downstream flow requirements are highest. Since Gavins Point reservoir is small, these releases must be backed up with similar magnitude releases from Fort Randall, and Fort Randall, in turn, requires similar support flows from Oahe via Big Bend. Here the chain can be interrupted; Oahe is large enough to support high releases for extended periods without high inflows. Generation at Fort Peck and Garrison are held to lower levels during the summer to allow more winter hydropower production unless the evacuation of water accumulated in the flood control zones or the desire to balance or unbalance storage among the upper three projects becomes an overriding consideration.

b. Winter Release Patterns. With the onset of the non-navigation season, conditions are reversed. Gavins Point releases drop to about one-third to slightly greater than half of summer levels and the chain reaction proceeds upstream, curtailing daily average discharges from Fort Randall, Big Bend, and Oahe. At this time, Fort Peck and Garrison daily releases are usually maintained at relatively high levels (within the limits imposed by downstream ice cover) to partially compensate for the reduction of generation downstream where high winter releases could result in significant flood damages in urban areas when the formation of ice impedes the flow.

c. Drawdown of Fort Randall Reservoir. An additional means of partially compensating for the reduced hydropower generation associated with the lower winter release rate from Gavins Point is the autumn drawdown of Fort Randall reservoir. In this regulation, releases from Oahe and Big Bend are reduced several weeks before the close of the navigation season. This leaves Fort Randall with the task of supplying a large portion of downstream flow requirements for the remainder of the navigation season, a process that results in evacuation of a portion of its carryover storage space. This vacated carryover storage space, or recapture storage capacity, is then refilled with higher releases from Oahe and Big Bend releases during the non-navigation season, allowing winter releases from the upstream projects to substantially exceed those from Fort Randall.

Fort Randall reservoir is normally drawn down to 1337.5 feet msl, which provides about 1,200,000 acre-feet of recapture storage capacity. During severe drought periods, the flexibility exists to draw down to elevation 1320.0 feet msl. This provides an additional recapture space of about 800,000 acre-feet and increases the average winter energy generation about 150 million kilowatt hours (kWh).

d. Recapture at Oahe. While not as significant (in terms of pool level fluctuation) as the drawdown and recapture regulation plan at Fort Randall reservoir, a similar recapture regulation plan at Oahe is coordinated with upstream Garrison and Fort Peck releases to significantly increase the amount of winter energy generation. During the 4-month winter period, Garrison releases normally can be expected to be at least 1 MAF more than Oahe releases. Recapture of these upstream releases generally results in a rise of about 5 feet or greater in Oahe reservoir elevation during the winter months, depending on the current storage level and whether the upper three reservoirs are intentionally unbalanced.

e. Balancing/Unbalancing the Upper Three Reservoirs. In the past, the volume of water stored in each of the upper three reservoirs was balanced at the beginning of March of every year. However, intentionally unbalancing the water stored in the upper three reservoirs can benefit the reservoir fisheries and increase tern and plover habitat. All AOP's since the 2000-2001 report have stated that unbalancing would be pursued during years when the reservoirs were at or near the base of their annual flood control pools on March 1st and when runoff forecasts were for median or greater annual runoff. However, drought conditions have prevented implementation of reservoir unbalancing to date. Additional information on unbalancing is included in Section IV.G.1.b on page 33.

4. Short-Term Intrasystem Adjustments. The interaction among projects described above, repeated as it is year after year, might make intrasystem regulation appear to be a routine and rigid procedure. However, routine regulation is often disrupted by the short-term extremes of nature. Heavy rains may raise river stages near the flood level, necessitating a release reduction at one project and a corresponding increase at others. Very hot or very cold weather may create sharp increases in the demand for power. Inflows for a week or for a season may concentrate disproportionately in one segment of the System, causing abrupt shifts in regulating objectives. In addition, short-term intrasystem adjustments are occasionally required to meet emergencies, including the protection of human health and safety, protection of significant historic and cultural properties, or to meet the provisions of applicable laws, including the Endangered Species Act. These adjustments are made to the extent possible after evaluating impacts to other System uses, are generally short term in nature, and continue only until the issue is resolved.

5. **Project Release Limits.** Limitations imposed upon System regulation (maximums and minimums) are related not only to System or individual project storage, which is varied in accordance with the flood control restrictions previously given and the requirements for active storage pools, but also to releases.

a. **Maximum Rates - Summer.** During the summer, releases at all projects other than Gavins Point are normally within the powerplant discharge capacity, the river channel downstream usually being more than adequate to carry such releases. Discharges from all projects will usually be made through the powerplant. At times, support for the downstream navigation or spawning cue flows may require releases from Gavins Point in excess of powerplant capacity. At all projects, special regulation considerations may require releases bypassing the powerplants but usually for only relatively short periods of time. Unusually large inflows during any particular year may require significant releases beyond those through the powerplants at any or all projects to evacuate flood waters and thereby maintain the future flood control capability of the System.

b. **Maximum Rates - Winter.** Releases are more restricted during the winter period. An ice cover can be expected to form over major portions of the Missouri River every winter and occasionally as far downstream as the river's mouth. During and after formation, this ice cover significantly reduces the discharge capacity of the river channel. In addition, during periods of ice formation and subsequent breakup, a substantial risk of ice jam formation and associated flooding exists. The maximum allowable winter releases are those that will not significantly increase the probability of flooding or intensify potential flooding during periods of ice cover. In the upper Missouri River, releases may be limited during periods of ice formation and then gradually increased once a stable ice cover is in place. Once formed, the ice cover can be expected to remain through the winter. Below Sioux City, ice formation or ice breakup can occur repeatedly throughout the season and may also jeopardize downstream navigation structures such as dikes and revetments. Since the travel time of any release from the System to areas of vulnerability is much longer than the time for which reliable forecasts of such events can be made, it is necessary to schedule winter System releases at a conservative level. During periods of normal or below water supply, winter releases from Gavins Point range from less than 9,000 cubic feet per second (cfs) to 17,000 cfs. During years with low winter releases, ice formation can result in significant stage reductions on the lower river; therefore, it is often prudent to increase System releases prior to the onset of river ice buildup or even during a significant jam to maintain adequate stages at water intakes. Experience during recent years indicates that increasing System releases speeds the recovery of the river to more normal stages and assures that the downstream water intakes are operational sooner or affected less by the icing conditions. The maximum daily winter release from Gavins Point usually ranges between 12,000 and 25,000 cfs. With an excess water supply and evacuation of flood control storage space as a primary consideration, an average Gavins Point release rate of between 25,000 and 30,000 cfs is scheduled. The extent and location of river ice cover is important in determining the release rate. Experience accumulated during past winters indicates that at times it may be necessary to reduce System releases below these levels when bankfull to slightly above bankfull stages occur in the Nebraska City to St. Joseph reach of the Missouri River.

No daily release limitations exist at Big Bend, where discharges are made almost directly into the downstream reservoir area. The maximum ice-covered channel capacity below Fort Peck and Garrison are estimated to be about 15,000 and 27,000 cfs, respectively, except during freeze-up. During freeze-up, releases are limited to lower levels until a stable ice cover is formed and the rough ice and streambed are smoothed sufficiently for the channel to accommodate increased releases. Winter releases from Fort Randall are generally 1,000 to 2,000 cfs lower than those from Gavins Point, but during period of ice formation may be scheduled at or slightly higher than Gavins Point releases to prevent rapid declines in the Gavins Point pool elevation. At Oahe peak hourly releases may be constrained to prevent urban flooding in the Pierre and Fort Pierre areas if severe ice conditions develop below the project.

c. Minimum Releases. There are no minimum daily flow requirements from Oahe or Big Bend except that, to the extent possible, weekend releases from Oahe are typically held above 3,000 cfs during the daytime hours of the recreation season in the interest of downstream fishing and boating. In addition, during periods of ice formation a one-unit minimum may be imposed at Oahe to prevent ice formation in the channel directly below the dam. Minimum daily releases from Fort Peck and Fort Randall are typically maintained during the fish spawning seasons. Fort Peck also has a year-round instantaneous minimum release of 3,000 cfs for the trout fishery below the dam, though to the extent possible, releases are maintained above 4,000 cfs. During periods of high inflow below the project, releases may be scheduled below 3,000 cfs for flood damage reduction, but these instances are rare. Minimum daily releases at Fort Peck, Garrison, Fort Randall, and Gavins Point are established as those necessary to supply water quality control and downstream water intake requirements, which generally also furnish more than an adequate quantity of water for irrigation withdrawals below the reservoirs. At Garrison a minimum average daily release of 9,000 cfs has been established as a guide to provide for downstream intakes. Access problems have been experienced at municipal, industrial, powerplant, and irrigation intakes along the length of the river due to channel degradation, inadequate intake screens, sandbar formation, winter ice formation, or relatively high elevation of the intakes. Temporary increases above the open-water minimum release rates may be made to the extent reasonably possible to allow intake owners to take remedial action. Maintaining access to water that is available in the river is the responsibility of the intake owner. All intake owners are encouraged to develop intake facilities which will operate through the full range of discharges required for other project purposes.

d. Hourly Fluctuation of Release Rates. At all projects except Gavins Point, hourly release rates may vary widely as necessary to meet fluctuating power loads. Changes in release rates at Gavins Point are subject to limitations to restrict stage fluctuations downstream. Minimum hourly release restrictions are applicable at Fort Peck and Garrison due to downstream intakes. A uniform peaking release pattern has been established during the summer months at Garrison and Fort Randall for endangered birds nesting along the river below the projects, and may be reinstated at Fort Peck if nesting patterns deem it necessary.

C. Sediment Investigations.

Hydrographic resurveys, sediment sampling activities, and special studies of the mainstem reservoirs are planned and scheduled to meet the short-term and long-term needs related to sediment. A total of 643 sediment cross-section ranges for both aggradation and degradation reaches have been established and maintained since the projects were completed, as shown in **Table 3**. Each reservoir reach is surveyed periodically (10- to 25-year intervals) to update reservoir capacities, to assess the progress of aggradation and degradation trends, to evaluate impacts of erosion or sedimentation on project functions, and to seek early solutions to problems in light of changing field conditions and goals. The frequency of reservoir surveys was established based on historic data and reservoir size. These regular reservoir surveys can be supplemented with reconnaissance inspections of major problem areas about once every 5 years. Intervening and/or partial resurveys may be conducted if warranted by a special study, or if findings from reconnaissance investigations reveal the need. High flood events are the most likely causes for these additional surveys.

Table 3
Hydrographic Survey Data

Project / Reach	Number of Cross Sections	Survey Interval (yrs)	Year Last Surveyed
Fort Peck – Fort Peck Lake	126	25	1986
Fort Peck Degradation Reach	47	10	1993
Garrison – Lake Sakakawea	102	20	1988
Garrison Degradation Reach	45	10	1999
Oahe – Lake Oahe	132	20	1989
Big Bend – Lake Sharpe	54	10	1997
Fort Randall – Lake Francis Case	38	10	1996
Fort Randall Degradation Reach	28	10	1995
Gavins Point – Lewis & Clark Lake	29	10	1995
Gavins Point Degradation Reach	42	10	2003
Total Cross Sections	643		

Table 4 summarizes the loss of System storage due to sediment deposition in the System reservoirs according to the latest information available. This table indicates a loss of 4.5 percent in total storage to the date of the last surveys with an annual sediment deposition rate of around 90,000 acre-feet. Sediment and hydrographic survey data collected, combined with hydrologic and hydraulic data in the System reservoirs, have been used extensively to investigate specific issues and concerns. Issues recently investigated include flooding and power constraints in the Bismarck-Mandan, North Dakota and Pierre, South Dakota areas; the raising of Highway 12 near Niobrara, Nebraska; claims for flooding damages on the Moreau, Cheyenne and Niobrara Rivers; downstream degradation impacts on tailwater and the powerplant operation below the Garrison, Fort Randall, and Gavins Point Dams; Missouri River aggradation and degradation trends below Gavins Point Dam, and the effects of future depletions and sedimentation on System uses and resources.

Table 4
Sediment Depletion of Reservoirs
(1,000 Acre-Feet)

Project	Storage Capacity Original	Storage Capacity Current	Percent Capacity Loss	Total Capacity Loss	Loss Per Year
Fort Peck	19,557	18,688	4.4	869	17.7
Garrison	24,728	23,821	3.7	907	25.9
Oahe	23,751	23,137	2.6	614	19.8
Big Bend	1,980	1,799	9.1	181	5.3
Fort Randall	6,208	5,418	12.7	790	18.4
Gavins Point	575	470	18.3	105	2.6
Total	76,799	73,333	4.5	3,466	89.7

Four suspended sediment sampling stations are presently in operation on major sediment producing tributaries and headwater areas of the System reservoirs to measure incoming sediment load. These include stations on the Missouri River at Landusky, Montana; the Yellowstone River at Sidney, Montana; the Bad River at Fort Pierre, South Dakota; and the White River at Oacoma, South Dakota.

Downstream of Gavins Point Dam, eight more sediment sampling stations are maintained at Sioux City, Iowa; Omaha, Nebraska; Nebraska City, Nebraska; St. Joseph, Missouri; Kansas City, Missouri; and Hermann, Missouri on the Missouri River, plus stations on major tributaries including above Schell City, Missouri on the Osage River and near Clinton, Missouri on the South Grand River. Data from these stations provide continuous observation of sediment load changes used to analyze impacts of the System reservoirs and channelization below Sioux City on the downstream reach and to furnish vital information for the investigation of sediment related problems and formulation of remedial measures. All sampling is done by the U.S. Geological Survey (USGS) under a cooperative stream gaging program, including the computation of sediment load records.

The accumulation of sediment in reservoir headwaters and at the mouths of sediment laden tributaries has impacted project purposes by reducing channel capacity and raising water surfaces, in some instances by several feet. Areas of particular concern include Williston, North Dakota (Garrison headwaters); Bismarck, North Dakota (Oahe headwaters); Pierre-Fort Pierre, South Dakota (Bad River delta and Big Bend headwaters); the White River delta; Verdel and Niobrara, Nebraska (Niobrara River delta); and Springfield, South Dakota (Gavins Point headwaters.) These localized problems will continue to increase in severity if no remedial actions are taken. Additional information on each of these areas is included in the following paragraphs.

Garrison headwater and backwater areas can extend upstream past the city of Williston, North Dakota. Corps-built levees protect Williston from the aggradation backwater effects. After construction of Garrison Dam, the Lewis and Clark and Buford-Trenton irrigation projects were operating in this backwater area. The Lewis and Clark project and a portion of the Buford-Trenton project were purchased by the Government for project lands. The remainder of the Buford-Trenton irrigation project continues to operate. Prior to 1979, there were numerous complaints and claims filed by landowners in this area alleging that high ground water levels resulted from the aggradation effects on the adjacent Missouri River near the Yellowstone confluence. Groundwater observation wells were monitored in this area in cooperation with the State of North Dakota since the construction of Garrison Dam. Studies indicated that acquisition of additional lands would be a less expensive alternative than any permanent structural solution to alleviate these problems. Acquisition of easements and relocation assistance under P.L. 91-646 began in fiscal year (FY) 1998. The project consists of the acquisition of permanent flowage and saturation easements within and surrounding the Buford-Trenton Irrigation District for land that has been affected by rising groundwater and the risk of flooding.

In years with normal to above-normal runoff, Fort Peck releases are generally decreased prior to the beginning of the winter period to prevent ice-jam flooding during the winter freeze-in period on the reach of the Missouri River from the dam to the Williston, North Dakota area. After a stable ice cover is in place, releases are gradually increased for the remainder of the winter period to meet critical winter hydropower demands. In drought years, winter release rates are generally low enough that a reduction during the freeze-in period is not necessary.

Continuing aggradation in the headwaters of Oahe has contributed to high water problems in the Bismarck, North Dakota area during the periods of high Garrison summer releases and during the winter ice-in periods. There is a considerable amount of new housing being developed along and near the river in the Bismarck-Mandan area. Releases from Garrison are reduced to 15,000 to 20,000 cfs during the winter ice-in period to prevent the stage at Bismarck from exceeding the critical ice-in stage of 14 feet. Flood stage at Bismarck is 16 feet. Once a stable ice cover is established, Garrison releases can be gradually increased.

Flooding in the Pierre-Fort Pierre area, especially at street intersections in the Stoeser Addition, has been a recurring problem since 1979. High Oahe releases, coupled with the formation of river ice downstream of the Pierre-Fort Pierre area cause water to back up into a storm sewer outlet flooding street intersections. P.L. 105-277, as amended by P.L. 106-224, authorized and funded the design and modification of infrastructure changes, acquisition of the most flood prone properties, and flood proofing other properties in the Fort Pierre and Pierre areas to prevent flood damages. Release restrictions were implemented in some previous years to prevent flooding. During periods of ice formation, a one-unit minimum may be imposed to prevent ice formation in the channel directly below the dam. In addition, peak hourly releases as well as daily energy generation will be constrained to prevent urban flooding in the Pierre and Fort Pierre areas if severe ice problems develop downstream of Oahe Dam. Any required reduction is always coordinated with the Western Area Power Administration (WAPA).

During the 1991 fall drawdown of the Fort Randall reservoir, it was observed that the White River delta, which extends across the reservoir, was having a damming effect that created two different reservoir elevations upstream and downstream of the delta. In recent times, the upper reservoir elevation has been as much as 6 feet higher than the reservoir downstream from the delta. The Corps has published a revised elevation capacity table for Fort Randall reflecting the effect of this phenomenon near elevation 1347 feet msl and below. On-going monitoring of this condition continues.

Sediment deposition in the vicinity of Springfield, South Dakota, has restricted access to Gavins Point reservoir from the Springfield boat ramp during periods of low reservoir elevation. Farther upstream, a large delta continues to develop near the mouth of the Niobrara River. The sediment deposition and related channel cross-section area changes from Niobrara down to Springfield increase the travel time of releases from Fort Randall to Gavins Point. In 1994 the Omaha District conducted a study on sedimentation impacts in this area. A steady release of 35,000 cfs from Fort Randall was made beginning on May 2, 1994 for 48 hours and the resulting water surface profile was surveyed. The water surface from upstream of Verdel, Nebraska, to below the mouth of the Niobrara River was higher than the water surface in the mid-1980's with a steady release of 44,000 cfs which, in turn, was higher than a steady release of 60,000 cfs in 1975. Some overbank flows occurred and rerouting of tributaries in this reach were noted during the test period. High releases coupled with degraded channel capacity caused lowland flooding in this reach during the period 1995 to 1997. In addition, the record high releases in 1997 caused a notable, but temporary increase in the channel capacity.

Downstream of Gavins Point, a general lowering trend (degradation) of the river bed and stages and the accumulation of sediment in marinas continue to be a concern for recreational boaters and marina operators. Sediment deposition resulting from high, short-duration flows, and extended periods of minimum service flow support have necessitated dredging of marinas below Gavins Point. During periods of extended drought, low release rates coupled with channel degradation in the Sioux City to Omaha reach and at Kansas City have adversely impacted powerplant and municipal water intake access downstream of Gavins Point.

D. Reservoir Water Quality.

The Corps' Water Quality Management Program for the System consists of monitoring, modeling, and assessing water quality conditions at the System reservoirs. Physical, chemical, and biological water quality conditions in the reservoirs are systematically monitored through a fixed-station, ambient monitoring network and intensive water quality surveys. Inflowing tributaries to the reservoirs are periodically monitored by the Corps, USGS, and State water quality agencies. Remote monitoring of water temperature has recently been added to USGS gaging stations on the major tributaries. Water quality conditions of water discharged through the System dams is continuously monitored at the hydropower plants. Hourly measurements of temperature, dissolved oxygen, and conductivity are recorded at all the projects, and monthly samples are collected year-round for laboratory analysis of selected physiochemical parameters. Monitoring at the System projects is conducted to detect water quality problems and determine compliance with Federal water quality criteria as well as state and local water quality standards. Current monitoring activities are also supporting the application and calibration of the revised CE-QUAL-W2 hydrodynamic and water quality model to the System reservoirs. The model is currently being applied to the Garrison project (2007) and plans are to apply it to the other System projects as follows: Fort Peck (2007-2008), Oahe (2008), Fort Randall (2009), Big Bend (2010), and Gavins Point (2011). Annual water quality reports summarize the water quality conditions at Corps projects and ongoing and planned activities of the Water Quality Management Program. These reports, and periodically prepared special water quality reports, discuss and assess water quality conditions at each reservoir and can be consulted for a detailed presentation of the water quality conditions at each project.

In general, water quality conditions at the System projects are favorable although some concerns exist that can be attributed to project regulation and non-project pollution sources. Potential water quality concerns attributable to the projects or their regulation include: (1) possible gas supersaturation in tailwater areas if spillway releases are made from Fort Peck and Gavins Point, (2) dissolved oxygen depletion in the hypolimnion of the reservoirs later in the summer prior to "fall turnover", (3) low dissolved oxygen levels in tailwater areas due to hypolimnetic reservoir releases during the late summer, and (4) localized algal blooms due to accumulation and recycling of nutrients in the mainstem reservoirs. Concerns attributable to natural and anthropogenic sources and land or water use policies outside the Federal project boundaries include: (1) pesticides detected in project waters, (2) high levels of selenium in the Missouri River and many of its tributaries, (3) elevated levels of mercury in fish caught in the reservoirs and consumed by fishermen, and (4) increased rates of eutrophication in the reservoirs due to nutrient enrichment. To date, these concerns have not affected the ability of the System to serve any Congressionally authorized purposes.

The System projects have a significant moderating influence upon the Missouri River water temperatures and sediment concentrations. Most of the inflowing sediment load is retained within the impoundments. Winter releases from the dams cause a slight warming of the downstream waters ranging from 1 to 3 degrees Celsius. In the late spring, summer, and early fall, river temperatures downstream of the upper three reservoir projects are depressed on the order of 5 to 10 degrees Celsius.

IV. RECURRING OPERATIONAL CONSIDERATIONS

A. Flood Control.

Flood control is the only authorized project purpose that requires the availability of empty storage space rather than impounded water. Actual flood events are generally unpredictable; therefore, detailed routing of specific major flood flows is accomplished when floods occur. There is a recurring pattern of high-risk flood periods during each year: a season when snowmelt, ice jams, and protracted heavy rains will almost surely occur with or without generating consequent floods; and a season when these situations are most unlikely and the flood threat is correspondingly low. The high-risk flood season begins about March 1st and extends through the summer. As a consequence, regulation of the System throughout the fall and winter months is predicated on the achievement of a March 1st System storage level at or below the base of the annual flood control zone. Exceptions to this will occur due to the availability of replacement flood control storage in major upstream tributary reservoirs. This type of storage, available in the USBR's Clark Canyon, Canyon Ferry, and Tiber Reservoirs, can effectively reduce the requirements for annual flood control storage in the System. The available storage for control of flood inflows in the combined System and tributary reservoirs has been scheduled in the past as discussed above after coordinating with the USBR in Billings, Montana; however, it has not been utilized in recent years.

Due to release limitations imposed by the formation of a downstream ice cover, a major portion of the required flood control space in the System must be evacuated prior to the winter season. Gavins Point winter releases exceeding 25,000 cfs are not normally scheduled. However, higher releases have been made on occasions when the downstream ice conditions permit or when required for evacuation of water during high runoff years. Since the impacts of ice-jam flooding can be more severe when higher releases are made during the winter months, additional vigilance is required.

In general, individual System projects will also be scheduled to be near or below their respective base of annual flood control by March 1st. Some departure is possible due to the availability of upstream tributary flood control storage space, intrasystem unbalancing of the upper three reservoirs to benefit the reservoir fishery and the protected species, and/or recognition of the relative ease by which the water in storage may be transferred downstream to other projects in the System even during the flood season.

During all but excessively dry years, water stored in the reservoirs will increase during the March-July period. The base of exclusive flood control defines the maximum level of storage that will be accumulated for purposes other than flood control. Water stored in the annual flood control and multiple-use zones will normally be released through the powerplant of each of the individual projects except when evacuation of this zone prior to the winter season necessitates higher flow rates requiring flood control outlet tunnel or spillway releases. When the exclusive flood control zone in a particular reservoir is encroached upon, the control of subsequent flood inflows becomes the paramount factor. During such periods, releases may substantially exceed the powerplant release capacity with the evacuation rate of any project dependent upon existing flood conditions, the potential for further inflows, and conditions of other reservoirs in the System. Maximum release rates at such times are based upon the Master Manual flood control criteria and the flood control status of the System. Detailed information regarding the adjustment of service levels for flood control evacuation and downstream flood control constraints can be found in Chapter 7 of the Master Manual.

Below Fort Peck, minor downstream flooding will occur when open-water flows exceed 35,000 cfs. Open-water channel capacity below each of the other reservoirs approximated 100,000 cfs or more at the time the reservoirs were constructed (1950's). Since that time, there is evidence that encroachment and deterioration of the channel have occurred and flood problems would be experienced with releases of this magnitude. In addition, releases may need to be reduced to less than the immediate downstream channel capacity due to uncontrolled actual and potential tributary flows below each project, particularly below Gavins Point, Garrison, and Fort Randall.

B. <u>Water Requirements Below Gavins Point</u>.

Just as the water supply and upstream uses must be evaluated each year to determine the net supply into the System, so must System release rates be established. This is the only means of regulating the System storage, since the weather and its resultant effects are not subject to control. Daily releases from Gavins Point, commonly referred to as the System releases, fall into two classes. Open-water releases, generally in the range of 21,000 to 35,000 cfs, are made in support of Missouri River navigation and other downstream uses. In years with above-normal water supply or extended periods of downstream flooding, the navigation releases are increased to the extent necessary to evacuate the flood control storage space by the succeeding March, with due consideration of reduced channel capacities during the winter ice-cover period. System releases during the non-navigation season generally range from 9,000 to 30,000 cfs, and are made for water supply, water quality control, power production, and flood evacuation purposes.

1. Navigation Season Requirements. The Missouri River navigation channel extends for 734.8 miles from near Sioux City, Iowa (River Mile 732.3) to the mouth (River Mile 0) near St. Louis, Missouri. Navigation on the Missouri River is limited to the normal ice-free season with a full-length season normally extending from April 1st through November 30th at the mouth. To permit a viable navigation industry during the ice-free months, it is desirable to maintain navigable flows throughout this 8-month period. During past navigation seasons in years of adequate water supply, 10-day extensions either at the beginning or end of this normal season have been scheduled, downstream river ice conditions permitting. Experience with extensions scheduled prior to the normal opening dates of the navigation season has not been satisfactory. In many years, the ice cover below the System is still in place at the time it is necessary to schedule increased releases from the System, prohibiting the early opening. Additionally, in those years when earlier-than-normal navigation releases are possible, experience has indicated that towboat groundings are more frequent during this early period than during the remainder of the season. The increased incidence of groundings appears to be related to the cold water temperatures and their effect upon channel bed configuration that results in reduced stages. Increased groundings are also experienced during the late fall, when stages lower despite constant releases. These problems are greatest in years when normal or lower reservoir releases are made. When water supplies are above normal, consideration is given to a 10-day extension of the season beyond the normal closing date.

Construction of the navigation works was declared complete in September 1981; although maintenance and corrective work will be required as the river continues to form its channel in response to changing flow conditions. In years with adequate water supply, System releases are scheduled to provide adequate flows for navigation at the target locations of Sioux City, Omaha, Nebraska City, and Kansas City if navigation is occurring on the reaches associated with those targets. If navigation is not occurring in one or more upstream reaches, flows may be allowed to fall below the respective targets, depending on the needs of other authorized project purposes at the time. The target flows increase in a downstream direction because of the increased flow requirements needed to maintain corresponding navigation channel widths and flow depths with naturally increasing channel dimensions. The assignment of target flows is based upon available water supply that, when combined with winter releases needed to ensure water supply requirements and winter hydropower demand, obligates all of the available water supply during a normal year. These target flows may need to be evaluated and adjusted periodically to ensure compatibility between available water supply and current navigation channel conditions.

a. **Navigation Service Level and Season Length.** As described in the Master Manual, flow support for navigation and other downstream purposes is defined based on service level. A "full-service" level of 35,000 cfs results in target flows of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Similarly, a "minimum-service" level of 29,000 cfs results in target flow values of 6,000 cfs less than the full-service levels.

Day-by-day regulation of the System to support navigation requires forecasts of inflow to the various river reaches below the System. These daily forecasts, along with anticipated navigation traffic or the absence of traffic in the various river reaches, are used to determine the target location (Sioux City, Omaha, Nebraska City, or Kansas City). After determining the target location, releases from the System are adjusted so that, in combination with the forecast tributary inflows, the resultant flow will meet the target flow at the control location. During periods when the target location is Kansas City, navigation flow support can also be provided from three Kansas basin reservoirs (Tuttle Creek, Milford, and Perry) since those projects are authorized to support Missouri River navigation. This regulation conserves water in the System and may also minimize incidental take of the ESA-protected species.

Regulation experience has shown that the full-service target flows will be adequate to maintain the designed 9-by-300-foot channel with a minimum of groundings and little or no emergency dredging. Slightly greater flows are required at the mouth (approximately 45,000 cfs) but tributary flows below Kansas City are usually adequate to provide the needed incremental flows. Although a 9-foot channel is not provided 100 percent of the time, the problem areas are generally transient and short term in nature. Increased flows would provide some relief, but experience has shown that, regardless of the support provided, some groundings occur.

When minimum-service flow levels are supported, experience has indicated that it is necessary to reduce drafts by 1 foot and restrict tow sizes to reduce the number of lost-time events and groundings and to minimize dredging. With the present level of streamflow depletions, inflows to the System are sufficient to support the minimum-service flow levels or higher for the full 8-month navigation season in 78 years of the 100-year record period (inflows from 1898 to 1997) and full-service flows or higher for the 8-month navigation season in 55 years of the 100-year period.

The relation of System storage to navigation service level is presented in **Table 5**. Selection of the appropriate service level is based on the actual volume of System storage on March 15th and July 1st of each year. The volumes presented in **Table 5** were derived from long-range model simulations that helped identify how the System should be regulated to best serve the authorized purposes during significant multi-year droughts. Straight-line interpolation defines intermediate service levels between full- and minimum-service. These service-level determinations are for conservation and normal System regulation. During years when flood evacuation is required, the service level is calculated monthly, or more frequently if required, to facilitate a smooth transition in System release adjustments.

Table 5
Relation of System Storage to Navigation Service Level

Date	System Storage	Navigation Service Level
March 15th	54.5 MAF or more	35,000 cfs (full-service)
March 15th	49.0 to 31 MAF	29,000 cfs (minimum-service)
March 15th	31.0 MAF or less	No navigation service
July 1st	57.0 MAF or more	35,000 cfs (full-service)
July 1st	50.5 MAF or less	29,000 cfs (minimum-service)

As shown in **Table 5**, the water control plan calls for suspension of Missouri River navigation if System storage is at or below 31 MAF on March 15th of any year. It should be noted that the occurrence of System storage at or below 31 MAF would likely coincide with a national drought emergency. If any of the reservoir regulation studies performed for the development of an AOP indicate that System storage will be at or below 31 MAF by the upcoming March 15th, the Corps will notify the Secretary of the Army. Per the Master Manual, the Corps will obtain approval from the Secretary of the Army prior to implementation of back-to-back non-navigation years.

Assuming the System storage is above 31 MAF on March 15th, a navigation season will be supported. The System storage check for navigation season length is made on July 1st of each year. A full 8-month navigation season will be provided if System storage is 51.5 MAF or above on July 1st, unless the navigation season is extended to evacuate flood control storage. However, if System storage falls below 51.5 MAF on July 1st, a shortened navigation season will be provided to conserve water. The specific technical criteria for season length are shown in **Table 6**. Straight-line interpolation between 51.5 and 46.8 MAF of storage on July 1st provides the last date of navigation support at the mouth for a season length between 8 and 7 months. If System storage on July 1st is between 46.8 and 41.0 MAF, a 7-month navigation season is provided. A straight-line interpolation is again used between 41.0 and 36.5 MAF, providing for a season length between 7 and 6 months. For System storage on July 1st at or below 36.5 MAF, a 6-month season is provided.

Table 6
Relation of System Storage to Navigation Season Length

Date	System Storage	Final Day of Navigation Support at Mouth of the Missouri River
July 1st	51.5 MAF or more	November 30th (8-month season)
July 1st	46.8 through 41.0 MAF	October 31st (7-month season)
July 1st	36.5 MAF or less	September 30th (6-month season)

The System release required to meet minimum- and full-service target flows varies by month in response to downstream tributary flows. In general, higher releases are needed to meet flow targets during years with below normal runoff in the upper basin than during years with higher upper basin runoff. Therefore, regulation studies use two levels of System release requirements: one for Median, Upper Quartile, and Upper Decile runoff scenarios, and another for Lower Quartile and Lower Decile scenarios. The average monthly Gavins Point release rates needed to provide full- and minimum-service flows at all target locations are shown in **Table 7**. Releases required for minimum-service flow support are 6,000 cfs less than full-service support. These releases are average monthly values that do not reflect the range of daily releases that may be required during any given month to meet downstream flow targets. Actual regulation requires daily adjustments to meet downstream flow targets.

Table 7
Gavins Point Releases Needed to Meet Target Flows
For Indicated Service Level
1950 to 1996 Data
(1,000 cfs)

Median, Upper Quartile, Upper Decile Runoff

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full-service	26.7	28.0	27.9	31.6	33.2	32.6	32.0	31.1
Minimum-service	20.7	22.0	21.9	25.6	27.2	26.6	26.0	25.1

Lower Quartile, Lower Decile Runoff

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full-service	29.8	31.3	31.2	34.3	34.0	33.5	33.1	31.2
Minimum-service	23.8	25.3	25.2	28.3	28.0	27.5	27.1	25.2

As reflected in the data presented in **Table 7**, the target location early in the season is generally at Sioux City with adequate tributary flows meeting the other downstream flow targets. Tributary flows normally decrease during the summer and the target location moves from Sioux City to Nebraska City, and then to Kansas City as the runoff season progresses. This requires higher releases from the System as the season progresses through summer. Often the target location moves upstream during the fall as downstream tributary flows traditionally increase. As previously stated, flow targets may not be met in upstream reaches without commercial navigation; therefore, the actual target location may be affected by the absence or presence of commercial navigation in a reach. With normal inflows below the System, Sioux City flows will average about 35,000 cfs over the entire 8-month navigation season during periods when full-service navigation targets are utilized for System regulation.

b. Release Patterns during Nesting Season. In general, releases from Gavins Point are adjusted as needed to meet target flow levels on the lower Missouri River, taking advantage of downstream tributary runoff. However, during the nesting season of the endangered interior least tern (tern) and the threatened piping plover (plover), care must be taken to avoid impacts to nesting areas. These two bird species are listed as threatened and endangered under the ESA and are protected under that Act. Several scenarios have been used in past years to regulate the System during the nesting season. Under the Steady-Release (SR) scenario, when the birds begin to initiate nesting activities in early to mid-May, the release from Gavins Point is set to the level expected to be required to meet downstream flow targets through August and maintained at that level until the end of the nesting season. This regulation results in releases that exceed the amount necessary to meet downstream flow targets during the early portion of the nesting season, and may result in targets being missed if basin conditions are drier than expected during the summer.

Gavins Point releases under the Flow-to-Target (FTT) scenario are adjusted as needed throughout the nesting season to meet downstream flow targets and would typically result in increasing releases as the nesting season progresses. This is due to reduced tributary inflows downstream as the summer heat builds, evaporation increases, and precipitation wanes. Increasing releases as the nesting season progresses has the potential to inundate nests and chicks on low-lying emergent sandbar habitat. Compared to the SR scenario, this scenario conserves more water in the System, which keeps the reservoirs at the upper three System projects at relatively higher levels. However, this scenario also increases the risk of inundating nests. The FTT scenario also ensures that targets on the lower river are met throughout the nesting season.

A third scenario for Gavins Point releases combines features of the other two options. This scenario, called the Steady Release - Flow-to-Target (SR-FTT) scenario, sets Gavins Point releases at an initial steady rate and then allows releases to be adjusted upward or downward during the nesting season to meet downstream flow targets, if necessary. Depending on the rate of the initial steady release, this regulation makes a larger amount of habitat available early in the nesting season and saves additional water in the upper three reservoirs when compared to the SR scenario. The SR-FTT scenario also reduces the potential for flooding nests when compared to the FTT scenario. The SR-FTT regulation also provides certainty for downstream users that releases could be increased if needed to meet Missouri River flow targets.

Under each of these regulation scenarios, releases from Gavins Point may be increased every third day to encourage terns and plovers to build their nests on higher habitat so that the nests would not be inundated later when higher releases are required to meet the regulation objectives of the System. This pattern of increasing releases every third day is referred to as "cycling". Cycling is generally not used during years when System storage is high but has been used during extended drought, when water conservation is of primary importance. Cycling is suspended when endangered and threatened chicks hatch to reduce the risk of stranding chicks on low-lying sandbars. Unfledged chicks can be lost if stranded on low-lying sandbars that are subsequently totally inundated. Cycling of Gavins Point releases when releases are reduced for downstream flood control during the protected bird species nesting season has also been used to keep birds nesting at sufficiently high elevations to maintain room for release increases when downstream flooding has subsided. The daily variation in releases is normally limited to 8,000 cfs to minimize adverse affects on downstream river users and fish.

2. <u>Non-navigation Season Requirements</u>. When releases are not being made for downstream flow support during navigation season, other factors, including water quality control and water supply, are used to establish the System release rates.

a. <u>Water Quality Control</u>. The regulation of the System under the Master Manual has significantly improved water quality in the river reach downstream of the System, as defined by State water quality standards, compared to the water quality in the Missouri River before the System was constructed. System project release levels necessary to meet downstream water supply purposes generally exceed the minimum release levels necessary to meet minimum downstream water quality requirements. The Missouri River minimum daily flow requirements for water quality control that are given in **Table 8** were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the Environmental Protection Agency in 1974 after consideration of (1) the current status of PL 92-500 programs for managing both point and non-point waste sources discharging into the river, and (2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 parts per million (ppm).

Table 8
Minimum Daily Flow Requirements
For Adequate Dissolved Oxygen
(cfs)

Metropolitan Area	January, February	December, March, April	May	August, September	June, July, October, November
Sioux City	1,800	1,350	1,800	3,000	1,350
Omaha	4,500	3,375	4,500	7,500	3,375
Kansas City	5,400	4,050	5,400	9,000	4,050

Low flows downstream from Gavins Point Dam may affect the ability of thermal powerplants to meet National Pollutant Discharge Elimination System (NPDES) permit standards for discharging cooling water back into the Missouri River and may increase the sediment content in some water supply systems.

b. <u>Water Supply</u>. Numerous water intakes are located along the Missouri River both within and below the System. These intakes are primarily for the purposes of municipal water supplies, nuclear and thermal electric powerplant cooling, and irrigation supplies withdrawn directly from the Missouri River. Reduced releases during periods of extended drought contribute to access problems at several of these intakes; however, in all cases the problems have been a matter of restricted access to the river rather than insufficient water supply. In several river reaches, including near Sioux City and near Kansas City, channel degradation at low flows has impacted several water intakes. Other water supply problems can occur due to the formation of sandbars or sediment deposition, or due to ice jamming on the river during the winter months. Floating ice, also know as frazil ice, can block the water intake facilities directly or reduce flow at the intakes to unacceptable rates. Modifications, both permanent and temporary, have been required at some intakes to ensure operability over a wide range of river conditions.

The minimum daily flow requirements established for water supply are designed to prevent operational problems at municipal and thermal powerplant intakes. Evaluations are continuing by appropriate state agencies in coordination with water plant operators to determine the minimum stage and flow requirement at each intake location for satisfactory hydraulic operation. During any non-navigation time period, releases will be made to ensure adequate flows to serve water supply in the river reaches downstream of the System and between the System dams to the extent reasonably possible.

3. Integration of Downstream Requirements. In years of excess inflows and storage, several options are utilized to evacuate flood control storage, including an extension of the navigation season, increased winter releases, and the provision of summer and fall releases above full service. Because releases above full service increase the risk of downstream flooding, the first option normally utilized is up to a 10-day extension of the navigation season. This increases the service to navigation by providing a longer season and to hydropower by increasing the amount of winter energy generation. If additional evacuation is required, winter releases are increased to evacuate flood control storage, and finally, the summer and fall service levels are increased. Increasing winter releases slightly increases the risk of minor ice-induced flooding; however, open-water flooding during the summer and fall has a higher flood damage potential because of the value of the agricultural crops on the floodplain at that time of year. Moderate increases above full-service requirements during the open-water summer and fall season can be beneficial to the navigation and power purposes.

With normal or below normal inflows and storage, conservation measures may be implemented that reduce navigation and hydropower releases during the open-water season based on System storage, and may provide less than full-service navigation flows and season lengths of less than 8 months as described in Section IV.B.1.a on page 23. Winter System releases are also reduced as a drought conservation measure. The winter System release rate is determined based on a September 1st System storage check and prorated from 17,000 cfs (at 58.0 MAF or more) to 12,000 cfs (at 55.0 MAF or less). This release rate in combination with average downstream tributary flows is normally sufficient to meet downstream water supply intake requirements, but may be adjusted based on tributary flows and the potential for ice formation. In an extended drought, System releases from Gavins Point may be reduced to a level that results in only the minimum flows necessary for downstream water intake or water quality requirements. Based on typical downstream tributary flow contributions, the minimum releases are 9,000 cfs during the non-summer open-water season (March-April and September-November), 18,000 cfs during the summer open-water season (May-August), and 12,000 cfs during the winter period (December-February). These minimum releases for downstream water intakes are average values; actual releases may vary significantly from the listed values.

C. Water Requirements Above Gavins Point.

The regulation of the System under the Master Manual has significantly improved water quality and water supply in the region compared to conditions prior to the construction of the System. However, low reservoir levels and reduced releases during periods of extended drought contribute to both intake access and water quality problems in the upper basin, including problems at several Tribal intakes.

1. **Water Quality Control.** Although the water quality in the System reservoirs is generally considered good and is expected to remain so, it has been deteriorating over time, essentially since the reservoirs were first filled. During late summer, dissolved oxygen levels in the lower depths of the hypolimnion of the reservoirs falls below 5.0 ppm, which is not conducive to support some types of fish. The number of algae blooms has increased during the life of the System. Water quality has deteriorated in some arms of the large reservoirs for short periods so that the water in these locations is not potable, but these situations have been rare. Low flows in the reach downstream from Garrison Dam may affect the ability of thermal powerplants in that reach to meet National Pollutant Discharge Elimination System (NPDES) permit standards for discharging cooling water back into the Missouri River. Low reservoir pool levels and minimum river stages may also increase the sediment content in some water supply systems.

2. **Water Supply.** The minimum releases established for water supply are designed to prevent operational problems at municipal and thermal powerplant intakes at numerous locations along the Missouri River. Similar to problems that have been experienced within the System at other locations, this is generally a matter of intake elevations or river access rather than inadequate water supply. Releases will be made to ensure adequate flows to serve water supply in the river reaches between the System dams to the extent reasonably possible.

At Fort Peck, a minimum daily average release of 3,000 cfs is satisfactory for municipal water supply; however, instantaneous releases of no less than 4,000 cfs are normally scheduled for the coldwater fishery directly below the dam. During periods of high inflow below the project, releases may be scheduled below 3,000 cfs for flood damage reduction, but these instances are rare. To the extent possible, releases are maintained above 6,000 cfs during the irrigation season.

At Garrison, it is desirable to maintain minimum average daily releases of at least 9,000 cfs during the open-water season and the ice-cover season to provide sufficient river depths for continued operation of municipal, irrigation, and powerplant water intakes in North Dakota. In this reach of the river, as well as that below Fort Peck, fluctuations in release levels at times require the resetting of irrigation pumping facilities to maintain access to available water or to prevent inundation of pumps.

Mean daily releases of 1,000 cfs are considered to be adequate to meet all water supply requirements below Fort Randall.

Low reservoir levels during periods of extended drought contribute to both intake access and water quality problems on Garrison and Oahe reservoirs, including problems at several Tribal intakes. There are no municipal intakes on Fort Peck reservoir. Problems at intakes located on the reservoirs are related primarily to access rather than inadequate water supply. In emergency situations, short-term regulation adjustments are made, to the extent reasonably possible, to assure continued operation at those intakes to protect human health and safety. As in the lower basin, modifications have been necessary at a number of intakes to ensure operability over a wide range of reservoir elevations.

D. Power Production.

Since the completion of the power production facilities at the System projects, virtually all project releases have been made through the respective powerplants. When releases are exceptionally high due to flood control storage evacuation, spillway releases are necessary at Gavins Point and Fort Randall and on rare occasions at Fort Peck and Garrison. The six System dams support 36 hydropower units with a combined plant capacity of 2,501 megawatts (MW) of potential power generation. These units provide an average of 10 million megawatt-hours (MWh) of energy per year. WAPA markets hydroelectric energy and capacity from the System. Firm energy is marketed on both an annual and a seasonal basis, recognizing the seasonal pattern of releases made for navigation and required for flood control. During the navigation season, releases from the four uppermost reservoirs are varied in an effort to generate the greatest amount of energy at the times the power loads are the greatest. During the winter period, the most critical with respect to maintaining load requirements, releases from Fort Peck and Garrison are scheduled at relatively high rates to compensate for reduced power production at the downstream powerplants. The fall drawdown at Fort Randall makes available space for recapture of winter power releases from upstream reservoirs. In years of low energy generation due to downstream ice problems or low water availability, energy from other sources is obtained in the winter to help serve firm loads. Generally, the navigation season energy generation is adequate to meet firm load requirements; however, during periods of reduced System releases for downstream flood control or during extended drought periods, WAPA must also purchase large amounts of energy in the summer to serve firm loads.

Pursuant to the Federal Energy Regulatory Commission's open-access transmission law, WAPA may be called upon to reduce generation on the mainstem hydropower system to preserve transmission reliability. This process, called Transmission Loading Relief (TLR), may be called on short notice at any time of the day and is performed by reducing the load at one or more of the powerplants for an unforeseen duration, usually a few hours. TLR reductions are usually accomplished by reducing Oahe generation but can also occur at Fort Randall and Garrison. Reductions in plant generation could be anywhere from a few megawatts to a few hundred megawatts. Depending on System release requirements, the reduction in powerplant releases could result in the need for supplemental releases through the spillways or outlet tunnels. In addition, TLR's may also restrict WAPA's ability to purchase and transmit energy to meet firm loads during period of low hydropower generation resulting in unscheduled increases in generation at the mainstem hydropower system.

The Federal power system consists of the facilities listed in **Table 9**. The hydroelectric powerplants, substations, and other power facilities are interconnected with the extensive Integrated Transmission System in WAPA's Eastern Division, Pick-Sloan Missouri Basin Program (P-S MBP) power-marketing area, which includes Montana east of the continental divide, North and South Dakota, eastern Nebraska, western Minnesota, and western Iowa. The transmission network is interconnected with numerous REA-financed cooperatives, municipal power systems, and investor-owned utilities. The Eastern Division transmission network is interconnected with the Southwestern Power Administration at Maryville, Missouri and with the Western Division transmission network through a 100 MW D.C. tie at Stegall, Nebraska. In addition, a variable number of units at the Fort Peck and Yellowtail powerplants can be operated on the Western Division by a split-bus operation. The Western Division is interconnected with the Colorado River Storage Project.

Table 9
Federal Hydroelectric Powerplants
Eastern Division, P-S MBP

Corps of Engineers	**Nameplate Capacity - kW**	**Number of Units**
Fort Peck	185,250	5
Garrison	583,300	5
Oahe	786,030	7
Big Bend	494,320	8
Fort Randall	320,000	8
Gavins Point	132,300	3
Subtotal	2,501,200	36
U.S. Bureau of Reclamation		
Canyon Ferry	50,000	3
Yellowtail (1)	125,000	4
Subtotal	175,000	7
TOTAL	2,610,650	43

Federal Transmission System

Circuit Miles	**Voltage**
7,745	34,500-345,000 Volts
Substations	**Capacity**
99	8,006,639 kVA

(1) Only 50 percent of 250,000 kW total capacity to Eastern Division

E. Irrigation.

Although none of the originally envisioned Federal irrigation projects have been constructed, numerous irrigators withdraw water directly from the reservoirs and downstream river reaches. While minimum releases established for water quality control and other uses are usually ample to meet the needs of irrigators, low reservoir levels and low river stages make access to the available water supply difficult or inconvenient to obtain for these users. To the extent reasonably possible, the System will be regulated to serve this authorized project purpose, and releases will be adjusted to meet downstream needs.

F. **Recreation**.

The six large reservoirs, the river reaches between the reservoirs, and the river reach below the System provide considerable recreational opportunities, including boating, fishing, hunting, camping, sightseeing, and swimming. Sport fishing is a major source of recreation along the entire river corridor.

Water levels are a key factor in recreational use of the reservoirs and river reaches. The lower three reservoirs, Big Bend, Fort Randall, and Gavins Point, are generally regulated in a consistent manner regardless of inflows and total System storage. Pool levels at the upper three reservoirs, however, vary widely in response to drought conditions. Although recreation may be affected by high reservoir levels and releases, periods of extended drought that result in significant lowering of reservoir levels and releases have a greater impact. At low reservoir levels, some boat ramps and recreational areas may not provide access to the reservoirs. Low releases may impact boat access and maneuverability between and below System dams. During the two major droughts since the System first filled, many boat ramps have been extended or relocated to maintain access. Shortening of the navigation season during droughts also has the effect of shortening the recreation season below the System due to the greatly reduced flows, and the shortening also results in an earlier drawdown for Fort Randall, impacting recreation access on that reservoir.

G. **Fish and Wildlife**.

Construction of the System has been one of the most important contributions to sport fishing in the Missouri River basin. The large, popular reservoirs attract fishermen from many states to fish for trophy size northern pike, walleye, sauger, lake trout, and chinook salmon. The construction and regulation of the System has, however, altered the natural streamflow of the Missouri River. An early spring rise and a late spring-summer rise characterized the natural hydrograph. High flows resulted from the plains snowmelt, from spring and summer rains, and from the mountain snowmelt. Low flows typically occurred in late summer and fall. Regulation of flows by the System has reduced spring flows and has increased late summer, fall, and winter flows to varying degrees, depending on how far downstream from Gavins Point the reach is located, thus altering the habitat of native riverine fish species. River reaches between the reservoirs are now characterized by cooler water temperatures with widely fluctuating daily stages. In addition, the System is regulated to provide protection for the three ESA listed species: the threatened interior least tern, the endangered piping plover, and the endangered pallid sturgeon.

1. Fish. Fish production and development in the System is related to water levels and releases during the spawning period and the availability of appropriate habitat. The Federal and state fish and wildlife agencies recognize that water supply is not always adequate, making it impossible to regulate each reservoir each year for optimum fish management. Therefore, one or more reservoirs may be selected each year to emphasize improvement of fish management to the extent that inflows and requirements for other purposes allow.

a. <u>Regulation during Fish Spawn</u>. The ability to provide steady-to-rising levels in the upper three reservoirs in low-runoff years is dependent on the volume, timing, and distribution of runoff. The current method of managing reservoir levels during the spawn consists of rotating emphasis between Garrison one year and both Fort Peck and Oahe the following year. During Garrison's year, a steady to rising pool is accomplished by adjusting the releases from Fort Peck and Garrison. The following year, a rising pool at Oahe is accomplished through adjustments in Garrison's releases; however, these adjustments may be restricted when the terns and plovers begin nesting in May. At Fort Peck, a rising pool is accomplished by setting releases at a level that maintains a rising pool, but no less than the minimum required to meet the needs of the coldwater fishery immediately downstream of the dam and irrigation needs below the project. The upper three reservoirs are managed to benefit the reservoir fisheries to the extent reasonably possible, while continuing to serve the other Congressionally authorized project purposes. The plan may also be adjusted to be opportunistic in regard to runoff potential and will continue to evolve as additional information becomes available.

b. <u>Reservoir Unbalancing</u>. Reservoir unbalancing is another feature that has been implemented to benefit the reservoir fisheries and the threatened and endangered species. When System inflows are above or below normal, the amount of water in the upper three reservoirs is balanced on March 1st of each year so that the effects are shared equally among the reservoirs. Reservoir unbalancing consists of purposely lowering one of the upper three reservoirs approximately 3 feet to allow vegetation to grow around the rim, then refilling the reservoir to inundate the vegetation. The unbalancing would rotate among the three reservoirs on a 3-year cycle. Higher spring releases would fill the downstream reservoir and provide a rising reservoir for game and forage fish spawning. The subsequent 2 years of lower flows would expose bare sandbar habitat in the river reach between the reservoirs for use by the terns and plovers. Unbalancing would also provide additional bare sandbar habitat around the perimeter of the reservoirs for the terns and plovers in the drawdown year. In subsequent years, the inundated vegetation around the perimeter would be used by adult fish for spawning and by young reservoir fish to hide from predators.

This regulation of the System is computed based on the percentage of the carryover multiple purpose pool that remains in Fort Peck, Garrison, and Oahe. The unbalancing would alternate at each project; high one year, float (normal regulation) the next year, and low the third year. **Table 10** presents the reservoir unbalancing schedule, while **Table 11** shows the reservoir elevations proposed by the Missouri River Natural Resources Committee (MRNRC) at which the unbalancing would not be implemented.

Table 10
Reservoir Unbalancing Schedule

	Fort Peck		Garrison		Oahe	
Year	**March 1st**	**Rest of Year**	**March 1st**	**Rest of Year**	**March 1st**	**Rest of year**
1	High	Float	Low	Hold Peak	Raise & hold during spawn	Float
2	Raise & hold during spawn	Float	High	Float	Low	Hold peak
3	Low	Hold peak	Raise & hold during spawn	Float	High	Float

Float year: Normal regulation, then unbalance 1 foot during low pool years or 3 feet when System storage is near 57.0 MAF on March 1st.
Low year: Begin low, then hold peak the remainder of the year.
High year: Begin high, raise and hold pool during spawn, then float.

Table 11
Reservoir Elevation Guidelines for Unbalancing
(feet msl)

	Fort Peck	Garrison	Oahe
Implement unbalancing if March 1st reservoir elevation is above this level.	2234	1837.5	1607.5
Implement unbalancing if March 1st reservoir elevation is in this range and the pool is expected to raise more than 3 feet after March 1st.	2227-2234	1827-1837.5	1600-1607.5
Scheduling Criteria	Avoid reservoir level decline during spawn period which ranges from April 15th to May 30th	Schedule after spawn period of April 20th to May 20th	Schedule after spawn period of April 8th to May 15th

c. Conservation of Coldwater Habitat. Fort Peck, Garrison, and Oahe reservoirs maintain "two-story" fisheries that are comprised of warmwater and coldwater species. The ability of these reservoirs to maintain "two-story" fisheries is due to their thermal stratification in the summer into a colder bottom region (hypolimnion) and a warmer surface region (epilimnion). The Chinook salmon is a coldwater species of recreational importance that is maintained in all three reservoirs through regular stocking. Other coldwater species present are rainbow smelt in Oahe and Garrison, and lake cisco in Fort Peck. Both these species are important forage fish that are utilized extensively by all recreational species in the respective reservoirs.

Two water quality parameters, temperature and dissolved oxygen, are of prime importance regarding the maintenance of coldwater fishery habitat in the hypolimnion of these reservoirs. During the summer, the amount of coldwater habitat available decreases with decreases in hypolimnetic volume as the thermocline lowers in depth. Also during summer thermal stratification, the reservoirs are experiencing ongoing degradation of dissolved oxygen in the hypolimnion as accumulated organic matter at the reservoir bottom is decomposed. The situation becomes most critical later in the summer when the reduced volume of colder water and the increasing volume of low dissolved oxygen at the reservoir bottom combine to limit the occurrence of suitable coldwater habitat. The situation is exacerbated by drought conditions that lower pool levels and dam releases that draw hypolimnetic water from the reservoir bottom. Of the upper three reservoirs, the greatest impact on the coldwater habitat is at Garrison, where the intake structure draws releases off the bottom of the reservoir. In 2005 plywood was bolted to the lower 50 feet of the trash racks on two of the penstocks to allow water to be drawn from a higher, therefore, warmer region of the reservoir. In 2007 plywood was installed on one additional trash rack. During the current drought, releases from Garrison during the summer months have been made through the three hydropower units with modified intakes to the extent possible. In addition, the manner in which the other hydropower units are operated has been adjusted to operate them at or near full capacity when in use, which also has the effect of drawing water off the upper portion of the reservoir. In combination, these two efforts have saved up to 800,000 acre-feet of coldwater habitat in the reservoir each year for the benefit of the coldwater fishery.

2. Wildlife. Waterfowl management along the Missouri River centers on the Charles M. Russell, Audubon, and Pocasse National Wildlife Refuges established on Fort Peck Garrison, and Oahe reservoirs, respectively. Under intensive management, wildlife production on the refuges has been substantial. Large numbers of migrating waterfowl use the reservoirs in the fall until time of freeze-up. Many then winter on the open water below dams, in nearby refuge areas, or on the open-river reach between Yankton and Sioux City.

3. Threatened and Endangered Species. The Endangered Species Act of 1973 (ESA), as amended, provides for the protection of Federally listed threatened and endangered (T&E) species. ESA requires Federal agencies to ensure that their actions do not jeopardize the continued existence of a threatened or endangered species.

a. ESA Consultation History. In 1985 the interior least tern and the piping plover were Federally listed as endangered and threatened species, respectively. These small shore birds nest on barren, low-lying sandbars and islands downstream from Fort Peck, Garrison, Fort Randall, and Gavins Point from early May through mid-August. When available, they also use beaches and islands on the reservoirs for nesting. The pallid sturgeon was Federally listed as an endangered species in October 1990. The Corps and the USFWS first completed formal Section 7 ESA consultation for terns and plovers on the regulation of the System in 1990. Formal Section 7 consultation for all three protected species was completed in 2000 and again in 2003.

The USFWS's November 2000 Biological Opinion on the Operation of the Missouri River Main Stem Reservoir System, Bank Stabilization and Navigation Project, and the Kansas River Reservoir System (2000 BiOp) concluded that the Corps' proposed action jeopardized the continued existence of the listed pallid sturgeon, piping plover, and interior least tern. The 2000 BiOp also recommended a Reasonable and Prudent Alternative (RPA) to avoid jeopardy. On November 3, 2003, the Corps requested reinitiation of formal ESA consultation. The request for reinitiation was based on the existence of new information regarding the effects of System regulation on the Federally listed species and a new critical habitat designation for one of the listed species. On December 16, 2003, in response to the Corps' request for the reinitiation of consultation, the USFWS issued an amendment to its 2000 BiOp. The 2003 Amended BiOp presented the USFWS's opinion that the regulation of the System would jeopardize the continued existence of the endangered pallid sturgeon. The 2003 Amended BiOp provided, among other things, an RPA to avoid jeopardy to the pallid sturgeon that included a provision for the Corps to develop a bimodal "spring pulse" from Gavins Point. In March 2006, the Master Manual was revised to include technical criteria for a bimodal spring pulse.

b. Regulation during Nesting Season. Prior to their Federal listings, tern and plover nests were periodically inundated as a result of project releases for flood control, navigation, and hydroelectric power generation. Since the time they were listed, the Corps has participated in habitat and population studies relative to the interior least tern and the piping plover in the Missouri River reach from Fort Peck, Montana to Ponca State Park, Nebraska. In the past, the Corps has provided additional habitat by removing vegetation from higher elevation islands and creating higher elevation habitat at historic nesting sites. Nesting use is monitored at these sites. The Corps is striving to avoid adverse impacts on these species and will continue to adjust System regulation to benefit Federally listed threatened and endangered species while continuing to serve all authorized project purposes. Ten stream gages were automated with satellite data collection platforms between 1986 and 1988 in the river downstream from Garrison, Fort Randall, and Gavins Point to provide the information needed to correlate nesting habitat with reservoir releases. The river reaches have been modeled using dynamic modeling so that stages can be estimated for various release patterns prior to making the releases; however, the models cannot accurately predict stage increases and nest flooding due to rainfall runoff events.

Releases from the mainstem projects are closely monitored during the nesting season. A uniform peaking release pattern has been established during the summer months at Garrison and Fort Randall for T&E nesting along the river reaches below these projects. In the past a peaking pattern was also established at Fort Peck; however, recent nesting patterns below that project have made it unnecessary. If nesting patterns change in the future, the peaking pattern at Fort Peck may be reestablished. Additionally, releases from Gavins Point are adjusted when the birds arrive to provide the System flexibility to meet navigation target flows later in the nesting season when downstream tributary flows begin their normal decline in July and

August. Additional information on these adjustments, including the steady release (SR), flow-to-target (FTT), steady release – flow-to-target (SR-FTT), and cycling is presented in Section IV.B.1.b on page 25.

c. **Gavins Point Spring Pulse**. **Table 12** summarizes the Gavins Point spring pulse technical criteria for the benefit if the endangered pallid sturgeon. Included in the technical criteria for each spring pulse is a System storage drought preclude below which the corresponding pulse would be foregone that year. The drought precludes for both the March and May spring pulses were initially set at 36.5 MAF. After the first occurrence of each pulse, its respective preclude was to be increased to 40.0 MAF. At the time of this report, the System storage drought preclude for the March pulse remains at 36.5 MAF; the drought preclude for the May pulse is 40.0 MAF.

Water for the spring pulses ultimately comes from storage in the upper three reservoirs. During normal to wet basin conditions, runoff into the System will be sufficient to maintain steady to rising pool levels at the upper three reservoirs. However, during periods of drought, the spring pulses could cause a pool level decline at one or more of the upper three reservoir(s). During periods of extended drought, primary consideration will be given to withdrawing the water needed for the May spring pulse from Fort Randall, rather than from one or more of the upper three reservoirs. This would avoid further declines at Fort Peck, Garrison, and Oahe. If using Fort Randall in this manner is not feasible, the Corps would then give consideration to distributing the upstream storage reductions due to the May pulse equally among the upper three reservoirs.

Table 12
Technical Criteria for Spring Pulses
From Gavins Point Dam

Criteria Applicable to the March Spring Pulse

Drought Preclude	36.5 MAF or below measured on March 1st.
Drought Proration of Pulse Magnitude*	None, 5 kcfs added to navigation releases, but no greater than 35 kcfs.
Initiation of Pulse	Extend the stepped System release increases that precede the beginning of the navigation season.
Rate of Rise before Peak	Approximately 5 kcfs for 1 day.
Duration of Peak	Two days.
Rate of Fall after Peak	Drop over 5 days to navigation target release.

(cont'd)

Table 12 (cont'd)
Technical Criteria for Spring Pulses
From Gavins Point Dam

Criteria Applicable to Time Period Between the Bimodal Pulses	
Release	Existing Master Manual criteria
Criteria Applicable to the May Spring Pulse	
Drought Preclude	40.0 MAF or below measured on May 1st.
Proration of Pulse Magnitude Based On System Storage*	Prorated from 16 kcfs based on a May 1st System storage check; 100% at 54.5 MAF; straight line interpolation to 75% at 40.0 MAF.
Proration of Pulse Magnitude Based On Projected Runoff*	After the proration of the spring pulse magnitude for System storage, the resultant magnitude would be further adjusted either up or down based on the May CY runoff forecast; 100% for Median; straight-line interpolation to 125% at Upper Quartile runoff; 125% for runoff above Upper Quartile; straight-line interpolation to 75% at Lower Quartile runoff; 75% for runoff below Lower Quartile.
Initiation of Pulse	Between May 1st to May 19th, depending on Missouri River water temperature immediately below Gavins Point Dam. If possible, pulse will be initiated after the second daily occurrence of a 16 degree Celsius water temperature; however, this decision will be made with consideration for the potential 'take' of threatened and endangered bird species.
Rate of Rise before Peak	Approximately 6 kcfs per day.
Duration of Peak	Two days.
Rate of Fall after Peak	Approximately 30% drop over 2 days followed by a proportional reduction in releases back to the existing Master Manual criteria over an 8-day period.

* Spring pulse magnitudes will be determined by taking the difference between pre-pulse Gavins Point releases and the peak pulse Missouri River flows measured just downstream of the mouth of the James River.

The magnitude of both the March and May spring pulses will be constrained by the Gavins Point spring pulse downstream flow limits. These downstream flow limits are at the same locations as the flood control constraints presented in the Master Manual. The spring pulse flow limits, shown in **Table 13**, are equivalent to the most conservative System flood control constraints at Omaha, Nebraska City, and Kansas City. If the Reservoir Control Center's daily Missouri River forecast with National Weather Service quantitative precipitation indicates that these flow limits will be exceeded during the occurrence of the spring pulse below Gavins Point, the spring pulse will be reduced, delayed within the available time window, or foregone completely that year to avoid exceeding the pulse flow limits.

Table 13
Downstream Flow Limits
During the Gavins Point Spring Pulse(s)

Location	Flow Limit
Omaha	41,000 cfs
Nebraska City	47,000 cfs
Kansas City	71,000 cfs

d. Fort Peck Flow Tests. The Master Manual also contains provisions for two Fort Peck flow modification tests for the benefit of the pallid sturgeon and other native river fish. These tests involve a combination of Fort Peck spillway and powerplant releases during the early-June timeframe. These tests are designed to evaluate the ability of the Fort Peck project to provide higher and warmer flows in the Missouri River downstream of the project. These tests are currently on hold because the Fort Peck pool level is well below the spillway crest; therefore, no water can be released from the spillway. However, the tests will be implemented when Fort Peck reservoir recovers from the current drought. The tests will allow (1) an evaluation of the integrity of the Fort Peck spillway structure, (2) an evaluation of data collection methodology, and (3) an opportunity to gather preliminary data on river temperatures with various combinations of releases from the spillway and powerhouse. Stream-bank erosion and fishery impacts will also be monitored. Stop protocols for the "mini-test" are identified in the Fort Peck Flow Modification Mini-Test Environmental Assessment, dated March 2004. Before this test and the subsequent "full-test" are run, the Corps will fully coordinate with the Tribes of the Fort Peck Reservation, the State of Montana, and any potentially affected stakeholders.

During the Fort Peck mini-test, which will last about 4 weeks, flows will vary from 8,000 to 15,000 cfs as various combinations of spillway and powerplant releases are monitored. The maximum spillway release of 11,000 cfs will combine with a minimum powerplant release of 4,000 cfs for 6 days. This regulation will be timed to avoid lowering the reservoir during the forage fish spawn. The mini-test will not be conducted if sufficient flows will not pass over the spillway crest (elevation 2225 feet msl). A minimum reservoir elevation of about 2229 feet msl is needed during the test to avoid unstable flows over the spillway.

A more extensive test, referred to as the “full-test”, with a combined spillway and power plant release of 20,000 to 25,000 cfs, is scheduled to be conducted beginning in early June in the year following the mini-test. This test would allow further evaluation of the integrity of the spillway and would attempt to determine if warm water releases will benefit the native river fishery. Peak outflows during the full-test would be maintained for 2 weeks within the 4-week test period.

4. **Environment.** Development of the System has transformed a major portion of the Missouri River valley extending from eastern Montana through the Dakotas from an area typical of alluvial streams into a chain of long, relatively deep reservoirs. This development, in an area where such reservoirs did not exist naturally and which is characterized as being relatively dry, has had a great effect upon the environment of the area. Acquisition and subsequent management of lands associated with the individual projects by the Corps has changed use patterns of areas adjacent to the reservoirs from those experienced prior to project development. Regulation of the reservoirs also has significantly affected the flow regime of the Missouri River between and below the projects where the river is still more or less in its natural state. Through observations and discussions with interested individuals and agencies, suggestions for environmental management have been received and are being implemented where practical.

A major environmental consideration has been the effect of various regulation practices on fish and wildlife, including threatened and endangered species. Improvement of fish spawning activities by appropriate habitat management and subsequent spawning is an important consideration in reservoir regulation. Suggestions for improving migratory waterfowl habitat and hunter access along the river below the projects have been made and adopted to the degree practical. However, some suggestions, such as reducing flows during the migration to provide more sandbars, are difficult to implement without seriously impacting other authorized project purposes. Nevertheless, as suggestions are received, they are considered and evaluated with Federal and state fish and wildlife agencies and, where feasible, implemented to the degree practical. Another area of environmental concern is the management of project lands. At the present time, the major development emphasis on these lands is for water-oriented recreation; however, large areas of project lands are now being managed almost exclusively for wildlife.

Fluctuating reservoir levels and releases are also a concern to many project users but are unavoidable if the projects are to serve authorized purposes. As a consequence, access to the reservoirs and river reaches may be difficult at times, fishing success may be affected, the sediment load in the river may be increased, and users of fixed boat docks may be inconvenienced. Release fluctuations are being minimized to the maximum practical extent considering release requirements for other authorized purposes. Improvement of the downstream water quality is another environmental consideration receiving emphasis at this time. As discussed elsewhere, relatively good quality water is stored and released from the reservoirs.

H. Historic and Cultural Properties.

As acknowledged in the 2004 Programmatic Agreement for the Operation and Management of the Missouri River Main Stem System (PA), wave action and fluctuation in the level of the System reservoir pools result in erosion along the banks of the reservoirs impacting historic and cultural sites. During periods of extended drought, additional sites become exposed as pool levels decline. The Corps will continue working with the Tribes utilizing 36 CFR Part 800 and the PA to address the exposure of these sites. The objective of a programmatic agreement is to deal "…with the potential adverse effects of complex projects or multiple undertakings…" The PA objective was to collaboratively develop a preservation program that would avoid, minimize, and/or mitigate adverse effects along the System reservoirs. **Plate 3** shows the locations of the Tribal Reservations.

The planned preservation program for the regulation of the System is outlined by multiple stipulations in the PA. One of the stipulations, or program components, is the Five Year Plan. This plan outlines how the Corps will accomplish its responsibilities under the PA and the National Historic Preservation Act. The "Draft Five Year Plan, dated February 2005" (see https://www.nwo.usace.army.mil/CR/) is currently being implemented. The plan includes inventory, testing and evaluation, mitigation, and other specific activities that will allow the Corps to avoid, minimize, and/or mitigate the adverse effects to cultural sites on Corps lands within the System. Two critical components of the Five Year Plan are applicable monitoring and mitigation, which are briefly discussed in the following paragraphs.

First, a collaboratively developed plan, entitled "Draft Monitoring and Enforcement Plan, dated April 2005" (see https://www.nwo.usace.army.mil/CR/) is in place. This monitoring plan outlines the sites that require monitoring and specifies a frequency for monitoring. The Corps plans to strategically monitor those sites within the potential operating pool elevations to document the effects of the regulation of the System. Specific sites are identified in the draft Monitoring and Enforcement Plan for the monitoring team, comprised of Corps rangers and Tribal monitors, to visit and document impacts. This focused monitoring will result in more accurate data on the current impacts to sites along the river plus it will assist in the identification of sites for mitigation.

Second, it is expected that implementation of the monitoring plan will identify sites that will require immediate mitigation. The Corps plans to compile the data from the monitoring efforts and determine which sites will require immediate mitigation, most likely stabilization. It is expected that there will be more sites than funding will allow, so the Corps will work with the affected Tribes, Tribal Historic Preservation Officers, the Advisory Council on Historic Preservation, State Historic Preservation Officers, and other consulting parties in the prioritization of those sites that need stabilization.

Results expected from the proposed monitoring and mitigation actions include more accurate horizontal and vertical data on existing cultural sites, detailed impact data, proactive protection, and preservation of sites.

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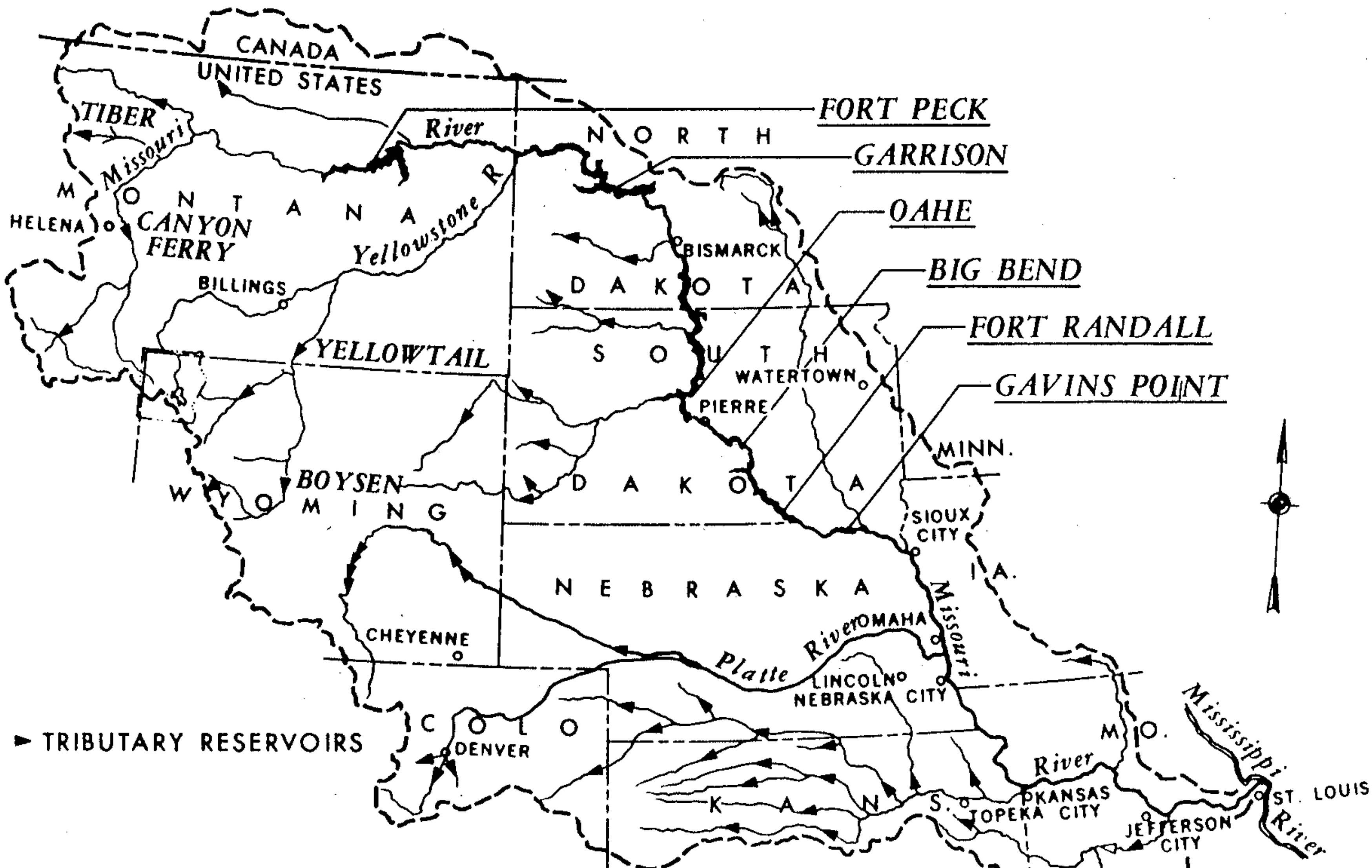


MISSOURI RIVER BASIN

PLATE 1

Summary of Engineering Data -- Missouri River Mainstem System

Item No.	Subject	Fort Peck Dam - Fort Peck Lake	Garrison Dam - Lake Sakakawea	Oahe Dam - Lake Oahe
1	Location of Dam	Near Glasgow, Montana	Near Garrison, ND	Near Pierre, SD
2	River Mile - 1960 Mileage	Mile 1771.5	Mile 1389.9	Mile 1072.3
3	Total & incremental drainage areas in square miles	57,500	181,400 (2) 123,900	243,490 (1) 62,090
4	Approximate length of full reservoir (in valley miles)	134, ending near Zortman, MT	178, ending near Trenton, ND	231, ending near Bismarck, ND
5	Shoreline in miles (3)	1520 (elevation 2234)	1340 (elevation 1837.5)	2250 (elevation 1607.5)
6	Average total & incremental inflow in cfs	10,200	25,600 15,400	28,900 3,300
7	Max. discharge of record near damsite in cfs	137,000 (June 1953)	348,000 (April 1952)	440,000 (April 1952)
8	Construction started - calendar yr	1933	1946	1948
9	In operation (4) calendar yr.	1940	1955	1962
	Dam and Embankment			
10	Top of dam, elevation in feet msl	2280.5	1875	1660
11	Length of dam in feet	21,026 (excluding spillway)	11,300 (including spillway)	9,300 (excluding spillway)
12	Damming height in feet (5)	220	180	200
13	Maximum height in feet (5)	250.5	210	245
14	Max. base width, total & w/o berms in feet	3500, 2700	3400, 2050	3500, 1500
15	Abutment formations (under dam & embankment)	Bearpaw shale and glacial fill	Fort Union clay shale	Pierre shale
16	Type of fill	Hydraulic & rolled earth fill	Rolled earth filled	Rolled earth fill & shale berms
17	Fill quantity, cubic yards	125,628,000	66,500,000	55,000,000 & 37,000,000
18	Volume of concrete, cubic yards	1,200,000	1,500,000	1,045,000
19	Date of closure	24 June 1937	15 April 1953	3 August 1958
	Spillway Data			
20	Location	Right bank - remote	Left bank - adjacent	Right bank - remote
21	Crest elevation in feet msl	2225	1825	1596.5
22	Width (including piers) in feet	820 gated	1336 gated	456 gated
23	No., size and type of gates	16 - 40' x 25' vertical lift gates	28 - 40' x 29' Tainter	8 - 50' x 23.5' Tainter
24	Design discharge capacity, cfs	275,000 at elev 2253.3	827,000 at elev 1858.5	304,000 at elev 1644.4
25	Discharge capacity at maximum operating pool in cfs	230,000	660,000	80,000
	Reservoir Data (6)			
26	Max. operating pool elev. & area	2250 msl 246,000 acres	1854 msl 380,000 acres	1620 msl 374,000 acres
27	Max. normal op. pool elev. & area	2246 msl 240,000 acres	1850 msl 364,000 acres	1617 msl 360,000 acres
28	Base flood control elev & area	2234 msl 212,000 acres	1837.5 msl 307,000 acres	1607.5 msl 312,000 acres
29	Min. operating pool elev. & area	2160 msl 90,000 acres	1775 msl 128,000 acres	1540 msl 117,000 acres
	Storage allocation & capacity			
30	Exclusive flood control	2250-2246 975,000 a.f.	1854-1850 1,489,000 a.f.	1620-1617 1,102,000 a.f.
31	Flood control & multiple use	2246-2234 2,717,000 a.f.	1850-1837.5 4,222,000 a.f.	1617-1607.5 3,201,000 a.f.
32	Carryover multiple use	2234-2160 10,785,000 a.f.	1837.5-1775 13,130,000 a.f.	1607.5-1540 13,461,000 a.f.
33	Permanent	2160-2030 4,211,000 a.f.	1775-1673 4,980,000 a.f.	1540-1415 5,373,000 a.f.
34	Gross	2250-2030 18,688,000 a.f.	1854-1673 23,821,000 a.f.	1620-1415 23,137,000 a.f.
35	Reservoir filling initiated	November 1937	December 1953	August 1958
36	Initially reached min. operating pool	27 May 1942	7 August 1955	3 April 1962
37	Estimated annual sediment inflow	17,700 a.f. 1030 yrs.	25,900 a.f. 920 yrs.	19,800 a.f. 1170 yrs.
	Outlet Works Data			
38	Location	Right bank	Right Bank	Right Bank
39	Number and size of conduits	2 - 24' 8" diameter (nos. 3 & 4)	1 - 26' dia. and 2 - 22' dia.	6 - 19.75' dia. upstream, 18.25' dia. downstream
40	Length of conduits in feet (8)	No. 3 - 6,615, No. 4 - 7,240	1529	3496 to 3659
41	No., size, and type of service gates	1 - 28' dia. cylindrical gate 6 ports, 7.6' x 8.5' high (net opening) in each control shaft	1 - 18' x 24.5' Tainter gate per conduit for fine regulation	1 - 13' x 22' per conduit, vertical lift, 4 cable suspension and 2 hydraulic suspension (fine regulation)
42	Entrance invert elevation (msl)	2095	1672	1425
43	Avg. discharge capacity per conduit & total	Elev. 2250 22,500 cfs - 45,000 cfs	Elev. 1854 30,400 cfs - 98,000 cfs	Elev. 1620 18,500 cfs - 111,000 cfs
44	Present tailwater elevation (ft msl)	2032-2036 5,000 - 35,000 cfs	1670-1680 15,000- 60,000 cfs	1423-1428 20,000-55,000 cfs
	Power Facilities and Data			
45	Avg. gross head available in feet (14)	194	161	174
46	Number and size of conduits	No. 1-24'8" dia., No. 2-22'4" dia.	5 - 29' dia., 25' penstocks	7 - 24' dia., imbedded penstocks
47	Length of conduits in feet (8)	No. 1 - 5,653, No. 2 - 6,355	1829	From 3,280 to 4,005
48	Surge tanks	PH#1: 3-40' dia., PH#2: 2-65' dia.	65' dia. - 2 per penstock	70' dia., 2 per penstock
49	No., type and speed of turbines	5 Francis, PH#1-2: 128.5 rpm, 1-164 rpm , PH#2-2: 128.6 rpm	5 Francis, 90 rpm	7 Francis, 100 rpm
50	Discharge cap. at rated head in cfs	PH#1, units 1&3 170', 2-140' 8,800 cfs, PH#2-4&5 170'-7,200 cfs	150' 41,000 cfs	185' 54,000 cfs
51	Generator nameplate rating in kW	1&3: 43,500; 2: 18,250; 4&5: 40,000	3 - 121,600, 2 - 109,250	112,290
52	Plant capacity in kW	185,250	583,300	786,030
53	Dependable capacity in kW (9)	181,000	388,000	534,000
54	Avg. annual energy, million kWh (12)	1,087	2,318	2,717
55	Initial generation, first and last unit	July 1943 - June 1961	January 1956 - October 1960	April 1962 - June 1963
56	Estimated cost September 1999 completed project (13)	$158,428,000	$305,274,000	$346,521,000

Summary of Engineering Data -- Missouri River Mainstem System

	Big Bend Dam - Lake Sharpe	Fort Randall Dam - Lake Francis Case	Gavins Point Dam - Lewis & Clark Lake	Total	Item No.
	21 miles upstream Chamberlain, SD	Near Lake Andes, SD	Near Yankton, SD		1
	Mile 987.4	Mile 880.0	Mile 811.1		2
	249,330 (1) 5,840	263,480 (1) 14,150	279,480 (1) 16,000		3
	80, ending near Pierre, SD	107, ending at Big Bend Dam	25, ending near Niobrara, NE	755 miles	4
	200 (elevation 1420)	540 (elevation 1350)	90 (elevation 1204.5)	5,940 miles	5
	28,900	30,000 1,100	32,000 2,000		6
	440,000 (April 1952)	447,000 (April 1952)	480,000 (April 1952)		7
	1959	1946	1952		8
	1964	1953	1955		9
	1440	1395	1234		10
	10,570 (including spillway)	10,700 (including spillway)	8,700 (including spillway)	71,596	11
	78	140	45	863 feet	12
	95	165	74		13
	1200, 700	4300, 1250	850, 450		14
	Pierre shale & Niobrara chalk	Niobrara chalk	Niobrara chalk & Carlile shale		15
	Rolled earth, shale, chalk fill	Rolled earth fill & chalk berms	Rolled earth & chalk fill		16
	17,000,000	28,000,000 & 22,000,000	7,000,000	358,128,000 cu. yds	17
	540,000	961,000	308,000	5,554,000 cu. yds.	18
	24 July 1963	20 July 1952	31 July 1955		19
	Left bank - adjacent	Left bank - adjacent	Right bank - adjacent		20
	1385	1346	1180		21
	376 gated	1000 gated	664 gated		22
	8 - 40' x 38' Tainter	21 - 40' x 29' Tainter	14 - 40' x 30' Tainter		23
	390,000 at elev 1433.6	620,000 at elev 1379.3	584,000 at elev 1221.4		24
	270,000	508,000	345,000		25
	1423 msl 61,000 acres	1375 msl 102,000 acres	1210 msl 31,000 acres	1,194,000 acres	26
	1422 msl 60,000 acres	1365 msl 95,000 acres	1208 msl 28,000 acres	1,147,000 acres	27
	1420 msl 57,000 acres	1350 msl 77,000 acres	1204.5 msl 24,000 acres	989,000 acres	28
	1415 msl 51,000 acres	1320 msl 38,000 acres	1204.5 msl 24,000 acres	450,000 acres	29
	1423-1422 60,000 a.f.	1375-1365 985,000 a.f.	1210-1208 59,000 a.f.	4,670,000 a.f.	30
	1422-1420 117,000 a.f.	1365-1350 1,309,000 a.f.	1208-1204.5 90,000 a.f.	11,656,000 a.f.	31
		1350-1320 1,607,000 a.f.		38,983,000 a.f.	32
	1420-1345 1,621,000 a.f.	1320-1240 1,517,000 a.f.	1204.5-1160 321,000 a.f.	18,023,000 a.f.	33
	1423-1345 1,798,000 a.f.	1375-1240 5,418,000 a.f.	1210-1160 470,000 a.f.	73,332,000 a.f.	34
	November 1963	January 1953	August 1955		35
	25 March 1964	24 November 1953	22 December 1955		36
	5,300 a.f. 430 yrs.	18,400 a.f. 250 yrs.	2,600 a.f. 180 yrs.	89,700 a.f.	37
		Left Bank			38
	None (7)	4 - 22' diameter	None (7)		39
		1013			40
		2 - 11' x 23' per conduit, vertical lift, cable suspension			41
	1385 (11)	1229	1180 (11)		42
		Elev 1375 32,000 cfs - 128,000 cfs			43
	1351-1355(10) 25,000-100,000 cfs	1228-1239 5,000-60,000 cfs	1155-1163 15,000-60,000 cfs		44
	70	117	48	764 feet	45
	None: direct intake	8 - 28' dia., 22' penstocks	None: direct intake		46
		1,074		55,083	47
	None	59' dia, 2 per alternate penstock	None		48
	8 Fixed blade, 81.8 rpm	8 Francis, 85.7 rpm	3 Kaplan, 75 rpm	36 units	49
	67' 103,000 cfs	112' 44,500 cfs	48' 36,000 cfs		50
	3 - 67,276, 5 - 58,500	40,000	44,100		51
	494,320	320,000	132,300	2,501,200 kw	52
	497,000	293,000	74,000	1,967,000 kw	53
	1,001	1,778	740	9,642 million kWh	54
	October 1964 - July 1966	March 1954 - January 1956	September 1956 - January 1957	July 1943 - July 1966	55
	$107,498,000	$199,066,000	$49,617,000	$1,166,404,000	56

Remarks

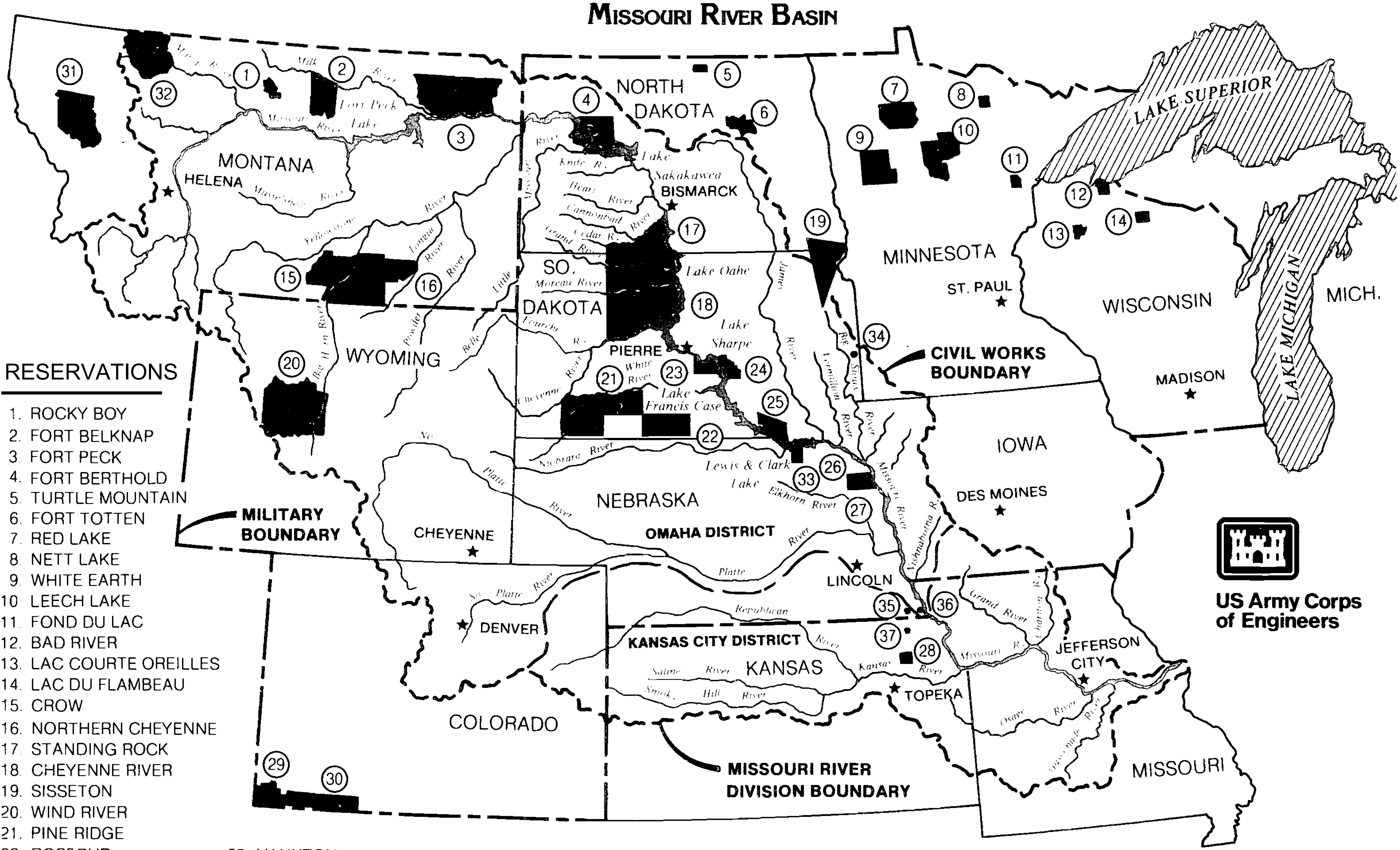
(1) Includes 4,280 square miles of non-contributing areas.
(2) Includes 1,350 square miles of non-contributing areas.
(3) With pool at base of flood control.
(4) Storage first available for regulation of flows
(5) Damming height is height from low water to maximum operating pool. Maximum height is from average streambed to top of dam.
(6) Based on latest available storage data.
(7) River regulation is attained by flows over low-crested spillway and through turbines.
(8) Length from upstream face of outlet or to spiral case.
(9) Based on 8th year (1961) of drought drawdown (From study 8-83-1985).
(10) Affected by level of Lake Francis case. Applicable to pool at elevation 1350.
(11) Spillway crest
(12) 1967-2006 Average
(13) Source: Annual Report on Civil Works Activities of the Corps of Engineers. Extract Report Fiscal Year 1999.
(14) Based on Study 8-83-1985

Corps of Engineers, U.S. Army
Compiled by
Northwestern Division
Missouri River Region
January 2007

Plate 2

American Indian Reservations

Missouri River Basin



RESERVATIONS

1. ROCKY BOY
2. FORT BELKNAP
3. FORT PECK
4. FORT BERTHOLD
5. TURTLE MOUNTAIN
6. FORT TOTTEN
7. RED LAKE
8. NETT LAKE
9. WHITE EARTH
10. LEECH LAKE
11. FOND DU LAC
12. BAD RIVER
13. LAC COURTE OREILLES
14. LAC DU FLAMBEAU
15. CROW
16. NORTHERN CHEYENNE
17. STANDING ROCK
18. CHEYENNE RIVER
19. SISSETON
20. WIND RIVER
21. PINE RIDGE
22. ROSEBUD
23. LOWER BRULE
24. CROW CREEK
25. YANKTON
26. WINNEBAGO
27. OMAHA
28. POTAWATOMI
29. UTE MOUNTAIN
30. SOUTHERN UTE
31. FLATHEAD
32. BLACKFEET
33. SANTEE
34. FLANDREAU
35. IOWA
36. SAC AND FOX
37. KICKAPOO

For illustrative purposes. No legal boundaries are implied.

Plate 3