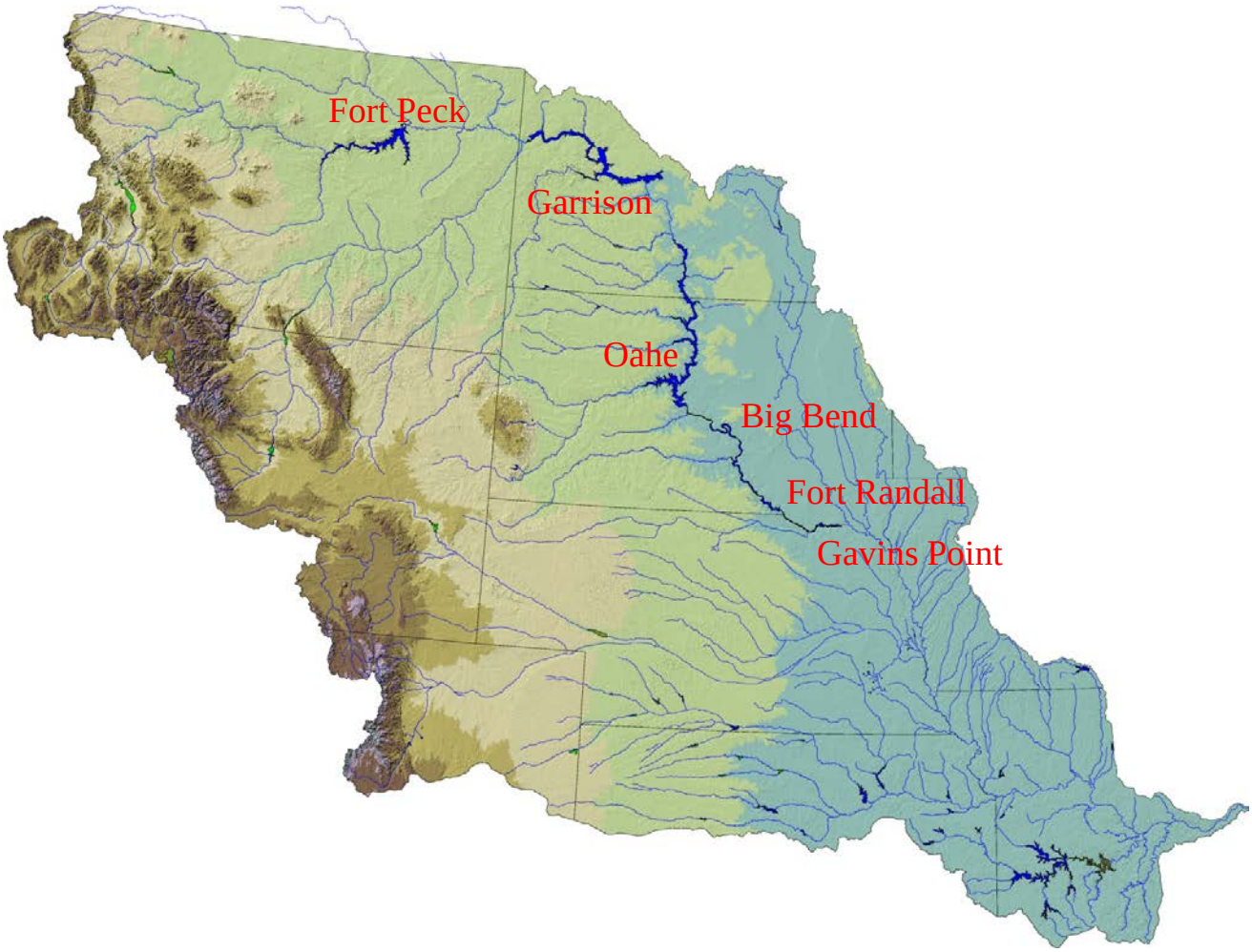
US Army Corps of Engineers ®
Northwestern Division

Missouri River Mainstem Reservoir System

Water Control Manual
Gavins Point Dam – Lewis and Clark Lake



Missouri River Basin Water Management Division
U.S. Army Corps of Engineers
Northwestern Division – Missouri River Basin
Omaha, Nebraska

December 2018

Missouri River Basin
Mainstem Reservoir System
Water Control Manual

In 7 Volumes Volume 7

GAVINS POINT PROJECT

Volume 1	Master Manual
Volume 2	Fort Peck (Fort Peck Lake)
Volume 3	Garrison (Lake Sakakawea)
Volume 4	Oahe (Lake Oahe)
Volume 5	Big Bend (Lake Sharpe)
Volume 6	Fort Randall (Lake Francis Case)
Volume 7	Gavins Point (Lewis and Clark Lake)

Prepared by
U.S. Army Engineer Division, Northwestern Division
Corps of Engineers
Omaha, Nebraska

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Mainstem Reservoir System
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ABBREVIATIONS / ACRONYMS

AF	-	acre-feet
AOP	-	Annual Operating Plan
BIA	-	Bureau of Indian Affairs
cfs	-	cubic feet per second
Co-op	-	Cooperative Streamgaging Program
Corps	-	U.S. Army Corps of Engineers
DCP	-	Data Collection Platform
DPR	-	Definite Project Report
EM	-	Corps' Engineering Manual
ER	-	Corps' Engineering Regulation
ESA	-	Endangered Species Act
°F	-	degrees Fahrenheit
GF&P	-	Game Fish and Parks
HEC-HMS	-	Corps' Hydrologic Modeling System
kAF	-	1,000 acre-feet
kcfs	-	1,000 cubic feet per second
kV	-	kilovolt
kW	-	kilowatt
least tern	-	interior least tern
M&I	-	Municipal and Industrial
MAF	-	million acre-feet
Master Manual	-	Master Water Control Manual
MBRFC	-	Missouri Basin River Forecast Center
MRBIR	-	Missouri River Basin Interagency Roundtable
MRBWM	-	Missouri River Basin Water Management
MRD	-	Missouri River Division
MRNRC	-	Missouri River Natural Resources Committee
MRR	-	Missouri River Region
MRRIC	-	Missouri River Recovery Implementation Committee
MW	-	megawatt
MWh	-	megawatt hour
NAVD88	-	National American Vertical Datum of 1988
NGVD29	-	National Geodetic Vertical Datum of 1929
NWD	-	Northwestern Division
NWDR	-	Northwestern Division Regulation
NWS	-	National Weather Service
O&M	-	Operation and Maintenance
PPCS	-	Powerplant Control System
QPE	-	Quantitative Precipitation Estimate
RCC	-	Reservoir Control Center
RM	-	River Mile (1960 mileage)
RPA	-	Reasonable and Prudent Alternative
SDF	-	Spillway Design Flood
Southwestern	-	Southwestern Power Administration
SPP	-	Southwest Power Pool

SWE	-	snow water equivalent
System	-	Missouri River Mainstem Reservoir System
T&E	-	threatened and endangered
USBR	-	U.S. Bureau of Reclamation
USFWS	-	U.S. Fish and Wildlife Service
USGS	-	U.S. Geological Survey
WCM	-	water control manual
Western	-	Western Area Power Administration
WMS	-	Water Management System

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I - Introduction

1-01. Authorization. This manual has been prepared as directed in the U.S. Army Corps of Engineers' (Corps) Engineering Regulation, ER 1110-2-240, which prescribes the policies and procedures to be followed by the Corps in carrying out water management activities, including establishment and the updating of water control plans for Corps and non-Corps projects, as required by federal laws and directives. This manual is prepared as the water control manual (WCM) for Gavins Point, as discussed in that regulation. This WCM is also prepared in accordance with pertinent sections of the Corps' Engineering Manual, EM 1110-2-3600, and titled *Management of Water Control Systems*. This WCM is prepared under the general format and recommendations described in ER 1110-2-8156, dated August 31, 1995 and titled *Preparation of Water Control Manuals*. This Gavins Point WCM, like the Mainstem Master Water Control Manual (Master Manual) and its selected water control plan, establish guidelines intended to be used by the Corps in regulating Gavins Point. However, changed conditions or unforeseen conditions may necessitate changes or deviations from these guidelines. This is consistent with Corps' regulations that allow for both updates for changes in normal regulation as well as for deviations to the approved WCM. Revisions to this WCM are processed in accordance with ER 1110-2-240. Deviations from this WCM are processed in accordance with ER 1110-2-1400 and the Northwestern Division Regulation, NWDR 1110-2-6.

1-02. Purpose and Scope. This WCM is one of the seven volumes prepared for the Missouri River Mainstem Reservoir System (System). Six of the volumes are for each of the six System projects (project name is the same as the name of the dam) and one is for total System regulation (Master Manual):

Volume	Project
1	Master Manual
2	Fort Peck – Fort Peck Dam / Fort Peck Lake
3	Garrison – Garrison Dam / Lake Sakakawea
4	Oahe – Oahe Dam / Lake Oahe
5	Big Bend – Big Bend Dam / Lake Sharpe
6	Fort Randall – Fort Randall Dam / Lake Francis Case
7	Gavins Point – Gavins Point Dam / Lewis and Clark Lake

1-02.1. This individual project WCM serves as a supplement to the Master Manual (Volume 1) and presents aspects of project regulation not common to the System as a whole. This includes detail on the incremental drainage areas regarding hydrology, hydrologic networks, forecasting, streamflow and runoff. This WCM also includes site-specific maps and regulation considerations. This individual project WCM, like the Master Manual, serves as a guide to the Missouri River Basin Water Management (MRBWM) Division in meeting the operational objectives of the System when regulating the six System reservoirs. Since Gavins Point is part of the System, any discussions regarding the regulation of Gavins Point that conflict with

statements presented in the Master Manual will be secondary and conducted to the extent possible only after regulation of the System as a whole is accomplished.

1-03. Related Manuals and Reports. The System projects were constructed by the Corps for the purpose of flood control, navigation, recreation, water supply, water quality control, fish and wildlife, hydropower and irrigation. To achieve the multi-purpose benefits for which the System was authorized and constructed, it must be regulated as a hydraulically and electrically integrated system. Therefore, the Master Manual presents the basic System operational objectives and the plans for their optimum fulfillment, with supporting basic data. The Gavins Point WCM supplements the Master Manual by discussing the factors pertinent to the regulation of Gavins Point. The regulation of major tributary reservoirs located within the Missouri River basin affecting the regulation of Gavins Point is detailed in separate WCMs prepared for the individual tributary projects.

1-03.1. In an effort to reduce redundancy, frequent reference will be made in this WCM to information contained in the Master Manual. This is particularly true with respect to details concerning organization, coordination with other projects and agencies, and other factors that are pertinent to regulation of the System as a whole. This WCM presents further information and expands or emphasizes details that are of particular importance to Gavins Point and serves as a supplement to the Master Manual.

1-03.2. In a further effort to reduce redundancy among the individual project WCMs, frequent reference will be made to the Fort Randall WCM in connection to Gavins Point inflows and releases. With the relatively small incremental drainage area contributing directly to the Gavins Point reservoir (Lewis and Clark Lake), the small amount of runoff usually originating from this area, and regulation procedures applicable to Gavins Point, release definition at Fort Randall defines both inflows and releases at Gavins Point most of the time.

1-04. Project Owner. Gavins Point was constructed and is owned by the Corps of Engineers, Department of the Army.

1-05. Operating Agency. The Corps operates the System, which includes Gavins Point. The Corps' Northwestern Division's (NWD) MRBWM office, formerly known as the Reservoir Control Center (RCC), located in Omaha, NE, oversees the day-to-day implementation of the System Water Control Plan. The Omaha District of the NWD has staff located at Gavins Point, as well as the other System projects, to carry out the day-to-day operation (based on the reservoir regulation/power production orders received from the MRBWM office in Omaha) and maintenance of each project. All System dams have hydropower as an authorized purpose and are automated into a system called the Powerplant Control System (PPCS) for regulation of hydropower production and project releases. The Western Area Power Administration (Western) uses the System projects as an integral part of the Midwest power grid. Reservoir regulation/power production orders, reflecting the daily and hourly hydropower limits imposed on project regulation, are generated by the MRBWM office and sent to each mainstem project on a daily basis, or more frequently, as required. Also during critical periods, coordination between project personnel and MRBWM staff is conducted on an as-needed basis to ensure that expected release rates are achieved.

1-06. Regulating Agencies. As the Gavins Point owner, the Corps has the direct responsibility of regulating the project, as well as the other five System projects, to meet the authorized project purposes. This is accomplished in coordination with many others, including federal, state and Tribal agencies and a myriad of stakeholders. As these other entities provide input to the Corps regarding the System regulation through the Annual Operating Plan (AOP) processes, the Corps must determine if the proposal is within the Corps' authority and has met all applicable laws and regulations regarding System regulation prior to incorporating any of this input into the AOP or day-to-day regulation. As part of its regulation of the System, the MRBWM office conducts day-to-day coordination with Western, which markets the power produced at each project, and frequent coordination with the U.S. Fish and Wildlife Service (USFWS), which advises the Corps on the effects of System regulation related to fish and wildlife, including threatened and endangered (T&E) species. Coordination with the other previously mentioned specific interest groups is conducted on an as-needed basis, following initiation by either the Corps or the stakeholder.

1-07. Vertical Datum. The System projects were designed and constructed to a local project datum while recent hydrologic updates such as elevation-area and elevation-capacity curves and rating curve datums are in National Geodetic Vertical Datum of 1929 (NGVD29).

1-07.1. Corps regulation, ER 1110-2-8160, dated March 1, 2009 and titled *Policies for Referencing Project Elevation Grades to Nationwide Vertical Datums*, specifies that a long-term effort should be programmed to transition from a legacy reference datum to the National Spatial Reference System (NSRS) which is currently the National American Vertical Datum of 1988 (NAVD88). However, conversion from local datum/NGVD29 to NAVD88 has not been conducted on the System projects at this time. See Table I-1 for adjustments for the three datums for Gavins Point. These are provided for reference only and should not be used for construction or other purposes.

Table I-1
Gavins Point Datums (in feet)

Local project datum	NGVD29	NAVD88
0.0	+0.8	+1.47
(ex.) 1208.0	1208.8	1209.47

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II - Legislative and Project Construction History

2-01. Project Authorization. The need for flood control projects along the Missouri River and its tributaries was long recognized. Comprehensive development was proposed by the Corps in House Document No. 238 (73rd Congress, 2nd Session, 1934). While Gavins Point, as it exists today, was not included in the document, the report did propose construction of reservoirs on both the main stem of the Missouri River and on tributary streams in the Missouri River basin together with levees along the lower Missouri River as a flood control measure. The beneficial influence of the reservoirs on Missouri and Mississippi River navigation was also recognized.

2-01.1. Initial surveys for dam locations were authorized by House Document No. 308, 69th Congress, and reported on by House Document No. 238, 73rd Congress, 2nd Session, generally referred to as the "308 Report". The 308 Report described the possibility of a dam 7 miles upstream from Yankton, SD. From 1943-1944, the Corps and the U.S. Bureau of Reclamation (USBR), working separately, completed investigations and presented to Congress their separate reports on the development of the Missouri River basin water resources. House Document No. 475, 78th Congress, 2nd Session, presented the Corps plan for the overall development of the main stem of the Missouri River including Gavins Point Dam 4 miles upstream from Yankton. The USBR in Senate Document No. 191, 78th Congress, 2nd Session, proposed several upstream Missouri River dams, but did not include a project near the present Gavins Point site. The differences between the plans were adjusted in an inter-departmental conference and the coordinated plan, including Gavins Point, was presented to Congress in Senate Document No. 247, 78th Congress, 2nd Session, otherwise known as the "Pick-Sloan Plan". Legislative history of the System projects is described in greater detail in Chapter II of the Master Manual.

2-01.2. Gavins Point was authorized by the Flood Control Act, approved December 22, 1944 (Public Law 534, 78th Congress, 2nd Session), which states:

> "Sec. 9 (a) The general comprehensive plans set forth in House Document 475 and Senate Document 191, Seventy-eighth Congress, second session, as revised and coordinated by Senate Document 247, Seventy-eighth Congress, second session, are hereby approved and the initial stages recommended are hereby authorized and shall be prosecuted by the War Department and the Department of the Interior as speedily as may be consistent with budgetary requirements."

2-02. Project Development. Gavins Point was planned and constructed by the Corps' Omaha District under supervision of the Missouri River Division (MRD) and the Chief of Engineers. Preparation of a Definite Project Report (DPR) by the Omaha District was directed by the Chief of Engineers with the initial report published in November 1949. Supplements to this initial report during the following three years modified portions of the original design.

2-02.1. Four sites were considered for possible location of Gavins Point Dam: above the mouth of the Niobrara River, 8 miles west of Yankton, at Yankton, and the selected site 4 miles west of

Yankton. The present location was selected as the most favorable for the project after extensive studies considered the development of the sites.

2-02.2. Investigations, preliminary design, the DPR and final design of the Gavins Point project were accomplished by the Omaha District under the supervision of the MRD and the Chief of Engineers.

2-02.3. Major Departures from the DPR. The present locations of the structures, which were presented in the third supplement to the DPR, dated January 1952 and revised May 1952, are quite different from those in the original DPR. The spillway is located in the right valley adjacent to the right abutment and slightly upstream from the old alignment. The powerhouse is located in the right abutment about 300 feet landward of the spillway. With this arrangement of the structures, better foundation conditions were obtained. In the DPR, dated November 1949, and appendices I through XV, the principal features of the dam consist of a gated, chute-type spillway in the right abutment controlled by 22 40-foot by 23-foot gates, a short embankment section, the powerhouse, and an embankment across the river valley to the left abutment. The supplemental report on spillway location and design, dated December 1950, recommended the reduction of the number of the spillway gates to 14 and the use of an emergency spillway located in the north abutment. The second supplemental report on the spillway, dated November 1951, recommended the elimination of the emergency spillway and an increase in the design discharge head on the spillway weir through 14 gates. The third supplemental report recommended a reduction in the height of the weir to elevation 1180.0 feet and the transposition of the locations of the spillway and the powerhouse.

2-02.4. During early site studies, efforts were directed toward finding a chalk ledge suitable for support of a 22-gate spillway. A suitable ledge was not found so the DPR plan was based on a layout with a 22-gate spillway located entirely in the abutment. A location with the spillway partially in the abutment and partially on the chalk ledge with the powerhouse at the DPR site was considered but abandoned because of the risk of differential movement of the structures. With the number of spillway gates being reduced from 22 to 14, it was possible to locate the entire spillway on the chalk ledge. Additional explorations indicated that if the chalk ledge was widened out somewhat upstream from the DPR site, the revised structures would be most advantageously located slightly upstream. The present location of the structures is approximately 600 feet upstream from the plan originally proposed. A further clockwise rotation of the spillway, although possibly desirable, was limited by the area of the bedrock shelf. The large quantities of excavation required made it unfeasible to shift the channel further into the bluff.

2-02.5. The lowering of the spillway peak to elevation 1180.0 feet provided the following advantages:

a. The increased depth of the peak permits greater spillway discharge without increasing the maximum operating pool elevation.
b. The pool elevation required to pass the Spillway Design Flood (SDF) is lower than the corresponding elevation shown in the second supplemental report. Reduction in the maximum pool elevation simplified powerhouse stability problems and permitted a reduction in the height of the embankment.

c. Under maximum discharge, the inflow energy to the stilling basin is decreased by a reduction in difference between the headwater and tailwater elevations.
d. The lowering of the spillway peak permitted a substantial reduction of the upstream dike protecting the closure section, which simplified diversion and closure problems.

2-02.6. The original DPR provided for a power installation of 87,000 kilowatts (kW). A preliminary report on the number and size of power units for Gavins Point power installation, dated May 19, 1950, and its addendum dated August 1950, was submitted for review to Region 6, USBR and to the Chicago Regional Office of the Federal Power Commission. This report for the District Engineer recommended a power installation of 100,000 kW with three generating units. At a conference held at the Omaha District Office, August 10, 1950, representatives of the participating offices agreed to the recommendations of the District Engineer. The 1st Indorsement by the Division Engineer, MRD, to the letter of transmittal of the DPR by the District Engineer, Omaha District, dated February 3, 1950, presented to the Chief of Engineers, the proposal for the present power installation. The 2nd Indorsement to the aforementioned letter by the Chief of Engineers, dated March 20, 1951, gives approval to the proposed plan.

2-03. Construction History. Construction of the Gavins Point project was initiated in February 1952, with awarding of the contract for the access road to the area. The first earthwork on the dam was begun in April 1952. Diversion and closure took place in July 1955. Partial flood control was available in March 1956. The first of three 33,333 kW power units started generating commercial energy in September 1956. The last of the three units was available for service in January 1957. The project was essentially complete in June 1958. Plate II-1 presents a summary of the significant dates of the System dams' construction, diversion, closure, filling of the minimum operating pool, and initial generation of the first and last units.

2-04. Relocations. Approximately 17 miles of county and local highways were relocated, raised or abandoned in the construction of Gavins Point. No existing state or federal highways or railroads were affected by project development. About 18 miles of rural telephone lines were affected. Sewage systems of Springfield, SD and Niobrara, NE required remedial action. Initially, no relocation of towns or cities were necessary. However, in the years following closure of Fort Randall in 1952, aggradation at the mouth of the Niobrara River, just upstream of the headwaters area of the Gavins Point reservoir, resulted in increased groundwater levels in the city of Niobrara, NE and in adjacent agricultural areas. As a consequence, most of the city of Niobrara was relocated to adjacent higher elevations.

2-05. Real Estate Acquisitions. Approximately 34,374 acres in fee and 212 acres in easements were acquired for the Gavins Point project. No Public Domain land was involved in this project. There are seven maps located in the Omaha District Real Estate Division that show the land acquired for this project. The guide-taking line for land purchased for the main body of the reservoir was to elevation 1210.0 feet, plus allowances for wave heights, erosion, bank caving, set-up and wave run-up. Provisions were also made for raising the elevation of the guide-taking line in the upper reaches of the reservoir to allow for sedimentation and backwater.

2-06. Regulation History. Closure of Gavins Point Dam and the first impoundment of water in the reservoir (Lewis and Clark Lake) occurred in July 1955. Deliberate storage within the reservoir began in June 1956 when the minimum operating pool (elevation 1195.0 feet at the

time) was filled and maintained. The Annual Flood Control and Multiple Use Zone (base at elevation 1204.5 feet) was reached during the first month of operation. The Exclusive Flood Control Zone (elevation 1208.0 to 1210.0 feet) was reached in 1958. The Surcharge Zone (above elevation 1210.0 feet) has been reached once, in 1960 (March 29 to April 3, with a peak of 1210.7 feet on April 2). The majority of releases have been through the powerplant since the first power unit became operational in September 1956, although due to the limited release capacity of the powerplant some supplementary releases have been necessary during numerous years. Detailed descriptions of each year's project regulation are detailed in that year's AOP and annual Summary of Actual Regulation reports published by the MRBWM office.

2-06.1. Gavins Point Reservoir Elevations. Since the reservoir was filled to the base of the Annual Flood Control and Multiple Use Zone (elevation 1204.5 feet) in 1956, the project has been generally regulated within its normal operating pool range of 1206.0 to 1207.5 feet. There have been times, usually during the colder months with ice formation, where the pool level has dropped below 1204.5 feet for short periods of time. Since the closure of the System in 1967, the minimum Gavins Point pool elevation has been 1199.8 feet (March 1969). Due to suddenly developing flood events and the relatively small amount of flood control space, the pool can quickly rise into the Exclusive Flood Control Zone (elevation 1208.0 to 1210.0 feet). This zone is used to offer some control of flood inflows originating between Fort Randall and Gavins Point. Since 1958, storage has accumulated in the Gavins Point Surcharge Zone once (above elevation 1210.0 feet) in order to provide some control during extremely large inflows from the incremental drainage area between Fort Randall and Gavins Point. See Appendix A for more information regarding Gavins Point regulation during flood events.

2-06.2. During the early spring to early summer months the average reservoir level is maintained near 1206.0 feet to create additional capacity to store rainfall runoff between Fort Randall and Gavins Point. In September, when the need for flood control storage space is lessened, the pool level is raised to 1207.5 feet to enhance power generation and recreational uses of the reservoir. A distinct seasonal pattern in pool level variations is evident, particularly during the more recent years. See Appendix A of this WCM for further information concerning historical regulation.

Missouri River Basin
Gavins Point Dam – Lewis and Clark Lake
Water Control Manual

III - Basin Description and Characteristics

3-01. General Characteristics. The Missouri River basin drainage area upstream from Gavins Point Dam includes all of Montana east of the continental divide, northern Wyoming, southwestern North Dakota, western South Dakota, a portion of northern Nebraska, and portions of the tributary Milk River drainage lying in southern Canada. The total area controlled by Gavins Point Dam is 279,480 square miles. This includes 57,500 square miles of drainage above Fort Peck Dam, 123,900 square miles between Fort Peck and Garrison dams, 62,090 square miles between Garrison and Oahe dams, 5,840 squares miles of drainage between Oahe and Big Bend dams, 14,150 square miles of drainage area between Big Bend and Fort Randall dams, and 16,000 square miles between Fort Randall and Gavins Point dams. The Missouri River and its drainage area below Gavins Point is discussed in the Master Manual as being pertinent to System regulation, although some details concerning the area contributing immediately below Gavins Point are included in the manual. Plate III-1 is a general map of the Missouri River basin. The incremental drainage area defined by Fort Randall and Gavins Point, and described in this WCM, is shown on Plate III-2.

3-02. Topography. The Missouri River drainage area between Fort Randall and Gavins Point dams forms a portion of the Great Plains province of the United States. The area to the north and east of the Missouri River is within the Glaciated Missouri Plateau consisting of gently rolling topography in which stream dissection and drainage are not well established except in areas immediately adjacent to the Missouri River. Drainage in upland areas is largely into potholes, small intermittent lakes and a few larger permanent lakes. Most of the incremental drainage area lies to the south and west of the Missouri River within the Unglaciated Missouri Plateau. These plains are characterized by rolling tablelands with hilly to rough broken areas along the sides of stream valleys. Stream dissection is well established with broad smooth divides between the larger drainages. Portions of the northern Nebraska Sandhills are also contained within the Fort Randall to Gavins Point drainage area. The soils in the Sandhills have a sandy characteristic that allows for rapid infiltration of precipitation with a high rate of recharge through the sands to the groundwater storage. Streams that originate in the Sandhills region have a relatively constant flow rate due to outflow from the groundwater.

3-02.1. The major portion of the Fort Randall to Gavins Point incremental drainage area lying to the west of the Missouri River has a general west to east slope of about 10 feet per mile. Elevations range from about 5,000 feet in the western extremity to less than 1,200 feet on bottomlands adjacent to the Missouri River. Immediately below Gavins Point, downstream to Sioux City, IA, the incremental drainage area lies almost entirely to the east of the Missouri River and is characterized by much flatter slopes than to the west, with maximum elevation in the 2,000-foot range.

3-03. Land Use. Agriculture represents the primary use of the land in the 16,000-square mile incremental drainage area between Fort Randall and Gavins Point. Forested and wetland areas

comprise about 5 percent of the drainage area. The Missouri River and the Gavins Point reservoir account for just over 1 percent of the total area. The remaining land use (less than 1 percent) consists of bare and residential areas. Woodlands, or forests, are generally restricted to bottomlands adjacent to streams or to woodlots and groves planted for protective or aesthetic purposes. Additionally, minor amounts of relatively sparse forests occur in extreme western portions of the incremental drainage area. Due to the general lack of an assured water supply, irrigation is practiced on only a minor amount of land in the incremental drainage area, with irrigated lands comprising less than 1 percent of total cropland. Water areas in this incremental drainage make up about 1 percent of the total area, but the rivers, lakes, reservoirs, farm ponds, and other bodies of water involved are extremely important to the region's economy. Refer to Plate III-3 for a graphical representation of land use in the Fort Randall to Gavins Point incremental drainage area.

3-04. Drainage Pattern. The drainage pattern of the Missouri River basin is shown on Plate III-1. Noteworthy in the drainage basin above Gavins Point is the large area of the upper Missouri River basin controlled by the Fort Peck, Garrison, Oahe, Big Bend and Fort Randall projects. These upstream mainstem projects control about 94 percent of the total drainage contributing to the runoff above Gavins Point, including all of the mountainous area contributing to the Missouri River above Gavins Point.

3-04.1. The prominent feature of the incremental portion of the Missouri River basin between Fort Randall and Gavins Point is the single major tributary of this reach, the Niobrara River, a right bank tributary flowing in an easterly direction (see Plate III-2). This direction of flow is of particular importance from the standpoint of flow contribution from storms that typically move in an easterly direction. Additionally, it becomes important at the time of snowmelt and ice break-up in the spring since normal temperatures at the time in the tributary headwaters are significantly higher than at the tributary mouths, resulting in an aggravation to ice jamming near their mouths during the ice break-up period. The drainage pattern contributing from the area west of the Missouri River in this reach is generally well defined. Numerous potholes and depressions exist east of the Missouri River. Portions of the region to the east will not contribute directly to streamflow unless substantial amounts of runoff were to occur that are sufficient to fill and overflow the low depressions that normally restrict runoff.

3-04.2. The Niobrara River originates in extreme eastern Wyoming and flows across almost the entire northern portion of Nebraska before joining the Missouri River immediately above the headwaters of the Gavins Point reservoir and 32.5 river miles upstream from Gavins Point Dam. The Niobrara River drainage area is 12,000 square miles, 75 percent of the total drainage between Fort Randall and Gavins Point (see Plate III-2). Right bank tributaries include Ponca Creek, which drains 827 square miles and enters the Missouri River 5.5 miles upstream from the mouth of the Niobrara River, and Bazile Creek, which drains about 450 square miles and enters the Missouri River about 5 miles downstream of the Niobrara-Missouri River confluence. Minor left bank tributaries include Choteau Creek, which has a 400-square mile drainage area, and enters the Missouri River about 10 miles upstream of Niobrara, NE and Emanuel Creek, which enters the Missouri River just upstream of Springfield, SD.

3-04.3. The James River is the first major tributary entering the Missouri below Gavins Point Dam. The James River enters the Missouri River below Yankton, SD and drains about 21,000

square miles in eastern North Dakota and South Dakota. The James River is extremely flat and travel times are measured in weeks, rather than hours or days. Given the very large drainage area and slow travel time, James River flows are considered when scheduling Gavins Point releases to meet downstream Missouri River flow targets. The same also applies, but to a lesser extent, to other major tributaries, such as the Vermillion and Big Sioux Rivers. Like the James River, these tributaries enter the Missouri River between Gavins Point Dam and Sioux City, IA, the most upstream of the four Missouri River navigation flow target locations in the 735-mile navigation reach.

3-05. Stream Slopes. The slope of the Missouri River from Fort Randall to Gavins Point averages about 1 foot per river mile. Tributary stream slopes entering from the right bank are significantly steeper, generally averaging between 5 and 8 feet per mile. The slopes of the tributary streams progressively tend to flatten toward their mouths. Left bank tributaries entering the Missouri River between Gavins Point and Sioux City have much flatter slopes than the right bank tributaries. This is particularly true for the James River. Slopes of less than a foot per mile prevail through much of its length, resulting in an extremely sluggish tributary stream.

3-06. Climate. The Fort Randall to Gavins Point incremental drainage area of the Missouri River basin is located near the geographical center of the North American continent. While the area lies near the center of the belt of westerly winds, the Rocky Mountains form a barrier to a Pacific moisture source. Consequently, the climate of the region is generally classified as continental semi-arid. The region is affected by a marked seasonal variation in all weather phenomena.

3-06.1. Annual Precipitation. Annual average precipitation over the Fort Randall to Gavins Point drainage area increases from west to east, ranging from about 14 inches in the headwaters of the tributary Niobrara River to almost 25 inches in the vicinity of Yankton, SD. Average yearly precipitation also increases in a north-south direction, reflecting decreasing distances from the main moisture source, the Gulf of Mexico. In the extreme headwaters of the tributary James River in central North Dakota, annual precipitation average about 17 inches. The pattern of average annual precipitation throughout the Missouri River basin is presented in Plate III-4. Monthly precipitation patterns are presented in the Master Manual (Plates III-4 through III-15). Wide variations from the average amounts may be experienced in any year, with severe, extended drought periods as well as successive years of well-above-normal amounts of precipitation occasionally occurring.

3-06.2. Seasonal Precipitation. Precipitation over the incremental drainage area between Fort Randall and Gavins Point usually occurs as snow during the November-March period and as rain during the remainder of the year. About 75 percent of the total yearly precipitation occurs during the rainfall season, with May, June and July normally being the wettest months. Most rainfall occurs as short, intense showers or convective thunderstorms; however, steady rains lasting for several hours or a day or two may occasionally occur. Excessive rainfall over a relatively large area is unusual. More common are intense convective thunderstorms resulting in large precipitation amounts in a short period of time over a very restricted area.

3-06.3. Snow. Precipitation occurring as snow usually is at a very slow rate. During the entire winter season about 10 to 15 inches of total snowfall can normally be expected through most of

the incremental region. Snow does not usually progressively accumulate through the winter season but is melted by intermittent thaws. However, there have been notable exceptions when plains area snow accumulations containing as much as 6 inches or more of water equivalent have blanketed large areas prior to a significant melt period. Snowfall is frequently accompanied by high winds resulting in much drifting. Plates III-5 and III-6 present a representation of mean annual snowfall and maximum annual snowfall, respectively, across the Missouri River basin.

3-06.4. Temperatures. Due to its mid-continent location, this region experiences temperatures noted for their wide fluctuations and extremes. Temperatures each year can usually range from a maximum of over 100 degrees Fahrenheit (°F) at some time during the summer months to a minimum of -30°F degrees or colder during the mid-winter period. Winters are long and cold. Cold temperatures may be interrupted during periods of downslope, or "Chinook", winds when mild temperatures, for the season, prevail. Moderate temperatures usually prevail during the non-winter season, although periods of high temperature can be expected during every summer season, interrupted by outbreaks of cooler air from the north and west. Average annual minimum and maximum temperatures for the Missouri River basin are shown on Plates III-7 and III-8, respectively. Temperature extremes are shown in the Master Manual (Plates III-20 and III-21).

3-06.5. Evaporation. Annual evaporation from the surface of the Gavins Point reservoir is about 3 feet. This evaporation loss equates to approximately 82,000 acre-feet (AF) of volume (refer to Plates III-9 through III-12). Evaporation studies made by the MRBWM office conclude that the average annual net evaporation is about 17 inches. The net evaporation, which is adjusted for precipitation on the reservoir surface, is the amount of evaporation that would have occurred from land area now inundated by the reservoir and the channel surface area existing prior to development of the Gavins Point project. Due to seasonal precipitation patterns, seasonal patterns of gross evaporation depths and the lag in normal reservoir surface temperatures from corresponding air temperatures, essentially all of the annual net evaporation from the Gavins Point reservoir can be expected to occur during the 6-month period from July through December.

3-06.6. Storm Potentialities. The major source of moisture for most major storms in the plains region of the Missouri River basin is the Gulf of Mexico. Based on available moisture alone, major storms would be most probable in late July or early August since it is at this time that normal and maximum recorded air mass moisture is at its highest. However, major storms result almost exclusively from conditions accompanying frontal systems. Since frontal passages are more numerous and more severe in May and June than later in the year, major storms occur more frequently in late spring and early summer than at the time of maximum moisture changes. Major storms alone do not provide a complete indication to the probability of large amounts of runoff within the region. A sequence of minor storms may saturate the soil and subsequently contribute much larger volumes to streamflow than would be the case if dry conditions prevailed prior to the runoff-producing events. During winter months, continued minor storms are the rule, occasionally producing significant snow accumulations over the drainage area. Usually the highest annual flows experienced in the region result from melt of these plains snow accumulations. Severe flooding will only occasionally occur over portions of the basin due to an individual major storm event.

3-07. Streamflow Records. With the exception of a few stations, records of runoff from the incremental areas considered in this WCM exist only from the early 1930s to date. As discussed in the Master Manual, planning of the System made it desirable to extend Missouri River streamflow records to the extent practicable. Daily records are available for the majority of streamgaging stations for the six System dams since their respective dates of closure, and daily flow data is available for the majority of gaging stations since 1930. Prior to 1930, there is a general lack of daily records in the basin. Representative daily data was constructed to cover the period from 1898 to 1929 because of the significance and statistical importance of the drought of the 1930s in System regulation. Inasmuch as water use for all purposes has expanded significantly since settlement of the region began, it is necessary to adjust System incremental inflow records to a common level of water resource development in order that flow data are directly comparable from year to year. The total flows originating in the Fort Randall to Gavins Point reach have been adjusted to the 1949 level of water resource development, with such adjustment being a continuing process as further data are accumulated. While any development level would have been satisfactory, the 1949 level was selected because that year was prior to significant resource development in the basin. As part of the 2004/2006 Master Manual revision, a continuous record of daily data was developed for the entire Missouri River basin for the time period of 1898-1997. A detailed explanation of the daily flow record and the modeling efforts is found in Section 6-04.1.6 of the 2004/2006 Master Manual. As part of ongoing studies, this continuous record of daily data is expanded as additional years become available. More information on this expanded dataset is found in Section 6-13 of the Master Manual.

3-08. Runoff Characteristics. The primary source of runoff from the Fort Randall to Gavins Point incremental drainage area is the melting of the plains snow during March and April that accumulated during the winter months. However, on occasion rainfall has resulted in substantial runoff amounts from the total incremental area. Runoff is extremely variable from year to year. Throughout most of the drainage area annual runoff averages less than one inch. Normal contributions to annual runoff from drainage areas within or near to the incremental drainage area discussed in this WCM are presented in Table III-1.

Table III-1
Missouri River Basin - Normal Annual Runoff
Between Fort Randall and Gavins Point Dams

Contributing Area	Drainage Area (square miles)	Average Annual Runoff(1)	
		kAF	inches
Ponca Creek at Verdel, NE	812	64	1.49
Niobrara River at Verdel, NE	11,580	1,271	2.06
Keya Paha River at Wewela, SD	1,121	59	0.98
Bazile Creek at Niobrara, NE	440	67	2.85
Missouri River (2)			
Fort Randall Dam	263,480	21,385	1.52
Gavins Point Dam	279,480	23,078	1.55
Fort Randall to Gavins Point			
Incremental Drainage	16,000	1,693	1.98
Local Drainage (3)	3,168	290	1.72

(1) Based on available record at each location.
(2) Missouri River runoff at the 1949 level of water resources development.
(3) Incremental drainage area between Fort Randall and Gavins Point dams less Ponca Creek at Verdel, Niobrara River at Verdel, and Bazile Creek at Niobrara.

3-08.1. Seasonal Runoff Pattern. Runoff from the Missouri River drainage area between Fort Randall and Sioux City, IA usually follows a characteristic seasonal pattern as follows:

1. Winter is characterized by frozen streams and intermittent snowfall and thaws in the area where the season usually ends with a “spotty” snow cover of relatively low water content and a considerable amount of water in ice storage in the stream channels. Runoff during this period, which usually extends from late November into March, is very low.
2. Early spring is marked by a rapid melting of snow and ice on frozen ground, usually in March or April, as temperatures rise rapidly, accompanied usually by very little rainfall. This causes a characteristic early spring ice break-up and rise. Ice jams are frequently experienced on tributary streams during this period. The rapid release of water from melting snow and ice jams results in flashy rises in tributary flows. Annual maximum peak stages and flows frequently occur at this time along tributary streams.
3. Late spring consists of the months of May and June. At this time extensive general rains may occasionally occur, sometimes accompanied by intense local rainstorms. Runoff is usually quite low unless these rains occur.
4. Summer and autumn in this portion of the Missouri River basin are generally characterized by a lack of general rainfall and frequent, widely scattered

thundershowers that contribute little to runoff. Total runoff in the Fort Randall to Gavins Point incremental drainage area is usually very low from July through the remainder of the calendar year.

3-08.2. Total unregulated Missouri River runoff originating above Gavins Point usually follows a definite and characteristic annual pattern. Plate III-13 lists the Missouri River basin monthly runoff above Gavins Point for the period 1898 to 2014. Total monthly runoff above Gavins Point (maximum, minimum and average) for each month is shown in Plate III-14. Average monthly runoff from the total contributing area shows a general increase from January through June and then decreases through December. As illustrated on Plate III-14, wide variations in total runoff have occurred during every month of the year. As would be expected, the variations are largest during the months comprising the March-July flood season, with total flood season volumes ranging from highs of 40.9 million acre-feet (MAF) in March-July 2011 (maximum), 31.2 MAF in March-July 1997, 29.5 MAF in March-July 1978, 26.5 MAF in March-July 1975, and 26.1 MAF in March-July 1927, to a minimum of 6.2 MAF in 1961. As seen in Plate III-14, the record May, June and July inflows all occurred in 2011, which contributed to the highest March-July runoff in 118 years of record (1898-2015). The effects of project regulation on these runoff patterns and regulation of various flood events is discussed in Appendix A of this WCM.

3-08.3. The average and maximum monthly runoff originating from the incremental drainage areas between Fort Randall and Gavins Point are illustrated on Plate III-15. Average runoff from these incremental areas is greatest during the March-July period with lesser amounts during the remainder of the year. However, the average runoff from the Fort Randall to Gavins Point reach is fairly uniform through the year. The uniform runoff illustrates the stabilizing effect and high initial infiltration capacity and steady baseflow conditions that the Sandhills drainage contributing to the Niobrara River has on seasonal flows. As shown on Plate III-15, the maximum greatest monthly incremental runoff in the Fort Randall to Gavins Point reach occurred in March 1952. The maximum monthly incremental volume of 0.6 MAF, which was mostly due to runoff from a heavy plains snowpack, is relatively small as compared to the other five mainstem projects. However, the flood control storage in Gavins Point is very small; total storage from 1206.0 to 1210.0 feet is about 100,000 AF or 0.1 MAF. Large rainfall events, such as what resulted in the maximum June runoff in 2010, can quickly fill the available flood control storage. The maximum observed monthly flows shown on Plate III-15 and the incremental inflow hydrographs shown on Plate III-16 illustrate that the largest amounts of incremental monthly runoff have occurred as a result of the melt of a large plains snow accumulation and/or rainfall event. Minimum runoff from the incremental areas has been calculated to be negative in some years during June through October, indicating that evaporation from the Missouri River channel (or other losses, such as ice build-up) may exceed the flow of tributaries entering the Missouri River in this reach.

3-08.4. The MRBWM Technical Report, *Hydrologic Statistics on Inflows*, dated June 2015, details the development of inflow volume probability relationships for various durations for both regulated and unregulated flows in the Fort Randall to Gavins Point reach. Some incremental runoff events of interest originating between Fort Randall and Gavins Point are illustrated on Plate III-16. See Section 6-15 and Plates VI-13 through VI-18 for regulated and incremental inflow volume probability relationships for various durations.

3-09. Effects on Basin-Wide Floods. Essentially all major Missouri River floods of past record at Gavins Point have resulted from runoff originating in the upper Missouri River basin, an area controlled by Fort Peck, Garrison and Oahe. At times these floods have been augmented by flows originating from the Fort Randall to Gavins Point incremental drainage area. Floods of this type are described in Appendix A of this WCM as well as Appendix A of the Master Manual.

3-10. Effects of Gavins Point on Flood Inflows. System regulation studies conducted by the MRBWM office indicate that regulation of Gavins Point, in conjunction with other upstream reservoir projects, would significantly reduce flood damages in the reach extending downstream from Gavins Point to Omaha, NE if any past floods of record were to recur. Further discussion of regulation effects on flood inflows is detailed in Appendix A of this WCM.

3-11. Water Travel Time. See Plate IV-1 of the Master Manual for estimates of water travel time throughout the Missouri River basin. See Plate III-17 for travel times for the Niobrara River, the only major tributuary between Fort Randall and Gavins Point. Water travel times are particularly pertinent to Gavins Point release requirements and are discussed in the Master Manual as an important factor to be considered in scheduling system releases. The water travel time from Fort Randall to Gavins Point is approximately 1.5 days. The water travel time from Nebraska tributary streamgaging stations entering the Missouri River in the Fort Randall to Gavins Point reach, namely Ponca Creek at Verdel, Niobrara River near Verdel, and Bazile Creek near Niobrara, to Gavins Point is slightly less than one day. Inflows to Gavins Point will reflect the gaged flows at these locations. Table III-2 lists the tributaries and their travel times that enter the Missouri River between Fort Randall and Gavins Point and between Gavins Point and Sioux City, IA.

Table III-2
Tributary Travel Times

Stream	Location	Approximate Travel Time in Days
Above Gavins Point (1)		
Missouri River	Fort Randall	1.5
Niobrara River	Spencer, NE Verdel, NE	1.5 <1.0
Ponca Creek	Verdel, NE	<1.0
Below Gavins Point (2)		
James River	Scotland, SD	-1.0
Vermillion River	Vermillion, SD	0.5
Big Sioux River	Akron, IA	0.5

(1) Stations above Gavins Point indicate travel time in days to the reservoir.
(2) Stations below Gavins Point indicate coincidence with releases made from the Gavins Point reservoir the given number of days earlier. Negative numbers indicate coincidence with releases to be made the given number of days later.

3-12. Water Quality. The Omaha District Water Control and Water Quality Section is responsible for the water quality monitoring of the mainstem projects and the Missouri River,

including the Gavins Point reservoir and the Missouri River downstream of Gavins Point. Omaha District conducts fixed-station ambient water quality monitoring at the mainstem reservoirs and on the lower Missouri River. Water quality conditions of the water discharged through each of the mainstem dams is continuously monitored. An intensive water quality survey of the lower Missouri River, which has been completed annually since 2010, is ongoing and conducted jointly with the Kansas City District and extends from Gavins Point to the mouth of the Missouri River at St. Louis, MO. Water quality stations and sampling is detailed further in Appendix C of this WCM and Section 5-11 and Appendix C of the Master Manual. Current and detailed water quality monitoring information is available in the Omaha District water quality reports on the Omaha District website.

3-13. Sediment. Long-term sediment inflow to the Gavins Point reservoir is estimated by the Omaha District to be 2,700 AF/year (see Plate II-1). At this rate the estimated sediment life of the reservoir is 159 years. Since the reservoir traps the inflowing sediment, Gavins Point releases are nearly free of sediment. Most sediment inflow to the Gavins Point reservoir originates in the Niobrara River basin or from erosion of the Missouri River banks between Fort Randall Dam and the Gavins Point headwaters. Long-term contribution of sediment from the Niobrara River is estimated to be about 55 percent of the total sediment inflow.

3-14. Missouri River Channel below Gavins Point Dam. Gavins Point is the most downstream of the System projects. The Missouri River channel remains largely in its natural state for a distance of about 60 river miles extending from Gavins Point downstream to Ponca, NE, about 20 miles upstream of Sioux City, IA. The navigation channel begins at the confluence of the Missouri and Big Sioux Rivers at River Mile (RM) 735 (1960 mileage). Control structures have been installed in connection with the Missouri River navigation and streambank stabilization project. These structures extend through the 735-mile reach of the Missouri River from Sioux City to the mouth. The navigation and stabilization project is described in the Master Manual.

3-14.1. Channel Description. The Missouri River channel between Gavins Point and Sioux City meanders through an alluvial floodplain. The Missouri National Recreational River is a 59-mile stretch of the Missouri River extending from one mile downstream of Gavins Point Dam to Ponca State Park near Ponca, NE. The recreational river designation was authorized in 1978 by Public Law 95-625 as part of the National Wild and Scenic River System. The Corps constructed nine streambank erosion control projects from Yankton, SD to Ponca State Park between 1976 and 1981. The projects were authorized under Section 32 of Public Law 93-251. The projects comprise more than 380 structures, stabilizing 22 miles of riverbank. The most recent maintenance contract was executed in 2002. Omaha District inspected the projects in 2012 following the 2011 flood. Structure damage that required repair was identified on 12 percent of the structures. Critical damage was noted on 11 structures. To date, federal funding has not been available to address the damages nor do local sponsors have adequate funding to rehabilitate the damaged structures.

3-14.2. Channel Capacity and Stage-Discharge Relationships. Flood stage at the Missouri River at Yankton, SD streamgaging site is 20 feet. The site is located about 4 miles downstream from Gavins Point Dam. There are no tributaries between the dam and the Yankton streamgaging site. Under open water conditions, a stage of 20 feet at this site represents a flow, or Gavins Point

release, of about 95,000 cubic feet per second (cfs). Further downstream at Sioux City, IA, the flood stage is 32 feet, which represents an open water flow of about 120,000 cfs. There are several major tributaries that enter the Missouri River between Yankton and Sioux City. Rating curves for these two locations are shown on Plates VI-10 and VI-11, respectively.

3-15. River Ice. During colder-than-normal winters, a virtually complete ice-cover can be expected to form on the Missouri River between Gavins Point and Sioux City, IA. An ice-cover will also form over some reaches of the channel downstream from Sioux City. This cover severely restricts the Missouri River conveyance capacity. During most winters pan ice forms on the Missouri River downstream of Gavins Point. Ice jams can occur when extended cold fronts, which can cause temperatures to plummet to subzero temperatures and could include strong winds, affect the lower Missouri River basin. Past regulation experience has shown that increasing the Gavins Point releases 2,000 to 4,000 cfs prior to the onset of the cold front lessens the chance of floating ice to develop into ice jams. The increase in river flow slightly increases the water surface area and flow velocity as well as offsets the loss of tributary water to ice formation. Impacts from lower Missouri River ice jams or blockages include flooding upstream of the jam/blockage as well as sharp drops in downstream stages. Either of these could impact water intakes for water supply purposes. At Sioux City, a stabilized ice-cover can be expected to raise freeze-in stages by 3 to 4 feet above the open water level associated with the discharges usually prevailing during the winter seasons. During the winter months, the MRBWM office collaborates with the Omaha District Missouri River Project Office and volunteer river ice observers to keep a daily record of Missouri River ice conditions downstream of Gavins Point.

3-15.1. Prior to the time that the System was constructed, severe ice jams were expected at the time of the spring break-up of the winter's Missouri River ice-cover. The reservoirs now act as a trap to upstream ice and severe jamming has been lessened on the Missouri River below Gavins Point Dam during the spring break-up period. However, a marked increase of Gavins Point releases into a solid downstream ice-cover can cause this cover to break up. While severe jamming is not probable due to the generally small ice volume in the downstream reaches, the large and hard ice floes can result in damage to downstream river control and navigation structures.

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IV - Project Description and History

4-01. Location. Gavins Point Dam is located at RM 811.1 (1960 mileage) in Cedar County, Nebraska and Yankton County, South Dakota, about 4 miles west of the city of Yankton, SD. As described in Section 2-02.1, four sites extending from Yankton to a point upstream from the mouth of the Niobrara River, were examined in detail prior to final site selection. The Gavins Point reservoir (Lewis and Clark Lake) extends 25 miles in a westerly direction from the dam along the Nebraska-South Dakota border, terminating near the town of Niobrara, NE and the mouth of the Niobrara River. A project photo is shown as Plate IV-1.

4-02. Embankment. The dam is a rolled earthfill structure 8,700 feet in length extending from the left bank of the Missouri River valley to the spillway and powerhouse structures located on the right bank of the valley. The embankment contains about 7 million cubic yards of fill consisting largely of compacted and uncompacted chalk obtained from the excavations for the spillway, powerhouse and downstream channels. A core and a blanket extending 300 feet upstream from the core were constructed from impervious material. The peak of the embankment is at elevation 1234.0 feet, representing a maximum height above streambed of 74 feet and an average height above the valley floor of about 60 feet. Between elevations 1203.0 and 1217.0 feet the upstream face of the dam has a slope of 1 vertical (V) on 15 horizontal (H). The uncompacted chalk forming the gradual slope through this range of elevation, where the level of the reservoir can be expected most of the time, provides protection for wave action on the embankment. The plan and sections of the embankment are shown on Plate IV-2. Refer to Plate II-1 for other pertinent System dam and reservoir information.

4-02.1. Embankment freeboard was based on a Gavins Point pool elevation of 1221.4 feet, the maximum level attained during routing of the SDF. A set-up allowance of 3.1 feet and wave height plus run-up allowance of 8.8 feet was developed in design studies. An additional safety factor of 0.7 foot resulted in a total freeboard allowance of 12.6 feet, establishing the embankment peak at elevation 1234.0 feet.

4-03. Spillway. The Gavins Point spillway is located on the right bank between the embankment and the powerhouse. Since no outlet works were constructed at this project, all releases in excess of powerplant discharge capabilities must be made through the spillway structure. The spillway is a chute type consisting of a short approach channel, a gated ogee crest structure, a concrete paved chute, a stilling basin and a discharge channel. The approach channel from the reservoir is relatively short with a bottom elevation of 1155.0 feet. The floodplain directly upstream has a surface elevation of approximately 1176.0 feet. The riverward or north approach wall, a semi-gravity type structure 184 feet in length, is an extension of the reinforced concrete north abutment. The south wall of the concrete-anchored type converges toward the south abutment from a point approximately 100 feet upstream of the peak of the spillway. A floating boom, consisting of steel floats 20 feet long by 30 inches wide, is located across the upper portion of the approach channel protecting both the spillway and the powerhouse. Plan and profile of the

spillway is shown on Plate IV-2 and spillway rating curves are on Plate IV-3. See Plate IV-4 for a photo of the Gavins Point spillway gates.

4-03.1. The spillway structure consists of a concrete ogee crest weir, surmounted by tainter gates, a roadway and service bridge and machinery platforms. The spillway has a gross length of 664 feet and is controlled by 14 tainter gates. Each spillway gate is 40 feet long and 30 feet high and are separated by 13 8-foot reinforced concrete piers. The net length of the spillway peak is 560 feet. The weir has an ogee crest of elevation 1180.0 feet, 25 feet above the approach channel floor. A paved chute, 664 feet in width and 216 feet in length, connects the weir and the stilling basin. The upstream end of the chute is at elevation 1155.0 feet. The downstream end of the chute terminates at the stilling basin floor at elevation 1123.0 feet. The chute walls are relatively short and slope downward from the spillway to the elevation of the stilling basin walls.

4-03.2. The 220-foot long reinforced concrete stilling basin slab extends from the spillway chute to the downstream face of the end sill. The stilling basin's floor is at elevation 1123.0 feet and has a width of 638 feet. The walls are sloped 4V on 1H from the floor to elevation 1175.0 feet, then vertical to the top of the wall at elevation 1180.0 feet. The stilling basin has two rows of baffles, each 12 feet wide and 8 feet high. A stepped-end sill provides a transition between the floor of the stilling basin and the upstream end of the discharge channel.

4-03.3. The unpaved spillway discharge channel begins at the stilling basin sill. From elevation 1132.0 feet at the end sill, the channel bottom slopes upward to a uniform elevation of 1140.0 feet. The stilling basin wall on the riverward side extends approximately 127 feet downstream. The landward side wall terminates at the stilling basin. A training dike on the riverward side restricts the flow to its present channel below the dam. The powerhouse tailrace channel joins the spillway discharge channel at an approximate 20 degree angle.

4-04. Outlet Works. Conventional outlet works structures were not provided at Gavins Point. Releases must be made either through the spillway or the powerplant.

4-05. Powerplant and Switchyard. The flow of water from the reservoir to the powerhouse intake is guided by a relatively short approach channel located at the right end of the dam. It is curved in plan along a circular arc of 220-foot radius and has a bottom elevation of 1155.0 feet. The bottom width of the channel is 240 feet and the side slopes are 1V on 1H, which results in a sectional area of 15,529 square feet when the reservoir is at pool elevation 1208.0 feet. Flow velocity in the approach channel is approximately 2.0 feet per second (fps) when the powerplant is discharging 33,000 cfs. About 102 feet upstream from the powerhouse intake, the bottom of the channel slopes downward on a 1V on 4H slope to elevation 1139.3 feet to provide sufficient entrance area at the intake. The sides of the approach channel at the intake to the powerhouse are closed off by the concrete abutment walls. The flow entering the powerhouse is confined to rectangular passages formed by the concrete floor, roof and piers of the intake structure. See Plate IV-5 for a photo of the Gavins Point powerhouse.

4-06. Intake Structure. The intake structure contains three separate intakes for each of the three turbines. Each unit intake is subdivided into three gate passages by intermediate piers that are 6.5 feet wide. The water passages are 34.75 feet high and have a horizontal floor at elevation 1139.5 feet. Each intake opening has five removable trash rack sections of welded steel

construction. Each passage contains two sets of gate slots. Nine tractor-type, vertical lift service gates operate in the downstream gate slots. One slide, vertical lift-type gate can be operated in any one of the upstream or bulkhead gate slots. The service gates are designed to close against flow in the event that the turbine's wicket gates fail to completely close. The flow velocity at the service gate slot, which is 41.75 feet upstream from the centerline of the units, is approximately 6.0 fps with a maximum 11,000-cfs turbine discharge.

4-07. Powerhouse. The powerhouse consists of two elements, the main structure and the service bay, and is constructed integrally with the intake. The main structure provides housing for the power units, service and storage rooms, and personnel facilities. The service bay, which is located along the downstream side, contains the control room, various service rooms, an office and public facilities. The generator bay substructure is made of mass concrete and is divided into three separate 80-foot wide monoliths. The monoliths are founded on shale strata underlying the site. The erection bay is located at the south end of the powerhouse and has a substructure of heavy reinforced concrete. The superstructure of the generator room and erection bay is constructed of massive reinforced concrete up to the elevation of the crane rails and of light reinforced concrete walls above the crane rails. An access road to the powerhouse leads from the vicinity of the city of Yankton along the right bank of the river. A service road provides access to the spillway, dam and switchyard.

4-07.1. The powerhouse contains three hydraulic turbines of the vertical shaft, single runner, adjustable-blade propeller, Kaplan-type, with governor controlled runner blades, concrete semi-spiral cases and concrete elbow-type draft tubes. Each turbine is rated at 54,000 horsepower at 48 feet net head operating at normal speed of 75 revolutions per minutes (rpm). Each turbine is provided with a cabinet actuator oil pressure-type governor.

4-07.2. The Gavins Point powerplant has three hydraulic turbine-driven, vertical-shaft generators each originally rated at 33,400 kW at 95 percent power factor and generating power at 13.8 kilovolts (kV). The generators were rewound in 1987 and 1988 and were uprated to 44,000 kW. Each generator is connected to a 3-phase step-up transformer delivering power to a 115 kV switchyard. The generator neutrals are grounded through a neutral air circuit breaker and a current limiting reactor. Power for station requirements is supplied from the first two generators through 13.8 kV air circuit breakers and dry-type transformers stepping down the generated voltage to 460 volts. To permit supply of station service power from the system when the generators are not in operation, 13.8 kV air circuit breakers are provided for these two units in the generator switchgear.

4-07.3. A straight tailrace channel conveys the flow from the draft tube outlets to the spillway discharge channel, which it joins at an angle of approximately 20 degrees. A concrete apron slab extending 99 feet downstream from the draft tube outlet is built on a 1V on 4H slope to match the inclined draft tube floor. The inclined tailrace bottom meets the horizontal bottom of the tailrace channel at the end of the apron at elevation 1134.0 feet. The vertical retaining wall along the south side of the tailrace channel is parallel to the flow and flush with the inside face of the draft tube end pier. It extends 99 feet from the end of the draft tube to the end of the inclined apron slab. At that point a vertical cut-off wall at right angle to the flow extends to the abutment. Downstream from that point the channel side is sloped 1V on 1H. The north bank of the tailrace

is sloped 1V on 1H along its entire length. The portion extending 99 feet from the draft tube is lined with concrete.

4-07.4. The transformer yard is separated from the switchyard and located adjacent to the erection bay at the same elevation as the erection bay floor. The transformers can be moved on tracks into the erection bay for servicing. The yard accommodates the three main step-up transformers, the cable riser structures for the 13.8 kV cable termination, and the take-off structure for the 115 kV overhead aerial conductors to the switchyard.

4-07.5. The switchyard is located at a higher elevation, approximately 40 feet above the transformer yard grade, and south of the transformer yard so that the bays in both yards are in line for straight overhead high-voltage connections. Initial installation provided for three transformer switching bays, one bus tie bay, and four outgoing line bays. All bays are 32 feet wide. Transformers and lines connect through oil circuit breakers of 3,500 MVA interrupting capacity to the 115 kV main bus. An underground duct provides for cable runs between the powerhouse and the switchyard.

4-07.6. A more detailed description of power facilities, as well as other structures at the dam site, is contained in the Gavins Point Operation and Maintenance (O&M) Manual. Plan and section of the powerhouse are shown on Plate IV-2. Powerplant tailwater rating curves and powerplant characteristic curves are shown on Plates IV-6 and IV-7, respectively.

4-08. Reservoir. The reservoir formed by Gavins Point Dam, Lewis and Clark Lake, extends westward forming the border between the states of Nebraska and South Dakota through its length. At the maximum normal operating level of 1208.0 feet the reservoir has a length of 25 miles, a shoreline of 90 miles, a surface area of 25,000 acres (based on 2011 survey data) and a maximum depth of 50 feet. The Gavins Point reservoir is long and relatively narrow and is confined almost entirely to the Missouri River valley, since no major tributaries enter the river within the reach occupied by the reservoir. See Plate IV-8 for a graphical representation of the reservoir area.

4-08.1. Allocation of storage in the Gavins Point reservoir was based on local mainstem system requirements as described in Section 7-03 of the Master Manual. Types of storage space, with associated elevations and storage quantities for each type, are given in Table IV-1 in this WCM. In addition to this allocated space, the reservoir level during the SDF would peak at elevation 1221.5 feet, representing a surcharge of about 420,000 AF of storage above the top of the Exclusive Flood Control Zone. The area-capacity table for the Gavins Point reservoir is on Plate IV-9.

Table IV-1
Gavins Point Reservoir Storage Space Allocations

Storage Designation (Zone)	Elevation in feet		Storage Space in AF
	From	To	
Exclusive Flood Control	1208.0	1210.0	54,000
Annual Flood Control and Multiple Use	1204.5	1208.0	79,000
Permanent	1160.0	1204.5	295,000
Total Storage			428,000

Note: Storage volumes are based on 2013 elevation-area-capacity tables (2011 surveys).

4-08.2. In addition to the storage zones listed in Table IV-1, the Gavins Point reservoir originally contained a Carryover Multiple Use Zone between elevations 1195.0 and 1204.5 feet. However, this zone is no longer recognized. The top of the Permanent Zone was raised from 1195.0 to 1204.5 feet after many years of operational experience. Numerous long-range regulation studies demonstrated the undesirability of drawing the reservoir below elevation 1204.5 feet. The only exception is during infrequent occasions when local snow conditions indicate large runoff volumes are imminent. The reservoir is typically held near elevation 1206.0 feet during the March-July flood season, after which it is raised to near 1207.5 feet by the end of September, 0.5 foot below the top of the Annual Flood Control and Multiple Use Zone.

4-09. Recreation Facilities. Fluctuating levels have a major effect on recreational use of reservoirs. However, the annual fluctuation in water level of the Gavins Point reservoir is normally less than on any of the other System reservoirs other than the Big Bend reservoir (Lake Sharpe). This is because these two projects have very little flood control storage and are generally regulated as run-of-the-river projects. Generally, the MRBWM office targets a Gavins Point spring and summer pool elevation of 1206.0 feet. Rainfall events that increase incremental runoff in the Fort Randall to Gavins Point reach will occasionally result in the pool level rising into the Exclusive Flood Control Zone (elevation 1208.0 to 1210.0 feet). During the fall and winter, the targeted pool elevation is 1207.5 feet because the incremental runoff events are less likely during these periods. Numerous public use areas have been established around the shoreline of the project with a common development of most of these areas being a boat ramp providing access to the reservoir. Recreation at System projects consists of both water-based and land-based activities. Water-based recreation includes boating, fishing, water skiing, jet skiing and swimming. Land-based recreation includes hunting, camping, picnicking, sightseeing, hiking and wildlife photography. Visitors participate in these activities at recreation areas that range from undeveloped reservoir access points to highly developed and extensively used campground areas. The six System projects have a total of 188 public recreation areas. Plates IV-10 and IV-11 present the 23 recreational facilities at the Gavins Point project. In 2002, most of the South Dakota federal recreation areas were transferred in fee title to the State of South Dakota or to the Bureau of Indian Affairs (BIA), which holds the areas in trust for the Lower Brule Sioux Tribe and the Cheyenne River Sioux Tribe, under Title VI of Public Law 105-53, Water Resources Development Act of 1999 (WRDA 1999) as amended by Public Law 106-541, Water Resources Development Act of 2000 (WRDA 2000). A total of 65 recreation areas on Oahe, Big Bend, Fort Randall and Gavins Point were transferred in fee title, along with the nine recreation areas leased in perpetuity, to be managed for the restoration of terrestrial wildlife

habitat loss that occurred as a result of the flooding of lands related to the construction of the projects.

4-10. Leasing of Project Lands. As indicated in Section 2-05, the Corps acquired essentially all lands surrounding the Gavins Point reservoir below elevation 1210.0 feet. Blocking out procedures and other allowances at the time of real estate acquisition also resulted in the purchase of some land above elevation 1210.0 feet. Unless unusual conditions occur, inundation of lands above elevation 1210.0 feet would not be expected during any given year. As a result of the Title VI portion of WRDA 1999 and subsequent technical amendments in WRDA 2000, all land lying above 1204.5 feet within recreation boundaries and above 1210.0 feet outside recreation boundaries was transferred to the State of South Dakota Game Fish and Parks (SD GF&P). Subsequently, the Corps has made land adjacent to those transferred lands available through a no-cost easement to the SD GF&P. The easement allows the State of South Dakota to use the land "for recreational and other purposes (including the construction, operation, maintenance and repair of water intake structures, publicly owned boat docks, publicly owned boat ramps and related publicly owned structures) ... and the administration of livestock grazing on said areas". This easement and all instruments issued under it provide for possible flooding of lands, if needed, for operational purposes and do not serve as an overriding constraint on regulation of the project for authorized purposes.

4-11. Reservoir Aggradation and Backwater. As mentioned in Section 3-13 of this WCM, the long-term sediment deposition rate in the Gavins Point reservoir is estimated to be 2,700 AF/year. According to the 2013 Omaha District report *Sediment Conditions at Lewis and Clark M.R.B Sediment Memorandum 29*, about 55 percent of the sediment contribution to the reservoir comes from the Niobrara River. The density of these deposits is about 75 pounds per cubic foot, dry weight, and its composition will average about 70 percent sand and the remainder silt and clay. Since the predominant portion of the sediment is of sand size, the major portion of the deposition is occurring immediately below the mouth of the Niobrara River and in the upper reaches of the reservoir above Springfield, SD. The reservoir aggradation ranges are shown on Plate IV-12.

4-12. Tailwater Degradation. Since the Gavins Point reservoir acts as a trap to inflowing sediment, releases from the project are almost sediment free. Releases immediately act on the downstream channel areas, scouring the sand from the banks and the channel bottom. The river degradation ranges are shown on Plate IV-13. A gradual lowering of the channel and associated water surface profile has occurred since Gavins Point was put into operation. During the 20-year period from 1955 to 1975 tailwater elevations corresponding to average Gavins Point releases have lowered by over 7 feet. During the 40-year period from 1975 to 2015, the tailwater elevation has lowered about 5 feet. The continuing degradation process is illustrated by the tailwater rating curves and tailwater stage trends as shown on Plates IV-6 and IV-14, respectively.

4-13. History of Water Resources Development. Due to the lack of other transportation facilities, development of water resources in the portion of the Missouri River basin in the vicinity of Gavins Point began soon after westward expansion into the West in the early 1800s. Initial development was concerned with navigation as a means of transportation in the region. The economy of the region is primarily agricultural. This, combined with the semi-arid climate,

would have been expected to foster irrigation development. However, the lack of perennial tributary streams in the region discouraged such development except in the headwaters area of the Niobrara River and in restricted areas immediately adjacent to the Missouri River. The most widespread development in relatively recent history has been construction of dams controlling small drainage areas to provide a water supply for the extensive livestock grazing practiced through this region. Control of floods became a major concern in the 1940s and in recent years municipal and industrial (M&I) water supply, recreation, water quality and control, fish and wildlife and environment have been of increasing importance.

4-13.1. Federal legislation pertinent to water resource development throughout the Missouri River basin is summarized in Chapter II of the Master Manual. As indicated in that manual, the Flood Control Act of 1944 is of primary importance. This act authorized the construction of the Gavins Point project, as well as four of the other System projects (Fort Peck was already constructed and was authorized by the Act to become part of the System) and many tributary reservoir projects, and emphasized the multiple-purpose aspects of water resource development for the region.

4-13.2. One important means of water resource development in this section of the Missouri River basin is the construction of dams controlling sizeable drainage areas and development of the associated reservoirs. In addition to Gavins Point, a few tributary reservoir projects have been constructed in the incremental drainage area between Fort Randall and Gavins Point and along the James River, which enters the Missouri River a short distance below Gavins Point Dam. While initially some of these tributary reservoirs may have been constructed for a single purpose, they all now serve several functions, although service to some functions may be incidental to a primary purpose. Most of the reservoir projects in this incremental drainage area of the Missouri River basin were developed by the USBR for the primary purposes of irrigation and water supply. Flood control is also served by some of the projects. Recreation and fish and wildlife enhancement are served by all of the projects. Within the Fort Randall to Gavins Point drainage area there are two reservoirs having a usable storage capacity of 5,000 AF or more: 1) Merritt Reservoir near Valentine, NE and 2) Box Butte Reservoir near Chadron, NE. Both were developed by the USBR and have the capabilities of storing 75,000 and 31,060 AF, respectively. The Merritt and Box Butte projects are located in the headwaters area of the Niobrara River and control respective drainage areas of approximately 600 and 1400 square miles, respectively. Spencer Dam on the Niobrara River in Holt County, Nebraska is owned and operated by the Nebraska Public Power District (NPPD). It is a hydroelectric dam draining 11,580 square miles. In September 2015, NPPD announced that the hydropower unit will cease being operated and NPPD will give up its water rights. The Nebraska Game and Parks Commission and a coalition of five local natural resources districts across northern Nebraska will get the right to the water for recreation, conservation and continued irrigation. There are two federal flood control projects with more than 5,000 AF of capacity in the Gavins Point to Sioux City, IA drainage area: USBR's Jamestown project and the Corps' Pipestem project. These projects are located in the upper James River basin near Jamestown, ND and have capacities (top of flood control pool) of 221,000 and 142,000 AF, respectively.

4-13.3. The tributary reservoirs in the Fort Randall to Gavins Point drainage area have very little effect on regulation of Gavins Point or other mainstem reservoirs. The tributary projects control only a small portion of the incremental drainage area and the controlled portion consists of large

areas that are noncontributing to surface runoff. Regulation of Merritt and Box Butte projects result in near negligible reductions to the peak of Missouri River incremental inflow, even during major flood occurrences. Consequently, these projects are regulated to meet local area requirements rather than mainstem requirements.

4-14. Flood Control. In addition to the flood control storage provided in the Gavins Point reservoir, flood control storage space has been allocated in the Pipestem and Jamestown projects. The projects are located near Jamestown, ND on Pipestem Creek and the James River, respectively. The James River is a major tributary that enters the Missouri River about 7 miles downstream of Gavins Point. Flood control storage space within these two projects totals 337,000 AF and can be expected to store significant volumes of runoff upstream of the projects during large plains snowmelt events such as occurred in 1950, 1952, 1997 and 2009. However, floods originating above these projects seldom have any appreciable effect on Missouri River flood peaks below the mouth of the James River. Consequently, since tributary flood control space is essentially not effective for mainstem flood control, the availability of tributary flood control storage space in this region has had little significant effect on either storage requirements or on regulation procedures of Gavins Point or other System projects. There are no local flood protection projects that affect, or are affected by, Gavins Point regulation, except those far downstream from the System, such as the protective works at Omaha and Kansas City.

4-15. Irrigation. Irrigation from surface water supplies is practiced in the headwaters area of the Niobrara River. Box Butte Reservoir supplies water for the USBR's Mirage Flats project and the Ainsworth irrigation unit is supplied from Merritt Reservoir. Box Butte and Merritt provide irrigation for approximately 12,000 and 34,500 acres, respectively. Additional scattered private irrigators withdraw water directly from streams in the region. Refer to Appendix E of this WCM or Appendix E of the Master Manual for additional information regarding irrigation.

4-16. Navigation. Although navigation on the Missouri River through South Dakota opened up this region for westward settlement, there is now no commercial navigation upstream of Sioux City, IA. The upstream terminus of the Missouri River navigation project is at Sioux City, IA at RM 735 at the confluence of the Big Sioux River. Storage space has been provided in the Gavins Point reservoir for multiple purposes, including Missouri River navigation; however, the space is so limited that it serves essentially only for re-regulation of upstream reservoir releases. Gavins Point releases are essential for satisfactory operation of the navigation project. A description of the Missouri River navigation project is contained in Chapters IV and Appendix G of the Master Manual.

4-17. Hydroelectric Power. The Gavins Point powerplant, with an installed capacity of 132,300 kW, is the main hydroelectric power generating facility located in the incremental Missouri River drainage area discussed in this WCM. A small generating facility is located on the Niobrara River near Spencer, NE (see Section 4-13.2). All power generated by federal facilities in the Missouri River basin is marketed by Western. Power generation at Gavins Point is integrated with generation from the other mainstem projects, as well as that generated from other federal and private facilities throughout the power marketing area. Further details concerning hydropower generation and the Western power marketing and transmission facilities are provided in Section 7-12 and Appendix F of the Master Manual and Appendix F of this WCM.

4-18. Municipal and Industrial Water Supply. The municipal surface water intake for Springfield, SD is located in the headwater's region of the Gavins Point reservoir. The intake has experienced continuing difficulties due to ongoing aggradation. Numerous municipal and industrial (M&I) water supply intakes are located in the Missouri River below Gavins Point. The most immediate downstream intake serves the city of Yankton, SD. Maintenance of adequate flows for continuing operation of the M&I intakes throughout the entire lower Missouri River is an important function of the Gavins Point project.

4-19. Land Treatment. In response to the program administered by the U.S. Department of Agriculture, land treatment measures designed to reduce erosion and local floods and to increase the local surface water supply are in operation throughout the Fort Randall to Gavins Point drainage area. Associated with this program are many stock ponds or farm ponds that have been developed. While these ponds and other land treatment measures have a depleting effect on the overall local water supply to the Missouri River and provide a degree of local flood protection, their effect on major Missouri River flood flows is minimal. The reduction of erosion however, could provide significant benefit to the System by reducing current and future sediment accumulation.

4-20. Fish, Wildlife and Recreation. The effects of water resource development on fish and wildlife are a consideration throughout the Missouri River basin in the planning and reservoir regulation processes. Recreation opportunities have generally been increased as a result of water resource development. To the degree practicable, fish and wildlife interests are considered prior to regulation of the projects. Recreational use of the Gavins Point reservoir continues to increase through the years. Since the South Dakota Title VI land transfer in 2002, recreation interests on the reservoir are primarily managed by the SD GF&P, the Tribes and various local entities. Appendix B of this WCM presents additional information regarding recreation.

4-21. Streambank Stabilization. Streambank erosion is a continuing process along the Missouri River and also along the tributaries in the region. Sediment inflow to the Gavins Point reservoir results largely from this erosion process along streams contained within the Fort Randall to Gavins Point incremental drainage area. Refer to Section 3-14 of this WCM for details regarding the nine Corps-constructed streambank erosion control projects from Yankton, SD to Ponca State Park near Ponca, NE.

4-22. Streamflow Depletions. The major effect of the water resource development in the incremental drainage between Fort Randall and Gavins Point on the regulation of Gavins Point is a depletion in the available water supply. As resource development continues, a growth in depletions can be expected. While increasing depletions probably benefit the flood control function, it is evident that they may have adverse effects on other functions that are dependent on the availability of a continuing water supply.

4-22.1. Prior to 1865 streamflow throughout the Missouri River basin was largely unused, except for transportation. Settlers and homesteaders in the late 1800s and soon after the turn of the century started substantial irrigation and mining ventures in several regions of the upper Missouri River basin. However, in the western South Dakota drainage area contributing to the Missouri River reach discussed in this WCM, the available water supply was very small and unreliable. Consequently, irrigation development occurred in only scattered areas, in the

tributary headwater's region where a more dependable water supply was available. No large irrigation projects were developed. Table IV-2 lists results of the 2005 USBR analysis of the historical and estimated future depletions in the Fort Randall to Gavins Point reach. Depletions are based on irrigation and as well as M&I uses. Future depletions are primarily based on projected population changes.

Table IV-2
Depletions in the Fort Randall to Gavins Point Reach

Time Period	Average Annual Depletions in kAF
1929 – 1940	310.6
1941 – 1950	642.8
1951 – 1960	872.8
1961 – 1970	813.3
1971 – 1980	893.9
1981 – 1990	858.1
1991 – 2002	855.5
Future (Estimated)	
2002 – 2010	1063.0
2010 – 2015	1063.7
2015 – 2020	1065.2
2020 - 2025	1066.6
2025 – 2030	1068.1
2030 – 2050	1071.1
2050 – 2070	1075.2
2070 - 2090	1076.5
2090 - 2110	1077.7

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V - Data Collection and Communications Networks

5-01. General. Refer to Chapter V of the Master Manual for an outline of the basic hydrologic data required for regulation of the System. This chapter outlines agency responsibilities, communications methods and other details relevant to the data collection process.

5-02. Gavins Point Project Data. Hourly data are automatically transmitted from the Gavins Point PPCS via satellite telemetry from a data collection platform (DCP) to the MRBWM office and also to the Corps' Kansas City District for redundancy. The data include hourly releases, generation, pool elevations, tailwater elevations, air temperature and wind conditions. The daily data files include daily maximum and minimum air temperatures, precipitation, manually-entered pan evaporation and tailwater temperatures. Tailwater temperatures are obtained from a thermometer located in a turbine unit. Precipitation, air temperature and wind data are obtained from a weather station located on the intake structure. In the event the automatic data collection and transfer is not working, Gavins Point personnel fax or email hourly and daily project powerplant data to MRBWM and the MRBWM staff manually inputs the information into the Missouri River Region's (MRR) Corps Water Management System Oracle database. The Gavins Point monthly summary is faxed or emailed to the MRBWM office and is used to verify daily data.

5-02.1. Throughout the year Gavins Point project personnel investigate requests and complaints that occur as a result of Gavins Point regulation and report their recommendations and findings to the MRBWM office. The MRBWM office keeps the Gavins Point project personnel advised concerning anticipated changes in releases and reservoir levels. Based on this information, project personnel assist in informing affected interests of any major changes in release rates or reservoir elevations that may be scheduled, and also informing affected interests of unusual reservoir elevations that may be anticipated. System coordination is discussed further in Chapter VIII of this WCM and also in the Master Manual.

5-03. Precipitation and Temperatures. Sections 5-03 and 5-04 of the Master Manual contains detailed descriptions of data collection procedures throughout the Missouri River basin. Precipitation data is available through automated precipitation gages at real-time DCP stations and observer precipitation stations, some described in greater detail later in this chapter. Spatially-distributed observed precipitation data is provided by the National Weather Service (NWS) through its quantitative precipitation estimates (QPE). Plate V-1 in the Master Manual presents NWS QPE site locations in the Missouri River basin. Forecasted precipitation grids 7 days in the future are also available for NWS quantitative precipitation forecasts (QPF) products. The hourly QPE and 6-hour QPF files are automatically retrieved from the NWS Missouri Basin River Forecast Center (MBRFC) on a near real-time basis and stored in gridded format on the MRR Water Management System (WMS).

5-03.1. Air Temperature. Air temperature data is available via real-time DCP stations as well as through a comprehensive NWS-supported network of automated and observer stations.

Spatially-distributed observed and forecasted temperature data derived by the NWS for the entire basin is provided to the MRBWM through a data exchange method developed and supported by the Corps' Cold Regions Research and Engineering Laboratory (CRREL) and HEC. The gridded temperature files are automatically created on a near real-time basis at the Corps' Central Processing Center in Vicksburg, MS and retrieved and stored in the MRR WMS. The observed air temperature data is converted into a gridded format at 1-hour time steps, both for observed data and for 16 days in the future. Additionally, forecasted temperature data at 6-hour time steps is available for 5-7 days in the future.

5-04. Snow. During the winter season, reports of snowfall and accumulated snow depths are received from numerous stations located throughout the Missouri River basin. Chapter V of the Master Manual presents detailed discussion regarding plains and mountain snow data.

5-05. Stages and Discharges. River stage information reported to the MRBWM office as indicated by the basic network in Chapter V of the Master Manual are supplemented by reports from many tributary locations, particularly during the March-July flood season or at other times of the year if unusual stages are occurring. See Plate V-1 and Table V-1 for key locations within the incremental drainage area, as well as the reach from Gavins Point to Sioux City, IA, where streamgaging stations (DCPs) are located. Additional DCP information and DCP locations can be found at the U.S. Geological Survey (USGS) Water Resources website.

5-06. Communication during Normal Regulation. Gavins Point is regulated as a component of the System. As such, regulation must be fully coordinated with regulation of the other five projects; therefore, regulation of all System projects is directed by the MRBWM office. Full details relating to organizational responsibilities, coordination, and communications pertinent to the System's regulation process are contained in Sections 5-21 through 5-23 of the Master Manual. Consequently, only a brief summarization is presented in this WCM and reference to the Master Manual is necessary for a complete understanding of these factors.

5-06.1. Reservoir regulation/power production orders to mainstem project personnel and Western are the basis of the regulation process. These are issued by the MRBWM office and are based on detailed analysis of current and expected hydrologic conditions throughout the Missouri River basin and releases needed to meet the Congressionally authorized purposes of Gavins Point and the System. The MRBWM office is responsible for coordinating project regulation as described in the Master Manual and also in Chapter VIII of this WCM.

5-06.2. Gavins Point personnel are expected to furnish the MRBWM office information they may receive that is pertinent to the regulation process. This includes observations made by project personnel as well as complaints or suggestions from those affected by project regulation. In addition, project personnel assist in informing the public in the local area of current and probable near-future regulation activities. It is the responsibility of the MRBWM office to keep project personnel informed of such activities. Any requests for information that are complex and/or of a long-term nature, or that involve policy, are to be referred to the MRBWM office.

Table V-1
Data Collection Platforms – Fort Randall Dam to Sioux City, IA

Corps ID	Location	USGS ID	DCP ID	NWS ID
FTRA	Missouri River at Fort Randall Dam, SD	n/a	CE0A8594	FRDS2
GWSD	Missouri River bl Greenwood, SD	06453020	CE1213CE	GRWS2
VDNE	Ponca Creek at Verdel, NE	06453600	CE35531E	VERN1
VENE	Missouri River bl Ponca Creek nr Verdel, NE	06453620	CE12C5A6	MRVN1
	Niobrara River nr Sparks, NE	06461500	D10492A2	SPKN1
	Long Pine Cr nr Riverview, NE	06463500	D10FE79A	RWN1
	Niobrara River at Mariaville, NE	06463720	D1109006	
	Keya Paha River nr Keypaha, SD	06464100	DDCFA5BE	PAHS2
	Keya Paha River at Wewela, SD	06464500	DDCFB6C8	WEWS2
VRNE	Niobrara River nr Verdel, NE	06465500	CE1DE5D8	VRDN1
	Verdigre Cr nr Verdigre, NE	06465700	DD9EB070	VEDN1
NINE	Niobrara River at Niobrara, NE	06466000	CE3CA5C6	NRBN1
NMNE	Missouri River at Niobrara, NE	06466010	CE377006	MRNN1
SPSD	Lewis and Clark Lake at Springfield, SD	06466700	CE12B336	SPGS2
	Bazile Creek at Center, NE	06466400	17128794	CBCN1
	Bazile Creek nr Niobrara, NE	06466500	17127710	NBZN1
GAPT	Missouri River at Gavins Point Dam, SD	n/a	CE0A96E2	GPDN1
YKN	Missouri River at Yankton, SD	06467500	CE50DE2A	YANS2
SCSD	James River at Scotland, SD	06478500	CE42726A	SC0S2
GASD	Missouri River at St. James, SD	06478523	CE12A0A0	MSJN1
MANE	Missouri River nr Maskell, NE	06478526	CE1295DA	MKLN1
VRSD	Vermillion nr Vermillion, SD	06479010	CE426FCE	VERS2
PONE	Missouri River at Ponca, NE	n/a	CE1286AC	MRPN1
AKIA	Big Sioux River at Akron, IA	06485500	CE428C3C	AKR14
SUX	Missouri River at Sioux City, IA	06486000	CE5DFBA0	SSCN1

5-06.3. The Corps' Omaha District is responsible for project O&M, including maintenance of those facilities required to support the regulation process. District staff collect snow survey data pertinent to Gavins Point regulation on request by the MRBWM office. The District is also responsible for flood fighting activities in the incremental drainage area. Information that is considered pertinent to the regulation of Gavins Point, or other System projects, is to be furnished to the MRBWM office.

5-07. Emergency Regulation. If emergency conditions develop at Gavins Point, project personnel are expected to take appropriate action, which varies depending on the nature of the emergency. When there is an immediate threat of serious injury or loss of life at the project, or the probability that serious damage may occur or has occurred to project facilities, project personnel are expected to take the actions deemed necessary and notify the Omaha District and the MRBWM office of the circumstances and actions initiated as soon as conditions permit. Subsequent modification or continuance of regulation of project facilities will be based on an evaluation of current conditions and potential effects by all appropriate offices. The MRBWM

office will direct this evaluation to ensure complete coordination in regulation of the project and the System.

5-07.1. During critical reservoir regulation periods and to ensure timely response, significant coordination is often conducted by telephone between Gavins Point and the MRBWM office. This direct contact ensures that issues are completely coordinated and concerns by both offices are presented and considered before final release decisions are made by the MRBWM office. The MRBWM's Reservoir Regulation and Power Production team leaders, as well as the MRBWM chief, are generally available by cell phone as are the mainstem Operations Project Managers. The MRBWM weekend worker also carries a cell phone and has the responsibility of notifying the appropriate MRBWM staff so that proper coordination can occur before significant changes are made to project releases. More information on emergency regulation procedures can be found in Chapter VII of this WCM.

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VI - Hydrologic Forecasts

6-01. General. Regulation of Gavins Point as a component of the System requires continuing analysis of available hydrologic information and, to the degree practicable, forecasts of future events. These are considered in conjunction with the anticipated demands imposed in serving the various project purposes. These considerations may be of a long-term nature or may be based on anticipated inflows and demands for a relatively short period in the future. AOP studies are discussed in Section 6-12.3 of the Master Manual. Also discussed in Chapter VI of the Master Manual are analyses, forecasts and studies, while important for the regulation of Gavins Point, have essentially the same degree of importance for all of the other mainstem projects. Analyses considered to be unique or particularly important to Gavins Point regulation are presented in the following sections.

6-02. Precipitation and Temperature Forecasts. As discussed in Section 6-04 of the Master Manual, NWS precipitation and temperature forecasts are monitored by the MRBWM office. The NWS's short-term precipitation forecasts, often referred to as Quantitative Precipitation Forecasts (QPF), are not integrated into the short-range runoff forecasts for day-to-day actual regulation, but may add value for short-term planning purposes. Precipitation forecasts of particular importance are those that could lead to substantial flow changes on the Niobrara River, a significant tributary entering the Missouri River above Gavins Point. Temperature forecasts are of particular importance during periods where an ice cover may form on the Missouri River below the project.

6-03. Runoff Forecasts. Short-range runoff forecasts are determined with water on the ground, per ER 1110-2-240, which consists of existing snowpack and recently observed rainfall. Particularly pertinent for the determination of inflows into Gavins Point are forecasts prepared for northeastern Nebraska and southeastern South Dakota, including the areas contributing to the Niobrara River and Ponca Creek, major contributors of inflow to the Gavins Point reservoir. Since Gavins Point is the most downstream of the mainstem projects, runoff forecasts for tributaries entering the Missouri River downstream of Gavins Point, which are factored into the System release determination as described in Chapter VII of the Master Manual, are very pertinent. The short-range runoff forecasts, which are discussed in greater detail in Section 6-08 of this WCM, are integral to the day-to-day regulation of Gavins Point.

6-04. Precipitation-Runoff Relationships. Infiltration of rainfall over the Missouri River basin between Fort Randall Dam and Yankton, SD, ranges from 0.5 to 1.00 inch for the initial loss and from 0.10 to 0.30 inch per hour constant infiltration loss. Losses from the downstream Missouri River contributing areas are somewhat higher. These values are based on a generalized soils and infiltration map of the basin. Snowmelt infiltration ranges from zero for frozen ground, or ice under snow, to approximately the loss values previously mentioned for rainfall. Runoff during any particular rainfall or snowmelt event would amount to the estimated depth of rainfall or snowmelt less the infiltration losses. In actual practice, estimating the rainfall runoff or

snowmelt rates is very imprecise in this area. This is due to the lack of a dense network of precipitation reporting stations, errors in estimating the snow cover and snow water equivalent (SWE) available for melt, errors in estimating the snowmelt rate, and marked departures from the previously stated average infiltration or loss rates. Use of NWS-provided QPE data has improved knowledge of rainfall events.

6-05. Unit Hydrograph Analyses. A conventional means of forecasting flows from a particular drainage area is by the use of unit hydrographs. However, unit hydrograph development and subsequent use of the developed hydrographs as a forecasting tool has been found to be impractical for the drainage area under consideration in this WCM. Reasons for this include the large size of the drainage area, which requires the division of the drainage area into many sub-areas, the lack of rainfall and subsequent runoff events for unit-hydrograph definition; the scarcity of rainfall reporting stations needed for both analysis and forecasting purposes; and the fact that by far the greatest amount of runoff that occurs from this drainage area does not result from particular rainfall events but results from progressive snowmelt, making runoff definition during a selected time period very imprecise. Runoff forecasting procedures will continue to receive consideration as a means of possibly improving the regulation process, and as discussed in the Master Manual, future runoff modeling efforts include the use of QPE within the Corps' Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), which should improve development of reliable real-time forecasting models.

6-06. Plains Snow. In many years a major portion of the total runoff from the incremental drainage area between Fort Randall and Gavins Point is a result of melting the plains snowpack accumulated during the winter months. This melt usually occurs during late March or April and often results in the annual maximum peak flow for that drainage area. Basic data pertinent to plains area snowmelt volume analyses are: 1) precipitation during the late fall and winter months, 2) winter season air temperatures, 3) water content of the accumulated snowpack prior to the melt period and 4) soil conditions. However, even with these data, forecasts of the plains snowmelt runoff volume are usually quite imprecise. The MRBWM office continues to investigate new and improved techniques including soil condition instrumentation and continuous soil moisture accounting modeling to more accurately predict runoff from plains snow. Section 5-06 of the Master Manual contains additional information on snow.

6-06.1. Plains area snow surveys, requested by the MRBWM office and conducted by the Omaha District, are made during any year that a substantial snow accumulation exists over the drainage area. Results from the snow surveys are compared to the interactive snow map for modeled SWE from the NWS's National Operational Hydrologic Remote Sensing Center to help in the verification process. Snow surveys are one method of obtaining quantitative estimates of runoff volume by comparing water content of the current survey with surveys made in preceding years. This comparison will indicate which of the past years is most analogous to the current year for each portion of the total drainage basin between Fort Randall and Gavins Point. Forecasts are developed by assuming that the volume of snowmelt runoff from each portion of the basin should be similar to that observed in the most analogous year. These estimates are tempered by available ground condition data, which could either increase or decrease the infiltration losses at the time of runoff. If analogous data are not available for a particular portion of the basin, it is necessary to estimate the runoff volume by noting runoff depths during previous years from other areas where snowpack conditions appear similar to the current year's snowpack over the

Fort Randall to Gavins Point incremental drainage area. For the entire Missouri River basin five years in particular, 1952, 1969, 1997, 2010 and 2011, experienced floods that were largely affected by melting of heavy snowpack on the northern plains. Table VI-1 contains information related to a plains snow comparison of the five years.

6-06.2. Improvement in the techniques of forecasting the runoff resulting from plains snowmelt is an ongoing priority of the MRBWM office. As technology continues to improve, more precise and objective forecasting methods are being developed. In addition, the NWS has initiated forecasts of plains snowmelt runoff volumes that are made just prior to the melt season. As experience is gained with new methods, it appears probable that better estimates of the runoff volume from plains snowmelt will be available than in the past. See Section 5-06.1.3 in the Master Manual for details regarding the Corps' Missouri Basin Snow Tool.

Table VI-1
Plains Snow in Major Floods

Late Winter Snow Moisture in Major Flood Years (SWE in Inches)						
Stream	**Location**	**17-Mar-1952***	**31-Mar-1969***	**18-Mar-1997***	**4-Mar-2010****	**11-Feb-2011****
Milk River	Nashua, MT	3.0	2.0	<1	1.5	3.2
Knife River	Hazen, ND	2.8	2.3	1.8	4.7	5.0
Heart River	Mandan, ND	3.5	3.0	1.8	4.4	4.7
Apple Creek	Bismarck, ND	3.0	3.0	3.0	4.7	5.1
Beaver Creek	Linton, ND	3.5	2.5	4.3	5.2	4.8
Cannonball R	Breien, ND	3.5	3.0	3.4	4.4	3.8
Grand River	Little Eagle, SD	3.6	2.3	2.6	3.8	2.7
Moreau River	Whitehorse, SD	4.0	2.3	1.7	3.0	1.9
Cheyenne River	Eagle Butte, SD	5.0	1.0	<1	1.2	1.0
Bad River	Fort Pierre, SD	3.0	1.5	<1	3.4	1.3
Elm River	Westport, SD	5.0	5.0	3.2	5.0	4.2
James River	Scotland, SD	3.6	4.0	3.9	4.6	4.0
Vermillion R	Wakonda, SD	0.5	4.5	3.4	3.5	3.2
Big Sioux River	Watertown, SD	3.8	4.2	4.2	6.7	5.3
Floyd River	Sioux City, IA	0.5	3.3	0	4.3	3.2
Little Sioux R	Turin, IA	0	3.2	<1	5.1	2.4

*From the 1997 Midwest Floods Post Flood and After Action Report, Volume 1
**From working files of Hydrology and Meteorology Section, Hydrologic Engineering Branch, Omaha District.

6-07. Monthly Reach Inflow (Runoff) Forecasts. Soon after the first of each month throughout the year, a forecast of incremental inflows originating between the System dams is made by the MRBWM office. These forecasts are utilized to develop System regulation studies, as described in Section 6-12 of the Master Manual. An exception is the Oahe to Big Bend reach. Due to the relatively small drainage area between Oahe and Big Bend, the normal lack of substantial runoff from this area and the small amount of deliberate seasonal storage space in the

Big Bend reservoir, this reach does not warrant a separate estimation of monthly runoff, and is included in the Oahe to Fort Randall reach.

6-07.1. Monthly reach inflow or runoff forecasts are based on, but are not limited to, monthly average reach runoff, antecedent reach runoff, antecedent soil moisture conditions, accumulated station and/or reach precipitation during March-April and May-July, observed reach temperature and accumulated snow over the incremental drainage area. In the Fort Randall to Gavins Point reach, snow contributions to runoff are important only during the early spring (March-April) period of plains snowmelt runoff. There have been years when warmer-than-normal January and February temperatures have resulted in some or all of the plains snow melting during these months. Consequently, long-range forecasts for periods other than this early spring period consist primarily of modifying the long-term normal runoff volume by observed antecedent basin conditions. These forecasts are utilized to develop System regulation studies, as described in Section 6-12 of the Master Manual. Details and techniques currently applicable for forecast development are contained in the MRBWM Technical Report, *Long-Term Runoff Forecasting,* dated February 2017.

6-08. Short-Range Forecasts of Daily Inflow. The MRBWM office develops forecasts of future daily inflows to the Gavins Point reservoir and the other associated System reservoirs at frequent intervals. Each week daily inflow forecasts extending three weeks into the future are developed. Experience has indicated that a satisfactory method of anticipating Gavins Point inflows for periods of up to a week beyond the current date consists of combining anticipated daily releases from the upstream Fort Randall project with anticipated daily flows from the Niobrara River, together with an allowance for local runoff. A simple translation multiplying and adding the previous day's and the current day's Fort Randall releases by 0.4 and 0.6, respectively, plus the previous day's flow of the Niobrara River at Spencer, NE, is the equivalent to the succeeding day's inflow to Gavins Point. This is a satisfactory method of forecasting inflows for a majority of the time when substantial runoff is not occurring from the drainage area adjacent to the reservoir. The Niobrara River near Verdel, NE streamgaging site is located near the confluence with the Missouri River and can also be used for estimating the proceeding day's flows into Gavins Point using the current day's flow and combining it with the previously discussed routed Fort Randall releases. However, caution should be exercised in using the Niobrara River at Verdel flows. Past experience has shown that the flows are accurate right after a streamflow measurement but that the accuracy will start to drop off in the next couple of weeks due to the shifting sand channel and rapidly changing river conditions. When only moderate runoff originates between Fort Randall and Gavins Point, the Gavins Point inflow can be considered in total, with inflow forecasts consisting largely of the extrapolation of past total runoff, modified as necessary to consider current hydrologic conditions. Typical inflow hydrographs from the total incremental area are discussed in Section 3-08 of this WCM. During significant flood events, Ponca Creek, Bazile Creek and Verdigre Creek real-time flows should be considered in addition to Niobrara River flows. Runoff forecasting procedures will continue to receive consideration as a means of possibly improving the regulation process. As discussed in the Master Manual, future runoff modeling efforts include the use of observed gridded precipitation in HEC-HMS models.

6-09. Stage-Discharge Relationships. Stage-discharge relationships, sometimes referred to as rating curves, are maintained by the MRBWM office for key tributary streamflow stations in the

Fort Randall to Gavins Point and Gavins Point to Sioux City, IA incremental drainage areas. These are kept current on the basis of discharge measurements made by the USGS. Refer to Plates VI-1 through VI-6 for the current stage-discharge relationships for tributary stations between Fort Randall and Gavins Point dams. These locations are used for developing short-range inflow forecasts pertinent to Gavins Point regulation. Refer to Plates VI-7 through VI-9 for the current stage-discharge relationships for tributary stations between Gavins Point Dam and Sioux City, IA. Refer to Plates VI-10 and VI-11 for current Missouri River stage-discharge relationships for Yankton, SD and Sioux City, IA, respectively. These locations are used for developing short-range Missouri River stage and flow forecasts to determine Gavins Point releases.

6-10. Flow Forecasts at Downstream Locations. Flows through the reach from Gavins Point Dam to Sioux City, IA predominantly consist of Gavins Point releases. During the April-June period the three major tributaries entering this reach, the James, Vermillion and Big Sioux Rivers, may contribute significant flow to the Missouri River. Estimation of flows from these largely unregulated tributaries are considered tributary flow supplementation. After rainfall events that are expected to result in significant tributary flows, forecasts of the flow supplementation consist of running MRBWM-developed HEC-HMS models for each of the major tributary watersheds to forecast rainfall runoff as well as plains snowmelt runoff. During times when no significant rainfall or snowmelt events have occurred, projected tributary flows are estimated via the persistence method or receded at rates consistent with that particular subbasin. These model results are integrated into the 14-day forecast model described in Section 6-11 of this WCM.

6-11. Downstream Stage and Flow Forecasts. Missouri River stage forecasts at Yankton, SD, which is about 4 miles downstream of Gavins Point, can be made on the basis of anticipated Gavins Point (System) releases and the Yankton rating curve (see Plate VI-10). As outlined in Section 6-03.2.2 in the Master Manual, the scheduling of Gavins Point releases is based on maintaining prescribed flow at the four downstream control points in the Missouri River – Sioux City, IA, Omaha, NE, Nebraska City, NE and Kansas City, MO. The proper scheduling of System releases require the development of accurate forecasts of the inflow originating between Gavins Point and the downstream target locations. Because the MRBWM office is responsible for scheduling all mainstem project releases, which includes Gavins Point, the MRBWM staff develop forecasts of reach inflow and flow and stage at each target location as a basis for System release scheduling. These forecasts are developed daily for the next 14 days in the future and are compared to daily forecasts developed by the NWS MBRFC.

6-12. Routing Procedures. For purposes of anticipating inflows to Gavins Point, a simple translation of observed or anticipated upstream flows by the approximate travel time from the upstream location is an adequate routing procedure for a majority of the time. On rare occasions it may be desirable to more accurately define the portions of Gavins Point inflow originating below Fort Randall. In such cases a lag-average approach to routing Fort Randall releases into Gavins Point is utilized. Experience has indicated that, if the Missouri River channel between the projects is free of ice, daily releases from Fort Randall can be converted to daily Gavins Point inflow increments by multiplying and adding the previous day's and the current day's Fort Randall releases by 0.4 and 0.6, respectively, plus the previous day's flow at the Niobrara River at Spencer, NE. With an ice cover in the channel, the travel time and the attenuation in Fort

Randall release fluctuations will be increased and modifications of the routing coefficients may be necessary.

6-13. Evaporation. Evaporation is an important component of the overall water budget of the Gavins Point reservoir due to the large reservoir surface area. An estimate of the daily evaporation volume is required for developing daily inflow estimates and for more precisely estimating the effects of reservoir development on the available water supply. Application of the commonly used 0.7 pan-to-reservoir factor is not considered reliable for Gavins Point due to the marked difference between the reservoir surface temperature and pan temperature. MRD-RCC Technical Report JE-73, *Missouri River Main Stem Reservoir System Reservoir Evaporation Estimates,* June 1973, addresses this problem in detail and recommends the use of a variable pan-to-reservoir factor. This factor for Gavins Point varies from as little as 0.53 (April-June) during periods when reservoir surface temperatures are less than air temperatures to as high as 1.59 (November), when reservoir surface temperatures materially exceed air temperatures. Plates III-9 through III-12 show pertinent evaporation information for the System reservoirs. During those periods of the year when pan data are not available, normal evaporation depths for each season of the year appears to offer the most practical means of developing evaporation estimates for day-to-day regulation activities. Reference is made to the cited technical report for further details pertinent to the development of evaporation estimates for this project.

6-13.1. The MRBWM office and Omaha District partnered with the Corps' Cold Regions Research and Engineering Laboratory to develop a more accurate real-time model, known as the Omaha District Evaporation Technique to determine reservoir evaporation. This real-time model uses local meteorological hourly parameters of air temperature, dew point, wind speed, relative humidity, air pressure and cloud cover to calculate solar radiation in addition to measured or estimated water temperature profiles. The MRBWM office plans to implement this new technique in 2019.

6-13.2. In addition to evaporation, development of the effects of the Gavins Point reservoir on streamflow must consider the offsetting effects of precipitation on the reservoir surface and must also make allowances for the channel area in existence prior to the impoundment of water in the reservoir. Also, allowance must be made for that portion of the rainfall now falling on the reservoir surface that prior to the formation of the reservoir would have contributed to direct runoff from the area now inundated. Precise calculations of these factors are impractical. As stated in MRD-RCC Technical Report JE-73, it is estimated that 75 percent of the precipitation that falls on the reservoir today historically would not have flowed into the Missouri River. This assumes that 10 percent of the precipitation would have fallen on original channel area and that 15 percent would have appeared as direct runoff from the former ground surface now inundated by the reservoir.

6-14. Wind Effects on Water Surface Elevations. The general orientation of the Gavins Point reservoir is to the west of the damsite where the pool level recorder is located. Winds with a component from this direction result in set-up at the dam while a wind component from the opposite direction results in set-down. See Plate VI-12 for wind correction tables for the pool level recorder at the dam at various elevations. An anemometer is located adjacent to the dam; however, it should be recognized that only approximations of the wind effect on the reported pool level can be obtained with data from this instrument. The time required for set-up to be

fully established, variations in wind velocity and direction over the reservoir surface, and the difficulty of having one location represent the entire length of the reservoir will result in deviations from calculated values. Synoptic surface weather maps may also be used for qualitative wind estimates or to determine the probable representativeness of the anemometer.

6-15. Daily Inflow Estimates. Estimates of inflow to the Gavins Point reservoir are made each day by the MRBWM office for regulation purposes. The steps involved consist of:

a. plotting hourly pool elevations as reported by the Corps' PPCS at Gavins Point;
b. utilizing reported wind reports to estimate the set-up or set-down effects on the reservoir to select an estimated midnight pool elevation;
c. calculating the reservoir storage change equivalent to the estimated 24-hour reservoir elevation change; and
d. using all this information in conjunction with reported releases and estimated evaporation to compute the daily reservoir inflow.

6-15.1. In addition, gaged Niobrara River flows are routed to the Gavins Point reservoir. These flows are combined with estimates of ungaged flow and precipitation on the reservoir surface to obtain an additional estimate of reservoir inflow. Differences in inflow estimates as determined by the previously defined process and the gaged Niobrara River flows are reconciled by using experience and engineering judgment. At times it will be necessary to adjust data for previous days on the basis on continuing trends in the reservoir level that were not previously evident. See Plates VI-13 through VI-18 for regulated and incremental inflow volume probability relationships for various durations. More information on the inflow volume probability for the mainstem projects can be found in the MRBWM Technical Report, *Hydrologic Statistics on Inflows*, dated June 2015. See Plate VI-19 for a graphical depiction of historical average daily and monthly elevations, inflows and releases for Gavins Point.

6-16. Unregulated Flows. Construction of the Gavins Point project, together with the other mainstem and tributary projects in the Missouri River basin, has materially altered flows downstream from the dam. Flood peaks have been reduced and low flows have been augmented by reservoir regulation. A quantitative estimate of the effects of regulation on flows at the damsite and important locations downstream is frequently required. This represents a continuing effort by the MRBWM office and involves such factors as reservoir evaporation, precipitation on the Gavins Point reservoir, variations in travel time resulting from reservoir development, channel area inundated by the reservoir, runoff that could have been expected from previous overbank areas now inundated by the reservoir, inflows, outflows, and storage changes. Refer to the MRD-RCC Technical Study S-73, *Upper Missouri River, Unregulated Flow Development*, dated September 1973, for addition details of the analysis.

6-16.1. In addition to unregulated flows, determination of flows at the 1949 level of basin development prior to construction of the Gavins Point project and other water resource development in the Missouri River basin represents a continuing effort of the MRBWM office. Gavins Point represents a location where such determinations of unregulated flows are made. Reference is made to Section 6-15 of the Master Manual for further details of these analyses.

6-16.2. Refer to Plates VI-20 through VI-26 for tributary flow probability curves for tributary locations in the Fort Randall to Gavins Point and the Gavins Point to Sioux City, IA reaches. Flow probability relationships were developed for tributary streams flowing into the Missouri River between Fort Randall Dam and Sioux City, IA and are shown in Table VI-2.

Table VI-2
Tributary Flow Probability Relationships

Tributary	Drainage Area (square miles)	Peak Discharge (in cfs) for Given Return Period (in years)			
		10	50	100	500
Ponca Creek at Verdel, NE	812	6,350	14,000	18,500	31,900
Niobrara River at Verdel, NE	11,580	14,900	32,400	45,000	96,400
Verdigre Creek near Verdigre, NE	470	5,900	17,700	27,400	74,700
Bazile Creek near Niobrara, NE	440	14,200	38,100	55,300	122,000
James River at Scotland, SD	20,672	12,600	35,100	51,200	114,000
Vermillion River at Vermillion, SD	2,254	7,900	18,400	25,500	51,700
Big Sioux River at Akron, IA	7,879	36,400	77,300	101,000	176,000

6-17. Evaluation of Regulation Effects. In evaluation of the effects of regulation on downstream flows and consequent flood damage reduction estimates, Gavins Point is considered to be a component of the total System. Damage reductions attributable to regulation of this individual project are not differentiated from those resulting from the six-project System as a whole. Details of the evaluation process are presented in Sections 6-15 and 6-16 of the Master Manual.

6-18. Long-Term Studies. Simulated regulation of Gavins Point as a component of the System, through the entire period of available hydrologic record, is a technique utilized by the MRBWM office for the development and improvement of regulation criteria. Current regulation criteria are the result of many involved and detailed studies, augmented by actual regulation experience. Accomplishment of the long-term studies is described in Chapter VI and Appendix H of the Master Manual and in the detailed reports that have been published describing specific studies. From the long-term studies that incorporate current regulation criteria and water use, as well as studies that assume various potential future levels of water resource development in the Missouri River basin, long-term examples of Gavins Point regulation are available. From the examples incorporating the present level of water resource development, conclusions relative to regulation of Gavins Point can be established, as described in succeeding sections.

6-19. Frequency Estimates. Frequency of occurrence estimates of reservoir elevations and releases at each of the System reservoirs were developed as described in MRBWM Technical Report, *Hydrologic Statistics*, dated September 2013. Per Table 24 of that report, the 1 percent chance of exceedance pool elevation is estimated to be 1210.0 feet. The maximum pool level of record (1967-2015) is estimated to be 1209.7 feet. The pool reached elevation 1209.7 feet in June 2010; however, it reached its maximum of 1210.7 feet in April 1960. Per Table 25 of that report, the 1 percent chance of exceedance maximum release from Gavins Point is estimated at 160,000 cfs. During the 2011 Flood, the maximum Gavins Point release was 160,700 cfs. See

Plates VI-27 through VI-30 for pool duration, pool probability, release duration and release probability curves, respectively.

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7-01. Multiple Purpose Regulation. Aspects of multi-purpose regulation that are pertinent to the System as a whole are discussed in Chapter VII of the Master Manual. Since continuing development of System operating plans requires coordination of plans for all mainstem projects, this subject has been explored thoroughly in the Master Manual and will not be repeated in this, the Gavins Point WCM. Rather, the following sections will be concerned with amplifying the operational objectives and requirements given in the Master Manual that are pertinent to regulation of Gavins Point for the authorized purposes of flood control, navigation, hydropower, water supply, water quality control, irrigation, recreation and fish and wildlife, which includes T&E species. Regulation of Gavins Point for flood control is discussed later in this chapter.

7-02. Basis for Service. As an introduction to regulation of Gavins Point, the need to conform to certain storage provisions and basic regulation criteria should be recognized. The bottommost zone, the Permanent Zone, is the portion of the reservoir lying below elevation 1204.5 feet and is to remain permanently filled with water. This ensures maintenance of minimum power heads, a minimum level for the design of irrigation diversion and water supply facilities, and a minimum pool for recreation, and fish and wildlife purposes. The Annual Flood Control and Multiple Use Zone extends from elevation 1204.5 to 1208.0 feet and is the preferred operating zone. The waters in this zone are used to meet all authorized purposes. The Exclusive Flood Control Zone extends from elevation 1208.0 to 1210.0 feet. This zone is reserved exclusively for flood control regulation of floods. The next zone is the Surcharge Zone, which is from elevation 1210.0 feet, the elevation of the top of spillway gates when closed, to elevation 1221.4 feet, the maximum reservoir elevation from the routing of the SDF. This zone, which does provide some downstream flood risk reduction, is used during extreme flooding events. When the pool elevation is in this zone, release decisions are primarily made to ensure the safety of the project. Embankment freeboard is provided above the Surcharge Zone from elevation 1221.4 feet to the top of the dam embankment (1234.0 feet).

7-03. General Approach to Regulation. The following general approach is observed during regulation of Gavins Point:

a. Regulation of Gavins Point as an individual project must be subordinate to regulation of the entire System as a whole.
b. To the extent practicable, flood control will be provided for by evacuating the storage space in the reservoir above elevation 1206.0 feet prior to March of each year and maintaining some reserve for this purpose throughout the year. In years with higher runoff potential during the March through July flood season, the reservoir may be drawn down to near the base of the Annual Flood Control and Multiple Use Zone, elevation 1204.5 feet.
c. All irrigation and other upstream water requirements for beneficial consumptive purposes will be served to the extent reasonably possible.

d. At all times when a reserve of vacant flood control storage is available in the Gavins Point reservoir, flood control releases will be scheduled on the basis of flood control considerations of the entire System.
e. Releases required to support Missouri River navigation will be maintained in accordance with system regulation criteria outlined in the Master Manual.
f. Downstream water supply and water quality flows will be at all times supported by appropriate releases.
g. By adjustment of Gavins Point releases within the criteria designated in Sections 7-03.a through 7-03.f, the efficient generation of power to meet the area's needs as consistent with other uses and market condition will be provided for.
h. Insofar as possible without serious interference with the aforementioned, Gavins Point will be regulated for maximum benefit to recreation and fish and wildlife, including T&E species.

7-04. Irrigation. There are no authorized or existing federal irrigation projects withdrawing water from this reservoir. Corps regulation responsibilities for irrigation are limited to estimating withdrawals and utilizing the estimates in the development of reservoir inflows and in deriving estimates of the actual available water supply.

7-04.1. Table E-3 in Appendix E of the Master Manual lists the Missouri River water supply intakes throughout the System. Current estimates show that there are approximately 27 irrigation intakes on the Gavins Point reservoir and 105 between Gavins Point and Hermann, MO that require maintenance of minimum flows. Similar to other reaches of the Missouri River below System projects, there may be some problems associated with access to the water due to fluctuating release or pool levels. Access to the available water supply from each System reservoir and the Missouri River is the responsibility of the intake owner.

7-05. Water Supply and Water Quality Control. As shown in Table E-3 in Appendix E of the Master Manual, there are two municipal water intakes on the Gavins Point reservoir and there is one municipal water intake on the Missouri River between Gavins Point and Sioux City, IA. The city of Springfield, SD withdraws water from the upstream end of the reservoir and has experienced problems associated with sedimentation of their intake. The city has modified their original intake by placing a "piggy-back" pipe above their original intake line and raising the original intake invert level by two feet, to elevation 1202.0 feet. The city of Yankton, SD withdraws water from the Missouri River just downstream of Gavins Point. If other intakes to serve water supply purposes from the reservoir are contemplated, their design should recognize the ongoing sedimentation deposition in the reservoir headwaters as well as planned variations in the reservoir and river levels. The availability of good quality water in the reservoir and lack of significant pollution sources in the immediate downstream reach makes it unnecessary to schedule releases to serve only the water quality function.

7-05.1. Minimum flows are required at major pollution sources along the Missouri River below Gavins Point. As discussed in Section 7-09.1 of the Master Manual, generally, System release levels necessary to meet the downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. Per Table VII-10 in the Master Manual, the minimum flows range from 1,350 cfs during the spring (March-April) and fall (October-November) months at Sioux City, IA to 9,000 cfs at Kansas City, MO during

the summer (June-September) months. Gavins Point releases for other authorized purposes will usually result in downstream flows well above these requirements. While highly unlikely, an exception could occur during a prolonged drought period, comparable to that experienced over the Missouri River basin in the 1930s. During such a drought, System releases may need to be markedly reduced and water quality flow requirements may become a controlling factor for releases.

7-05.2. City of Yankton Water Supply. A minimum Gavins Point release of 6,000 cfs was made during July 1993 to reduce flooding impacts on the lower Missouri River. Since 1993, continued channel degradation has resulted in minimum Gavins Point releases of 12,000 cfs, or a stage of 9 feet at the Missouri River at Yankton streamgaging station, being needed to keep the standard river-fed water intake operational. In the fall of 2016 the city of Yankton finished construction on a collector well water supply system. The collector well field was put into operation in 2017 and operates alongside the standard river-fed water intake, which will be taken out of operation at the end of 2019. As of the finalization of this WCM, the city blends the two water sources together. The collector wells are located approximately 100 feet below the river and are fed by groundwater. The water treatment plant, which is used to treat the groundwater, is expected to be put in operation in the spring of 2020. Once the water treatment plant is put into operation, all of the city's water supply will be via the collector well water supply system and there will no longer be a Gavins Point release restriction regarding the city of Yankton's water supply.

7-05.3. Lower River Intakes. Many other intakes are in the reach from Sioux City, IA to the mouth of the river, including intakes supplying cooling water to major fossil fueled and nuclear power facilities. While it is the responsibility of the intake owner to ensure that they have access to the water, minimum daily flow requirements established for water quality purposes would create operational problems at many of the intakes with problems resulting primarily from high intake elevations or access to the supply rather than the rate of Missouri River flows. While no longer needed for the city of Yankton, minimum winter releases of 12,000 cfs should be maintained insofar as possible. If releases at a level of less than 12,000 cfs should be necessary, continuing surveillance of downstream intakes will be required in order to assure proper action by affected interests to obtain adequate supplies. Per Section 7-11.3.5 of the Master Manual, during any non-navigation time period, releases will be made to ensure adequate flow to serve water supply in the river reaches downstream of the System and between the System dams, to the extent reasonably possible. Some intakes require more than 9,000 cfs (minimum release required in the early 1990s) during the open-water non-navigation season for effective operation, particularly if tributary flows are less than average.

7-06. Navigation. Since Gavins Point is the most downstream of the mainstem projects, Missouri River navigation flow support is directly provided by Gavins Point releases. Releases to provide navigation flow support are scheduled on the basis of criteria presented in Chapter VII of the Master Manual. Due to the limited storage in the Gavins Point reservoir, releases from Gavins Point must be backed up with releases out of the upper System reservoirs. The relatively small amount of storage space in the Gavins Point reservoir between elevations 1204.5 and 1208.0 feet is primarily used for flow re-regulating to smooth out the release fluctuations of the upper projects to better serve downstream purposes. The availability of this space in the Gavins Point reservoir does allow for daily fluctuations in the upstream Fort Randall release that, if

uncontrolled, would be inconsistent with providing steady flows to support Missouri River navigation.

7-07. Power Production. Hydroelectric power generated by Gavins Point is integrated with the power generated by the other mainstem projects and many other public and private generation facilities in the Missouri River basin and surrounding areas. To the extent practical, all releases from Gavins Point are made through the powerplant. Releases from Gavins Point are generally at their highest during the navigation season when downstream flow requirements are highest. Releases are generally lower during the non-navigation season and may be restricted during the period when the lower Missouri River is ice-covered. Gavins Point releases in excess of powerplant capacity can be expected to occur and are usually made during the non-winter period. From the period of 1967-2015, the maximum annual release has exceeded 35,000 cfs in 26 of the 49 years. While the design maximum capacity of the three installed units is about 35,000 cfs, current capability ranges from 33,000 to 35,000 cfs. Normal annual unit maintenance involves each unit being offline for about a month during the December-February period. Additional unit-related maintenance and upgrades may require units being offline during the non-winter period. This may require use of the Gavins Point spillway during periods when the necessary release exceeds the available powerplant capacity. Also, during some drought years navigation flow support requirements will exceed the powerplant capacity and in high runoff years evacuation of flood control storage from the System often requires releases in excess of powerplant capacity.

7-07.1. The hourly loadings of the Gavins Point powerplant are scheduled by Western, the system power dispatcher in Watertown, SD. These hourly loadings are based on the water target (System release) prescribed by the MRBWM office. While Gavins Point releases are generally held steady throughout the day, there may be times when the project personnel or Western request small and short-term variations in loading. These requests are made to, and approved by, the MRBWM office on a case-by-case basis.

7-08. Fish and Wildlife. Regulation of the System reservoirs for fishery purposes largely involves pool level manipulations, which will provide a suitable environment for the spawning and initial growth of game and forage fish. As it relates to the regulation of Gavins Point, while some species, such as the northern pike, require the inundation of terrestrial vegetation during the late March and April period for a suitable spawning habitat, meeting such a provision in the Gavins Point reservoir has been found to be impractical without serious consequences to the other purposes for which the project was designed. Maintenance of the full flood control capability of the Gavins Point reservoir during the spring and early summer months is considered essential; therefore, a continuing rise in pool elevations during this period cannot be permitted within the flood control range of elevations. Re-regulation of upstream releases and incremental inflows causes fluctuations in the reservoir level that are pronounced due to the relatively large change in level that accompanies moderate storage changes. Minimizing these changes would require fluctuating releases often in excess of downstream requirements. Consequently, no effort is made to manipulate Gavins Point pool levels to enhance spawning activities.

7-08.1. Another effect of the relatively small amount of storage space in the Gavins Point reservoir, when related to discharges from the project, is the rapid exchange rate (sometimes referred to as a flushing rate) of the water in the reservoir. The flushing rate for the Gavins Point

reservoir generally averages about one week. Fisheries interests claim that the rapid rate is detrimental to the fish population in the reservoir. However, the exchange rate is mostly dependent on runoff from the upstream drainage area and the physical dimensions of the reservoir. Neither can be changed by modified regulation procedures.

7-09. Threatened and Endangered Species. Releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate endangered interior least tern (least tern) and threatened piping plover nesting since 1986. Releases from Fort Peck were also modified for several years, but no longer are due to the nesting patterns below that project. As noted in Section 7-07.1 of this WCM, Gavins Point releases are generally held steady throughout the day. Daily hydropower peaking patterns are developed for Fort Randall and Garrison prior to T&E nest initiation in early to mid-May and are provided to Western; peaking may be restricted in both magnitude and duration at those two projects. Planned operations to address Endangered Species Act (ESA) requirements will normally be provided in the AOP. Refer to Appendix D of this WCM for further discussion of fish and wildlife and T&E species.

7-09.1. All reasonable measures to minimize the loss of nesting T&E bird species will be used. These measure include, but are not limited to, a relatively high initial steady release from Gavins Point during the peak of nest initiation, the use of the three Kansas River basin reservoirs (Perry, Tuttle Creek and Milford) for Missouri River navigation flow support, moving nests to higher ground, and monitoring nest fledge dates to determine if delaying an increase a few days might allow threatened chicks to fledge. The location of navigation tows and river conditions at intakes would also be monitored to determine if a Gavins Point release increase could be temporarily delayed without impact. Cycling releases every third day may be used to conserve water early in the nesting season if extremely dry conditions develop. In addition, cycling may be used during downstream flood control regulation.

7-10. Recreation. Water-based recreation at Gavins Point is dependent on the constructed access facilities. Boat ramps constructed around the perimeter of the reservoir have top elevation of about 1210.0 feet and bottom elevations near 1200.0 feet, as described in Section 4-08 and shown on Plate IV-10 of this WCM. Insofar as practicable, consistent with the water supply, other project purposes, and conditions in the other mainstem projects, the Gavins Point reservoir levels are scheduled to provide continued access to the reservoir area for recreational use. Recreational use of the project exceeds that of any other mainstem reservoir project in spite of the fact that the Gavins Point reservoir surface area is much less than any of the other projects. This higher level of use is due largely to its closer proximity to large population centers. As a means of enhancing recreation by increasing the area of the reservoir and also improving the shoreline conditions, the reservoir level is normally kept near elevation 1206.0 feet from the beginning of March through the end of the T&E nesting season in late August, and then raised to 1207.5 feet by the end of September. A pool elevation of 1207.5 feet is the target elevation during the remainder of the year.

7-11. Release Scheduling. As discussed in the Master Manual, scheduling of releases from Gavins Point and other System projects is normally based on continuing studies by the MRBWM office in which all authorized purposes, including flood control, are considered. These continuing studies are made at maximum intervals of one month and incorporate current conditions with the most recent estimates of future runoff, as expressed in terms of forecasted

inflow, to the individual System projects. Service to all authorized purposes receives consideration, including navigation requirements. The frequency of these studies is increased when previously unanticipated inflows occur that may have a substantial effect on System regulation. An example of these studies is included in the AOP, published each year as described in Section 6-12.3 of the Master Manual.

7-11.1. On a short-term basis there are often modifications to the general long-term scheduling of Gavins Point and Fort Randall releases, usually dictated by requirements of the downstream Gavins Point release requirements. In the winter season, long-term scheduling is usually followed much more closely than during the navigation season. Day-by-day variations in navigation release requirements must be reflected almost immediately by variations in the Fort Randall release level due to the lack of any substantial storage in the downstream Gavins Point reservoir. As discussed in the Master Manual, a short-range forecast is prepared in addition to the long-term monthly forecasts. The Three-Week forecast is developed using a short-range System regulation model of the same name. The forecast presents forecasted inflows, releases, reservoir elevations and hydropower generation for a 3- to 5-week period for each of the System projects. The forecast serves as a guide for short-term System modifications and is used to make regulation adjustments within the range normally determined by the long-term monthly studies.

7-11.2. Reservoir regulation/power production orders, furnished by the MRBWM office to operating personnel at Gavins Point and Western, are the basis for scheduling average daily releases from this project. Since exact daily power demands cannot be anticipated, power production/reservoir regulation orders usually allow a specified variation from the scheduled average daily release rate for the upper five System projects that allow for hydropower peaking. As described in Section 7-07.1 of this WCM, Gavins Point releases are generally held steady and hourly loading variations are rare.

7-12. Objectives of Flood Control Regulation. The flood control regulation objectives of Gavins Point are to 1) coordinate regulation of Gavins Point with the regulation of the other System projects to prevent runoff from the drainage basin above Gavins Point from contributing to damaging flows through the lower reaches of the Missouri River and 2) utilize available, but limited, storage space in the best possible manner to prevent or reduce flooding in the reach below Gavins Point. The first objective is primary flood control for the mainstem System as a whole. As a consequence, it is discussed in Section 7-04 of the Master Manual. The concerns of this WCM relate to the second objective, which is to amplify System regulation procedures as they apply particularly to Gavins Point and to discuss regulation pertaining to the reduction in flooding along the Missouri River immediately below Gavins Point.

7-13. Method of Flood Control Regulation. In general, the developed method of regulation of Gavins Point may be classified as Method C, as defined in EM 1110-2-3600. This represents a combination of the maximum beneficial use of the available storage space in the reservoir during each flood event, with regulation procedures based on the control of floods of approximate project design magnitude.

7-14. Storage Space Available for Flood Control Regulation. During any specific flood event all available space in the Gavins Point reservoir will be utilized to the maximum extent practicable for flood control purposes. The control of floods will be combined with regulation

for other beneficial water uses. As shown in Table IV-1, storage space allocated for flood control in the Gavins Point reservoir totals about 133,000 AF (elevation 1204.5 to 1210.0 feet), significantly less than the amount contained in any of the other mainstem reservoirs. Of this total space, about 54,000 AF (elevation 1208.0 to 1210.0 feet) is exclusive flood control storage space, to be utilized only during unusually large flood season inflows. The remainder is annual flood control and multiple-use storage space that will be kept available during the season of maximum flood potential for flood control purposes and, after this season, filled in the interest of other beneficial uses. Surcharge storage space has also been provided in the Gavins Point reservoir to ensure the safety of the Gavins Point project during extreme floods. Utilization of surcharge storage will usually provide some downstream flood reductions during these extreme flood events. Storage space provided in tributary reservoirs within the incremental drainage area discussed in this WCM has little effect on regulation of Gavins Point or other mainstem System projects.

7-15. Flow Regulation Devices. Releases from Gavins Point may be made through the powerplant and the spillway. Normally, discharge through the powerplant will be used to the fullest extent possible in order to achieve the maximum economic return from the project. As detailed in Section 7-07 of this WCM, the discharge capacity of the Gavins Point powerplant ranges from 33,000 to 35,000 cfs. When it is necessary to release at rates greater than the powerplant is capable of maintaining, the spillway, which is capable of passing almost 600,000 cfs (see Plate IV-3), will be used. Since the powerplant is essentially capable of releasing only normal navigation requirements, flood control releases or releases in excess of powerplant capacity, will require spillway operation.

7-16. General Plan of Flood Control Regulation. Flood control regulation of Gavins Point to meet the stated objectives is based on consideration of the following factors:

a. coordination of flood control regulation of Gavins Point with the regulation of the other mainstem reservoirs and upstream tributary reservoirs as described in Chapter VII of the Master Manual;
b. channel capacity through the reach of the Missouri River immediately downstream from Gavins Point;
c. observed and anticipated inflows to the Gavins Point reservoir;
d. space currently available within the Gavins Point reservoir for storage of future inflows;
e. anticipated inflows, releases and storage levels in the upstream Fort Randall reservoir; and
f. release requirements from upstream Fort Randall for purposes other than flood control.

7-16.1. The general plan of regulation applicable to most of the System reservoirs, including the Gavins Point reservoir, is to have the flood control storage space evacuated prior to the beginning of the March-July flood season. The Gavins Point reservoir levels are reduced to the appropriate level, elevation 1206.0 feet, in late February to reduce adverse effects on the hydropower generation purpose. Maintaining a pool level of about 1207.5 feet through the winter season has a beneficial effect on the power function as a result of increased head. If an exceptionally large amount of runoff is expected to originate from the Fort Randall to Gavins

Point incremental drainage area, the MRBWM office may schedule a drawdown below elevation 1206.0 feet. A drawdown below elevation 1206.0 feet must carefully consider any impacts on other authorized purposes in the reservoir, such as water supply and recreation.

7-16.2. Deliberate long-term storage in the Annual Flood Control and Multiple Use Zone to satisfy future multiple-use requirements, as is done in the larger upstream mainstem reservoirs, is not scheduled for Gavins Point. Rather, deliberate storage in Gavins Point is largely to improve recreational use, although the hydropower generation purposes also receives some benefit due to the increased head. Normally, a pool level of about 1206.0 feet is maintained during the March-July high inflow period. By the end of July the flood potential normally decreases to such an extent that additional water may be stored in the Annual Flood Control and Multiple Use Zone. An increase above the 1206.0 feet level is generally not made until after the least tern and piping plover nesting season, and the reservoir typically rises to elevation 1207.5 feet by the end of September. If there is a marked increase in the flood potential of the incremental drainage area during such time water is stored in the Annual Flood Control and Multiple Use Zone, evacuation of this zone to the extent deemed necessary will be accomplished by appropriate short-term adjustments in the Fort Randall release rate.

7-17. Local Flood Control Considerations. As described in Section 7-04.7.3 in the Master Manual, the early spring flood potential is defined by the amount of accumulation of plains snow and the soil conditions in the incremental areas above and between the System reservoirs. Because it is possible to manipulate the Gavins Point reservoir level in a relatively short period of time, the reservoir level at the start of the flood season will be somewhat dependent on this spring flood potential. When the spring flood potential between Fort Randall and Gavins Point is high, the Gavins Point reservoir level may be drawn down below the base of Annual Flood Control and Multiple Use Zone immediately prior to the start of the snowmelt period and then refilled from the snowmelt runoff. The limits of the drawdown will be dependent on the potential for flooding based on the forecasted runoff in the Fort Randall to Gavins Point drainage area. When the runoff potential between Fort Randall and Gavins Point is very low, as evidenced by the lack of a plains snow cover or by a lack of antecedent rainfall over the incremental drainage area, complete evacuation of the Gavins Point Annual Flood Control and Multiple Use Zone may not be necessary.

7-17.1. Continued surveillance of the runoff potential in this incremental area is required. If the runoff potential increases during the March through July flood season, appropriate measures will be taken to lower the level of the Gavins Point reservoir to near the base of the Annual Flood Control and Multiple Use Zone, which is 1204.5 feet; however, consideration of the state of T&E nesting must be made prior to lowering the reservoir. The potential effects on the recreational use of Gavins Point will be a consideration in the any decision made to reduce the elevation of the Gavins Point reservoir to capture additional runoff. In this area, there is continued pressure from recreation-specific interests to maintain the Gavins Point reservoir levels at the highest practicable level consistent with the flood runoff potential.

7-17.2. Keeping the Gavins Point reservoir level as high as practicable, along with a corresponding storage decrease in upstream reservoirs, increases System power production because the small size of the Gavins Point reservoir provides a greater amount of power per unit of storage than any of the other System projects. Because releases from Gavins Point are

normally greater than from other upstream System projects, the additional head is more effective for increased energy production than a corresponding head increase at another System project.

7-17.3. The Gavins Point reservoir level following the March through July flood season and the completion of the T&E nesting season will normally be maintained at 1207.5 feet to enhance both recreation and power generation. The base of the Exclusive Flood Control Zone is 1208.0 feet. Manipulation of the Gavins Point and Fort Randall reservoir levels has no effect in the overall availability of evacuated flood control storage space in the System prior to the early spring floods. This is because desired reservoir levels are realized by scheduling releases from upstream projects.

7-17.4. As stated in Section 7-04.8.4 of the Master Manual, flood control releases from Gavins Point will be made in such a manner as to satisfy the following general requirement: when allocated flood control storage in Fort Randall is available to capture existing or forecasted flood events, maximum Gavins Point releases will normally be limited to a rate that will not contribute to flows that exceed 120,000 cfs at Sioux City, IA. If insufficient storage is available in the Fort Randall reservoir for controlling the existing or forecasted runoff, Gavins Point releases will be increased as necessary to ensure project safety while at the same time providing significant downstream flood reductions.

7-18. Coordinated System Flood Control Regulation. The System, of which Gavins Point is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River below the System. Release scheduling from Gavins Point to accomplish this objective is based on studies performed by the MRBWM office. The long-range studies of current operations extend from the current date through the succeeding months up to the subsequent March 1, when the start of the runoff season generally occurs. All factors listed in Section 7-16 of this WCM are considered to the extent possible in these studies. Such studies are made at a maximum interval of one month as new estimates of future inflows are developed. If conditions change materially from those anticipated in previous monthly studies, additional within-month studies are made. Details of flood control regulation procedures applicable to the System are described in Section 7-04 of the Master Manual.

7-19. Exclusive Flood Control Regulation Techniques. Gavins Point will usually be regulated at an elevation of 1208.0 feet or less. Occasionally flood inflows will be of such magnitude that encroachment into the Exclusive Flood Control Zone above elevation 1208.0 feet will occur. Consequential action is to reduce Fort Randall releases to the extent necessary to lower the Gavins Point pool elevation below 1208.0 feet as soon as practicable. Fill of the Exclusive Flood Control Zone, and encroachment into the Surcharge Zone of the Gavins Point reservoir, should be avoided by reducing Fort Randall releases to the extent possible. If anticipated incremental inflows are of such magnitude that significant encroachment into the Surcharge Zone is expected despite reduction of Fort Randall releases, Gavins Point releases should be appropriately increased to keep the encroachment at an acceptable level without contributing to substantial downstream flood damages. If releases in excess of the powerplant capacity appear necessary, releases will be made through the spillway.

7-20. Surcharge Regulation Techniques. During exceptionally large flood inflows, all available flood control storage space may be utilized and the Gavins Point reservoir may rise into

the Surcharge Zone above elevation 1210.0 feet. The primary reason for providing surcharge space is to ensure the safety of the Gavins Point project. Real estate surrounding the reservoir (Lewis and Clark Lake) has, in general, not been acquired much above elevation 1210.0 feet. Therefore, significant surcharge encroachment should be allowed only when necessary to prevent extensive downstream damage or if unprecedented flood inflows were to occur. When unprecedented flood inflows occur and reservoir levels exceed elevation 1210.0 feet, the regulation procedures given with the emergency instructions in Exhibit A should be used as a guide for release scheduling. Portions of these regulation curves relate reservoir level and inflow to suggested release, with the suggested release based on typical recession curves, by the method outlined in EM 1110-2-3600. Use of these curves should prevent significant surcharge space encroachment except during the most extreme floods. If the reservoir should rise into the Surcharge Zone, release of inflows up to the full spillway capacity should be scheduled to prevent any further significant elevation increase.

7-21. Responsibility for Application of Flood Control Regulation Techniques. As described in Section 7-04.23 of the Master Manual, the MRBWM office is responsible for and directs all regulation, including flood control regulation, of Gavins Point and the other System projects. Instructions to ensure continuation of Gavins Point regulation during periods of communication failure between the project and the MRBWM office are detailed in succeeding sections and in Exhibit B of this WCM.

7-22. Emergency Regulation. Reliable and rapid communication is usually available between the MRBWM office and Gavins Point personnel. When communications are interrupted for any extended period of time, project personnel will be required to continue regulation, as discussed in Section 5-07 of this WCM. Exhibit B of this WCM outlines the emergency procedures to be followed. In general, these procedures are such that they will continue service to multiple-use functions through the period of communications failure at the approximate level prevailing prior to the communications outage if Gavins Point inflows continue in the range of those previously anticipated. The emergency procedures also allow for increased inflows, up to those occurring during maximum possible floods, as developed for spillway design purposes.

7-22.1. Emergency regulation curves, shown on Plate VII-1, were developed by the method described in EM 1110-2-3600. A recession constant, or T_s value, of 1.5 days was selected in curve development with this value based on experienced incremental inflow hydrographs as well as the Gavins Point reservoir inflow hydrographs of maximum possible floods developed during spillway design studies. This value is somewhat less than most of the T_s values for incremental inflow hydrographs shown on Plate III-16; however, use of a near minimum T_s value is encouraged by EM 1110-2-3600 and provides more assurance that available storage space will be filled prior to making releases at full spillway capacity. Routings indicated that such accumulation had no significant effect on maximum reservoir levels or releases during the SDF, and additionally, provided better control over the smaller floods much more likely to occur.

7-22.2. Gavins Point releases under emergency conditions are related to inflows, subject to the following:

a. the minimum release will be that specified on the most recent available regulation order, which assures continuation of service to navigation, power and downstream water supply requirements;
b. releases in excess of 100,000 cfs, the approximate Missouri River channel capacity below the System, will not be scheduled until the level of the Gavins Point reservoir exceeds, or is forecast to exceed, the base of the Exclusive Flood Control Zone, elevation 1208.0 feet;
c. with a falling Gavins Point reservoir level between elevations 1208.0 and 1213.0 feet, releases will be limited to a maximum of 100,000 cfs; and
d. full spillway capacity will be utilized to maintain the Gavins Point reservoir level at or below elevation 1213.0 feet or to lower it to this elevation. A transitional zone between elevations 1212.0 and 1213.0 feet is provided for adjusting releases between the 100,000 cfs rates and full spillway capacity.

7-23. Spillway Design Flood. The flood developed for the purpose of designing the Gavins Point spillway is of the late spring type and combines runoff resulting from design mountain snowmelt and rainfall in the Missouri River drainage area above Fort Randall with runoff from a maximum possible rainstorm centered between Fort Randall and Gavins Point. Releases from Fort Randall entering the Gavins Point reservoir have a long flat peak in the 200,000 cfs range prior to the incremental area rainstorm. As a result of the rainstorm the total inflows to Gavins Point peak sharply at 647,000 cfs. In the spillway design studies the Gavins Point pool was maintained at elevation 1210.0 feet until inflows exceeded the spillway capacity of about 350,000 cfs at elevation 1210.0 feet. Subsequent free outflow over the spillway resulted in a peak reservoir level at elevation 1221.4 feet and a maximum discharge over the spillway of 584,000 cfs. The powerplant was assumed to be inoperable at the time inflows exceeded the spillway capacity. More information can be found in the Omaha District report *Review of Design Features of Existing Dams*, dated March 1967.

7-23.1. Routing of the SDF by the developed emergency procedures entailed maintaining the Gavins Point reservoir at elevation 1212.0 feet by gradually opening the gates to release inflows until inflows exceed the spillway capacity of about 380,000 cfs at elevation 1212.0 feet. The powerplant was assumed to be inoperable and the spillway gates were fully opened as the reservoir level rose above elevation 1212.0 feet. The resulting peak reservoir level was slightly above elevation 1221.4 feet, and a peak outflow of 585,000 cfs was computed. This was essentially identical to the outflow hydrograph and peak reservoir level of the design studies. Since the emergency regulation outflow hydrograph and peak reservoir elevation are so similar to the design conditions, hydrographs have not been included in this WCM.

7-24. Reservoir Design Flood. The flood used for developing the flood control storage allocations in the Gavins Point reservoir was of the rainfall type of an approximate 100-year frequency. Runoff from the rainstorm centered between the Fort Randall and Gavins Point dams was combined with assumed releases from Fort Randall to provide the total Gavins Point inflow. Routing procedures in design studies consisted of releasing inflow up to 50,000 cfs, then maintaining a 50,000 cfs release rate through the peak inflows and extending until flood control storage space had been completely evacuated. Design regulation assumed an initial Gavins Point pool at elevation 1204.5 feet, the base of the Annual Flood Control and Multiple Use Zone. With this regulation, the reservoir peaked at elevation 1210.0 feet, the selected top of the

Exclusive Flood Control Zone. The peak inflow of about 145,000 cfs was reduced to the maximum release rate of 50,000 cfs.

7-24.1. Hydrographs pertaining to routing of the reservoir design flood (RDF) by the developed emergency procedures are shown on Plate VII-2. In the RDF routing it was assumed that the initial reservoir level would be 1205.5 feet, a level that is considered more likely to occur than elevation 1204.5 feet, the base of the Annual Flood Control and Multiple Use Zone. The 30,000 cfs release rate assumed prior to the flood was continued until the combination of inflows and reservoir levels were such that an increase in release rate was indicated by the emergency regulation curves (see Plate VII-1). Continuing use of these curves resulted in a peak release of 75,000 cfs about 8 to 14 hours after the peak inflow occurred, after which outflows were reduced to 65,000 cfs. The reservoir level peaked at elevation 1210.2 feet about 30 hours after the peak inflow occurred. Since the release rate at the time of the reservoir peak was 65,000 cfs, this release rate was maintained until the Exclusive Flood Control Zone was entirely evacuated, after which the release rate of 30,000 cfs prevailing prior to the flood was resumed.

7-24.2. Although the emergency procedures resulted in higher peak releases and reservoir levels than the design studies, it is not believed that the assumptions made in the design studies are entirely realistic for actual regulation of Gavins Point. The emergency peak release of 75,000 cfs is within the downstream channel capacity prior to significant damage while the peak elevation does not significantly encroach into the Surcharge Zone. If emergency loss-of-communication conditions were not occurring and flooding was present downstream of Gavins Point, it is quite possible that inflows of the magnitude assumed for the RDF would result in use of a greater amount of induced surcharge space than shown on Plate VII-2. If releases had been limited to 50,000 cfs following peak inflows, as assumed in the design studies, the reservoir level would have peaked at elevation 1211.4 feet. As evidenced by the SDF routing, where an elevation 1212.0 feet was maintained prior to the peak inflows (see Section 7-23.1), such an operation would not compromise the integrity of Gavins Point.

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VIII - Water Management Organization

8-01. Responsibilities and Organization. This chapter describes the personnel and coordination necessary to regulate Gavins Point. Gavins Point is regulated as part of the System, which is comprised of six projects on the Missouri River main stem. The Corps has the long- and short-term direct responsibility for regulating Gavins Point as a hydraulically and electrically integrated project. This has been the case since July 1955, when Gavins Point was closed to begin storing water.

8-01.1. NWD's MRBWM Division of the Programs Directorate, located in Omaha, NE, is comprised of a 12-person staff of engineers, biologists, information management specialists and support staff. The MRBWM office is comprised of two teams: Reservoir Regulation and Power Production. The Corps' Guidance Memorandum titled, *Reservoir Control Center*, dated March 1972, serves as the document that details the role and responsibilities of the MRBWM office in managing and regulating the System. The RCC, now known as MRBWM, was founded in 1954 and was the first RCC established in the Corps. The organization chart for the MRBWM office is provided on Plate VIII-1.

8-01.1.1. The Corps started construction of Gavins Point in 1952. Gavins Point is one of the six System projects that were constructed during the period from 1933 to 1966. The Corps is the sole owner and regulator of the six dams that comprise the System. The Chief of Engineers for the Corps has delegated the regulation of this System to the NWD Commander, who has in turn delegated the day-to-day regulation of the System to the MRBWM office. The MRBWM office has the direct responsibility of regulating the System and issuing daily reservoir regulation/ power production orders to accomplish this mission. The O&M of the System dams and associated structures are the responsibility of the Omaha District of NWD. The Omaha District has staff physically located at the System projects to make the regulation changes stated on the reservoir regulation/power production orders developed and sent by the MRBWM office. The System is the largest reservoir system in the United States based on storage capacity. The MRBWM office prepares long- and short-term runoff and streamflow forecasts that are integrated into model simulations to effectively regulate the System, as described in Chapter VI of this WCM. Refer to Exhibit B of this WCM for instructions to the Gavins Point operations manager in case of loss of communication for an extended period of time during a significant or catastrophic event. The MRBWM staff maintains communication with Corps staff at the System projects via cell phones and computers that are available from work, their homes, and while they are on travel status. Maintaining these communication devices ensures that staff can be reached at any hour of any day of the year. Also, there is at least one staff person that physically reports to the MRBWM office, for at least part of each day. Detailed calling lists are provided to the System projects and Omaha District Emergency Operations staff in case there is a need to contact MRBWM staff during off-duty hours.

8-01.1.2. The two teams within the MRBWM office have the responsibility for regulating the System. The Reservoir Regulation Team in MRBWM has the responsibility of running the daily Missouri River streamflow forecast to determine releases (often called the System release) from the lowermost System dam (Gavins Point). This team forecasts runoff volumes for long-range monthly model simulations, and for some short-range simulations. The Reservoir Regulation Team reviews the deviation requests from the Omaha and Kansas City Districts for Corps tributary reservoirs and USBR tributary reservoirs that have Corps-regulated flood control zones. The Reservoir Regulation Team also coordinates tributary reservoir releases during significant basin-wide flood regulation to provide System flood control for the Missouri River basin. The Power Production Team has the responsibility of intrasystem regulation and forecasts runoff volumes for short-range model simulations. This team has the responsibility of T&E species coordination relating to System regulation. Intrasystem regulation oversight by this team is conducted to respond to widely varying Missouri River basin runoff to meet the operational objectives stated in the Master Manual. It also performs all hydropower-related activities.

8-01.1.3. A third team, the Missouri River Master Manual Team, was formed in 1989 to oversee the studies and documentation required for the review and update of the 2004/2006 Master Manual. This team also provided program management and oversight of the non-flow related actions for the Missouri River and tributaries necessary to comply with the ESA. This team also had the responsibility to ensure that the overall adaptive management process for both the flow and non-flow ESA-related actions was established and proceeded in an effective and efficient manner. A reorganization of the MRBWM office dissolved this team in 2008 with functions transferred to the Power Production Team, the Omaha District and the Programs Directorate at NWD.

8-01.1.4. Adaptive Management. The Corps has implemented some System regulation changes via an adaptive management process for many years. The Corps, in implementing the current water control plan described in the Master Manual, will continue the use of the adaptive management process. The Corps recognizes that changes in the operation of the System may impact many river uses and is committed to ensuring that the public is actively involved and well informed of potential changes in System regulation and has the opportunity to comment on those proposed changes prior to any decision on implementation. The adaptive management process will be used to implement changes designed to improve the benefits provided by the System, including benefits to the T&E species. Decisions regarding actions proposed through the adaptive management process will meet the Corps' treaty and trust responsibilities to the Tribes and conform to all of the applicable requirements of federal laws including the National Environmental Policy Act (NEPA), ESA and the Flood Control Act of 1944. Additional details regarding adaptive management are presented in Section 7-10 of the Master Manual.

8-02. System Coordination. The MRBWM office strives to keep those interested in the short- and long-term regulation of the System informed as to the amount of water stored in the System, the outlook for future runoff, and the short- and long-term plans for System water management. As the largest storage reservoir system in the United States with the potential for a wide array of positive and negative impacts, the regulation of this System generates a high level of interest within and outside of the basin. The AOP process, developed by the MRBWM office, provides an important tool for the Corps to interact with, inform and coordinate with the public on a semi-annual basis. Other interests have a need to keep informed of changes and project status of the

System on an almost continual basis. Successful regulation of the System to meet the regulation objectives stated in the Master Manual is dependent on a group of well-informed stakeholders and partners providing dialog on the effects of actual and proposed System regulation. The following sections detail how this coordination is accomplished.

8-02.1. News Releases. The MRBWM office provides monthly and other special news releases concerning the regulation of the System. The NWD Public Affairs Office is responsible for issuing the official MRBWM news releases.

8-02.2. MRBWM Website. The MRBWM office maintains a public website at the following address: www.nwd-mr.usace.army.mil/rcc. This site contains information concerning System regulation. It includes forecasted reservoir levels and dam releases as well as historic data in both tabular and graphic formats. The website contains user-friendly, clickable maps to observe graphical streamflow and System project data. While the NWS has the responsibility for issuing streamflow forecasts, the MRBWM office performs streamflow forecasting at select locations needed to regulate the System. These results are provided for information only. The NWS forecasts are available as a link from the MRBWM website. The website contains both normal monthly new releases and special news releases concerning other significant items that occur on an unscheduled basis. In addition, the Corps produces numerous reports on a daily basis that provide updates of the System's status and regulation changes.

8-02.3. AOP Public Meetings. The Corps follows a public process as part of the AOP preparation and implementation process for regulating the System. This process involves the development and publishing of a draft AOP in the fall of each year. The draft AOP simulates the regulation of the System for five runoff scenarios for the remainder of the current year, plus the following calendar year. The draft AOP is generally provided to all interested stakeholders in late September via hardcopy or the MRBWM website. Public meetings are held at three to six sites within the basin, normally in October, to accept verbal comments from the public and provide a forum for discussion on the draft AOP. Written comments on the draft AOP are also accepted generally through mid-November. After considering the comments from the public meetings and any written comments provided during the comment period, appropriate changes are made to the draft AOP to produce a final AOP, which is normally made available in December. In the spring, the Corps again conducts public meetings to provide information on the current hydrologic conditions in the basin and the expected effects of System regulation for the remainder of the year given the most-likely forecast and other possible runoff scenarios. Once again, comments are obtained for fine-tuning the System regulation for the spring and summer. Actual real-time regulation of the System is accomplished using the best information and tools available and is adjusted to respond to changing conditions on the ground. The process begins again in August for the next AOP. It should be stated that not all circumstances are covered in the AOP. Actual real-time regulation plans may indicate runoff volumes, reservoir levels and releases outside those described in the AOP. Flexibility in these situations allows the Corps to regulate the System for maximum benefit in an area of the continent where extreme climatic conditions can and frequently do occur.

8-02.4. National Weather Service Coordination. The NWS is the official federal agency responsible for issuing streamflow forecasts to the public. The Corps considers these forecasts in its regulation of the System. The NWS office interface for the MRBWM office is the NWS

MBRFC, located in Pleasant Hill, MO. The MBRFC has the forecasting responsibility for the entire Missouri River basin. The Corps and NWS share real-time data, USGS measurements and flood information, and forecasts for streamflow and runoff. The MRBWM office provides the MBRFC with System regulation data on a daily basis. The MBRFC integrates the Corps' forecasted System project releases with its short- and long-range streamflow forecasts for the Missouri River. The normal method of data and file exchange is through email and other file exchange methods or by direct telephone contact, when required. The Corps receives MBRFC forecasts and QPE rainfall radar imagery, as described in Section 5-03 of this WCM for integration into the MRBWM real-time forecasting models. During years of significant plains snowpack, additional coordination between the Corps and MBRFC is necessary to ensure proper data exchange between the two agencies for the forecasting of plains snowmelt. In addition, whenever the Corps conducts special reconnaissance surveys of ice conditions on the Missouri River, the obtained information is readily shared with the MBRFC.

8-02.5. U.S. Geological Survey Coordination. The USGS is the primary source of data and hydrologic support to the Corps. The USGS obtains streamflow measurement data that it supplies to the MRBWM office in a real-time mode. This prompt delivery of data allows the MRBWM office to meet its mission of managing the basin's water resources. This effort is conducted through a cooperative streamgaging program (Co-op), as described in Section 5-07.2 of the Master Manual. This Co-op program covers the 1) maintenance of DCP stations, 2) measurement of streamflow at select locations, and 3) sediment and water quality sampling at select locations. The MRBWM office has review responsibility for this program but has delegated the implementation of the program to the Corps' Omaha and Kansas City District Water Management staffs. The Districts negotiate separate programs with each state and manage these programs throughout the year.

8-02.6. Western Area Power Administration Coordination. Reservoir regulation/power production orders, reflecting the daily and hourly hydropower limits imposed on project regulation, are generated by the MRBWM office, and are sent to the mainstem projects on a daily basis. This information is also shared with Western via a daily phone call. Long-term (monthly) and short-term (weekly) regulation forecasts of energy generation and capability are coordinated with Western. These forecasts serve an important role in determining when surplus energy is available during high-water years, otherwise referred to as surplus sales, and when firm energy commitments cannot be met during low-water years, otherwise referred to as energy purchases. These "short-term" forecasts are also used to reflect unanticipated adjustments in project releases, such as flood control regulation that can dramatically alter energy generation schedules. Scheduled and forced outages of the generating units are closely coordinated with Western. Coordination with Western is required during the planning and execution of major rehabilitation of the System powerplants.

8-02.7. U. S. Fish and Wildlife Service Coordination. The USFWS is the primary federal agency in charge of administering the ESA as it relates to protected species in the Missouri River basin. The MRBWM and the USFWS coordinate extensively on regulation of the System during the T&E nesting season and on other issues relating to the implementation of the USFWS's 2018 Final Biological Opinion on the *Operation of the Missouri River Mainstem Reservoir System, the Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, the Operation of the Kansas River Reservoir System, and the Implementation of the Missouri*

River Recovery Management Plan, dated April 13, 2018. Additional interagency coordination will continue and expand as the adaptive management process evolves.

8-03. Interagency Agreements. No permanent interagency agreements are in effect with regard to the regulation of the System. A considerable amount of coordination has been conducted between the MRBWM office and the federal agencies that have missions that are affected by the System. In 2003, the MRBWM office participated in a Memorandum of Understanding with the Southwestern Power Administration (Southwestern) with regard to hydropower generation on the Corps' tributary projects in the Kansas City District.

8-03.1. Replacement Storage. The MRBWM office has an existing agreement with the Great Plains Region of the USBR for the use of replacement System flood control storage. The agreement concerns the USBR Clark Canyon, Canyon Ferry and Tiber projects. These three USBR tributary projects contain authorized Flood Control Storage Zones that are regulated by the Omaha District when water is stored in this zone. The flood control storage space provided in the System was developed on the basis that no upstream storage space existed although it was recognized that, as upstream space became operational, a re-evaluation of the mainstem System space requirements would be necessary. Continuing analysis of inflows into the mainstem System and into tributary reservoirs constructed upstream from the System has indicated that in certain instances, particularly when inflows are distinctly seasonal in nature, storage space provided in upstream reservoirs could effectively replace a portion of the annual flood control and multiple-use space initially provided in the mainstem System. Effective operations require a coordinated regulation of the upstream tributary storage space with the space in the mainstem System, which results in the most efficient overall utilization of the basin water resources. Such space provided in upstream reservoirs has been designated as "replacement System flood control storage space." Replacement storage does not impact the regulation of Gavins Point.

8-04. Commissions, River Authorities, Compacts and Committees. Refer to Section 8-04 of the Master Manual for a detailed history of the various commissions, river authorities, compacts and committees in the Missouri River basin. The Missouri River Recovery Implementation Committee (MRRIC), the Missouri River Basin Interagency Roundtable (MRBIR), and the Missouri River Natural Resources Committee (MRNRC) are three such groups discussed in the following sections.

8-04.1. Missouri River Recovery Implementation Committee. This group is a 70-member committee made up of federal, state, Tribal and stakeholder representatives from throughout the Missouri River basin. MRRIC serves as a collaborative forum developing a shared vision and comprehensive plan for the restoration of the Missouri River ecosystem. The committee provides guidance and recommendations to the Corps and USFWS on the current Missouri River Recovery Program for the river's T&E species and on the Missouri River Ecosystem Restoration Plan (currently not funded). MRRIC was established by Section 5018 of the Water Resources Development Act of 2007 under the authority of the Secretary of the Army.

8-04.2. Missouri River Basin Interagency Roundtable. This group was re-activated in 2001 to promote interagency cooperation among the federal agencies within the Missouri River basin. The mission is to foster effective communication and coordination among federal agencies, and, when possible and where appropriate, to communicate to other basin interests with a single

federal voice. The cooperating agencies include, but are not limited to the Corps, National Park Service, USGS, USFWS, USBR, BIA, Environmental Protection Agency, Western, U.S. Forest Service and the USDA's Natural Resources Conservation Service. Members are composed of executives of federal agencies with activities in the basin.

8-04.3. Missouri River Natural Resources Committee. The MRNRC is a non-profit corporation formed in 1988 by the Missouri River basin states to promote and facilitate the preservation, conservation and enhancement of the natural resources of the Missouri River. Its official members are the fish and wildlife conservation agencies of the states of Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas and Missouri. The MRNRC's ex-officio members are the Corps, the USFWS and Western.

8-05. Non-Federal Hydropower. All hydropower facilities located either at or in association with the System are federally owned and operated. This includes all hydropower facilities at Gavins Point. No non-federal hydropower facilities are currently located either at the System projects or on System project lands.

8-06. Reports. The MRBWM office prepares several reports to serve as summaries of activities and to communicate to others the current status and proposed regulation of the System. Most reports are available on the MRBWM website: www.nwd-mr.usace.army.mil/rcc. This website is used for public dissemination of water resource information related to regulation of the System. In addition to the reports shown in Table VIII-1, the MRBWM office prepares technical reports and flood reports on an as-required basis to provide information and additional guidance in regulation of the System.

Table VIII-1
Missouri River Basin Water Management Reports

Frequency	Type of Report	Reporting Requirement[1]
Hourly	15-day plots of hourly data of stream and reservoirs with DCP transmissions in basin.	
Daily	Daily Bulletin	
	Weekly Bulletin	
	Monthly Bulletin	
	Yearly Bulletin	
	Reservoir Summary Bulletins	
	Flood Report (as needed)	
	Power Production Orders	
	Missouri River Streamflow Forecast – 14 days	
	Ice Report (Seasonal Dec-Apr)	
	Mainstem Release and Energy Schedule	
Weekly	Reach Runoff Report	
	Three-Week Model Simulation	
	Weekly Mountain Snowpack Report	
Monthly	Basin Calendar – Year Runoff	
	Monthly Mountain Snow Report (Seasonal)	
	Runoff Outlook	ER Requirement
	Long-Range Monthly Model Simulation	
	Project Monthly Summary (MRD 0168)	ER Requirement
	Monthly News Release	
	Monthly Project and System Energy Summary	
Yearly	Draft Annual Operating Plan (AOP)	
	Final Annual Operating Plan (AOP)	
	Annual Summary of Actual Operations	
	Division Annual Report	ER Requirement, includes District Reservoirs
	Flood Damages Prevented Report	ER Requirement – MRBWM office provides holdouts[2] and districts provide estimated damages prevented
	Stage Trends Report	
	Annual Sediment Report	
	Annual Water Quality Report	ER Requirement
	Cooperative Stream Gage Program (Co-op)	ER Requirement

[1] Report required per Corps Engineering Regulation (ER).
[2] Unregulated flows.

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Appendix A - Historic Droughts and Floods with Regulation Examples

A-01. Floods. Regulation provided by Gavins Point, along with the other upstream System projects and augmented by upstream tributary reservoir projects, has greatly reduced flooding along the portion of the Missouri River in the vicinity of Gavins Point. Many instances of above-bankfull flows were experienced on the Missouri River prior to the construction of the System. All floods recorded in this portion of the Missouri River prior to System regulation occurred in the March-July flood season. The Master Manual contains relatively detailed descriptions of several of the experienced Missouri River floods, including data that is pertinent to the incremental reach described in this WCM. Since there is little additional data beyond that given in the Master Manual for several of these floods, they will not be discussed further in this WCM.

A-02. Flood of 1952. The largest monthly runoff of record in the Fort Randall to Gavins Point incremental drainage area of 652,000 AF occurred in March 1952 as a result of melting of an extremely large snow accumulation (see Plate III-15). This was a portion of the large basin-wide flood discussed in Appendix A of the Master Manual. Very few streamgaging stations in the Niobrara River basin were in place during 1952 so determination of tributary runoff is very difficult to ascertain. The System was not in operation in 1952 and Gavins Point Dam was not closed until 1955. However, as discussed in the Master Manual, studies conducted by the MRBWM office indicate that the System would have controlled inflow to prevent downstream damages with a reserve of vacant exclusive flood control space remaining throughout the flood. The total annual runoff in the Fort Randall to Gavins Point drainage area was 2.0 MAF, which is slightly higher than the long-term average of 1.7 MAF.

A-03. Flood of 1960. Very large amounts of snow accumulated over the Fort Randall to Gavins Point incremental drainage area during the 1959-1960 winter period, prior to initial fill of the System. Per the Weather Bureau (now the NWS) report (Technical Paper No. 45) *Snowmelt Flood of March-April 1960, Missouri and Upper Mississippi Basins*, "…snow surveys during March by the Corps, Weather Bureau, and Weather Bureau cooperative observers indicated the accumulation of snow ranged from a few inches at the Colorado line to 3-foot depths over a broad band extending across northern Kansas, eastern Nebraska, southeastern South Dakota, all of Iowa and northern Missouri. Water equivalent of the snow measured from 1 to 2 inches in western Kansas … rapidly increased to 4 inches or more of equivalent water for the snowpack in eastern Nebraska … a warming trend began March 19 … spread slowly northward and eastward to embrace the whole basin by March 25." As shown on Plate A-7, the maximum unregulated flow at the Gavins Point damsite, which represents the Missouri River flow if no upstream mainstem or tributary projects were in operation, was nearly 210,000 cfs on April 7. The daily maximum incremental runoff of 46,300 cfs between Fort Randall and Gavins Point occurred on March 28. Much of the incremental runoff was contributed by the Niobrara River subbasin. The average daily and instantaneous peak flows at the Niobrara River at Verdel, NE streamgaging site were 25,100 and 39,000 cfs, respectively.

A-04. Flood of 1962. During the 1961-1962 winter season, snow progressively accumulated over the plains area of southeastern South Dakota and northern Nebraska to such an extent that substantial runoff amounts were anticipated from the melting of this snow. This was also at a time that initial fill of the System's conservation storage was taking place, and as a consequence,

major emphasis was being place on retaining as much water as possible within the System. As seen in Plate A-8, unregulated flows at Gavins Point exceeded 80,000 cfs for nearly 2 months, from May 29 through July 20. However, much of the runoff was captured and stored in the upper three reservoirs. During this 7-week period, Fort Peck, Garrison and Oahe pools increased nearly 8, 15 and 14 feet, respectively.

A-05. Flood of 1967. Total Missouri River basin runoff above Gavins Point during the June-July period of 1967 was 14.6 MAF, among the largest of record for this 2-month period. This runoff volume was nearly two times the long-term 2-month average of 8.2 MAF. Combined with this runoff above Gavins Point were severe flood flows originating in the lower Missouri River below Gavins Point. As seen in Plate A-9, unregulated flows at the Gavins Point damsite exceeded 60,000 cfs for most of June and July. Just like in 1962, much of the runoff was captured and stored in the upper three reservoirs. During this 2-month period, Fort Peck, Garrison and Oahe pools increased nearly 9, 12 and 6 feet, respectively.

A-06. Flood of 1975. Runoff originating above Gavins Point during the April-July period in 1975 was 24.7 MAF, the third highest since runoff records began in 1898, exceeded only in 1997 (24.7 MAF) and 2011 (35.7 MAF). The 1975 4-month runoff exceeded the previous April-July maximum, which was 22.4 MAF in 1927. While the July 11 daily peak unregulated flow of 176,000 cfs at Gavins Point was not as high as previous floods (peak in 1967 was 210,000 cfs), the then-record runoff occurred over four months with large unregulated flows extending from late April through July, as illustrated on Plate A-10. Most of the well-above-normal precipitation contributing to the record high runoff occurred from early April through July.

A-07. Flood of 1978. Drought conditions persisted over the entire Missouri River basin during the early part of 1977 but gave way to above-normal rainfall during the fall. Above-normal precipitation continued over much of the basin during the last few months of the 1977 calendar year and, at the end of the year, snow accumulations in the mountainous areas of the basin were 50 percent above normal. By March 1, the mountain SWE averaged 130 percent of average, while an unprecedented snow cover blanketed most of the plains areas of the basin. Much of the upper Missouri River basin had at least 3 inches of SWE by late February and some areas had as much as 6 inches. April precipitation was 150 to 200 percent of normal over much of the basin. In May, the Yellowstone River basin received 3 to 6 times normal precipitation. The result of the high mountain snowpack, unprecedented plains snowpack and above-normal spring rainfall resulted in a then-record annual runoff of 40.6 MAF above Sioux City, IA.

A-08. Flood of 1997. Flood season (March-July) runoff from the drainage area controlled by the System (above Gavins Point) during 1997 was 31.2 MAF. This 5-month runoff volume above Gavins Point is exceeded only by the record 2011 5-month total of 40.9 MAF. The annual runoff in the upper Basin (above Sioux City, IA) was 49.0 MAF, which was almost double the average annual runoff volume above Sioux City, and until 2011, was the highest annual runoff on record. The high runoff was the result of an unprecedented heavy plains snowpack concurrent with a near-record mountain snowpack. The melt sequence was more rapid than normal due to much-above-normal temperatures during the melt period. Temperatures reached as high as 80°F, which significantly increased the total volume of runoff. Mountain snowpack for both January and February above Fort Peck (181 percent and 155 percent of average, respectively) and Garrison (169 percent and 159 percent of average, respectively) was notable.

In addition, plains snowpack ranged from 6 inches in eastern Montana to as much as 36 inches in the eastern portions of North Dakota and South Dakota. The 1997 runoff volume above Sioux City during March and April of 7.2 MAF and 8.6 MAF, respectively, nearly mirrored the previous maximum of 15.0 MAF that occurred in 1952 before the System was constructed. Runoff in 1997 was primarily the result of mountain and plains snowmelt. Fortunately, heavy spring and summer rains did not materialize across the lower basin during the month of May. Dry conditions also continued to deepen in North Dakota and eastern Montana with less than half the normal May precipitation. During the summer, dryness continued to dominate in eastern Montana and western North Dakota and the lower basin experienced normal to slightly-below-normal June rainfall. During July, the lack of intense thunderstorms in the lower basin eased the adverse impacts of evacuating the flood waters stored in the System reservoirs.

A-09. Flood of 2010. Total runoff during 2010 was 38.7 MAF, the fourth highest on record. Plains snowfall accumulation began in the fall of 2009, and continued to accumulate through the winter as above-average snowfall and colder-than-normal temperatures persisted into March. By the beginning of the plains snowmelt, many areas in the basin had accumulated 4 to 6 inches of SWE from western North Dakota through much of South Dakota to northwestern Iowa, and 3 to 4 inches in surrounding regions of Montana, Nebraska and southwestern Iowa. In general, the precipitation during the 2010 calendar year was above average in the Missouri River basin. Areas of the basin received well-above-normal precipitation throughout 2010; however, much greater-than-normal precipitation occurred in April through August. As shown on Plate III-15, June runoff in the reach from Fort Randall to Gavins Point was a record high. Runoff from above-normal rainfall between Fort Randall and Gavins Point resulted in the Gavins Point pool elevation reaching a maximum of 1209.7 feet on June 15, just 0.3 foot from the top of the Exclusive Flood Control Zone, since the System closed in 1967. The project's maximum reservoir elevation of 1210.7 feet occurred in June 1960. Annual maximum Gavins Point releases reached 49,100 cfs in late October.

A-10. Flood of 2011. The 2011 runoff year was the highest runoff year of record (1898-2014) in the upper Missouri River basin since record-keeping began, resulting in a total annual runoff of 61.0 MAF, almost 2.5 times average. It also marked the fourth consecutive year of above-average runoff in the upper Missouri River basin, immediately following the 2000-2007 drought. May (9.2 MAF), June (14.8 MAF) and July (10.2 MAF) recorded the highest inflows for their respective months in the 117-year period of record (1898-2014). The 34.3 MAF of runoff received during that 3-month period exceeded the total annual runoff in 102 of the previous 113 years. The winter of 2010-2011 marked the third consecutive year of significant plains snowpack, and mountain snowpack was much above average. During May, heavy rains fell across eastern Montana, western South Dakota and northern Wyoming. In some isolated areas, 10 to 15 inches of rain fell over a 3-day period. Because this runoff came in the form of rainfall runoff rather than snowmelt runoff, the volume of runoff over this very large area quickly made its way to the Fort Peck and Garrison reservoirs and dictated a need to increase releases from all six System projects. System storage peaked at 72.8 MAF on July 1, occupying 98 percent of the allocated flood control storage space (16.0 MAF of 16.3 MAF).

A-11. Droughts. As outlined in Section 7-15 of the Master Manual, regulation of the System during drought was a significant consideration in the update of the 2004/2006 Master Manual. The System is the largest reservoir system in the United States and was designed to serve all

authorized purposes during an extended drought like the 1930s. As outlined in Section 7-03.2.1.1 of the Master Manual, the System water-in-storage checks, which occur on March 15, July 1 and September 1 of each year, allow the System to function to meet authorized purposes during significant multi-year drought periods. Refer to Tables VII-2, VII-3 and VII-5 in the Master Manual for the relation of System storage to service level, navigation season length and winter releases, respectively. With the original design consideration of the System and with the implementation of the aforementioned water-in-storage checks, no separate drought contingency plan is needed or required for the System. See Section A-07 (Appendix A) of the Master Manual for additional information regarding Missouri River basin droughts and regulation of the System projects during droughts.

A-12. Historical Regulation and Effects. The historical effects of regulation provided by Gavins Point, combined with effects of regulation of upstream reservoir projects, at the Gavins Point damsite are illustrated on Plates A-1 through A-6. Average daily unregulated flows shown on these plates are the computed estimates of flow at the damsite if none of the upstream projects, including Gavins Point, had been in operation. Regulation of the mainstem and tributary projects has resulted in substantial reductions to all annual peak flows that would have been experienced at the Gavins Point damsite. Conversely, water stored in the conservation pools in the three upper mainstem reservoirs allowed for Gavins Point releases to be made and maintain adequate downstream Missouri River flows to support the authorized purposes of navigation, irrigation, recreation, water supply, hydropower generation, water quality control and fish and wildlife during drought periods. Sections A-13 through A-27 discuss Gavins Point regulation during significant flooding and drought periods.

A-13. 1960 Regulation. Regulation practices during this period was for the intended purpose of filling the conservation storage in the reservoir system. Since Gavins Point was closed in 1955, the project's regulation criteria had not evolved to those presently in use. In 1960 Gavins Point reservoir levels up to elevation 1208.0 feet were permissible until the rainfall runoff season began in May. Consequently, the regulation provided by the reservoir was not entirely indicative of that provided by current criteria. However, it does illustrate the control that can be provided over large volumes of runoff originating from the incremental contributing area. Reservoir levels, inflows and outflows for this flood event are shown on Plate A-7. Of particular interest is the low level of Fort Randall releases, in the range of 1,000 cfs or less, for several days duration, thereby adding little to the incremental inflow. As illustrated on Plate A-7, the Gavins Point reservoir levels reached it historical maximum elevation of 1210.7 feet, with a maximum encroachment in the Surcharge Zone of 0.7 foot. During this time, the spillway gates remained closed with spill over the top of gates reaching a maximum of 1,600 cfs.

A-14. 1962 Regulation. In anticipation of large runoff amounts in the Fort Randall to Gavins Point incremental drainage area, the Gavins Point pool was drawn down during the latter part of March to elevation 1201.9 feet, 2.6 feet below the base of the Annual Flood Control and Multiple Purpose Zone. Unregulated flow, releases and pool elevation hydrographs pertaining to Gavins Point through the flood period are shown on Plate A-8. Regulated inflows into the Gavins Point reservoir during this flood period were minimized by operation of the upstream System projects. During the 11-day period extending from March 25 through April 4, average daily Fort Randall releases were no more than 1,000 cfs and were near 0 cfs during a 3-day period in that 11-day stretch. Minimum Gavins Point releases of 5,000 cfs were synchronized

with downstream tributary flows into the Missouri River. The low project releases during the flood enabled retention of storage within the reservoir System. The peak pool elevation at 1209.8 feet, just 0.2 foot from the top of the Exclusive Flood Control Zone, was reached in early June. However, Gavins Point releases never exceeded 33,000 cfs during 1962. Rather, releases from upstream reservoirs were reduced and runoff was stored in upstream mainstem projects. The emphasis on System storage retention at the time precluded a rapid evacuation of flood control storage space. If the System had been at near normal storage levels, larger Gavins Point releases following the peaks of downstream tributary inflows would have likely been scheduled in an effort to make evacuated space available sooner.

A-15. 1967 Regulation. Regulation of the mainstem system during 1967 resulted in damages prevented of an estimated $250 million. As illustrated on Plate A-9, unregulated peak flows exceeded 210,000 cfs and unregulated flow in excess of 150,000 cfs would have continued for a 23-day period without upstream regulation. Throughout this same period Gavins Point releases were maintained in the 25,000 to 29,000 cfs range. Prior to the summer of 1967 initial fill of the System had not been completed; the System was considered "closed" in June 1967. Consequently, Gavins Point releases greater than required to sustain downstream navigation were not necessary during the open-water season. Regulation of the System, including Gavins Point releases, during 1967 is illustrative of flood control provided by fill of the System Carryover Multiple Use Zone.

A-16. 1975 Regulation. During the early part of the runoff season, Gavins Point releases were at near-average levels and the Gavins Point pool level fluctuated between 1205.0 and 1206.0 feet. Downstream constraints prohibited significant release increases during May and June. It was not until late June that Gavins Point releases were increased to levels that significantly exceeded those necessary to maintain full service navigation flows through the lower Missouri River in order to evacuate stored flood waters. As shown on Plate A-10, releases during the late summer and fall were maintained at a uniformly high level to evacuate stored flood waters captured by the upstream System reservoirs. The Gavins Point sustained releases of 60,000 cfs from late July through late November resulted in downstream Missouri River stages being close to flood stage at several locations. Further information relating to this flood and regulation afforded by all reservoirs in the mainstem System is given in the Master Manual and in the special RCC report *Summary Report on Regulation of the Missouri River Main Stem Reservoir System to Control the 1975 Inflows*.

A-17. 1977 Regulation. The System storage was 58.6 MAF on January 1 and 58.8 MAF on March 1, 0.4 and 0.6 MAF above the base of the Annual Flood Control and Multiple Use Zone, respectively. Mountain and plains snowpack accumulation was below average and March-July runoff was below average. The May-July runoff above Sioux City was 5.5 MAF, less than half of the average. The annual runoff above Sioux City, IA was 16.1 MAF, more than 8 MAF less than average. Full service navigation flows were provided for the entire 8-month navigation season. Because of the less-than-average tributary runoff in the lower basin, Gavins Point releases ranging from 30,000 to 33,000 cfs were needed during the entire 8-month navigation season to meet the downstream navigation flow targets (see Plate A-11). The combination of low runoff and high System releases resulted in the end-of-year System storage to decline to 51.8 MAF, 6.4 MAF below the base of the Annual Flood Control and Multiple Use Zone.

A-18. 1978 Regulation. The March 1 System storage was 51.6 MAF, 6.6 MAF below the base of the Annual Flood Control and Multiple Use Zone. However, the March 1 runoff forecast was 31.2 MAF, more than 6 MAF above average, mostly due to the much higher-than-average mountain and plains snowpack as described in Section A-07. Even though System storage was below average for that time of the year, full service flows were provided by the beginning of the navigation season. This provided some early evacuation for the expected above-average runoff. As shown on Plate A-12, unregulated flows were very high during late March and early April as the plains snow melted. By May 1, the annual runoff forecast had increased to 33 MAF, nearly 8 MAF above average. Gavins Point releases were increased to 10,000 cfs above the full service level to provide for evacuation of current and forecasted flood storage prior to the next runoff season. The March-May runoff was 20 MAF, more than two times average for this 3-month period. As seen on Plate A-12, Gavins Point releases were gradually increased from 22,000 cfs in early April to 50,000 cfs in early August as downstream conditions permitted. System releases were increased to 52,000 cfs in early October through the end of the navigation season and winter releases were scheduled at 23,000 cfs to continue evacuating stored flood waters. The System storage was 59.0 MAF at the start of the 1979 runoff season, 0.8 MAF above the base of the Annual Flood Control and Multiple Use Zone. Per Section A-03.3 of the Master Manual, the 1975 and 1978 runoff events resulted in many operational studies of the System to determine the best System regulation approach during years when above-average mountain and plains snowpack indicated high runoff years. Further information relating to this flood and regulation afforded by all reservoirs in the System is given in the Master Manual and in the special MRBWM flood report describing the 1978 flood and accompanying System regulation.

A-19. 1987 Regulation. The 1987 runoff year is a good example of floods occurring during drought years. The mountain snowpack accumulation for the 1986-87 winter was much below average. Total runoff during 1987 was 21.3 MAF, 85 percent of average. Significant rainfall events during the last half of March resulted in significant storage gains in the System reservoirs. On March 22, the System gained 478,000 AF of storage, the highest 1-day storage gain in the last 20 years. The regulation of the System of reservoirs during the March event resulted in $450 million of damages prevented. A late May flood occurred on the lower basin when a 5- to 8-inch band of rainfall centered on southeastern Nebraska. These rains caused the Missouri River to exceed flood stage from Plattsmouth, NE to the mouth. As seen on Plate A-13, releases from Gavins Point were reduced from 30,000 to 20,000 cfs to lessen downstream damages. However, because the rainfall occurred so far downstream of Gavins Point (more than 4 days of travel time), the reductions in Gavins Point releases did not affect the peak stages. This event demonstrates that the System cannot reduce the impact of all downstream flooding events.

A-20. 1987-1992 Regulation. Refer to Section A-07.2.4 in the Master Manual for a detailed description of System regulation during the 1987-1992 drought. Refer to Table A-14 in the Master Manual for a year-by-year outline of how drought conservation measures were implemented during the 1987-1992 drought. Regulation during an extended drought is very different than flood regulation. Water conservation measures are implemented as drought conditions continue year to year and System storage levels decline. The regulation during 1988 is an example of System regulation during a drought year. The regulation of the System during 1988 is detailed in two reports: *1988-1989 AOP and Summary of Actual 1987-1988 Operations* and *1989-1990 AOP and Summary of Actual 1988-1989 Operations*. As shown on Plate A-14, runoff was extremely low in the upper basin. Runoff was also much below average in the lower

basin. Thus, higher-than-average Gavins Point releases were needed in the spring to meet downstream navigation targets. As the summer progressed, drought conditions worsened throughout the basin. From mid-June through mid-August Gavins Point releases were restricted to no more than 32,000 cfs due to nesting of T&E species on sandbars downstream of Gavins Point. The incremental runoff between Gavins Point and Nebraska City, which includes the Platte River, and between Nebraska City and Kansas City, which includes the Kansas River, was not sufficient to meet the Nebraska City and Kansas City navigation flow targets of 37,000 and 41,000 cfs, respectively. During August water was drafted from Kansas River projects with authorized navigation support (Tuttle Creek, Milford and Perry) to help meet the Kansas City flow target. During the last week of August, Gavins Point releases were increased from 33,000 to 36,500 cfs as T&E birds had fledged and increased System releases were needed to meet downstream navigation flow targets. As a result of the outlook for less-than-desired System storage, the Corps announced in early August that the 1988 navigation season would be reduced by two weeks, providing a 7½-month season, and the 1989 navigation season would open one week later than normal as an additional water conservation measure. This was the first year since 1981 that the navigation season was reduced in length and only the second time for a reduced navigation season length since the System filled in 1967.

A-21. 1993 Regulation. The Great Flood of 1993, as it is commonly called, caused a large amount of devastating, downstream flooding below the System. The lower basin rains that fell during the late spring and persisted through the summer were spectacular in their intensity and duration. The regulation of the System during 1993 was quite simple. Due to the 1987-1992 drought, the System storage at the beginning of the 1993 runoff season was 43.0 MAF, more than 15 MAF lower than base of the System's Annual Flood Control and Multiple Use Zone. Because there was so much available storage space in the System, Gavins Point releases could be reduced to minimum levels to maximize downstream flood damage risk reduction. As shown on Plate A-15, the System release averaged only 8,000 cfs during July and was as low as 6,000 cfs for a 7-day period in early July. The System stored nearly 10 MAF of runoff during July, July and August. The U.S. Coast Guard closed the Missouri River for navigation on July 3 and did not open it until August 20. This 57-day closure was the longest since the System became operational in 1967. The flood damages that occurred below the System, which totaled nearly $12 billion, emphasized how the System provides less flood prevention as the distance downstream from Gavins Point increases. While the actual damages were high, System regulation during the 1993 flood did prevent over $4.4 billion in damages. A total of $15 billion of damages were prevented in 1993 due to the regulation of all federal reservoirs and levees in the Missouri River basin.

A-22. 1995 Regulation. March 1 System storage was 55.9 MAF, 1.3 MAF below the base of the Annual Flood Control and Multiple Use Zone. The runoff above Sioux City in 1995 was 37.2 MAF, which was exceeded only by the 40.6 MAF in 1978 as the largest runoff from 1898 to 1995. Since 1995, however, that runoff has been exceeded in 1997 (49.0 MAF), 2010 (38.7 MAF) and 2011 (61.0 MAF). The first of two flood events in 1995 occurred as a result of April rains in addition to melt from a significant plains snowpack. The second flood occurred from mid-May through July as the above-average mountain snowpack melted and significant rainfall events occurred in the lower basin. As seen on Plate A-16, Gavins Point releases were gradually reduced from 26,500 to 12,000 cfs from late March to mid-April to provide downstream flood control. From early May to mid-August, Gavins Point releases were steadily increased to 54,000

cfs to evacuate stored flood waters from the System. Maximum releases of 56,000 cfs were made in late November and winter releases were set at 23,000 cfs to evacuate all stored flood water prior to the start of the 1996 runoff season.

A-23. 1996 Regulation. The above average fall and winter releases in 1995 were made so that the 1996 runoff season would start with all 16.3 MAF of flood storage available. However, an early start to the 1996 runoff season prevented the complete evacuation of the Annual Flood Control and Multiple Use Zone. The 1996 runoff season started on February 2, with a System storage of 58.1 MAF, 0.9 MAF above the base of the Annual Flood Control and Multiple Use Zone. During February, System releases were being made so that the System storage would be at the base of the Annual Flood Control and Multiple Use Zone (57.2 MAF) by March 1. However, record February runoff of 3.5 MAF, which is more than three times average, resulted in the System storage increasing to 60.2 MAF by March 1. This resulted in 15.4 MAF of the 16.3 MAF of flood control storage being available to capture runoff during the March-July runoff season. At the beginning of March, mountain and plains snowpack accumulations were above average. As shown Plate A-17, much-above-average Gavins Point releases were made in March and April to prepare the System for anticipated snowmelt runoff: March Gavins Point releases averaged 34,900 cfs, almost 9,000 cfs higher than average, and April Gavins Point releases average 44,000 cfs, almost 16,000 cfs higher than average. The System release was increased three times during May, reaching 25,000 cfs above full service on June 1. Maximum System releases of 55,000 cfs were made in early November, the navigation season was extended 10 days, and winter releases in excess of 20,000 cfs were made to evacuate all stored flood waters prior to the start of the 1997 runoff season.

A-24. 1997 Regulation. As was the case in 1995, high fall and winter releases in 1996 were made to evacuate stored flood water. The 1997 runoff season started on February 1 with a System storage of 57.7 MAF, 0.5 MAF above the base of the Annual Flood Control and Multiple Use Zone. As noted in Section A-08, mountain snowpack accumulation was significantly above average in January and February. As seen on Plate A-18, Gavins Point releases were as high as 39,300 cfs in mid-March and 42,000 cfs on March 31 to pre-release a considerable amount of water from the System in preparation for the large volume of runoff that would occur later in the runoff season. Average March Gavins Point releases are about 20,000 cfs. By May 9 Gavins Point releases had been increased to 60,000 cfs, a record high for May and exceeded only in the fall of 1975 (61,100 cfs). Prolonged high System releases created additional downstream channel capacity. Degradation of the river channel that occurred after 2 or 3 weeks of above-average System releases often resulted in no increase in the river stage as the next increment of flow increase was added to evacuate the unprecedented (at that time) runoff. In all, over 3 feet of channel degradation occurred on the Missouri River from 1996 through 1997 in the Sioux City area. This degradation represents over 12,000 cfs of increased channel capacity in this reach. Ultimately, a new then-maximum record System release rate of 70,000 cfs occurred during November. The evacuation of the stored flood waters continued through the winter. The navigation season was extended 10 days and the December releases average 37,000 cfs, nearly 18,000 cfs more than the long-term average. The January and February 1998 average releases of 24,800 cfs and 28,000 cfs were more than 7,000 cfs and 10,000 cfs above average, respectively. Even with the higher-than-average spring, summer, fall and winter releases during 1997, the 1998 runoff season started with 0.8 MAF of the 1997 runoff in the System's Annual Flood Control and Multiple Use Zone.

A-24.1. Maximum reservoir regulation benefits were attained because the Exclusive Flood Control Zones at Fort Peck and Garrison were completely filled, and a small portion of their Surcharge Zones were utilized, without having to make high damaging releases from either project. The peak pool levels at the Fort Peck and Garrison reservoirs were 0.3 and 0.4 foot into the Surcharge Zone, respectively. The Oahe reservoir neared its historic maximum level of 1618.6 feet, occupying 1.6 feet of its 3-foot Exclusive Flood Control Zone. The Fort Randall reservoir elevation exceeded its previous maximum level by 4.3 feet, peaking at elevation 1372.2 feet, occupying 7.2 feet of its 10-foot Exclusive Flood Contol Zone. The early anticipation of a very large runoff and unprecedented high releases early in the year prevented major flood damages in the river between projects and downstream from the System. More than $5.2 billion in damages were prevented during 1997 as a result of mainstem System regulation.

A-25. 2000-2007 Regulation. Refer to Section A-12 of the Master Manual for details regarding System regulation during the 2000-2007 drought. Refer to Table A-1 in this WCM for a year-by-year outline of how drought conservation measures were implemented during the 2000-2007 drought. As stated in Section A-20, regulation during an extended drought is very different than flood regulation. The regulation during 2003 and 2007 are indicative of System regulation during a drought year before and after the update of the 2004/2006 Master Manual, respectively. The regulation of the System during 2003 and 2007 are detailed in two MRBWM reports: *Summary of Actual Calendar Year 2003 Operations* and *Summary of Actual 2007 Regulation*, respectively.

A-25.1. Regulation during 2003. The March 15 System storage was 42.6 MAF, 15.1 MAF below the base of the Annual Flood Control and Multiple Use Zone. Per the 1979 Master Manual, minimum flow support was provided for the first half of the navigation season. Annual runoff was 17.4 MAF, about 8 MAF less than average; runoff during the first six months was 12.3 MAF, about 4 MAF less than average. As shown on Plate A-19, System releases were increased in late March to provide minimum flow support for navigation. Due to below-average runoff downstream of Gavins Point, System releases of 26,000 cfs were necessary in early May to meet the minimum service target flows of 31,000 cfs at Nebraska City and 35,000 cfs at Kansas City. The lower-than-average January-June runoff, along with only providing minimum flow support for navigation during the first half of the season, resulted in a July 1 System storage of 45.1 MAF. Per the 1979 Master Manual, minimum flow support was provided for the second half of the navigation season as well as a 6-day shortening of the season. The September 1 storage was 42.8 MAF. Lower-than-average winter runoff downstream of Gavins Point combined with cold temperatures for much of the winter resulted in actual System releases averaging 14,500 cfs to ensure that downstream water supply intakes were operational throughout the winter.

A-25.2. Regulation during 2007. As shown in Table A-1, runoff continued at below-average levels from 2003 through 2007. The Master Manual was updated in March 2004 and the drought conservation measures for 2004 forward, per the March 15, July 1 and September 1 System storage checks, had been adjusted to provide additional water conservation. The March 15 System storage was 35.0 MAF; historical minimum System storage of 33.9 MAF was reached on February 7. Per the 2004/2006 Master Manual, minimum flow support was provided for the first half of the navigation season. The July 1 System storage of 40.2 MAF resulted in minimum service for the second half of the navigation season as well as a 35-day shortening of the season.

Per the 2004/2006 Master Manual, the September 1 System storage of 38.4 MAF called for minimum winter releases of 12,000 cfs; actual winter releases averaged 12,300 cfs.

A-25.3. Recovering from the Drought. As shown on Table A-1, runoff in 2008 and 2009 was above average. However, System storage in 2008 and the first half of 2009 was below desired levels. Per the 2004/2006 Master Manual, drought conservation measures continued in the form of minimum flow support for navigation, a shortened navigation season and minimum winter releases. Per the July 1, 2009 System storage check, the System had recovered from the 2000-2007 drought, and Gavins Point releases were adjusted to provide full navigation flow support for the second half of the season and a full-length 8-month season. Winter releases of approximately15,500 cfs were scheduled per the September 1 storage check.

Table A-1
System Storage Check Information for 2000-2007 Drought

Year	Calendar Year Runoff* (MAF)	Mar 15 Storage (MAF)	Level of Service (kcfs)	Jul 1 Storage (MAF)	Level of Service (kcfs)	Sep 1 Storage (MAF)	Winter Release (kcfs)	Actual Winter Release** (kcfs)	Season Shortening (days)
2000	16.5	57.7	full	57.0	-1.5	54.3	14.4	14.0	0
2001	22.5	50.3	-3.0	54.7	-3.0	53.2	13.6	13.4	0
2002	15.8	48.6	-4.0	48.8	min	46.9	10.0	13.3	0
2003	17.4	42.6	min	45.1	min	42.8	10.0	14.5	6
2004	16.2	39.0	min	38.6	min	36.5	12.0	12.0	47
2005	20.1	35.7	min	38.4	min	37.3	12.0	13.0	48
2006	18.2	36.7	min	39.0	min	40.2	12.0	13.2	44
2007	21.1	35.0	min	40.2	min	38.4	12.0	12.3	35
2008	26.6	36.9	min	44.2	min	45.0	12.0	12.3	30
2009	33.4	46.0	min	56.9	full	recovered from drought			

*Average annual runoff is 25.3 MAF; **Average Gavins Point release from Dec 1 – Feb 28/29

A-26. 2010 Regulation. The 2010 runoff season began with more than the 16.3 MAF of flood control storage available. System storage on March 1 was 54.6 MAF, 2.2 MAF below the base of the Annual Flood Control and Multiple Use Zone. The melting of a heavy plains snowpack, as well as below-average System releases of 15,000 cfs as shown on Plate A-20, increased the System storage to 59.4 MAF by May 1. System releases were also kept at below-average levels in June as heavy precipitation in the lower basin led to high tributary and Missouri River flows. System releases were increased to a maximum of 49,000 cfs in the fall, the navigation season was extended 10 days, and winter releases up to 21,000 cfs were made to evacuate all the stored flood waters prior to the start of the 2011 runoff season.

A-27. 2011 Regulation. All 2010 runoff was evacuated from the system by January 28, 2011 when the System storage reach 57.8 MAF, the base of the Annual Flood Control and Multiple Use Zone. As was the case with 2009 and 2010, a heavy plains snowpack blanketed the upper basin. As seen on Plate A-21, System releases were maintained at 21,000 cfs from February through early April as runoff from the largely unregulated basins downstream of Gavins Point resulted in high tributary and Missouri River flows. In early April, per the 2004/2006 Master

Manual and based on the System storage, upstream USBR tributary storage and the April 1 annual runoff forecast above Gavins Point, the service level was increased 10,000 cfs to prepare the System for above-average runoff. In mid-April, an additional service level increase of 5,000 cfs was made. The service level increase did not result in an immediate increase in Gavins Point releases due to high flows that were already occurring along the lower river, but it did raise the downstream flood control constraints at Omaha, Nebraska City and Kansas City by 15,000 cfs. Because of high tributary flows from the largely unregulated basin downstream of the dam causing high Missouri River flows, Gavins Point release were not substantially increased during the first part of the runoff season. Gavins Point releases of 32,000 cfs were made in mid-April and were raised to 45,000 cfs in early May. The March and April runoff above Sioux City, which is primarily from plains snowpack and rainfall runoff, was 6.4 MAF and 7.7 MAF, respectively. While much of this runoff was captured and stored in the mainstem reservoirs, the Gavins Point to Sioux City reach, which is largely unregulated, recorded a March-April runoff total of 3.3 MAF. That 2-month total is more than 1.5 times the average annual runoff for that reach. Based on the System storage, upstream USBR tributary storage and the May 1 annual runoff forecast above Gavins Point, the service level was increased an additional 10,000 cfs in early May. Gavins Point releases of 57,000 cfs were being made by mid-month. From May 20-22 heavy rains, 10 to 15 inches in some isolated areas, fell across eastern Montana, western South Dakota and northern Wyoming. The runoff from the rain, along with the forecasted runoff from the above-average mountain snowpack, resulted in record releases being made from every mainstem project. A Gavins Point release of 160,000 cfs, more than two times the previous record release, was made from June 25 to July 29. For a detailed timeline of System regulation during the 2011 Flood, refer to the External Independent Review Report, *Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011*.

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Appendix B - Recreation

B-01. General. The six reservoirs of the System and the Missouri River reaches between and downstream of these reservoirs provide recreation opportunities. Recreational activity is a source of income for businesses catering to boating, hunting, fishing, camping, and other recreational pursuits. Service-related establishments located near the Missouri River also benefit from those recreating on the System reservoirs. A variety of recreational opportunities are available within the System and the lower Missouri River. Water-based recreation includes boating, fishing and swimming. Sport fishing is a primary component of recreation along the entire river. The wetlands along the river corridor provide waterfowl habitat and waterfowl hunting is popular. Hunting for small and large game such as pheasant, grouse, rabbit and deer occurs on land along the System reservoirs and the river reaches. The aesthetically pleasing character of the reservoirs and river reaches attracts sightseers. Camping facilities vary from fully developed to primitive. Over 80,000 acres of recreational lands are located along nearly 6,000 miles of System reservoir shoreline. Of these 80,000 acres of recreational lands, 6,457 acres are designated as existing recreational areas located on Tribal Reservation lands along the main stem of the Missouri River with another 925 acres identified as future recreational areas. Recreation, an authorized System project purpose, has grown beyond original expectations. With time, recreational facilities became more developed and opportunities for recreation have increased. The introduction of additional fish species attracted greater numbers of fishermen to the reservoirs. Road improvements made the reservoirs and river reaches more accessible. Recently, the national trend towards outdoor recreation and the number of recreationists willing to travel longer distances have added to the recreational visitation all along the System. There is also a thriving recreation industry below the System on the lower Missouri River; approximately 30 percent of the total recreation benefits attributed to the Missouri River occur below the System.

B-02. System Recreation Visitation. Visitation data is maintained by the Corps in the Natural Resource Management's Visitation Estimation and Reporting System database. The methodology used for the Corps to determine visitation hours has been under revision since 2013. The new methodology will leverage metered data that is collected as vehicles enter and exit the recreation areas. Plate B-1 shows the annual visitation for the total System and the six individual System projects from 1954 to 2012. This plate shows that, for the six projects, the trend is upward except during extended drought, when the trend leveled off or is slightly reversed depending on the year. However, since the Gavins Point reservoir level is held fairly steady during droughts, that trend does not apply to Gavins Point. Other factors also affect the visitation numbers such as the overall United States economy. A survey completed in 1999 showed that of the annual visits made to the six projects, approximately 37 percent are made by sightseers, 29 percent by fishermen, 24 percent by boaters, 10 percent by picnickers, 9 percent by swimmers, 2 percent by campers, 2 percent by water skiers, 2 percent by hunters, and 22 percent by visitors who participate in other activities. The visit percentages total more than 100 percent (137 percent) and indicate that some visits include multiple activities.

B-03. Gavins Point Recreation Visitation. Refer to Table B-1 for a history of Gavins Point recreation visitation. The reservoir levels of the lower three reservoirs (Big Bend, Fort Randall and Gavins Point) do not vary with annual runoff as much as the larger, upper three reservoirs. The lower reservoirs do not contain the flood storage volume or conservation storage that the

upper three reservoirs (Fort Peck, Garrison and Oahe) do. Thus, recreation visitation in the lower three reservoirs is not affected as much during drought periods or flood periods because access issues do not normally occur.

Table B-1
Gavins Point Recreation Visitation of Corps' Recreation Areas

Year	Visitation in hours	Year	Visitation in hours
1954	300,440	1984	8,446,064
1955	422,540	1985	9,334,956
1956	2,037,960	1986	9,399,402
1957	3,358,860	1987	8,810,300
1958	4,834,790	1988	8,673,500
1959	6,278,900	1989	9,336,400
1960	5,552,960	1990	9,405,600
1961	6,957,850	1991	10,800,000
1962	8,229,910	1992	7,192,200
1963	6,368,810	1993	8,318,800
1964	6,346,980	1994	8,688,600
1965	6,868,680	1995	9,135,900
1966	7,130,270	1996	9,339,500
1967	7,801,820	1997	8,722,700
1968	8,393,080	1998	9,036,100
1969	8,580,300	1999	8,826,800
1970	9,421,680	2000	8,290,470
1971	10,300,000	2001	8,647,200
1972	10,700,000	2002*	8,358,200
1973	11,600,000	2003*	8,744,400
1974	11,100,000	2004*	8,907,900
1975	11,800,000	2005*	8,800,200
1976	14,400,000	2006*	8,928,300
1977	15,600,000	2007*	9,075,100
1978	13,600,000	2008*	9,612,300
1979	11,800,000	2009*	8,880,300
1980	9,516,400	2010*	9,410,000
1981	9,829,050	2011*	10,737,522
1982	8,953,630	2012**	8,877,500
1983	8,277,270		

* In 2002 many of the Corps' recreation areas were transferred to the State of South Dakota in the Title VI Land Transfer. The lower visitation numbers since 2002 reflect collection of visitation data at the remaining Corps recreation areas.
** 2012 visitation data is only January through September.

Appendix C - Water Quality

C-01. Missouri River Basin Water Quality. Water quality characteristics that are of greatest concern in the basin are chemical constituents, which affect human health and plant and animal life; temperature, which affects fisheries and the aquatic environment; biological organisms, which affect human health; and taste, odor and floating materials, which affect the water's potability and the aesthetic quality of the environment. In general, the mainstem reservoirs function as pollutant "sinks" in that sediment and adsorbed pollutants settle out and are deposited on the bottom of the reservoirs. Bottom-release deep reservoirs, such as Fort Peck, Garrison and Fort Randall may withdraw stagnant water of degraded quality from the bottom of the reservoir during prolonged thermal stratification and pass it downstream. This is not an issue at Gavins Point; the reservoir is shallow and Gavins Point is a run-of-the-river project with a fairly short detention storage time. Although the Missouri River has historically contained high sediment loading and naturally occurring high concentrations of metals such as arsenic and selenium, the water quality characteristics of the Missouri River have changed within the past several decades. These water quality changes are a result of past and current changes in land use practices, increased urbanization, atmospheric deposition of pollutants, and dam construction and regulation within the Missouri River basin. Water quality impacts arising from the construction and regulation of the System can be broadly classified as direct impacts and indirect impacts.

C-02. Direct Water Quality Impacts of System Regulation. The System and its regulation have significantly changed water quality in the river reaches between the reservoirs and downstream of the System, compared to the water quality in the Missouri River before the System was constructed. The water quality has improved as seen through the Clean Water Act because the river has become clearer and cooler and improved recreation and sport fishery. Conversely, the water quality has degraded as seen through the ESA because the natural turbid, warm river has become clearer and cooler which may affect the native river fish. Downstream flow support from the System for the authorized purposes other than water quality more than meets the minimum flow requirements for Missouri River water quality.

C-02.1. The majority of the water quality impacts, that are a direct result of System regulation and hydrologic conditions, occurs in the upper portion of the Missouri River basin. These direct water quality impacts include temperature changes in the reaches downstream from several of the dams, low concentrations of suspended solids in the releases, and temperature and dissolved oxygen problems when the upper three reservoirs are drawn down during droughts. These impacts are more physical in nature, involving the management of streamflow and water storage in the System. Water temperature is recognized as an important water quality condition affecting the fishery population in the Missouri River reaches downstream of the dams. Because releases from the System dams contain low concentrations of suspended solids, some native riverine fish species may be adversely affected. The drawdown of the three larger reservoirs during extended droughts diminishes the coldwater habitat (the temperature increases are a direct impact of System regulation and less dissolved oxygen being available in the reservoirs is an indirect impact, as discussed in Section C-03. In turn, coldwater fish species in the reservoirs may be adversely affected.

C-03. Indirect Water Quality Impacts of System Regulation. Most water quality issues in the Missouri River basin are indirect impacts as they result from a combination of pollutant sources

and hydrologic conditions throughout the watersheds. The Missouri River reservoirs and the tributaries receive pollutant loading from point and non-point sources within the watersheds. The Corps reservoirs are not the source of the pollutants that enter the Missouri River; however, they directly affect the hydrologic regimes that store or transport pollutants downstream. Water quality impairments and problems may, therefore, arise when the Corps is regulating the System to meet the Congressionally authorized System project purposes. Brief descriptions of these indirect water quality issues and impacts are discussed below.

C-03.1. During extended droughts, low reservoir levels in the summer result in reduced volumes of deeper, cooler hypolimnetic water in the three larger System reservoirs (Fort Peck, Garrison and Oahe). The low reservoir levels may cause an increase in the overall temperature of the water in the reservoir and may reduce the total amount of oxygen available in hypolimnetic waters to meet demands of sediment and decomposing organic material, such as decaying algae.

C-03.2. Dissolved oxygen concentrations, especially in hypolimnetic waters, can be lowered through the decomposition of accumulated organic matter and the oxygen demand of sediments and reduced substances. The absence of dissolved oxygen (i.e., anoxic conditions) during summer conditions may result in an influx of metals, such as iron and manganese, from the sediments into the water column. Anoxic conditions, through the oxidation-reduction process, can also liberate nutrients such as phosphorus from the sediments. This can lead to nutrient enrichment and possible nuisance growth of algae.

C-03.3. Elevated metal concentrations have been detected in the water column and fish tissue and within the sediments of the System. The major metals of concern in the System are arsenic and mercury. The Fort Peck and Garrison reservoirs currently have fish consumption advisories issued for mercury. Natural background concentrations of arsenic, selenium and mercury in the System reservoirs are associated with the local geology, specifically the presence of Upper Cretaceous Age Pierre Shale. Elevated arsenic concentrations are a localized occurrence associated with large storm events that cause high sediment loading or wind action that results in re-suspension of the reservoir sediments. Arsenic is a naturally occurring metal within the watershed and readily adsorbs onto fine soil particles as they are transported downstream and deposited in the reservoirs. The majority of arsenic entering the System is adsorbed onto sediment particles. The sources of mercury are naturally occurring soils, point-source discharges, and sediments generated from historical mining practices that have been transported downstream into the System reservoirs. Elemental mercury can be transformed to methyl mercury in rivers and reservoirs when organic matter and hypoxic conditions are present. Methyl mercury bioaccumulates in the aquatic food chain and accumulated levels in fish pose a threat to human health when the fish are consumed. Other metals that have been detected in the System reservoirs are copper, iron, manganese, nickel and zinc.

C-03.4. Agricultural practices, both past and present, include the application of pesticides throughout much of the Missouri River basin. The Omaha District's Water Control and Water Quality Section currently scans for the following pesticides: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, deethylatrazine, deisopropylatrazine, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, metolachlor, metribuzin, pendimethalin, phorate, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate and trifluralin.

C-03.5. Throughout the Missouri River basin, tributary waters exhibit significant nutrient loadings because of effluent discharges, urban storm water and agricultural runoff, and other non-point sources of pollution. High nutrient levels in the Missouri River and its tributaries can deliver nutrients to the System reservoirs and lead to accelerated eutrophication and undesirable algal blooms.

C-04. Gavins Point Reservoir. The State of South Dakota has designated the following water quality-dependent beneficial uses for the Gavins Point reservoir in the state's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters and fish and wildlife propagation. The State of Nebraska has designated the following water quality-dependent beneficial uses for the Gavins Point reservoir in the state's water quality standards: primary contact recreation, Class A warmwater aquatic life, drinking water supply, agricultural water supply, industrial water supply and aesthetics. The uses designated by the two states are consistent with each other. The State of Nebraska has placed the Gavins Point reservoir on the state's Section 303(d) 2014 list of impaired waters for impairment to the aquatic life use due to high levels of chlorophyll *a*. The current estimated loss of the multipurpose pool volume of the reservoir (due to sediment aggradation) exceeds Nebraska's impairment identification criteria of 25 percent volume loss. Neither state has issued a fish consumption advisory for the reservoir.

C-05. Missouri River Downstream of Gavins Point Dam. The states of South Dakota, Nebraska, Iowa and Missouri have designated water quality-dependent beneficial uses for appropriate reaches of the Missouri River downstream of Gavins Point Dam to Rulo, NE:

South Dakota – primary contact recreation, warmwater fishery, drinking water supply and industrial water supply.

Nebraska – primary contact recreation, warmwater aquatic life, agricultural water supply and aesthetics. Also, the use of drinking water supply to the Missouri River downstream of the confluence of the Niobrara River and industrial water supply to the Missouri River downstream of the confluence of the Big Sioux River.

Iowa – primary contact recreation, warmwater fishery, and high quality state resource water. Also, the use of drinking water supply to the Missouri River in the area of Council Bluffs, IA.

Missouri – primary contact recreation, warmwater fishery, drinking water supply, agricultural water supply and industrial water supply.

C-05.1. Based on Nebraska and South Dakota's impairment assessment methodologies, the water quality conditions monitored in Gavins Point discharge during the 5-year period from 2010 through 2014 did not indicate impairment of any designated water quality beneficial uses of the downstream Missouri River.

C-06. Source for Drinking Water. The reservoir is utilized by two rural water districts that provide public drinking water: Cedar Knox Rural Water District (CKRWD) and the Bon Homme-Yankton Rural Water District (BYRWD). The city of Yankton draws source water for drinking water use from the Missouri River approximately 5 miles downstream of Gavins Point

Dam. Both rural water districts and the city of Yankton monitor their source and treated drinking water for compliance with federal drinking water standards.

C-07. Water Quality Monitoring at the Project. The Corps has monitored water quality conditions at Gavins Point since the late 1970s. The near-dam reservoir monitoring location has been continuously monitored since 1980. Water quality monitoring locations include sites on the reservoir and on the inflow to and outflow from the reservoir. There are three long-term monitoring locations on the reservoir. For reporting of existing water quality conditions, water quality data are summarized in 5-year periods. For reporting water quality long-term trends, water quality data from the late 1970s to present is analyzed. Data collection has varied through this period and has included the monitoring of ambient water quality conditions at the following locations: 1) three deepwater sites in the Gavins Pont reservoir near the dam, mid-reach, and in the headwaters; 2) the Missouri River about 1 mile downstream of the dam; 3) within the Gavins Point powerplant on water discharged through the turbines; and 4) Missouri River inflow to the Gavins Point reservoir downstream of the Niobrara River confluence.

C-08. Water Quality Monitoring on the Lower River. The Omaha District, in cooperation with the Nebraska Department of Environmental Quality (NDEQ), conducts fixed-station water quality monitoring at seven sites along the Missouri River from Gavins Point Dam to Rulo, NE: Gavins Point tailwaters, near Maskell, NE, near Ponca, NE, at Decatur, NE, at Omaha, NE, at Nebraska City, NE and at Rulo, NE.

C-09. Water Quality Trends. Water quality trends since 1980 are determined for the Gavins Point reservoir for Secchi depth, total phosphorus, chlorophyll *a* and TSI (i.e., trophic status). The assessments are based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site. Since 1980, the near-dam area of the reservoir has generally remained in a eutrophic state. See Table C-1 and C-2 for typical 5-year water quality summaries (2010-2014) of a reservoir and river monitoring site, respectively. The Omaha District Water Control and Water Quality Section is the primary office responsible for water quality data collection, analysis and documentation. The section publishes an annual water quality report regarding the district tributary projects as well as the System projects.

Table C-1
2010-2014 Water Quality Conditions – Gavins Point Reservoir

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	1206.4	1206.3	1205.4	1207.6	-----	-----	-----
Water Temperature (°C)	0.1	283	21.0	21.6	9.3	28.9	27[1,2,6], 29[1,2,6]	4, 0	1%, 0%
Dissolved Oxygen (mg/L)	0.1	283	8.7	8.6	1.2	15.1	5[1,7]	9	3%
Dissolved Oxygen (% Sat.)	0.1	283	100.3	101.1	14.5	165.4	-----	-----	-----
pilimnion/Metalimnion Dissolved Oxygen (mg/L)[E]	0.1	257	8.9	8.7	5.3	15.1	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/L)[E]	0.1	26	6.2	5.8	1.2	10.7	5[1,7]	9[F]	35%[F]
Specific Conductance (uS/cm)	1	283	789	783	665	914	2,000[4]	0	0%
pH (S.U.)	0.1	283	8.4	8.4	7.7	9.3	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0, 6, 0	0%, 2%, 0%
Turbidity (NTUs)	1	283	11	8	n.d.	49	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	271	313	336	157	426	-----	-----	-----
Secchi Depth (M)	1	24	1.01	0.95	0.38	1.83	-----	-----	-----
Alkalinity, Total (mg/L)	7	49	157	159	133	170	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	48	4.2	4.1	2.9	5.5	-----	-----	-----
Chloride (mg/L)	1	19	12	12	10	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/L) – Field Probe	1	238	12	8	1	191	10[10]	105	44%
Chlorophyll *a* (ug/L) – Lab Determined	1	25	13	9	3	85	10[10]	9	36%
Colorized Dissolved Organic Matter (ug/L)	4	39	24	25	15	34	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	48	562	541	386	830	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total (mg/L)	0.02	49	-----	0.02	n.d.	0.28	3.9 [1,6,9], 0.78[1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	49	0.42	0.38	n.d.	1.42	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	49	-----	0.07	n.d.	0.30	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/L)	0.1	49	0.50	0.43	n.d.	1.54	1[10]	1	2%
Phosphorus, Dissolved (mg/L)	0.02	48	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus, Total (mg/L)	0.008	49	0.03	0.03	n.d.	0.11	0.05[10]	9	18%
Phosphorus-Orthophosphate (mg/L)	0.02	48	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/L)	1	49	235	230	191	295	875[3,6], 500[3,8]	0	0%
Suspended Solids, Total (mg/L)	4	19	12	9	n.d.	82	158[1,6], 90[1,8]	0	0%
Microcystin, Total (ug/L)	0.1	25	-----	0.1	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/L and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e. log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate state water quality standards.

[1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).

[2] South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.

[3] Criteria for the protection of domestic water supply waters.

[4] Criteria for the protection of agricultural water supply waters.

[5] Criteria for the protection of commerce and industry waters.

[6] Daily maximum criterion (monitoring results directly comparable to criterion).

[7] Daily minimum criterion (monitoring results directly comparable to criterion).

[8] 30-day average criterion (monitoring results not directly comparable to criterion).

[9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[10] Nutrient criteria – Lewis and Clark Lake has been assigned the following nutrient criteria by Nebraska water quality standards: Chlorophyll *a* = 10 ug/L, Total Nitrogen = 1 mg/L, and Total Phosphorus = 50 ug/L. Chlorophyll *a* represents the desired biological condition (response) and is generally influenced by the amount of phosphorus and nitrogen (cause). Thus, if the chlorophyll *a* criterion is met, total phosphorus or total nitrogen values above the listed values will not be considered to violate their respective criteria.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates a decrease of 1.0°C or more over a 1-meter depth increment, or a decrease of at least 0.5°C and a decrease of at least 1 mg/L dissolved oxygen over a 1-meter depth increment. The top of the hypolimnion is delineated as the depth where the above changes occur.

[F] According to South Dakota's beneficial use support decision criteria, dissolved oxygen levels are not considered impaired if a region exists in the depth profile (i.e. epilimnion) where the dissolved oxygen levels are ≥5 mg/L. Nebraska's dissolved oxygen criteria do not apply to the hypolimnion.

Note: The highlighted values indicate use impairment based on State of Nebraska 2012 Section 303(d) impairment assessment criteria.

Table C-2
2010-2014 Water Quality Conditions – Gavins Point Tailwater

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedances	Percent WQS Exceedance
Gavins Point Dam Discharge:									
Streamflow (cfs)	1	58	33,619	27,255	11,895	159,760	-----	-----	-----
Field Measurements:									
Water Temperature (°C)	0.1	56	12.0	10.6	0.0	26.2	27[1,2,6], 29[1,2,6]	0, 0	0%, 0%
Dissolved Oxygen (mg/L)	0.1	56	10.8	11.2	7.1	14.5	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	56	100.8	99.1	88.1	132.6	-----	-----	-----
Oxidation-Reduction Potential	1	56	348	352	150	450	-----	-----	-----
pH (S.U.)	0.1	55	8.2	8.3	7.0	9.4	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0, 1, 0	0%, 2%, 0%
Specific Conductance (uS/cm)	1	54	768	750	620	897	2,000[4]	0	0%
Turbidity (NTU)	1	56	17	10	n.d.	149	-----	-----	-----
Laboratory Results:									
Alkalinity, Total (mg/L)	7	58	161	162	138	176	-----	-----	-----
Carbon, Dissolved Organic (mg/L)	0.05	35	3.9	3.9	n.d.	5.6	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	57	4.2	4.2	2.4	6.4	-----	-----	-----
CBOD 5-day (mg/L)	2	36	-----	n.d.	n.d.	3	-----	-----	-----
Chemical Oxygen Demand (mg/L)	2	58	11	11	n.d.	20	-----	-----	-----
Chloride (mg/L)	1	37	12	12	10	14	438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/L)	1	36	13	8	n.d.	48	-----	-----	-----
Colorized Dissolved Organic Matter (ug/L)	4	42	23	23	16	32	-----	----	-----
Dissolved Solids, Total (mg/L)	5	58	526	504	382	774	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	0	0%
Nitrogen, Ammonia Total	0.02	58	-----	0.02	n.d.	0.11	4.7 [1,6,9], 1.4 [1,8,9]	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	58	0.41	0.40	n.d.	0.87	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total (mg/L)	0.02	58	0.18	0.18	n.d.	1.06	10[3,6], 100[4,6]	0	0%
Nitrogen, Total (mg/L)	0.1	58	0.59	0.59	0.14	1.42	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	55	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	58	0.04	0.03	n.d.	0.19	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	58	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/L)	1	58	227	223	169	292	-----	-----	-----
Suspended Sediment, Total (mg/L)	4	38	16	12	n.d.	61	-----	-----	-----
Suspended Solids, Total (mg/L)	4	57	13	11	n.d.	57	158[1,6], 90[1,8]	0	0%
THM Formation Potential, Total (mg/L)	4	34	178	173	13	356	-----	-----	-----
Acetochlor, Total (ug/L)[D]	0.05	56	-----	n.d.	n.d.	0.3	-----	-----	-----
Atrazine, Total (ug/L)[D]	0.05	56	-----	n.d.	n.d.	0.5	330[10], 12[11], 3[3]	0	0%
Metolachlor, Total (ug/L)[D]	0.05	56	-----	n.d.	n.d.	0.4	390[10], 100[11]	0	0%

n.d. = Not detected.

[A] Detection limits given for the parameters Streamflow, Water Temperature, Dissolved Oxygen (mg/L and % Sat.), Specific Conductance, pH, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e. log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate state water quality standards.

[1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).

[2] South Dakota's temperature criterion is 27°C and Nebraska's is 29°C.

[3] Criteria for the protection of domestic water supply waters.

[4] Criteria for the protection of agricultural water supply waters.

[5] Criteria for the protection of commerce and industry waters.

[6] Daily maximum criterion (monitoring results directly comparable to criterion).

[7] Daily minimum criterion (monitoring results directly comparable to criterion).

[8] 30-day average criterion (monitoring results not directly comparable to criterion).

[9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[10] Acute (CMC) criterion for the protection of freshwater aquatic life.

[11] Chronic (CCC) criterion for the protection of freshwater aquatic life.

[12] Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e. cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

Appendix D - Fish and Wildlife

D-01. General. The USFWS has identified three protected species – the endangered least tern, the threatened piping plover and the endangered pallid sturgeon – that are affected by the regulation of the System. As it relates to the Gavins Point project, the least tern and piping plover utilize the natural and manmade sandbars for nesting purposes. These sandbars are located in the headwaters of the reservoir and on the Missouri River reach downstream of the dam. 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 a quantity of surface water did not exist naturally and that is characterized as having a relatively dry climate, has had a great effect on the environment of the area. The purchase and subsequent management of lands associated with the individual System projects has changed use patterns of lands adjacent to the System projects from the use experienced prior to the construction of the projects. Regulation of the reservoirs also has affected the regime of the Missouri River through those reaches below the System and in those reaches between the System reservoirs where the river is still more or less in its natural state. The full impact of each of the reservoirs and its regulation on the environment is constantly changing as they adapt to new conditions. The environmental emphasis has changed since the System was authorized. As discussed in the Master Manual, current efforts are focused on increased stewardship of the Missouri River and surrounding affected lands by maintaining them in as natural a condition as possible through enhancing and supporting native plants and species. The two basic goals of the Corps stewardship are to manage lands and waters to ensure their availability for future generations and to help maintain healthy ecosystems and biodiversity. Balancing the needs of the people with those of nature is the basic challenge. Through observations and discussion with interested individuals and agencies, many suggestions for environmental enhancement of the System have been received and are being implemented by the Corps. The adaptive management process discussed in Chapter VII of the Master Manual provides additional focus on this effort, and, through implementation of the actions developed and tested through this process, Missouri River ecosystem restoration will occur.

D-01.1. Another major point of emphasis in environmental considerations has been the effect of the various System regulation practices on fish and wildlife, including T&E species. Improvement of fish spawning activities by appropriate management for habitat development and subsequent spawning is an important consideration in System regulation. Suggestions have been made and adopted to the degree practicable for improving migratory waterfowl habitat and hunter access along the Missouri River below the projects. Other suggestions, such as reduction of flows during the migration period so that more sandbars could be available, cannot always be implemented without serious effects on other authorized project purposes. As further suggestions are received, they will be evaluated through the adaptive management process. Another area of environmental concern is the management of project lands. Currently, the major emphasis on the development of these lands is for water-oriented recreation; however, large areas of project lands are now being managed almost exclusively for wildlife purposes.

D-02. Fish and Wildlife. Fish and wildlife enhancement has been discussed in other portions of the Master Manual. Section 4-06.6 of the Master Manual presents information on the activities of two existing federal fish hatcheries and the Fort Peck State Fish Hatchery. At all times of the

year, but particularly during the fish spawning period and the T&E nesting season, the MRBWM office recognizes and integrates fish and wildlife purpose considerations into System regulation decisions to the extent possible with consideration to other authorized purposes. The Corps coordinates closely with the USFWS and the state organizations to assure that the consideration of effects on fish and wildlife is provided. Appendix D of the Master Manual provides a detailed discussion of the existing Missouri River basin environment and historical System regulation related to this authorized purpose.

D-03. Regulation for Endangered and Threatened Species – Least Terns and Piping Plovers. Releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate endangered least tern and threatened piping plover nesting since 1986. The AOPs includes specific information regarding Gavins Point releases for regulation for least terns and piping plovers. Additional System regulation criteria used for T&E species is discussed in Section 7-09 of this WCM and Section 7-10 and Appendix D of the Master Manual.

Appendix E - Water Supply and Irrigation

E-01. Introduction. System regulation has assured a relatively uniform supply of water for downstream municipalities and industrial uses. The Corps provides more than adequate flow in the river to meet the requirements of all who choose to utilize the Missouri River for their water supply. At times, releases from individual System projects have been adjusted to ensure continued satisfactory functioning of water intakes on a short-term basis. The Missouri River and its System reservoirs are a source of water for municipal water supply, irrigation, cooling water, and commercial, industrial, and domestic uses. Approximately 1,600 water intakes of widely varying size are located within the System and the lower Missouri River. Access to water is a key concern because low water levels limit the ability of some intakes to access the water and increase the cost of getting water from both the reservoirs and Missouri River. Water supply is a purpose that has grown more than originally envisioned. The regulation of the System in such a predictable manner provides a dependable domestic and industrial water supply for many river communities for using the Missouri River as a source for domestic as well as industrial water supply. Releases have been of a uniformly good quality. There have been times when intake access becomes a problem, primarily during release reductions for flood control or because of reduced releases and low reservoir levels during an extended drought. It is the intake owner's responsibility to maintain adequate access to the water supply available in the Missouri River. Per the MRRMP-EIS, of the approximately 3.2 million persons served by water supply from the System, 89 percent are downstream of Gavins Point (see Table E-1 of the Master Manual). More detailed discussion on water supply and irrigation can be found in Appendix E of the Master Manual.

E-02. Gavins Point Reservoir. As shown on Table E-3 of the Master Manual, 37 water supply intakes are located on the Gavins Point reservoir (Lewis and Clark Lake). These include 2 municipal water supply facilities, 27 irrigation intakes, 6 domestic intakes, and 2 public intakes. The municipal water supply facilities serve a population of approximately 10,377 persons. Of the 37 water supply intakes located on the Gavins Point reservoir, 7 are serving the Santee Reservation. These include 5 irrigation intakes and 2 public intakes.

E-03. Missouri River – Downstream Water Supply Intakes. As shown on Table E-3 of the Master Manual, the lower river (below Gavins Point Dam) has 161 water supply intakes that depend on the Missouri River as their source of water.

a. Gavins Point Reach. There are 42 water supply intakes located on the Missouri River below Gavins Point to Sioux City, IA. These include 1 municipal water supply facility, 33 irrigation intakes, 7 domestic intakes and 1 public intake. The municipal water supply facility serves a population of approximately 15,000 persons.
b. Sioux City Reach. There are 48 water supply intakes located on the Missouri River in the Sioux City, IA to Blair, NE reach. These include 2 powerplant intakes, 1 municipal water supply facilities, 1 industrial intake, 42 irrigation intakes, and 2 public intakes. The two powerplants have nameplate generating capacity of 1,280 MW. The municipal water supply facilities serve a population of approximately 88,800 persons. Of the 48 water supply intakes located on the Missouri River in the Sioux City reach, 1 irrigation intake is located on the Winnebago Reservation and 2 irrigation intakes are located on the Omaha Reservation.

c. Omaha Reach. There are 19 water supply intakes located on the Missouri River in the Blair to Bellevue, NE reach. These include 1 powerplant (nuclear) intake, 2 municipal water supply facilities, 1 industrial intake, 8 irrigation intakes, 2 domestic intakes, and 5 public intakes. The powerplant has a nameplate generating capacity of 2,303 MW. The municipal water supply facilities serve a population of approximately 530,000 persons.
d. Nebraska City Reach. There are 25 water supply intakes located on the Missouri River between Bellevue and Rulo, NE. These include 2 powerplant (one nuclear) intakes, 22 irrigation intakes, and 1 domestic intake. The two powerplants have a nameplate generating capacity of 2,191 MW.
e. St. Joseph Reach. There are 10 water supply intakes located on the Missouri River between Rulo, NE and Kansas City, MO. These include 4 powerplant intakes, 4 municipal water supply facilities, and 2 public intakes. The 4 powerplants have a nameplate generating capacity of 1,730 MW. The municipal water supply facilities serve a population of approximately 418,000 persons. None of the 10 water supply intakes located on the St. Joseph reach of the Missouri River are on the Iowa and the Sac and Fox Reservation.
f. Kansas City Reach. There are 8 water supply intakes located on the Missouri River between Kansas City and the Grand River confluence with the Missouri River. These include 3 powerplant intakes, 4 municipal water supply facilities, and 1 public intake. The 3 powerplants have a nameplate generating capacity of 1,690 MW. The municipal water supply facilities serve a population of approximately 845,500 persons.
g. Boonville Reach. There are 5 water supply intakes located on the Missouri River between the Grand River and Osage River confluences. These include 1 powerplant intake, 3 municipal water supply intakes and 1 public intake. The 1 powerplant has a nameplate generating capacity of 1,236 MW. The municipal water supply intakes serve a population of approximately 46,740 persons.
h. Hermann Reach. There are 4 water supply intakes located on the Missouri River between the mouth of the Osage River and St. Louis. These include 1 powerplant (nuclear) intake and 3 municipal water supply facilities. The powerplant has a nameplate generating capacity of 2,390 MW. The municipal water supply facilities serve a population of approximately 940,000 persons.

Appendix F - Hydropower

F-01. General. Hydropower generation by System powerplants represents one of the authorized project purposes. The hydropower production of the System continues to be of great importance and of direct interest because of the day-by-day direct benefits realized by a large segment of the Missouri River basin's population in the form of relatively low-cost power and the annual return of revenues to the U.S. Department of the Treasury. Hydropower plays an important role in meeting the electricity demands of our Nation. It is a renewable energy source that helps conserve the nonrenewable fossil and nuclear fuels. It helps meet the basin's needs at an affordable price in an environmentally safe way. Nearly $6 billion in cumulative hydropower benefits amortized to current dollars has occurred from the regulation of the System. At the six System dams, 36 hydropower units provide a combined capacity of 2,500 megawatt (MW), as shown in Table F-1. These units have provided an average of 9.3 million (1967 – 2015) megawatt hours (MWh) per year. Western, of the U.S. Department of Energy, markets power generated at the System dams within the Southwest Power Pool (SPP). Western joined the SPP market in October 2015. Western had previously marketed energy in the Mid-continent Area Power Pool region.

F-02. Hydropower Capacity. The aggregate installed capacity of all powerplants in the Missouri River basin exceeds 20,000 MW, with an annual generation of over 90 million MWh. The investor-owned systems have about 60 percent of the basin's generating capacity. The publicly-owned systems consist of about 40 percent federal hydroelectric capacity and 60 percent thermal capacity owned by non-federal public bodies. Hydropower installations in the basin total about 3,300 MW, of which about 82 percent is federal, 14 percent is investor owned, and 4 percent is publicly owned. The federal power system in the upper Missouri River basin includes the six Corps System powerplants as well as the Canyon Ferry and Yellowtail powerplants constructed by the USBR. Until October 1, 1977, power from all Missouri River basin federal powerplants was marketed by the USBR. At that time, the power marketing responsibility shifted to Western. The federal hydroelectric powerplants are connected with the extensive federal transmission system within Western's Eastern Division, Pick-Sloan Missouri Basin Program, power-marketing area, which includes Montana east of the Continental Divide, North Dakota, South Dakota, eastern Nebraska, western Minnesota and western Iowa. The transmission network is interconnected with numerous Rural Electric Association-financed cooperatives, municipal power systems, and investor-owned utilities. The Eastern Division transmission network is interconnected with Southwestern at Maryville, MO, and with the Western Division through a 100 MW direct current tie at Stegall, NE, owned by the Tri-States Cooperative. In addition, by a split-bus operation, a variable number of units can be operated on the Western System at the Fort Peck and Yellowtail (USBR reservoir project) powerplants.

F-03. Hydropower Facilities and Historic Regulation. The following sections describe the individual System project hydropower and generation. Chapter IV in the Master Manual contains a more detailed description of the hydropower and powerplant facilities. Table F-1 presents hydropower related information for the System projects. Refer to Appendix F of the Master Manual for additional hydropower information on System projects.

Table F-1
System Project Hydropower Data

Dam	Generator Capacity (MW)	Energy (million MWh)	Average Annual Energy Plant Factor (%)	Units	Average Gross Head (feet)	Average Flow (kcfs)	Normal Powerhouse** Capacity (kcfs)	Average Annual Flow Plant Factor (%)	Type
Fort Peck	185	1.0	63	5	194	9.2	16	58	Semi-Peaking
Garrison	583	2.2	43	5	161	21.6	41	53	Semi-Peaking
Oahe	786	2.6	38	7	174	23.2	54	43	Peaking
Big Bend	517	1.0	22	8	70	23.7	103	22	Peaking
Fort Randall	320	1.7	61	8	118	25.1	44.5	56	Semi-Peaking
Gavins Point	132	0.7	62	3	48	27.6	36	77	Baseload
Total	**2,523**	**9.3**		**36**					

** Normal powerhouse capacity is based on average reservoir elevation.

Note: Flow plant factors are calculated based on average flows versus powerhouse flow capacities. These differ from energy-based plant factors to the extent that actual plant head is less than maximum gross head.

Source: Corps, 1967-2015 actual data.

F-04. Gavins Point Dam. Three units operate at Gavins Point, with a generating capacity of 132 MW. These units came on line in 1956 and 1957. The powerhouse capacity is approximately 36,000 cfs, but under varying conditions 33,000 cfs to 35,000 cfs may be expected, and the average release is 27,600 cfs (1967-2015). The average annual flow plant factor is 77 percent, which is the highest of the six System powerplants. On average, the powerplant produces 0.7 million MWh of energy per year. Gavins Point is the only dam that is not operated to provide peaking power. Generally, daily releases from Gavins Point are constant to allow for stable downstream navigation and other project purposes.

F-05. Gavins Point Releases. Since full regulation began, the reservoir has usually been regulated in the narrow zone extending from elevation 1204.5 to 1208.0 feet. A maximum reservoir level of 1210.7 feet occurred in 1960. Since the System filled in 1967, a maximum elevation of 1209.7 feet was attained in 2010. Also, Lewis and Clark Lake was drawn down to elevation 1199.8 feet in 1969 in anticipation of large amounts of inflow from plains snowmelt. Since 1967, average daily releases from the project were as low as 6,000 cfs in 1993 and as high as 160,700 cfs in 2011.

F-06. System Hydropower Generation Considerations. Power generation at the six System dams generally must follow the seasonal pattern of water movement through the System. Adjustments, however, have been made to the extent possible to provide maximum power production during the summer and winter months when demand is high. Oahe and Big Bend power generation is relatively high during the winter. Since System release in the winter is low, the winter Oahe and Big Bend powerplant releases must be stored in the Fort Randall reservoir

(Lake Francis Case). To allow for this, the Fort Randall reservoir is drawn down during the fall of each year, as discussed in Section F-06.2 of this WCM.

F-06.1. Hourly patterning of the average daily releases is also of major importance in realizing the full power potential of the System powerplants. Based on past experience with both open water and a downstream ice cover, in most cases no limits need to be placed on daily peaking (with the exception of Gavins Point) up to the capacities of the individual powerplants, except during the T&E nesting seasons, provided the limiting average daily discharge is not exceeded. The minimum allowable hourly generation, and corresponding release, is dependent on the hydraulic characteristics of the river below each of the projects and the effect on water use in the downstream reaches. Downstream water supply intakes, fish spawning activities in the downstream channel, recreational usage, and other factors that may be seasonal in nature influence the selection of minimum limits. These constraints at particular projects are summarized in the Master Manual and other System project WCMs.

F-06.2. Due to the flexibility inherent in such a large system of reservoirs, it is possible to pattern project releases (with the exception of Gavins Point) to cycles extending for periods longer than a day in duration for maximum power production while still providing full service to the authorized project purposes other than hydropower. During the navigation season when downstream flow requirements are high, large amounts of water are normally released from Gavins Point. This requires that large volumes of inflow to Gavins Point be supplied from Fort Randall. Fort Randall, in turn, requires similar support from Big Bend, and Big Bend from Oahe. Here the chain can be interrupted because Oahe is large enough to support high upstream releases for extended periods without correspondingly high inflows. High summer releases from Gavins Point, Fort Randall, Big Bend and Oahe result in high generation rates at these plants. To avoid generating more power than can be marketed advantageously under these circumstances and to provide more winter hydropower, the usual practice during this time of year is to hold releases and generation at Fort Peck and Garrison at lower levels unless the evacuation of flood control storage space or the desire to balance storages between projects becomes an overriding consideration. With the end of the navigation season, conditions are reversed. Releases from Gavins Point drop to about half of summer levels and the chain reaction proceeds upstream, curtailing releases from Fort Randall, Big Bend and Oahe. A means of partially compensating for the lesser amount of hydroelectric energy associated with lower winter release rates from Fort Randall and other mainstem reservoirs is the pre-winter drawdown of the Fort Randall reservoir. As part of this regulation, Oahe and Big Bend releases are reduced several weeks prior to the end of the navigation season. This leaves the Fort Randall reservoir in the position of supplying a majority of downstream releases requirements from accumulated storage, resulting in a lowering reservoir level. This vacated storage space is refilled during the winter months by releases from Oahe and Big Bend in excess of those that would have been possible if drawdown of the Fort Randall reservoir had not been made. At this time, Fort Peck and Garrison winter releases are usually maintained at relatively higher levels as permitted by the downstream ice cover to partially compensate for the reduction in generation downstream.

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Appendix G - Navigation

G-01. General. The Missouri River Bank Stabilization and Navigation Project (BSNP) was designed to prevent bank erosion and channel meandering and to provide reliable commercial navigation on the Missouri River. This project, authorized by Congress in the Rivers and Harbors Act of 1945, is designed to secure a permanent, continuous, open-river navigation channel with a 9-foot depth and width of not less than 300 feet under full navigation service conditions for a distance of 735 miles from the confluence of the Big Sioux River and the Missouri River near Sioux City, IA to the mouth near St. Louis, MO.

G-02. Construction. Construction of the navigation works was declared complete in September 1981, although corrective work will be required as the Missouri River continues to form its channel in response to changing flow conditions. The navigation project is not accomplished by using locks, as is the case on most of the inland waterway systems, but by using river structures placed to confine and control the channel. The use of these structures produces velocities high enough to prevent the accumulation of sediment in the channel and permits an open river self-scouring channel condition for the entire length of the project. Full service flow support is generally sufficient to provide a 9-foot deep by 300-foot wide navigation channel, although challenges may exist in localized areas. These issues are generally short-lived, but in some instances may necessitate additional channel reconnaissance and/or adjustments to navigation structures or localized dredging.

G-03. Service Level. The explanation of the use of service level to serve the authorized System project purposes is contained in Section 7-03.2 of the Master Manual. The selection of the service level is based on criteria explained in Section 7-03.2.1.1 of the Master Manual. The season length is based on a System water-in-storage check and is presented in Section 7-03.4 of the Master Manual. Flows for full service navigation are 31,000 cfs at Sioux City, IA and Omaha, NE; 37,000 cfs at Nebraska City, NE; and 41,000 at Kansas City, MO. The full service flows provide a 9-foot deep channel and allow the capability to load barges to an 8.5-foot draft. The difference between minimum and full service flow support is 6,000 cfs. The minimum service level of flow support is generally sufficient to provide an 8-foot deep channel.

G-04. Historic Service Levels and Season Lengths. Flow support is provided for a normal navigation season of 8 months from April 1 to December 1 at the mouth of the Missouri River. As explained in Section 7-03.4 of the Master Manual, the length of each year's navigation season is based on the July 1 System storage check. Refer to Plate G-1 for historic service levels since 1967. Refer to Plate G-2 for historic season lengths and the tonnages moved in each year since 1967.

G-05. Missing Navigation Flow Targets. There are times during a navigation season when downstream flow targets, primarily at Sioux City and Omaha, are intentionally not met. Recent regulation experience has indicated that, if there is no commercial navigation scheduled to use the upper reaches of the navigation channel, it is prudent for the Corps to consider not providing navigation flow support in those reaches. This allows for water conservation in the System, reduces flood risk in downstream reaches, and can sometimes minimize incidental take of the T&E species during the nesting season.

G-06. Mississippi River Navigation Support. The System was not authorized to support Mississippi River navigation. It is recognized that the Missouri River does contribute flow to the Mississippi River; however, the benefit that occurs to Mississippi River navigation is incidental to the operation of the system for Missouri River navigation. It is not within the System's current authorities for releases to be made from the System to solely benefit the Mississippi River.

Exhibit A

Missouri River Mainstem Dams

Operational Restrictions and Best

Practices for Spillway Gates and

Outlet Tunnels

CENWO-ED-DF 14 April 2017

MEMORANDUM FOR CENWD-PDR

SUBJECT: Missouri River Mainstem Dams, Operational Restrictions and Best Practices

1. In response to your 7 March 2017 request regarding current gate restrictions and/or operating guidelines, this memorandum contains all known operating restrictions that have been enacted by Engineering Division for the mainstem dams. Additional guidance regarding best practices and/or special considerations at the mainstem dams is also provided. The references listed in enclosure 1 provide the basis for these operational restrictions, best practices, and special considerations. More detailed information may be found within these documents.

a) General Operational Restrictions and Best Practices:

(1) Operation of Adjacent Tainter Gates - Operation of the tainter gates shall be sequenced such that differences in openings between adjacent gates shall not exceed 6 feet at any time in order to avoid excessive eccentricity of load on the trunnion beam and anchors. (ref. 1)

(2) Operation Adjacent to a Dewatered Tainter Gate - Do not operate a tainter gate that is subject to hydrostatic load if it is adjacent to a dewatered gate in order to avoid excessive eccentricity of load on the trunnion beam and anchors. (ref. 1)

(3) Ice on or Adjacent to Spillway Gates - Spillway tainter gates and spillway vertical lift gates shall not be operated if ice is present on the gate or if there is lake ice adjacent to the gate. Operation of a gate with ice either on or adjacent to the gate would risk overstressing of steel members, overload of the hoist mechanism, and damage to the seals. (ref. 1)

(4) Overtopping of Spillway Gates – Releases shall be managed to prevent the reservoir from rising above the top of the tainter gates and vertical lift gates. Overtopping would increase stresses in the steel framing beyond the design forces. (ref. 1 & 2)

(5) Operation of Gates with Wave Splash Over - There is no restriction against operating gates while waves are splashing over the top of the gate if the average pool elevation is not above the top of the gate. (ref. 1)

(6) Operation of Spillway Gates with Exceptionally Large Waves - If possible, operation of the spillway gates should be postponed until exceptionally large waves have subsided. (ref.1)

b) Project Specific Operational Restrictions and Best Practices:

(1) Oahe Dam Tainter Gate Deflector Plates - Releases shall be managed to prevent the Oahe Reservoir from rising above the top of the tainter gates and onto the wave splash deflector plates. The deflector plates were added in 1994 to the top of the tainter gates to prevent wave splash-over from impacting the top girder on the downstream side of the gate. The deflector plates were not intended to allow pool elevations higher than the original top of gate. (ref. 3)

(2) Fort Peck Spillway Vertical Lift Gates - Operation of spillway gates 11, 12, 13 and 16 shall be restricted as much as possible until the counterweight plates connected to the lifting

chain on those gates have been replaced. Ultrasound inspection of those connectors observed internal delamination. (ref. 4)

(3) Fort Peck Outlet Tunnels - Previous studies have reported damage to the ring gates, shaft, and tunnels during releases through the outlet works. The studies also questioned the ability to place the emergency gates during flow conditions. It is recommended that ring gates should not be used except in a case of a dam safety emergency. Engineering Division shall be notified in advance of any planned releases through the outlet works. (ref. 5)

(4) Garrison Dam Outlet Regulating Gates - The regulating gates shall not be operated at or below the 6 inch open position. The regulating gates in tunnels no. 7 and 8 shall not be operated at an opening greater than 19.0 feet, except in an emergency and then the gate must be fully opened. The regulating gate in tunnel no. 6 shall not be operated at an opening greater than 23.5 feet. Hydraulic model testing revealed unstable flow conditions at certain openings. The O&M manual states that the controls for these gates have been set to prevent operation of these gates at the openings identified above. (ref. 7)

c) Project Specific Special Considerations:

(1) Gavins Point Lake Yankton Embankment - The Lake Yankton Embankment includes the original training dike which starts at the left spillway wall and extends approximately 3,400 feet downstream to the hydraulic fill section. The Lake Yankton Embankment impounds water for recreational use, but Lake Yankton also provides a stabilizing effect on the under seepage performance of the Gavins Point Dam Embankment. The loss of Lake Yankton could initiate rapid development of high exit gradients immediately downstream of the relief wells and potentially threaten the integrity of Gavins Point Dam. While a formal operational restriction is not recommended, releases from the Gavins Point spillway should be coordinated with Omaha District Dam Safety staff so that release does not compromise the integrity of the Lake Yankton Embankment. Integrity concerns for Lake Yankton Embankment could include scour due to high spillway releases, overtopping of the embankment or sudden drawdown stability concerns caused by significant reduction in spillway releases in a short time period. (ref. 8)

2. Point of contact for this memo is Wayne Boeck, Chief, Structural Section, (402) 995-2151, email Wayne.R.Boeck@usace.army.mil.

JOHN J. BERTINO, JR., P.E.
Chief, Engineering Division

Encl:
1. References

CF:
CEWNO-OD-GP (Becker)
CENWO-OD-FR (Curran)
CENWO-OD-BB
CENWO-OD-OA (Stasch)
CENWO-OD-GA (Lindquist)
CENWO-OD-FP (McMurry)

REFERENCES

1. *Missouri River Mainstem Dams, Spillway Gate Plan of Action*, Memorandum from CENWO-ED for CENWO-OD (10 March 2015)

2. *Overtopping of the Fort Peck Spillway Gates*, Memorandum from CENWO-ED-DA for CENWO-ED-G (22 December 1997)

3. *Design Report on Overtopping Tainter Gates/Oahe Tainter Gate Renovation* Memorandum from CEMRO-ED-DI for Commander, Missouri River Division)18 March 1994)

4. *Fort Peck Dam, Spillway Gate Operational Restrictions*, Memorandum from CENWO-ED for CENWO-OD (21 June 2016)

5. *Outlet Works Modifications, Fort Peck Dam, Major Rehabilitation Evaluation Report* (March 1994)

6. *Oahe Outlet Works Bridge Scour Monitoring Plan* ,CEBIS Bridge File (03 March 2012)

7. *Operation and Maintenance Manual, Garrison Dam,* Paragraph 5-04L *Regulating Gates and Associated Equipment* (1982)

8. *2011 Flood Surveillance and Assessment, Gavins Point Dam Missouri River* (March 2012)

Exhibit B

Emergency Regulation Procedures

for

Gavins Point Project

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, NORTHWESTERN DIVISION
1616 CAPITOL AVENUE
OMAHA NE 68102

REPLY TO
ATTENTION OF

CENWD-PDR (11-2-240a) 1 September 2017

MEMORANDUM FOR Gavins Point Operations Manager

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Gavins Point

1. Procedures applicable to the regulation of Gavins Point during any period that communication with the Missouri River Basin Water Management (MRBWM) Division or the Omaha District Water Control and Water Quality Section is not possible are outlined in the following paragraphs. These instructions supersede all previously furnished emergency regulation criteria.

2. Normally, reservoir regulation orders specifying future project releases and power production are furnished by the MRBWM office to Gavins Point. Gavins Point shall provide to the MRBWM project data such as observed reservoir elevations, releases, power generation and related hydrologic data.

3. The MRBWM office normally transmits the reservoir regulation orders via e-mail to Gavins Point on a daily basis. Regulation instructions for the weekend and holidays are contained in the previous normal working day's orders. Gavins Point utilizes the Power Plant Control System (PPCS) to transmit observed hourly and daily project data, via the Data Collection Platforms (DCPs) to the MRBWM office. If e-mail or network communication between the MRBWM office and Gavins Point is not available, an alternate means of communication and/or data transfer shall be used. Alternate means of communication includes facsimile (fax), land-line telephone, cellular telephone, relay of data by other Missouri River Mainstem project offices and utilization of Western Area Power Administration (Western) facilities.

4. When communication, as outlined in paragraph 3 above, cannot be established, the following will apply:

a. Every reasonable effort will be made to re-establish communication between Gavins Point and the MRBWM office.

b. During this initial period of communication failure, project personnel should note the reservoir elevations and releases on the latest regulation forecasts (three-week and monthly) if available. As long as reservoir elevations do not vary significantly from these regulation forecasts, the provision of the latest regulation order will be extended. If significant variations occur from the current forecasts, follow procedures as outlined in 4.c. and 4.d.

c. Following a communications failure, the provision of the latest regulation order will be extended. These procedures will continue to be utilized until communications are re-established as long as the Gavins Point reservoir level remains below elevation 1205.0 feet.

d. If the Gavins Point reservoir level is above elevation 1205.0 feet, procedures outlined in paragraph 4.b. will be applicable during the first day of communication failure, after which conditions will be reviewed to determine if the release level should be changed. Procedures are as follows:

(1) Minimum release will be the release specified in the most recent available regulation order.

(2) The mean inflow for the preceding 6 hours will be estimated by computing the storage change during the 6-hour period on the basis of pool elevations observed at the damsite. Normally, the pool elevation will follow a relatively smooth curve. Therefore, any sudden fluctuations in the pool level recorder trace from a smooth curve (probably due to wind effects on the reservoir gage) should be disregarded and the storage change based on an extrapolation of the smoothed pool level curve through the 6-hour period. The approximate mean inflow in cfs is equivalent to the mean outflow in cfs plus twice the storage change in acre-feet during the 6-hour period. Six-hour inflow may also be approximated by the equation:

Inflow = Outflow + (52,000 x elevation change in feet)

(3) With a rising reservoir level between elevation 1205.0 and 1212.0 feet.

(a) Utilizing the mean inflow for the past 6 hours as developed above and the current pool elevation (as indicated by the smoothed pool level curve), determine the rule curve release by use of the emergency curves shown on Plate VII-1 in the Gavins Point Water Control Manual and as Enclosure 1 to this document.

(b) If the rule curve release developed by (3)(a) is greater than the release given by (1), make release specified by the rule curve. If inflows are less than 50,000 cfs, the release should be per the last regulation order.

(4) With a reservoir level between elevation 1212.0 and 1213.0 feet, release inflows up to a maximum of full spillway capacity in order to prevent any further increase in the reservoir level. The minimum release in this range of elevations will be 100,000 cfs.

(5) With a reservoir level above elevation 1213.0 feet, release the full capacity of the Gavins Point spillway.

(6) With a reservoir level between elevations 1208.0 and 1212.0 feet and falling, continue the release rate occurring at the time the reservoir level crested, subject to a maximum release rate of 100,000 cfs.

(7) With a falling reservoir level below elevation 1208.0 feet, release as specified in the most recent available regulation order.

f. The analyses and release adjustments made necessary by these instructions during periods of communication failure should be made at intervals of six hours until such time communication with the MRBWM is re-established.

5. In the event of downstream flooding, as reported to or anticipated by the Gavins Point Operations Manager, during such time the Gavins Point elevation is below elevation 1208.0 feet, releases will be reduced as deemed necessary to alleviate these conditions. However, with the Gavins Point reservoir above elevation 1208.0 feet, releases will not be reduced below those levels defined by the preceding emergency instructions.

6. The foregoing procedures are not intended to relieve the Gavins Point Operations Manager of taking such additional measures believed necessary to assure the safety of the project.

// signed copy on file

JODY S. FARHAT, P.E.
Chief, Missouri River Basin
Water Management Division

Encl

Gavins Point Dam – Lewis & Clark Lake

Water Control Manual

Plates

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 245,000 acres	1854 msl 383,000 acres	1620 msl 386,000 acres
27	Max. normal op. pool elev. & area	2246 msl 240,000 acres	1850 msl 365,000 acres	1617 msl 362,000 acres
28	Base flood control elev & area	2234 msl 211,000 acres	1837.5 msl 308,000 acres	1607.5 msl 311,000 acres
29	Min. operating pool elev. & area	2160 msl 89,000 acres	1775 msl 125,000 acres	1540 msl 115,000 acres
	Storage allocation & capacity			
30	Exclusive flood control	2250-2246 971,000 a.f.	1854-1850 1,495,000 a.f.	1620-1617 1,107,000 a.f.
31	Flood control & multiple use	2246-2234 2,704,000 a.f.	1850-1837.5 4,211,000 a.f.	1617-1607.5 3,208,000 a.f.
32	Carryover multiple use	2234-2160 10,700,000 a.f.	1837.5-1775 12,951,000 a.f.	1607.5-1540 13,353,000 a.f.
33	Permanent	2160-2030 4,088,000 a.f.	1775-1673 4,794,000 a.f.	1540-1415 5,315,000 a.f.
34	Gross	2250-2030 18,463,000 a.f.	1854-1673 23,451,000 a.f.	1620-1415 22,983,000 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	17,200 a.f./year 1073 yrs.	21,600 a.f./year 1,086 yrs.	14,800 a.f./year 1553 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	1669-1677 15,000- 60,000 cfs	1422-1427 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., 24' 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)	1,035	2,254	2,622
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 29,000 acres	1,206,000 acres	26
1422 msl 60,000 acres	1365 msl 94,000 acres	1208 msl 25,000 acres	1,146,000 acres	27
1420 msl 57,000 acres	1350 msl 76,000 acres	1204.5 msl 21,000 acres	984,000 acres	28
1415 msl 51,000 acres	1320 msl 36,000 acres	1204.5 msl 21,000 acres	437,000 acres	29
1423-1422 61,000 a.f.	1375-1365 986,000 a.f.	1210-1208 54,000 a.f.	4,674,000 a.f.	30
1422-1420 118,000 a.f.	1365-1350 1,306,000 a.f.	1208-1204.5 79,000 a.f.	11,626,000 a.f.	31
	1350-1320 1,532,000 a.f.		38,536,000 a.f.	32
1420-1345 1,631,000 a.f.	1320-1240 1,469,000 a.f.	1204.5-1160 295,000 a.f.	17,592,000 a.f.	33
1423-1345 1,810,000 a.f.	1375-1240 5,293,000 a.f.	1210-1160 428,000 a.f.	72,428,000 a.f.	34
November 1963	January 1953	August 1955		35
25 March 1964	24 November 1953	22 December 1955		36
5,300 a.f./year 430 yrs.	15,800 a.f./year 334 yrs.	2,700 a.f./year 159 yrs.	77,400	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			43
1351-1355(10) 25,000-100,000 cfs	32,000 cfs - 128,000 cfs 1228-1237 10,000-60,000 cfs	1153-1161 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
980	1,726	725	9,342 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

(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) 1967-2015 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
August 2016

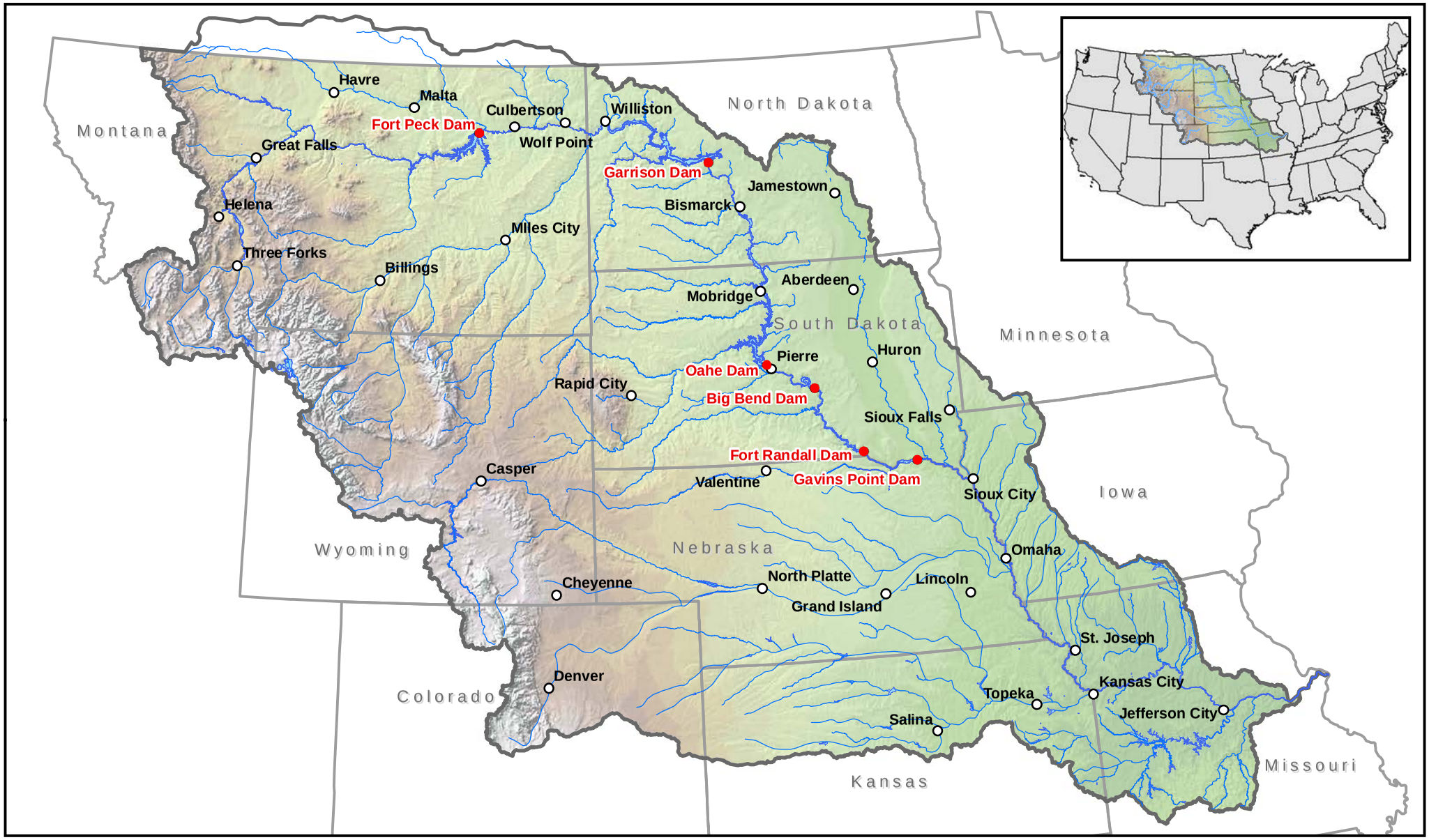

Plate III-1

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Omaha/Kansas City District Boundaries
State Boundaries

0 50 100 200 300 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
GENERAL LOCATION
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

River	Drainage Area (sq.mi.)
Niobrara River	11580
Ponca Creek	810
Choteau Creek	620
Bazile Creek	450
Emanuel Creek	180
Other	2360
Total	16000

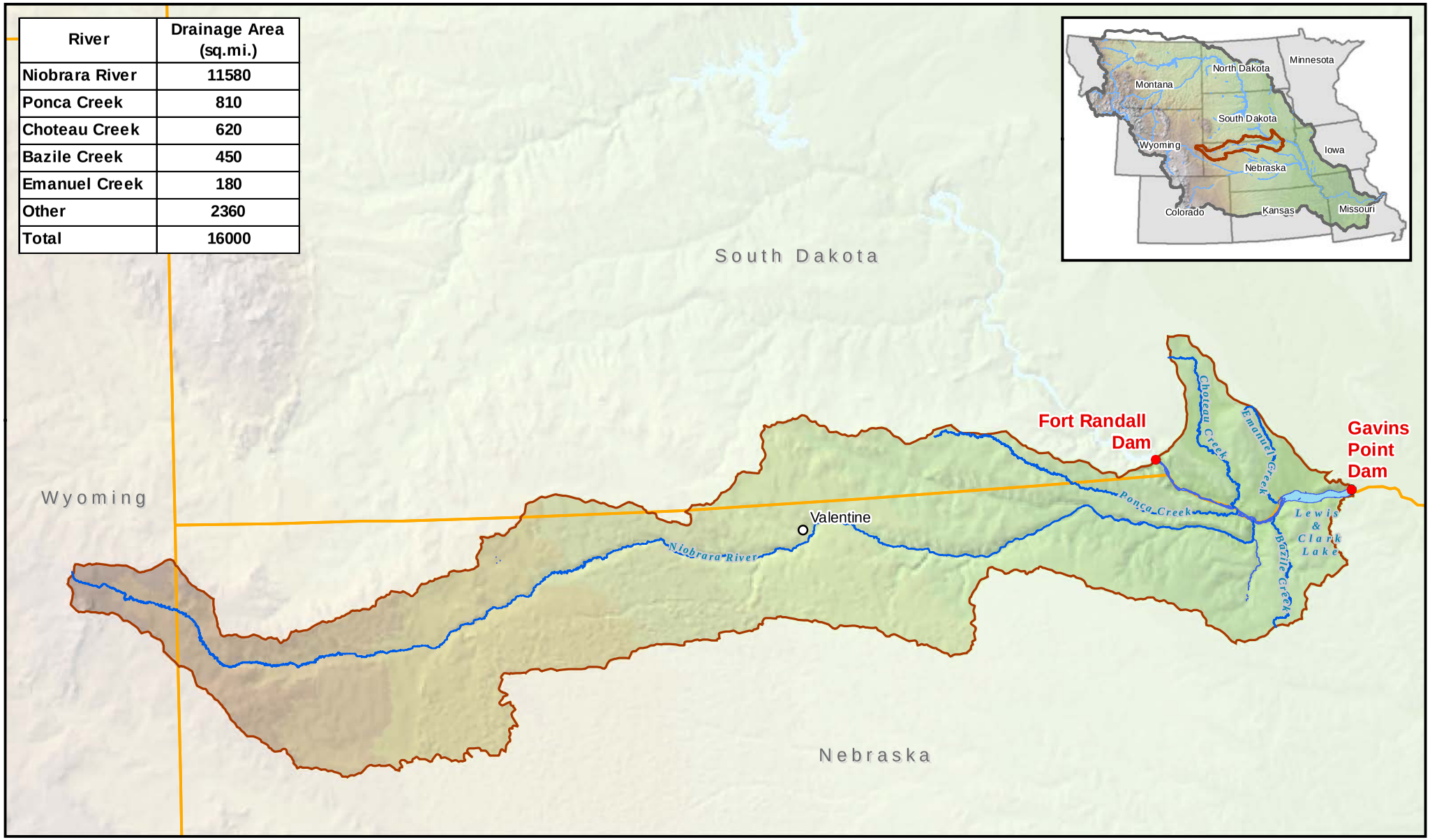

Plate III-2

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Gavins Point Drainage Area
Omaha/Kansas City District Boundaries
State Boundaries

0 20 40 80 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

N W E S

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Missouri River Basin
GAVINS POINT DRAINAGE AREA
INCREMENTAL DRAINAGE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

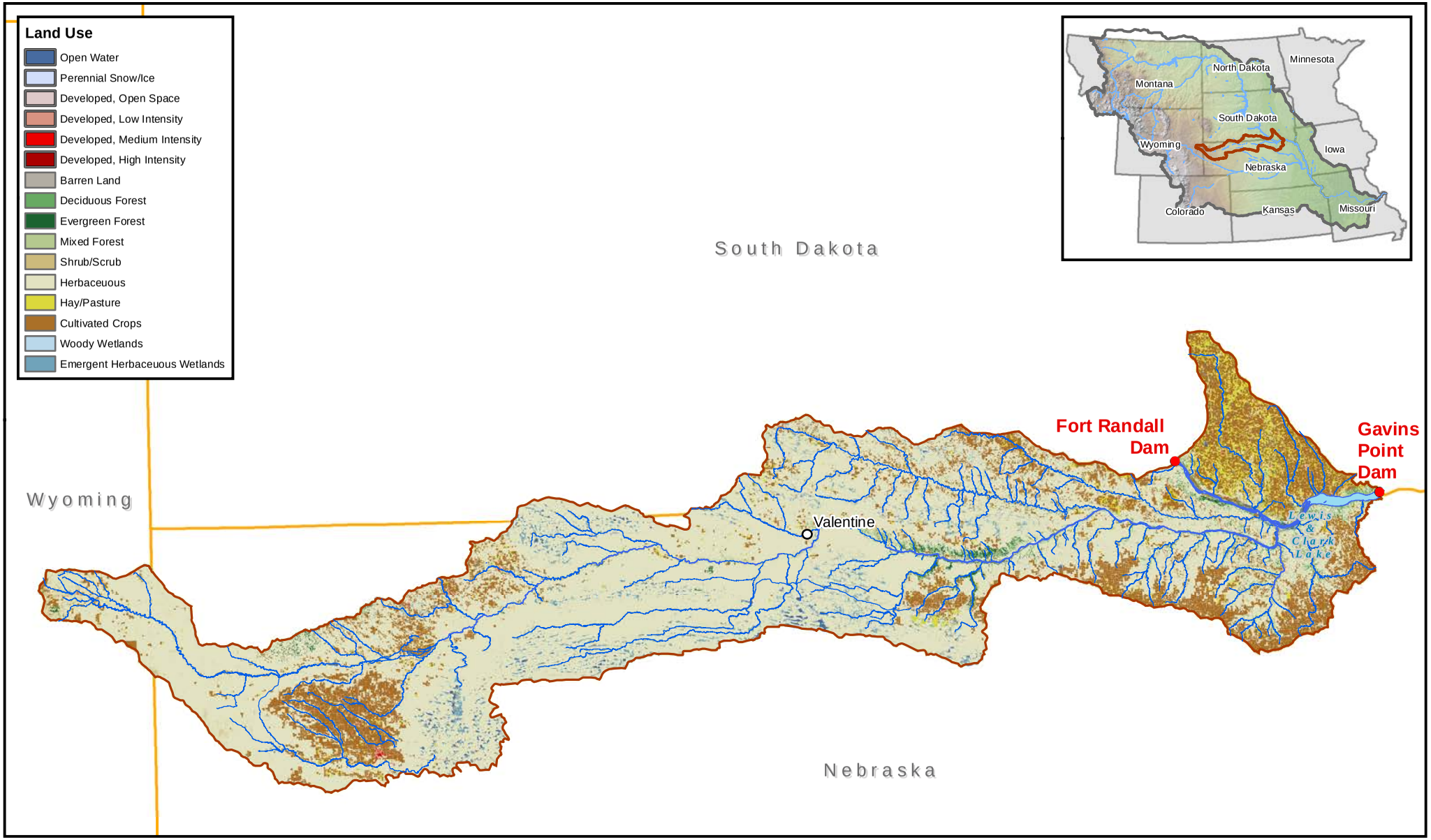

Plate III-3

US Army Corps of Engineers®
Northwestern Division

- Mainstem Dam
- Cities
- Rivers
- Reservoirs/Lakes
- Omaha/Kansas City District Boundaries
- Gavins Point Drainage Area
- State Boundaries

0 20 40 80 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

N W E S

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Missouri River Basin
GAVINS POINT DRAINAGE AREA
LAND USE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate III-4

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Omaha/Kansas City District Boundaries
State Boundaries

Average Precipitation - Annual
< 8.0"
8.0" - 20.0"
20.0" - 40.0"
40.0" - 60.0"
> 60.0"

0 50 100 200 300 Miles

Data Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
AVERAGE PRECIPITATION
ANNUAL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

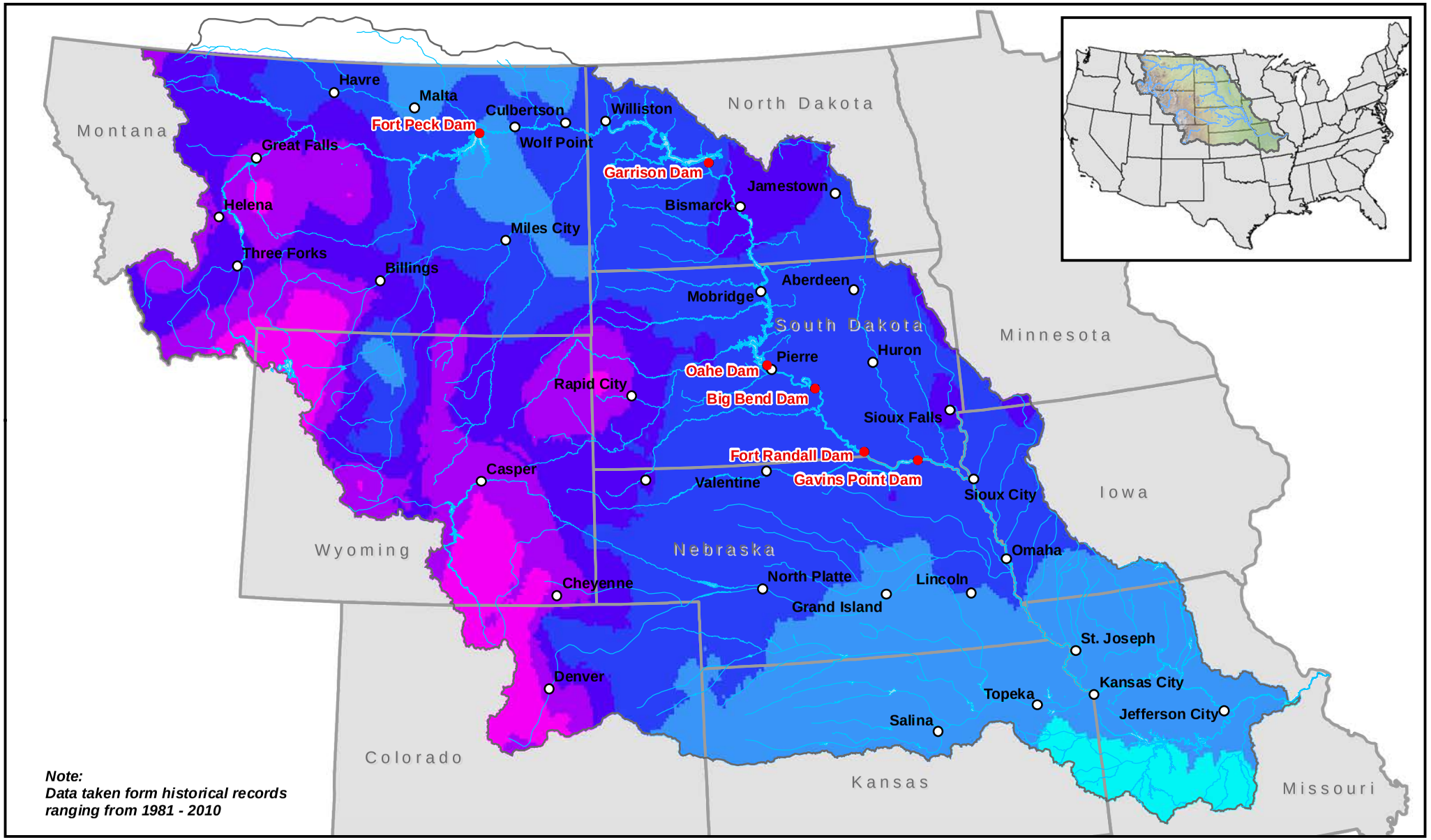

Plate III-5

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Omaha/Kansas City District Boundaries
State Boundaries

Annual Mean Snowfall
< 12 Inches
12 - 24 Inches
24 - 36 Inches
36 - 48 Inches
48 - 72 Inches
> 72 Inches

0 50 100 200 300 Miles

Data Source:
http://scacis.rcc-acis.org

N W E S

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Missouri River Basin
ANNUAL MEAN SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

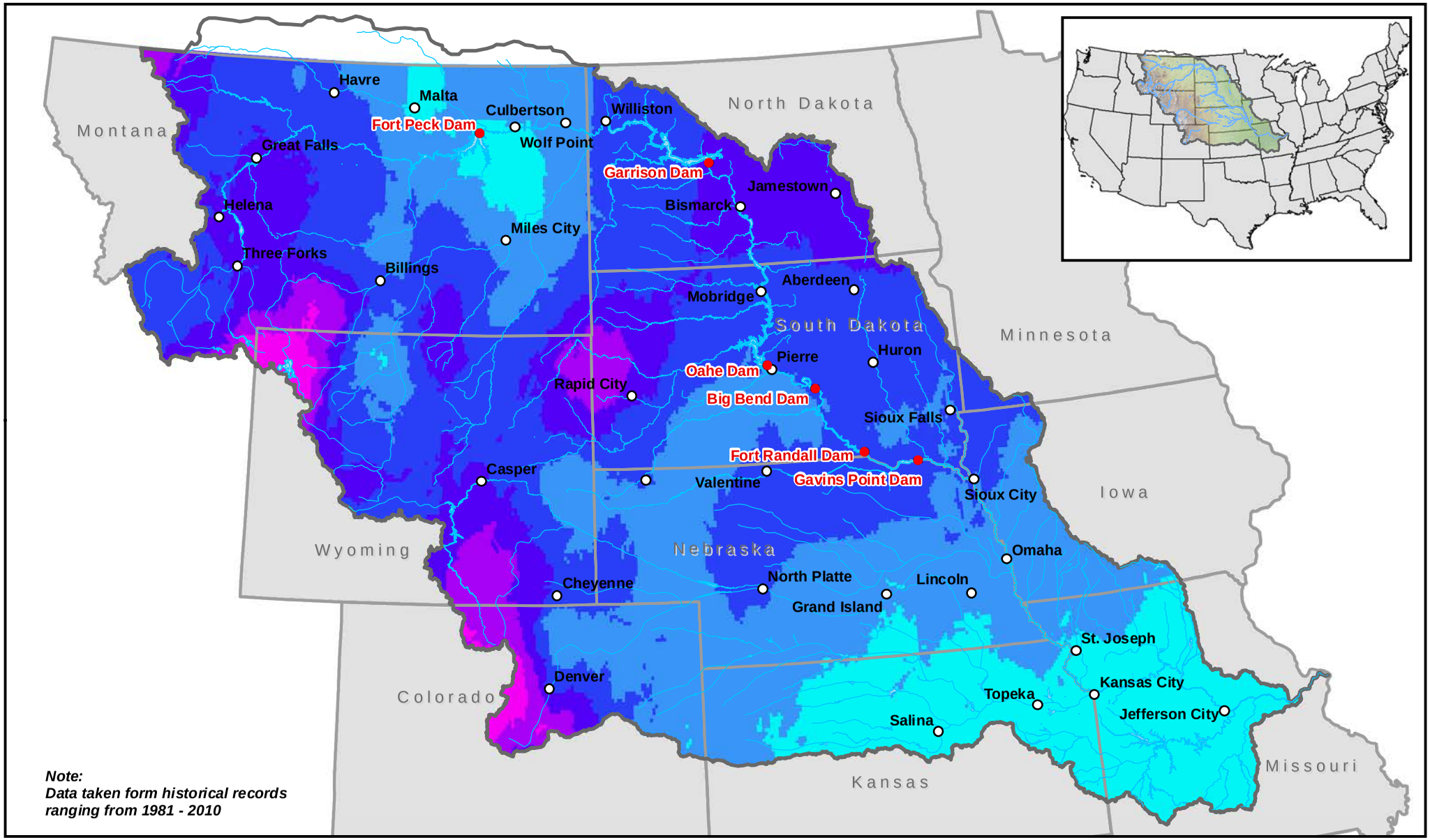

Plate III-6

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Omaha/Kansas City District Boundaries
State Boundaries

Annual Maximum Snowfall
< 40 Inches
40 - 60 Inches
60 - 80 Inches
80 - 110 Inches
110 - 150 Inches
> 150 Inches

0 50 100 200 300 Miles

Data Source:
http://scacis.rcc-acis.org

N W E S

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Missouri River Basin
ANNUAL MAXIMUM SNOWFALL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

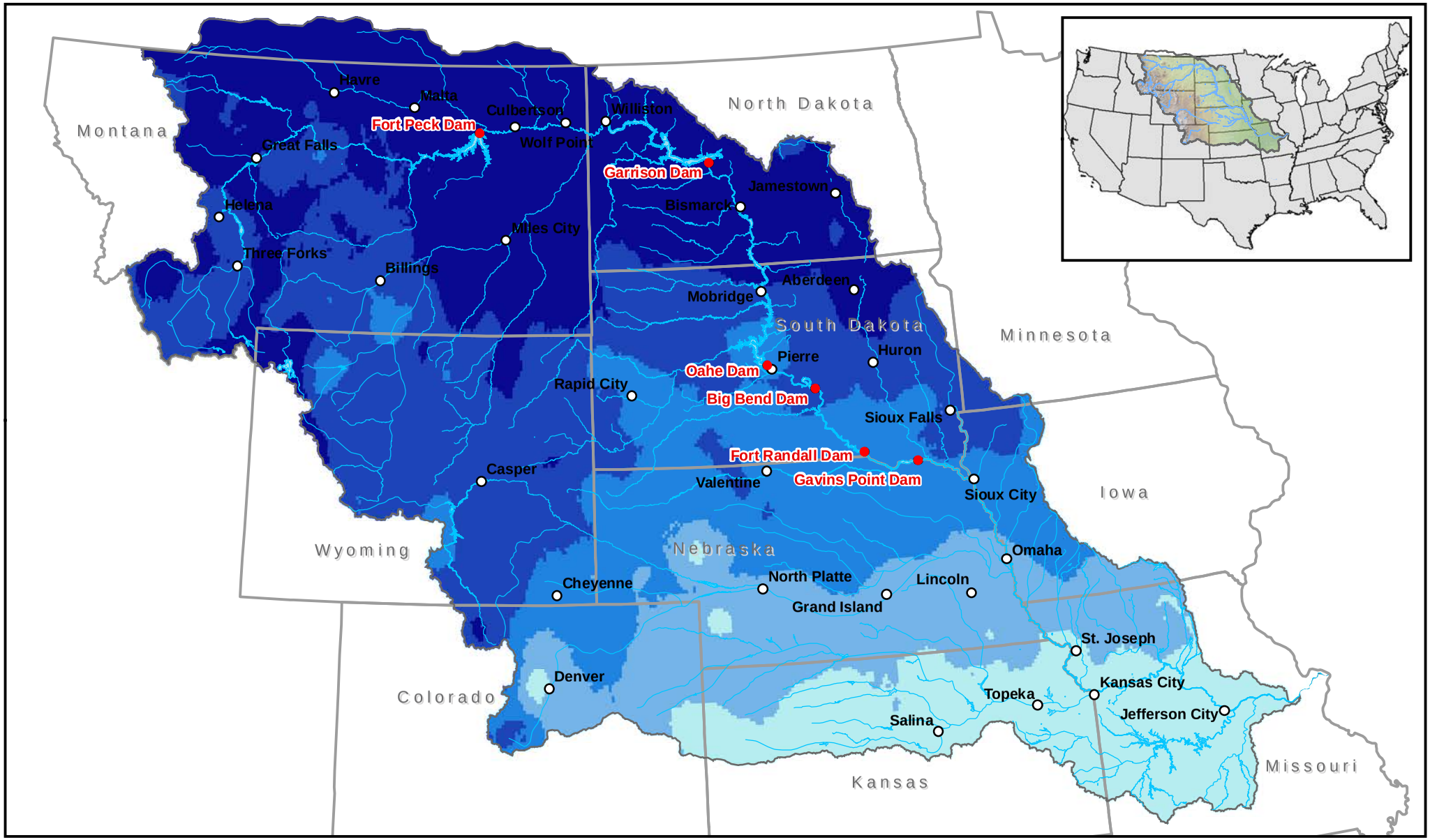

Plate III-7

US Army Corps of Engineers®
Northwestern Division

Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Omaha/Kansas City District Boundaries
State Boundaries

Average Minimum Temperature
-36°F to -25°F
-25°F to -20°F
-20°F to -15°F
-15°F to -10°F
-10°F to 2.6°F

0 50 100 200 300 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
AVERAGE MINIMUM TEMPERATURE
ANNUAL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

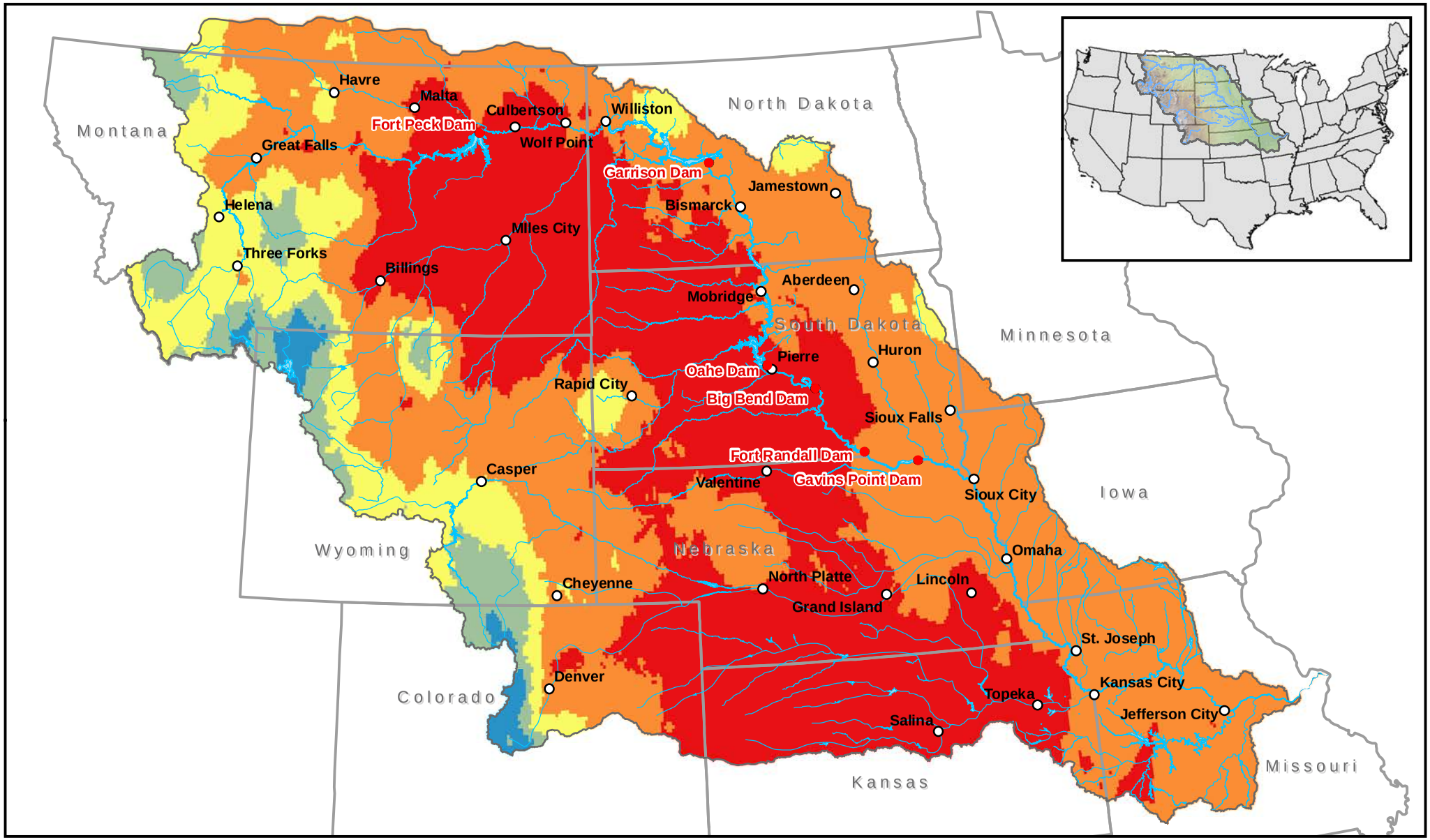

Plate III-8

US Army Corps of Engineers®
Northwestern Division

- Mainstem Dam
- Cities
- Rivers
- Reservoirs/Lakes
- Omaha/Kansas City District Boundaries
- State Boundaries

Average Maximum Temperature

- 78°F - 85°F
- 85°F - 90°F
- 90°F - 95°F
- 95°F - 100°F
- 100°F - 105.5°F

0 50 100 200 300 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
AVERAGE MAXIMUM TEMPERATURE
ANNUAL
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Missouri River Mainstem Reservoir System

Normal Monthly Pan Evaporation
Inches of Depth

Month	Missouri River Mainstem Project					
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
January	0.62	0.51	1.02	0.80	1.02	0.74
February	0.74	0.58	1.14	0.98	1.16	0.91
March	1.68	1.42	2.24	1.97	2.31	1.91
April	3.50	2.79	4.70	4.48	4.27	4.19
May	6.96	6.35	7.80	7.83	6.74	7.30
June	8.05	7.07	8.51	8.47	7.54	8.30
July	10.45	8.97	10.74	10.85	9.00	9.64
August	10.22	8.56	10.44	10.31	8.13	8.41
September	5.97	6.63	7.25	7.26	5.07	5.57
October	4.03	4.07	4.92	4.06	4.42	4.46
November	1.96	1.38	2.25	1.83	2.34	1.79
December	0.83	0.70	1.19	1.04	1.24	0.87
Annual	55.01	49.03	62.20	59.88	53.24	54.09

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 9.

Normal values in the above table were defined by all available pan data through the years 1963-1972. During months pan data were not available, pan depths were computed by a mass-transfer equation assuming pan water temperature to be equivalent to air temperature. Values given are for current pan installations and include depths for Oahe and Big Bend, which are believed to be unrepresentative. Adjustments for Oahe and Big Bend are accounted for in the lake evaporation coefficients table (Plate III-10).

Missouri River Basin
Gavins Point Water Control Manual
Normal Monthly Pan Evaporation in Inches

U.S. ARMY ENGINEER DIVISION,
NORTHWESTERN CORPS OF ENGINEERS,
OMAHA, NEBRASKA
September 2017

Missouri River Mainstem Reservoir System

Normal Pan to Lake Evaporation Coefficients

Month	Missouri River Mainstem Project					
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
January	1.28	0.70	0.73	0.63	0.70	0.70
February	0.70	0.70	0.56	0.63	0.70	0.70
March	0.60	0.70	0.49	0.54	0.63	0.62
April	0.11	0.14	0.13	0.47	0.19	0.53
May	0.22	0.20	0.16	0.35	0.32	0.53
June	0.32	0.21	0.18	0.39	0.37	0.53
July	0.39	0.26	0.22	0.53	0.42	0.56
August	0.64	0.64	0.50	0.70	0.78	0.70
September	1.21	1.13	0.89	0.82	1.31	0.93
October	1.32	1.44	1.19	1.05	1.42	0.97
November	2.57	3.74	2.22	1.52	1.62	1.59
December	4.22	5.04	3.42	1.36	1.39	1.57

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 11.

These coefficients are applicable to the pan installations currently in operation in conjunction with the projects. They make allowances for the fact that the Oahe and Big Bend installations are not considered to be representative installations. If pan evaporation is available, lake evaporation depths are estimated by application of the above coefficients.

For example: Garrison, May = 6.35 in (Plate III-9) x 0.20 (Plate III-10) = 1.27 in (Plate III-11).

Missouri River Basin
Gavins Point Water Control Manual
Pan to Lake Evaporation Coefficients

U.S. ARMY ENGINEER DIVISION,
NORTHWESTERN CORPS OF ENGINEERS,
OMAHA, NEBRASKA
September 2017

Missouri River Mainstem Reservoir System

Normal Monthly Lake Evaporation
Inches of Depth

Month	Missouri River Mainstem Project					
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
January	0.79	0.36	0.74	0.50	0.71	0.52
February	0.52	0.41	0.64	0.62	0.81	0.64
March	1.01	0.99	1.10	1.06	1.46	1.18
April	0.38	0.39	0.61	2.11	0.81	2.22
May	1.53	1.27	1.25	2.74	2.16	3.87
June	2.58	1.48	1.53	3.30	2.79	4.40
July	4.08	2.33	2.36	5.75	3.78	5.41
August	6.54	5.48	5.22	7.22	6.34	5.89
September	7.22	7.49	6.45	5.95	6.64	5.18
October	5.32	5.86	5.85	4.26	6.28	4.33
November	5.04	5.16	5.00	2.78	3.79	2.85
December	3.50	3.53	4.07	1.41	1.72	1.37
Annual	38.51	34.75	34.82	37.70	37.29	37.85

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 12.

Normal depths for each project as shown above were developed by application of the normal pan to lake coefficients in Figure 11 (Plate III-10) to the normal monthly pan evaporation as shown on Figure 9 (Plate III-9).

Missouri River Basin
Gavins Point Water Control Manual
Normal Monthly Lake Evaporation in Inches

U.S. ARMY ENGINEER DIVISION,
NORTHWESTERN CORPS OF ENGINEERS,
OMAHA, NEBRASKA
September 2017

Missouri River Mainstem Reservoir System

Normal Monthly Lake Evaporation in 1000 Acre-Feet

Month	Missouri River Mainstem Project						System
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point	
January	14	9	19	2	5	1	50
February	9	11	17	3	5	1	46
March	18	26	29	5	10	3	91
April	7	10	16	10	5	5	53
May	27	33	33	13	14	8	128
June	46	39	40	16	19	10	170
July	73	61	62	27	25	12	260
August	117	144	136	34	42	13	486
September	129	167	168	28	44	11	547
October	95	154	153	20	42	9	473
November	90	135	130	13	25	6	399
December	63	93	106	7	11	3	283
Annual	688	882	909	178	247	82	2,986

Source: Missouri River Mainstem Reservoir Evaporation Estimates, MRD-RCC Technical Report JE-73, June 1973, Figure 13.

Volumes computed by assuming that each reservoir was at the base of its flood control pool.

Missouri River Basin
Gavins Point Water Control Manual
Normal Monthly Lake Evaporation in 1000 AF

U.S. ARMY ENGINEER DIVISION,
NORTHWESTERN CORPS OF ENGINEERS,
OMAHA, NEBRASKA
September 2017

Monthly Runoff - Missouri River Basin Upstream of Gavins Point Dam
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development

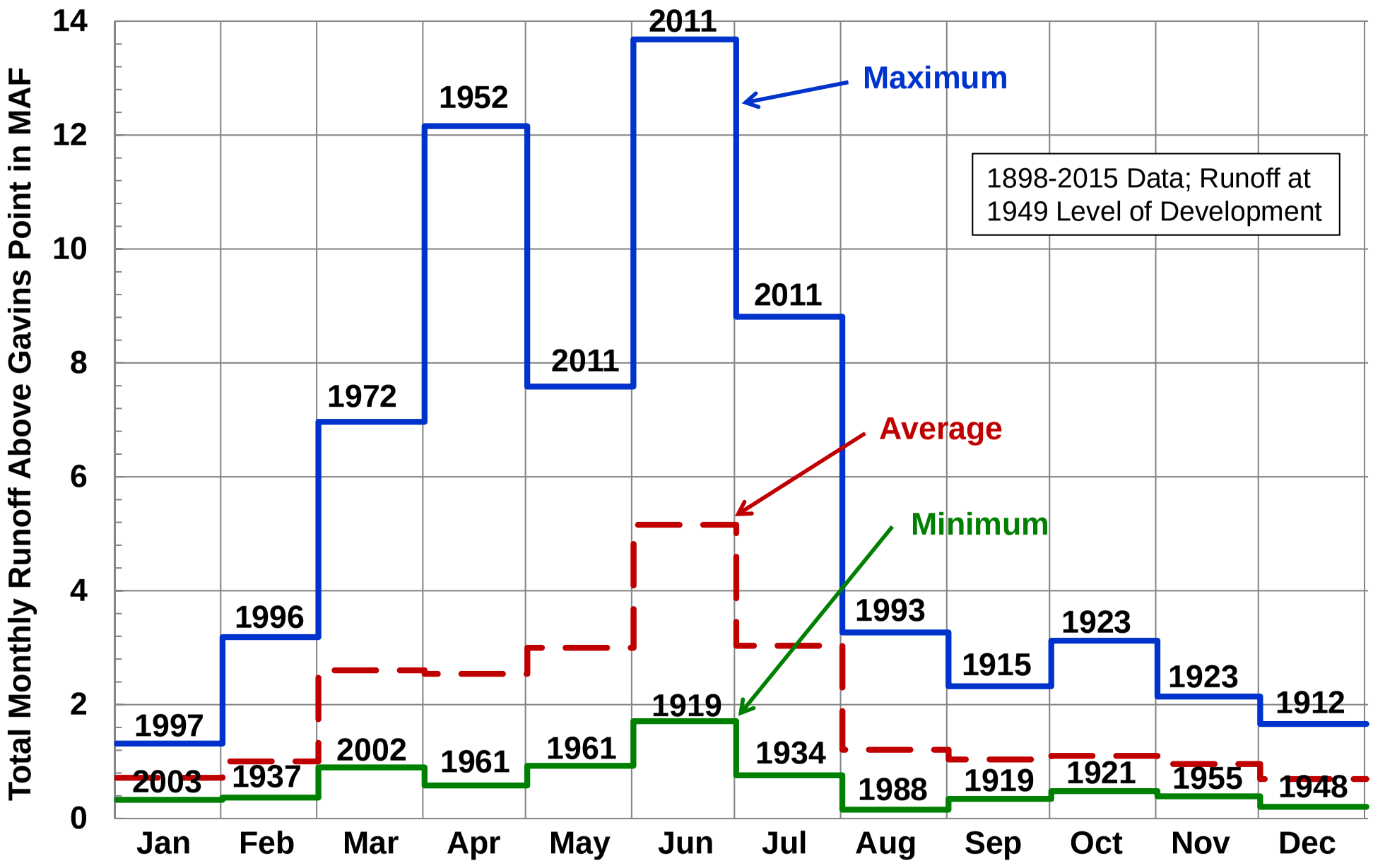
	Runoff in 1,000 acre-feet												Annual	Mar-Jul
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1898	487	781	2,296	2,712	4,181	7,702	3,835	1,041	983	970	977	582	26,547	20,726
1899	593	655	2,643	4,735	3,398	7,576	6,253	1,442	1,120	892	1,009	540	30,856	24,605
1900	570	853	3,011	2,314	3,703	4,912	1,687	602	897	1,009	821	548	20,927	15,627
1901	573	661	2,329	1,595	4,842	5,106	2,293	730	1,545	1,064	764	577	22,079	16,165
1902	591	768	2,831	1,309	2,664	4,530	2,269	846	1,248	999	910	539	19,504	13,603
1903	567	877	2,172	2,131	2,150	4,959	3,166	1,267	1,832	1,343	958	672	22,094	14,578
1904	681	922	2,093	2,539	3,566	6,393	3,377	1,209	1,143	853	763	473	24,012	17,968
1905	488	766	2,298	1,249	1,783	4,884	2,996	966	766	577	698	635	18,106	13,210
1906	565	677	2,248	2,239	3,323	6,244	2,800	1,388	2,256	1,500	1,219	858	25,317	16,854
1907	872	816	2,350	1,862	3,327	7,219	7,135	2,290	1,417	1,732	1,545	861	31,426	21,893
1908	782	946	2,483	2,206	3,121	8,944	4,975	1,728	1,164	1,176	1,291	1,229	30,045	21,729
1909	861	1,033	2,360	1,973	3,590	9,581	5,311	1,812	1,678	1,212	1,025	652	31,088	22,815
1910	673	903	3,199	2,806	3,978	4,108	1,915	977	761	877	779	487	21,463	16,006
1911	496	665	1,796	1,537	2,014	5,947	2,854	1,468	2,057	1,519	928	753	22,034	14,148
1912	778	758	2,575	3,998	3,520	6,071	4,386	2,053	2,259	1,925	1,735	1,662	31,720	20,550
1913	1,079	710	1,586	2,712	3,313	6,950	3,251	1,796	1,763	1,461	1,466	1,275	27,362	17,812
1914	886	865	2,399	2,361	3,900	6,566	2,374	978	1,434	1,497	1,912	1,045	26,217	17,600
1915	1,067	1,097	2,719	2,519	2,967	6,191	4,308	1,904	2,323	2,117	1,531	953	29,696	18,704
1916	775	1,095	4,354	2,408	3,114	6,738	5,646	1,765	1,168	1,354	1,365	775	30,557	22,260
1917	787	918	2,810	4,202	4,308	7,564	5,165	1,359	1,426	1,372	1,378	784	32,073	24,049
1918	789	942	3,154	2,838	2,845	6,736	3,221	1,422	1,247	665	770	378	25,007	18,794
1919	1,185	886	2,018	2,051	1,964	1,710	791	406	345	509	419	451	12,735	8,534
1920	473	925	3,323	2,642	4,090	6,776	3,758	1,215	869	725	734	859	26,389	20,589
1921	579	852	2,485	1,967	2,949	6,753	2,461	793	780	483	586	489	21,177	16,615
1922	498	949	2,722	2,221	3,668	6,762	2,588	1,077	877	720	900	454	23,436	17,961
1923	476	819	2,243	2,704	2,940	5,243	4,827	1,523	1,441	3,123	2,143	1,365	28,847	17,957
1924	980	1,490	2,595	3,831	3,726	4,711	2,472	950	898	1,294	1,395	799	25,141	17,335
1925	802	1,468	2,595	2,755	3,414	6,630	3,417	1,259	892	1,188	1,089	693	26,202	18,811
1926	696	1,164	2,029	2,156	3,665	3,447	2,433	1,146	1,679	1,452	1,061	573	21,501	13,730
1927	583	1,108	3,686	3,555	5,134	9,256	4,508	2,145	2,020	1,569	1,070	782	35,416	26,139
1928	786	1,120	3,426	2,275	5,072	6,064	4,968	1,537	1,241	1,000	1,041	594	29,124	21,805
1929	572	636	3,575	2,447	2,956	4,842	2,631	820	752	963	761	461	21,416	16,451
1930	538	1,128	2,940	2,626	2,316	2,568	1,193	1,295	950	1,088	711	450	17,803	11,643
1931	547	984	1,045	1,099	1,249	2,048	811	674	527	650	480	438	10,552	6,252
1932	401	561	1,505	2,338	2,900	5,381	1,874	1,222	775	783	517	293	18,550	13,998
1933	601	489	2,376	1,434	3,483	4,332	1,338	935	979	752	835	369	17,923	12,963
1934	724	648	1,672	1,380	1,608	1,766	760	482	439	591	607	286	10,963	7,186
1935	330	687	972	1,489	1,587	4,112	2,360	660	567	561	405	393	14,123	10,520
1936	433	428	2,634	1,787	2,027	2,285	917	687	557	710	698	492	13,655	9,650
1937	381	369	1,240	1,431	1,273	3,875	2,053	685	512	718	439	380	13,356	9,872

Monthly Runoff - Missouri River Basin Upstream of Gavins Point Dam
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development

	Runoff in 1,000 acre-feet												Annual	Mar-Jul
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1938	517	488	2,265	1,222	2,123	5,328	3,697	821	922	804	563	308	19,058	14,635
1939	746	438	4,523	706	2,358	3,396	1,269	680	569	741	676	571	16,673	12,252
1940	394	529	911	1,682	1,803	2,391	927	461	551	930	448	712	11,739	7,714
1941	553	577	1,034	1,515	1,350	3,925	1,188	923	1,422	1,625	1,093	785	15,990	9,012
1942	611	702	1,849	2,325	5,714	6,121	2,421	1,083	753	898	866	656	23,999	18,430
1943	746	1,708	3,725	5,401	2,597	7,712	4,181	1,416	946	1,007	1,124	420	30,983	23,616
1944	730	738	1,910	4,569	2,380	8,093	3,739	1,370	898	922	1,065	328	26,742	20,691
1945	673	1,261	4,046	1,473	1,583	4,214	2,941	1,309	829	1,027	823	624	20,803	14,257
1946	905	933	2,152	1,459	2,098	3,776	2,477	820	1,141	1,450	999	722	18,932	11,962
1947	804	1,160	3,932	3,518	3,467	6,251	2,941	1,218	942	1,243	741	542	26,759	20,109
1948	786	865	2,766	3,569	3,321	7,371	3,312	1,318	651	916	907	206	25,988	20,339
1949	616	671	4,216	4,181	2,848	3,397	1,567	616	674	1,043	1,104	407	21,340	16,209
1950	498	723	2,332	7,670	2,935	4,364	3,389	1,643	1,193	1,457	751	881	27,836	20,690
1951	961	801	1,890	4,330	3,013	4,442	2,874	1,960	1,803	1,665	1,095	444	25,278	16,549
1952	838	1,347	2,283	12,159	4,373	3,891	2,278	1,124	772	786	729	446	31,026	24,984
1953	757	924	2,440	1,511	2,792	8,362	2,617	1,282	741	912	1,022	628	23,988	17,722
1954	587	1,381	1,420	2,127	2,135	3,085	2,403	1,243	941	953	1,048	580	17,903	11,170
1955	346	582	1,688	2,595	2,320	3,300	2,281	831	610	794	392	810	16,549	12,184
1956	870	693	2,220	2,106	2,311	4,732	1,889	1,086	766	775	1,090	584	19,122	13,258
1957	471	673	1,721	1,651	3,106	5,586	3,151	882	982	1,057	1,252	871	21,403	15,215
1958	522	636	1,599	2,067	2,048	3,655	2,236	853	686	887	816	674	16,679	11,605
1959	648	653	3,752	1,712	1,818	3,599	2,416	763	791	1,215	829	1,359	19,555	13,297
1960	602	969	3,922	3,422	2,004	2,419	870	686	591	712	720	340	17,257	12,637
1961	677	816	1,272	581	927	2,642	762	506	817	977	1,062	228	11,267	6,184
1962	611	1,190	1,836	2,371	3,715	6,885	4,474	1,573	947	1,115	946	610	26,273	19,281
1963	524	1,531	2,040	1,310	2,168	5,597	2,611	910	973	939	676	516	19,795	13,726
1964	768	828	954	1,547	3,088	7,175	4,362	966	1,012	879	760	639	22,978	17,126
1965	1,085	1,105	1,342	3,822	4,433	6,135	5,486	1,842	1,478	1,581	1,190	1,027	30,526	21,218
1966	678	916	4,090	2,117	1,899	2,367	1,870	904	885	810	949	714	18,199	12,343
1967	638	1,139	2,618	2,440	3,295	9,442	5,193	1,237	1,207	1,164	1,286	440	30,099	22,988
1968	951	1,093	2,407	1,661	1,772	5,657	3,297	1,661	1,693	1,325	1,330	659	23,506	14,794
1969	974	946	3,400	5,122	3,398	3,447	4,796	1,283	927	1,059	1,186	728	27,266	20,163
1970	537	1,067	1,547	2,552	5,018	6,207	3,701	1,182	1,169	1,254	1,096	778	26,108	19,025
1971	779	2,336	3,890	3,592	3,561	6,444	3,983	1,456	1,481	1,866	1,372	822	31,582	21,470
1972	807	1,285	6,966	1,977	3,845	6,213	2,891	1,951	1,352	1,370	1,542	832	31,031	21,892
1973	1,178	1,196	2,491	1,621	3,032	3,585	1,971	1,060	1,575	1,366	1,096	981	21,152	12,700
1974	1,041	1,284	1,657	2,160	2,755	5,773	3,856	1,520	1,220	1,044	1,161	997	24,468	16,201
1975	456	689	1,815	4,070	6,891	6,794	6,924	2,179	1,274	1,371	1,195	1,334	34,992	26,494
1976	1,037	1,752	2,547	2,204	4,062	5,478	3,489	1,716	1,302	1,171	1,028	874	26,660	17,780
1977	581	1,036	1,790	1,641	1,979	2,338	1,088	735	1,208	1,212	648	811	15,067	8,836

Monthly Runoff - Missouri River Basin Upstream of Gavins Point Dam
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development

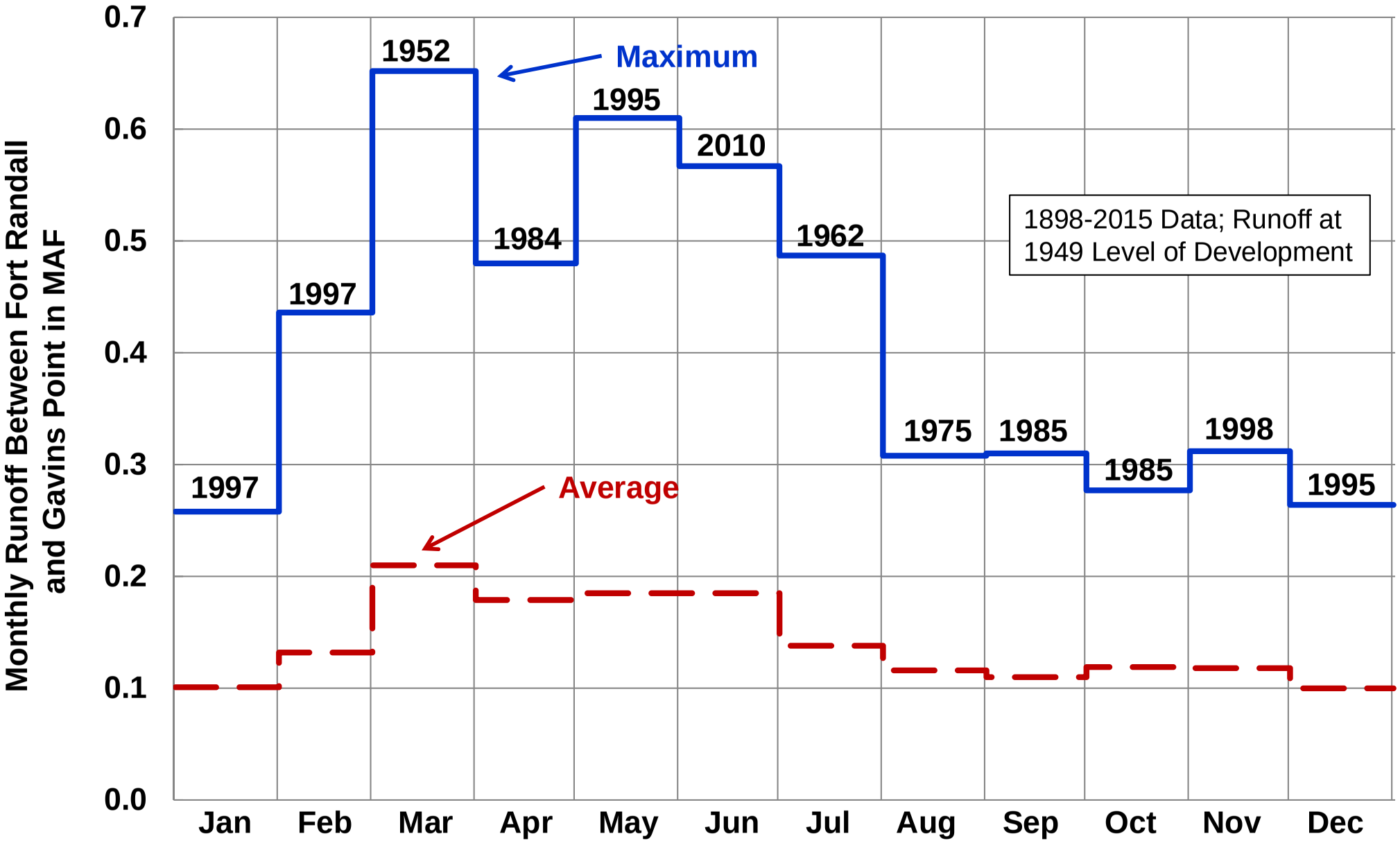
	Runoff in 1,000 acre-feet												Annual	Mar-Jul
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Total**
1978	631	833	6,679	6,182	5,736	5,772	5,087	1,813	2,034	1,257	782	1,035	37,841	29,456
1979	738	822	4,061	5,680	3,320	3,788	2,314	1,145	1,113	639	906	699	25,225	19,163
1980	354	752	1,549	1,630	2,148	3,864	1,778	722	932	1,320	1,043	633	16,725	10,969
1981	1,025	864	1,329	809	2,602	5,453	2,078	1,033	508	1,006	1,138	698	18,543	12,271
1982	403	1,474	2,907	4,080	4,165	5,934	4,964	1,753	1,152	1,999	1,174	1,110	31,115	22,050
1983	1,092	1,466	2,496	1,573	2,668	4,079	3,511	1,180	748	1,292	1,239	466	21,810	14,327
1984	1,174	1,679	2,036	2,139	3,260	5,270	2,940	1,226	677	1,143	1,003	606	23,153	15,645
1985	1,003	839	2,561	1,777	1,643	1,964	904	1,136	943	1,489	856	935	16,050	8,849
1986	1,124	1,001	5,962	2,958	4,469	5,256	2,568	879	1,961	2,068	1,031	1,088	30,365	21,213
1987	750	1,233	4,246	2,976	2,072	2,219	1,288	1,162	1,027	805	902	610	19,290	12,801
1988	405	878	1,693	1,104	2,142	1,907	950	157	355	576	701	570	11,438	7,796
1989	418	544	2,273	2,259	2,780	2,772	1,703	784	938	895	1,105	523	16,994	11,787
1990	1,090	786	1,687	1,332	1,996	3,207	2,246	964	706	707	1,031	262	16,014	10,468
1991	713	885	1,334	1,151	3,206	6,755	3,032	747	893	791	1,104	818	21,429	15,478
1992	678	991	1,358	929	1,290	2,144	2,757	1,082	633	902	1,030	265	14,059	8,478
1993	620	877	2,959	1,905	2,975	4,581	5,648	3,269	1,339	1,206	1,156	1,135	27,670	18,068
1994	833	1,020	4,945	1,841	3,156	2,752	1,313	527	616	1,129	741	844	19,717	14,007
1995	692	1,430	2,760	2,566	5,462	6,613	4,661	1,335	921	1,262	1,303	1,161	30,166	22,062
1996	914	3,188	3,941	3,485	3,763	7,373	3,351	1,033	1,023	1,092	1,152	1,135	31,450	21,913
1997	1,319	2,769	6,461	6,240	4,740	8,931	4,790	2,302	1,333	1,052	1,133	1,320	42,390	31,162
1998	521	1,602	1,824	2,117	2,138	3,926	4,550	1,795	956	1,742	1,407	834	23,412	14,555
1999	1,164	1,526	3,212	2,230	4,102	5,768	3,721	1,310	1,237	991	833	887	26,981	19,033
2000	537	1,045	1,704	1,489	1,757	3,052	1,933	581	468	839	786	531	14,722	9,935
2001	1,031	752	3,269	2,530	1,578	2,394	2,002	799	411	519	598	601	16,484	11,773
2002	611	698	900	1,416	1,213	3,485	2,080	824	604	617	692	545	13,685	9,094
2003	329	868	2,614	1,521	2,042	3,835	1,789	660	404	600	402	665	15,729	11,801
2004	400	765	2,174	1,209	976	2,479	1,950	878	789	840	817	407	13,684	8,788
2005	546	1,009	1,113	975	2,363	4,516	2,954	853	496	863	736	393	16,817	11,921
2006	1,189	599	1,252	1,953	2,094	3,308	1,443	673	444	848	753	522	15,078	10,050
2007	487	885	2,228	1,522	2,654	4,114	1,411	919	380	849	555	501	16,505	11,929
2008	385	698	1,285	1,111	2,335	7,528	4,628	1,293	924	1,059	969	451	22,666	16,887
2009	1,034	1,595	4,038	5,549	3,087	5,155	3,870	1,603	1,126	1,099	949	659	29,764	21,699
2010	1,039	941	4,165	2,573	2,779	7,008	4,460	1,416	1,266	932	716	824	28,119	20,985
2011	958	1,764	5,195	5,589	7,586	13,681	8,811	2,761	1,195	1,246	912	1,056	50,754	40,862
2012	718	1,493	1,911	1,523	2,414	3,659	2,191	924	386	655	895	677	17,446	11,698
2013	680	1,029	1,372	1,950	2,403	5,976	2,436	1,322	853	2,527	873	577	21,998	14,137
2014	1,216	1,094	3,871	2,539	3,890	6,869	4,219	2,983	1,846	1,183	680	1,405	31,795	21,388



Source: MRBWM Runoff Statistics (1898-2015)

Missouri River Basin
Gavins Point Water Control Manual
Unregulated Monthly Runoff
Distribution above Gavins Point

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

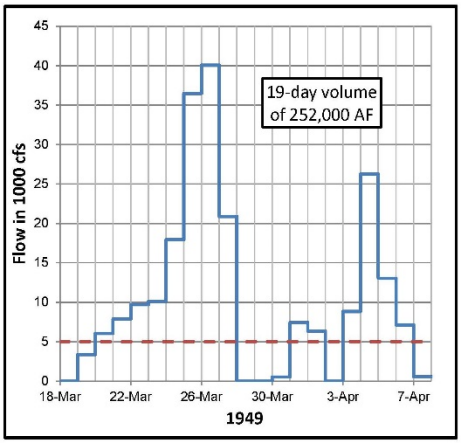


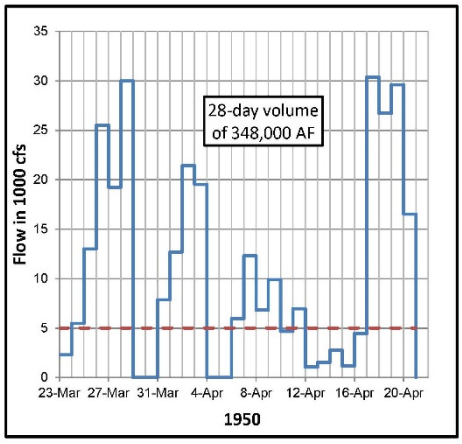
Source: MRBWM Runoff Statistics (1898-2015)

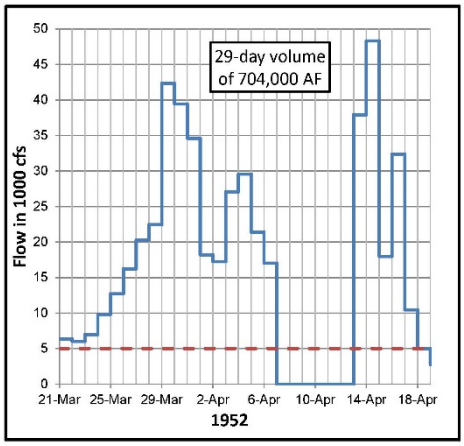
Missouri River Basin
Gavins Point Water Control Manual
Monthly Runoff Between Fort Randall and Gavins Point

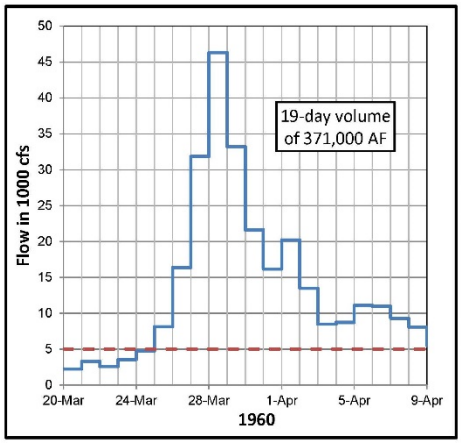
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

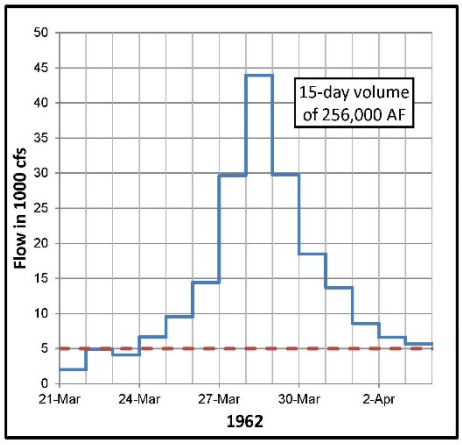
Incremental Inflow Hydrographs - Fort Randall to Gavins Point

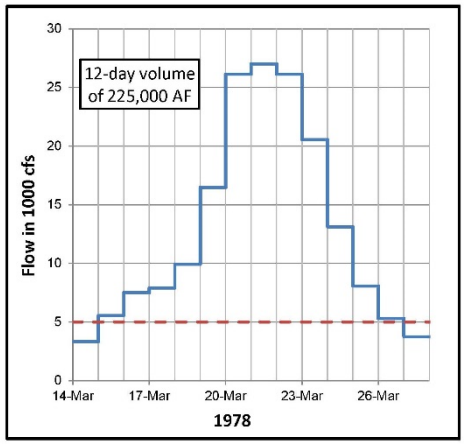


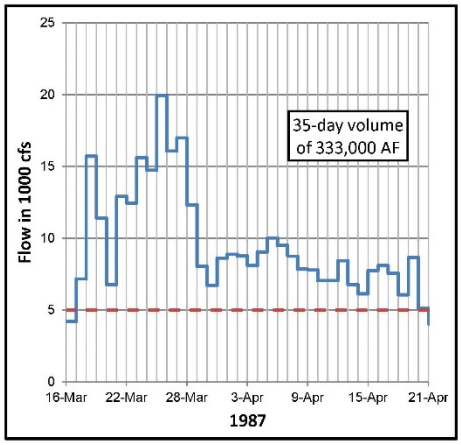


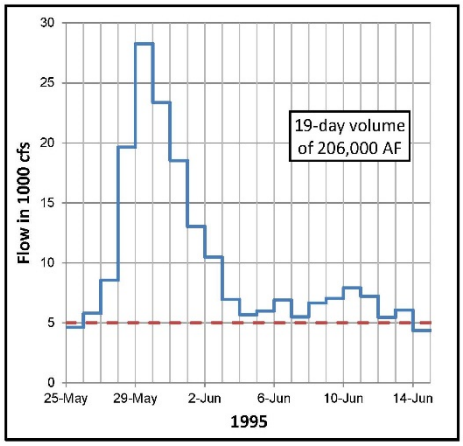


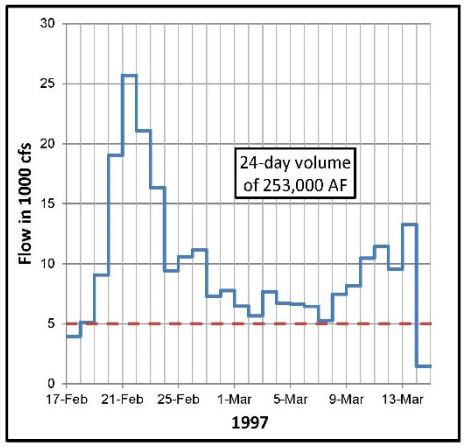


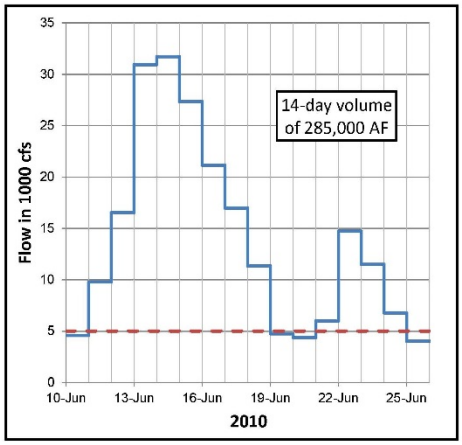












Year	Timeframe	No. Days	Total Volume (kAF)	Volume above 5 kcfs baseflow (kAF)	Average flow above 5 kcfs baseflow (kcfs)
1949	19 Mar-6 Apr	19	440	252	6.7
1950	24 Mar-20 Apr	28	626	348	6.3
1952	21 Mar-18 Apr	29	991	704	12.2
1960	23 Mar-10 Apr	19	560	371	9.8
1962	21 Mar-18 Apr	15	404	256	8.6
1978	15 Mar-26 Mar	12	344	225	9.5
1987	17 Mar-20 Apr	35	680	333	4.8
1995	26 May-13 Jun	19	395	206	5.5
1997	18 Feb-13 Mar	24	491	253	5.3
2010	11 Jun-24 Jun	14	424	285	10.3

Data Source: Incremental flow data set used in the Hydrologic Statistics on Inflows Technical Report – June 2015.

Missouri River Basin
Gavins Point Water Control Manual
Incremental Inflow Hydrographs
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Plate III-17

US Army Corps of Engineers®
Northwestern Division

Travel Time - Days
Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Gavins Point Drainage Area
Omaha/Kansas City District Boundaries
State Boundaries

0 15 30 60 90 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

N W E S

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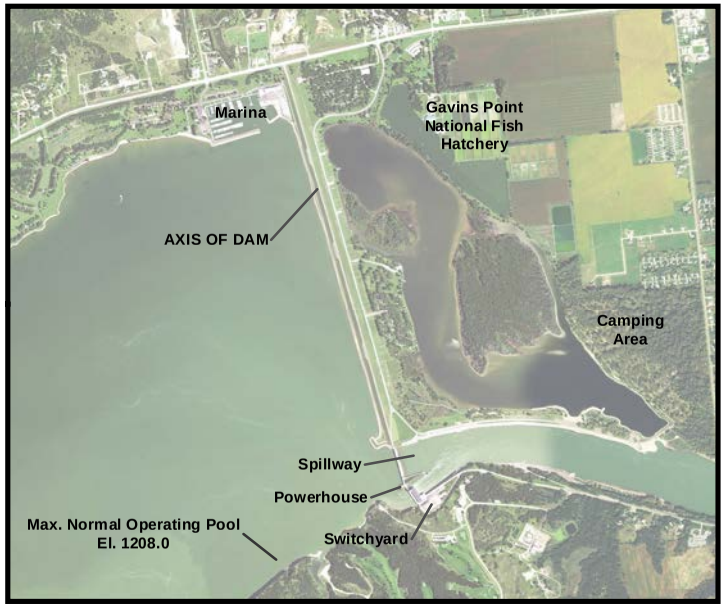
Missouri River Basin
GAVINS POINT DRAINAGE AREA
TRAVEL TIMES
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Missouri River Basin

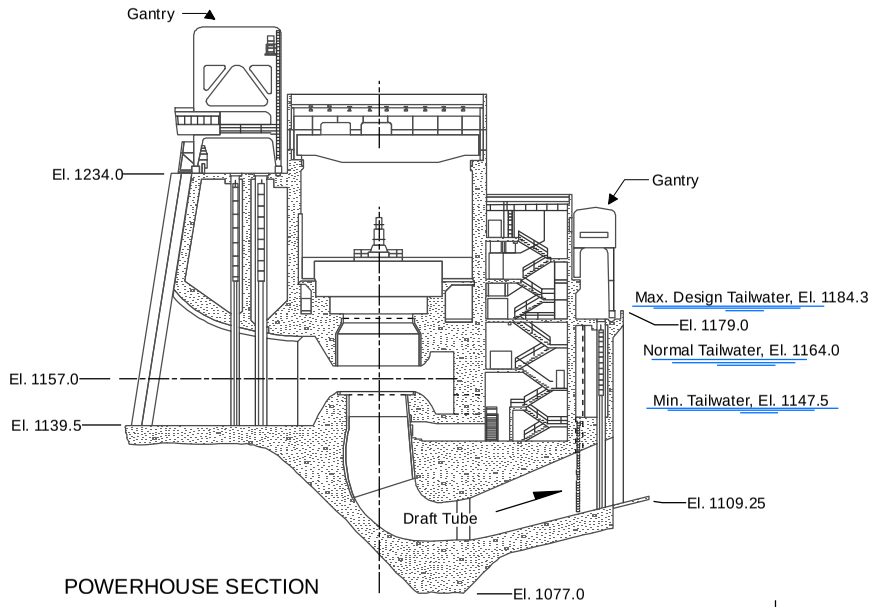
Gavins Point Water Control Manual

Reservoir, Embankment, Intakes, Powerhouse and Spillway

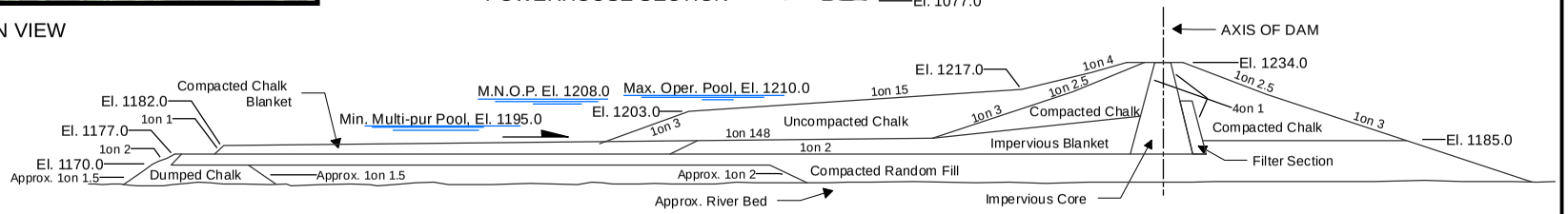
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



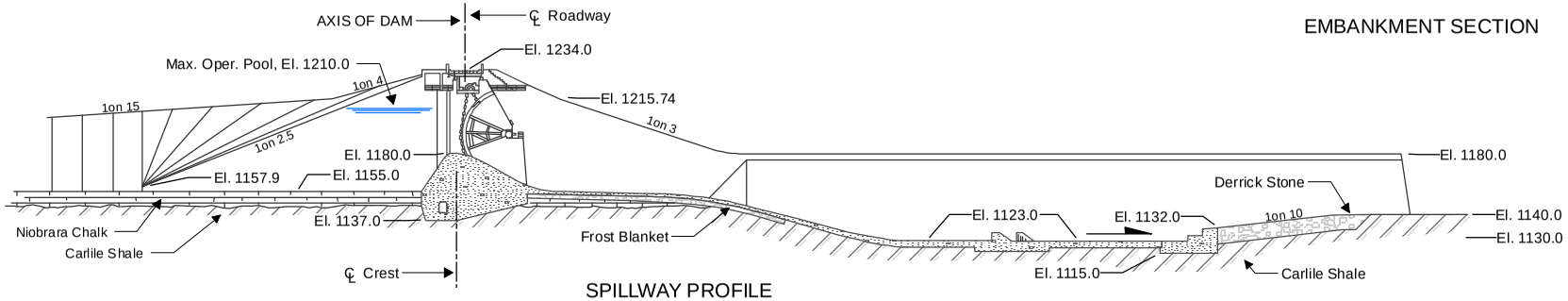
PLAN VIEW



POWERHOUSE SECTION



EMBANKMENT SECTION



SPILLWAY PROFILE

Plate IV-2

US Army Corps of Engineers®
Northwestern Division

PLAN & SECTIONS DETAIL

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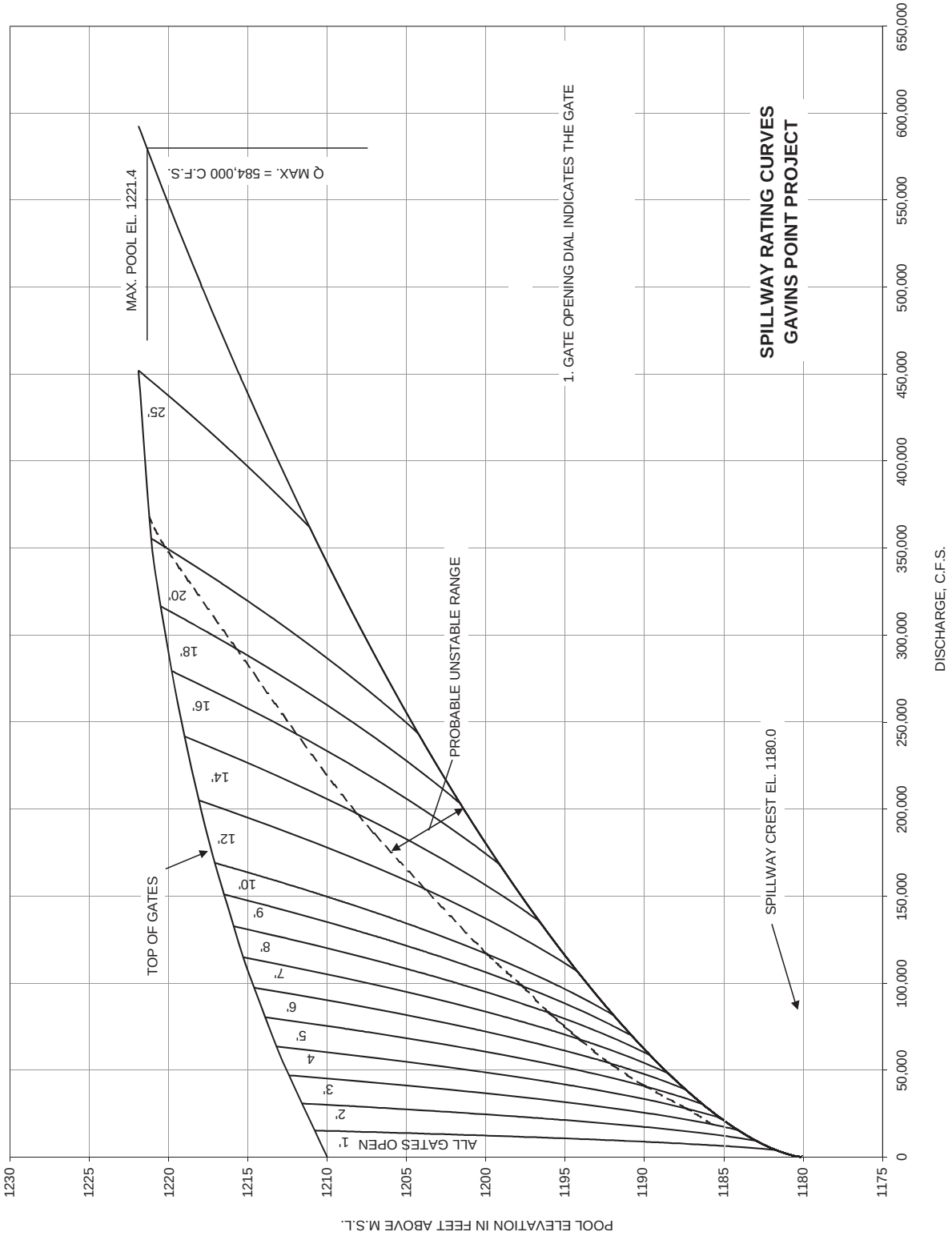
Missouri River Basin
GAVINS POINT DAM
WATER CONTROL PROJECT
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin

Gavins Point Water Control Manual

Spillway Rating Curves

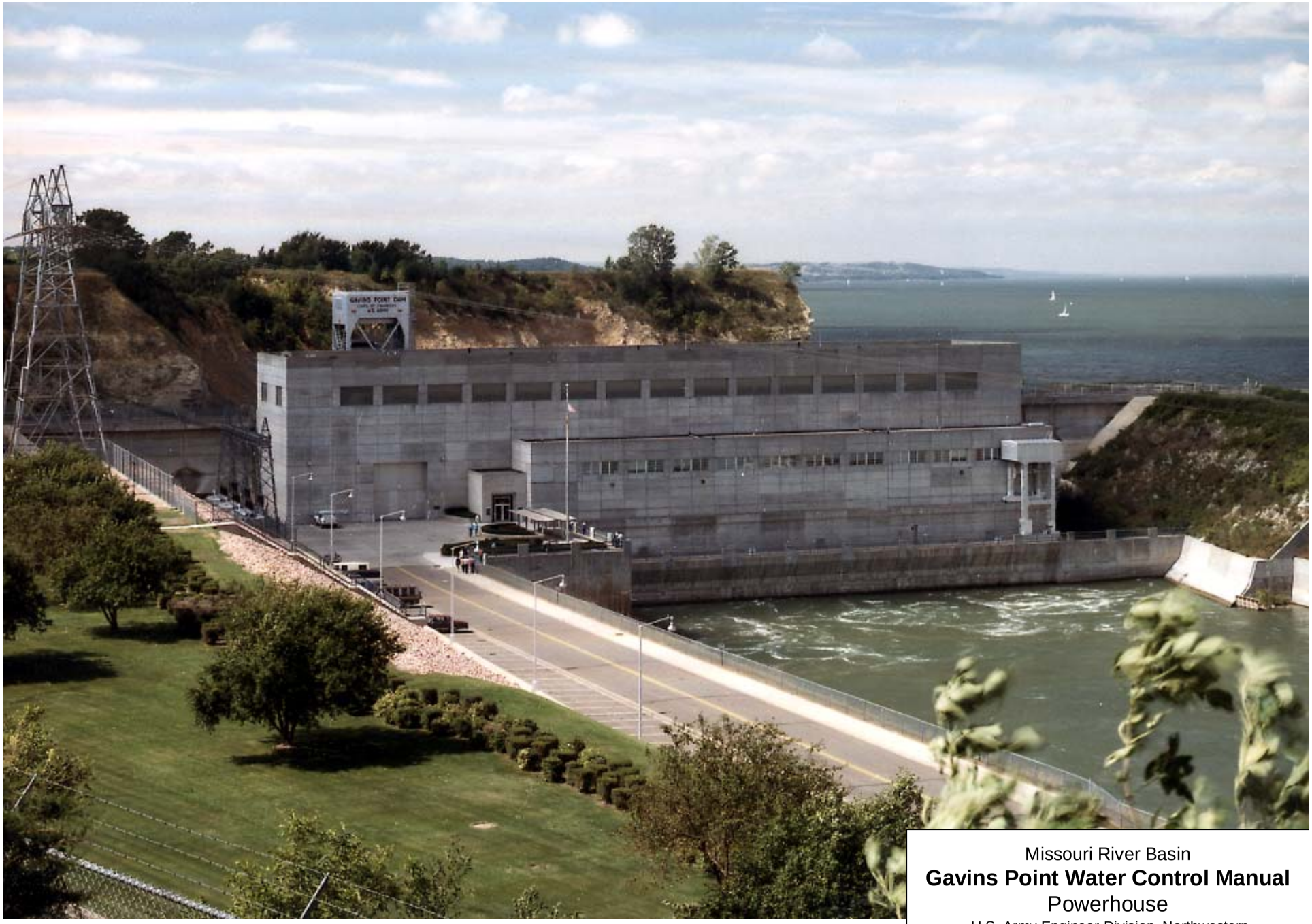
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Missouri River Basin

Gavins Point Water Control Manual

Spillway Gates

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

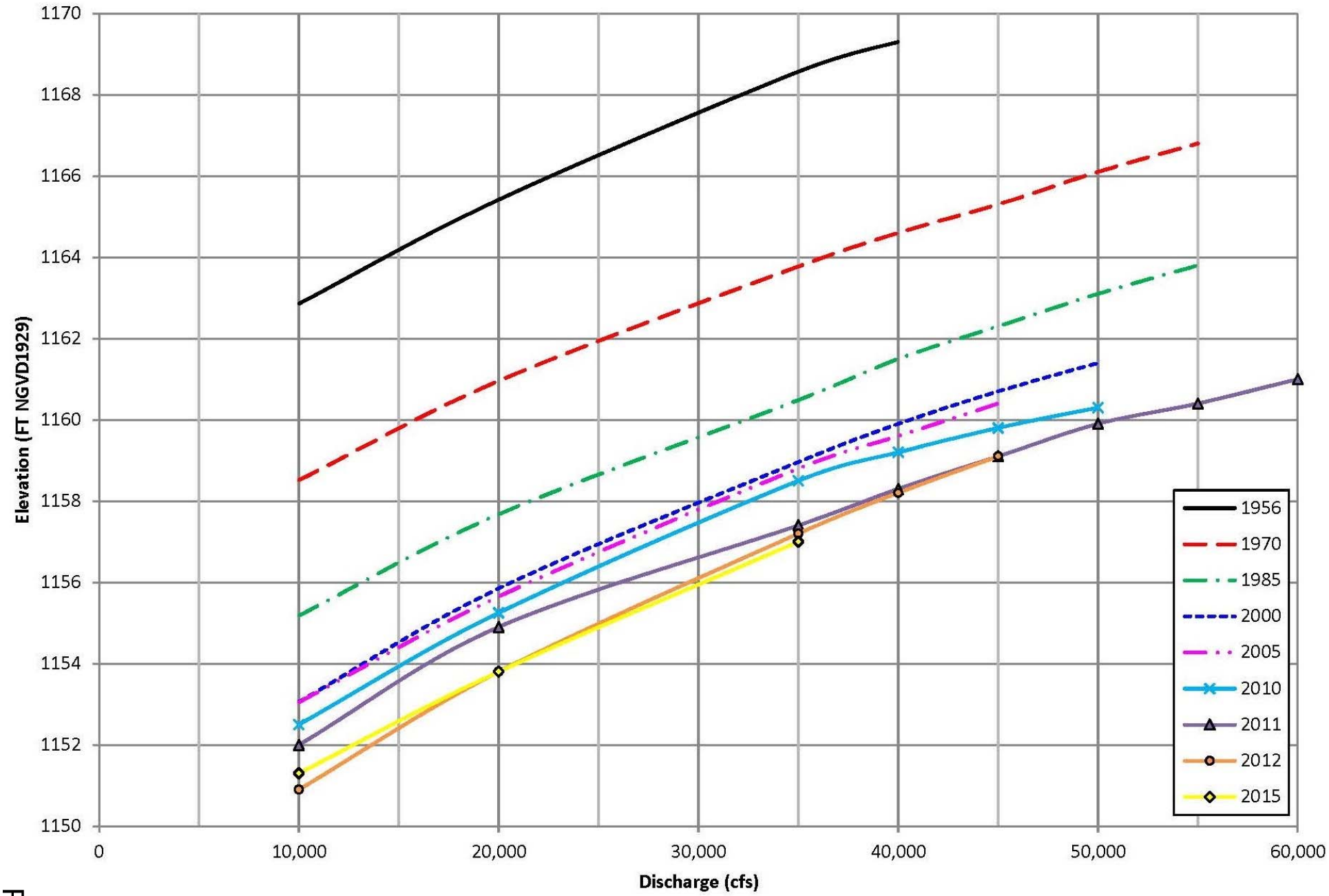


Missouri River Basin

Gavins Point Water Control Manual

Powerhouse

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Source: Omaha District, January 2016

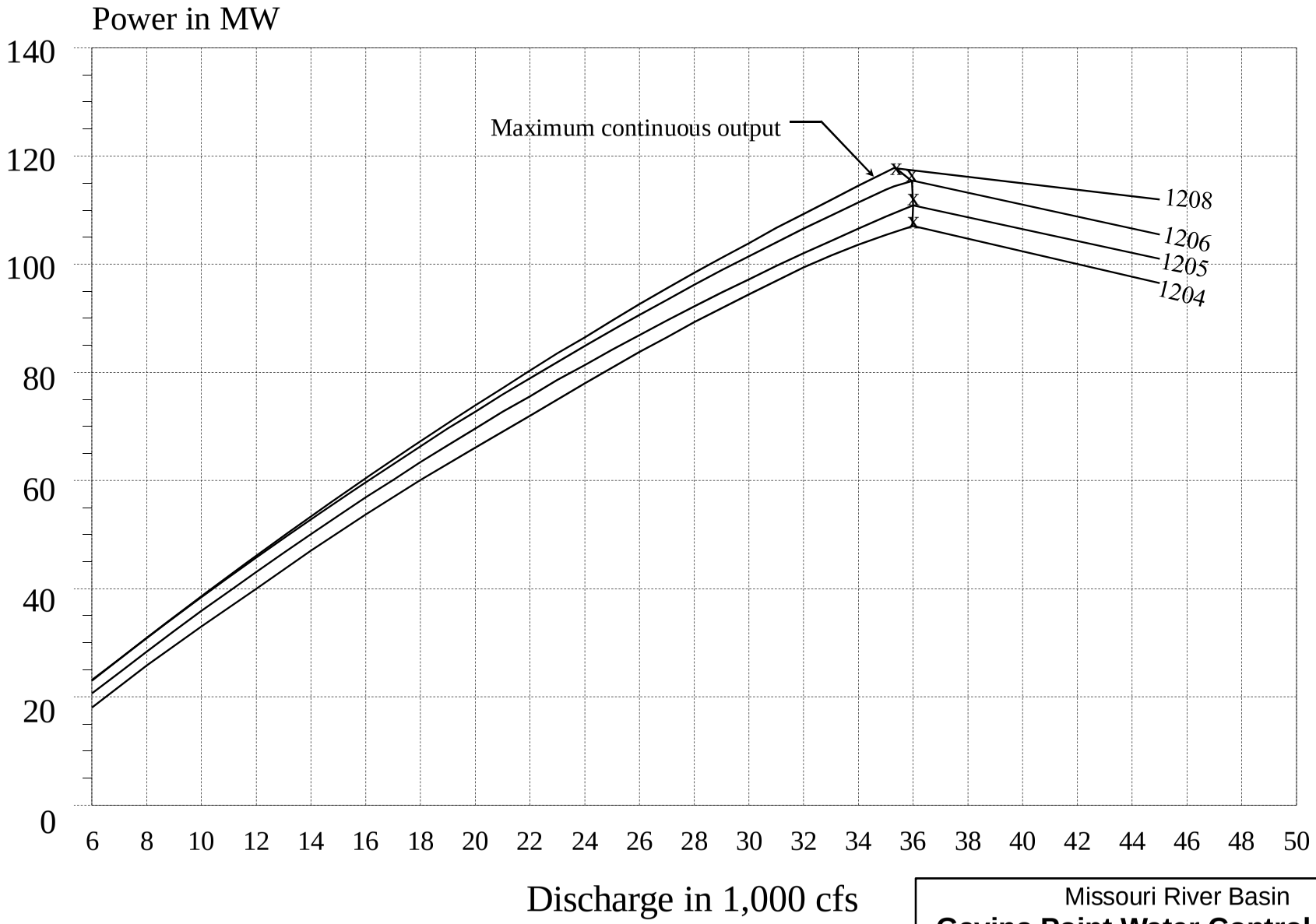
Missouri River Basin

Gavins Point Water Control Manual

Tailwater Rating Curves

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Gavins Point Powerplant



Missouri River Basin
Gavins Point Water Control Manual
Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

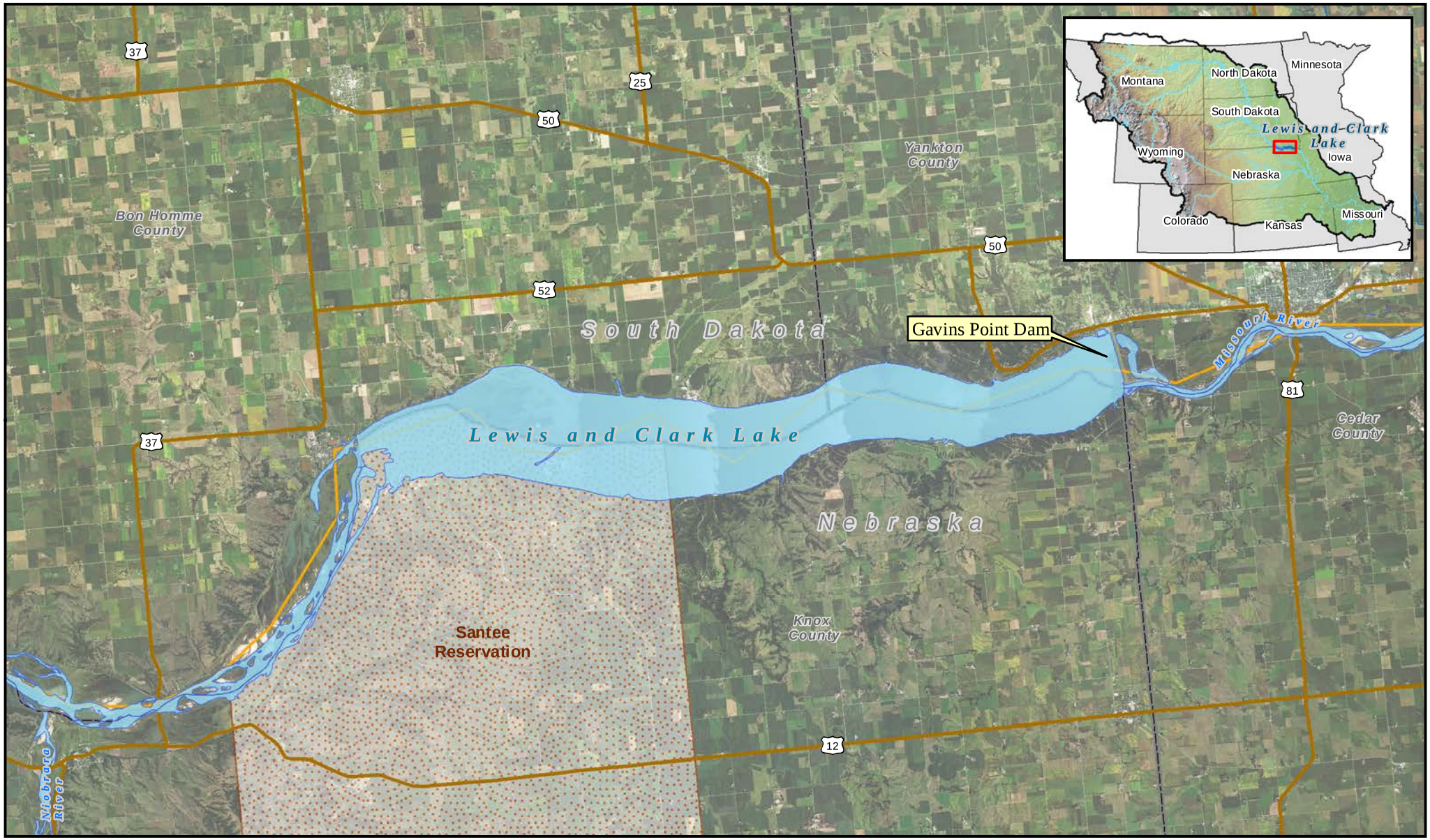


Plate IV-8

US Army Corps of Engineers®
Northwestern Division

Cities
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

0 2.5 5 10 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
GAVINS POINT PROJECT
PROJECT MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Gavins Point Area and Capacity Tables Surface Area in Acres Implemented by MRBWM August 2013 (2011 Surveys)										
ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	0	0	0	0	0	0	0	75	146
1170	232	284	308	402	567	804	1112	1491	1940	2461
1180	2855	2959	3024	3267	3687	4285	5059	6011	7140	8446
1190	9828	11099	12231	13280	14248	15134	15937	16658	17298	17855
1200	18259	18530	18880	19425	20165	21101	22232	23559	25081	26799
1210	28552	30106	31511	32891	34246	35577	36882	38163	39419	40650
1220	41878	43136	44413	45690	46966	48242	49519	50796	52072	53349
1230	54625									

Gavins Point Area and Capacity Tables Capacity in Acre-Feet Implemented by MRBWM August 2013 (2011 Surveys)										
ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	0	0	0	0	0	0	0	32	150
1170	325	615	893	1231	1698	2366	3307	4591	6289	8472
1180	11211	14182	17129	20231	23664	27606	32234	37725	44256	52005
1190	61148	71661	83347	96123	109908	124620	140176	156494	173493	191090
1200	209203	227608	246264	265368	285114	305698	327316	350163	374434	400326
1210	428033	457430	488245	520452	554027	588945	625181	662710	701507	741548
1220	782807	825305	869080	914132	960460	1008064	1056945	1107103	1158537	1211248
1230	1265235									

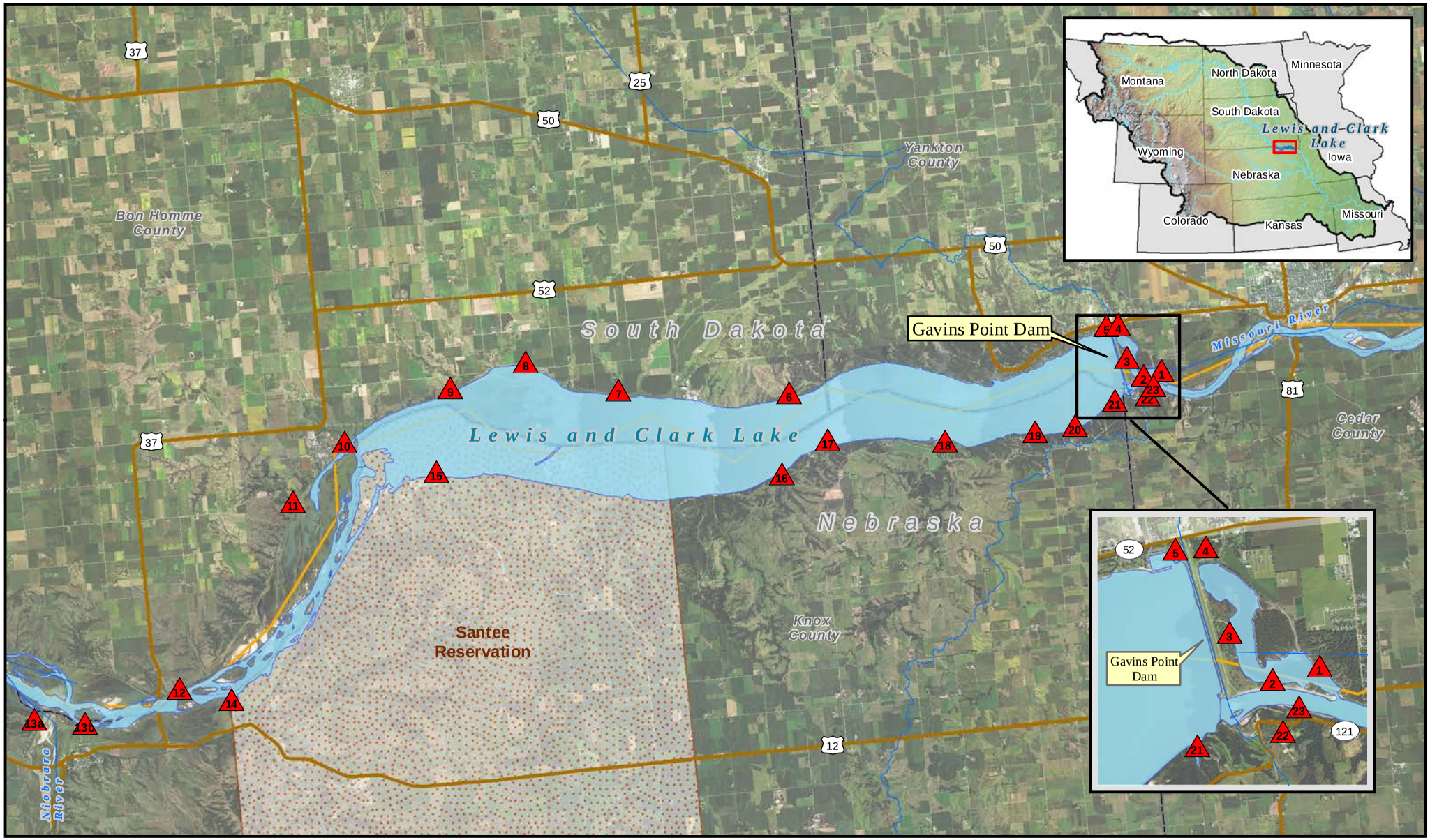

Plate IV-10

US Army Corps of Engineers®
Northwestern Division

Recreation Area
Cities
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

0 2.5 5 10 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

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Missouri River Basin
GAVINS POINT PROJECT
RECREATION AREAS
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

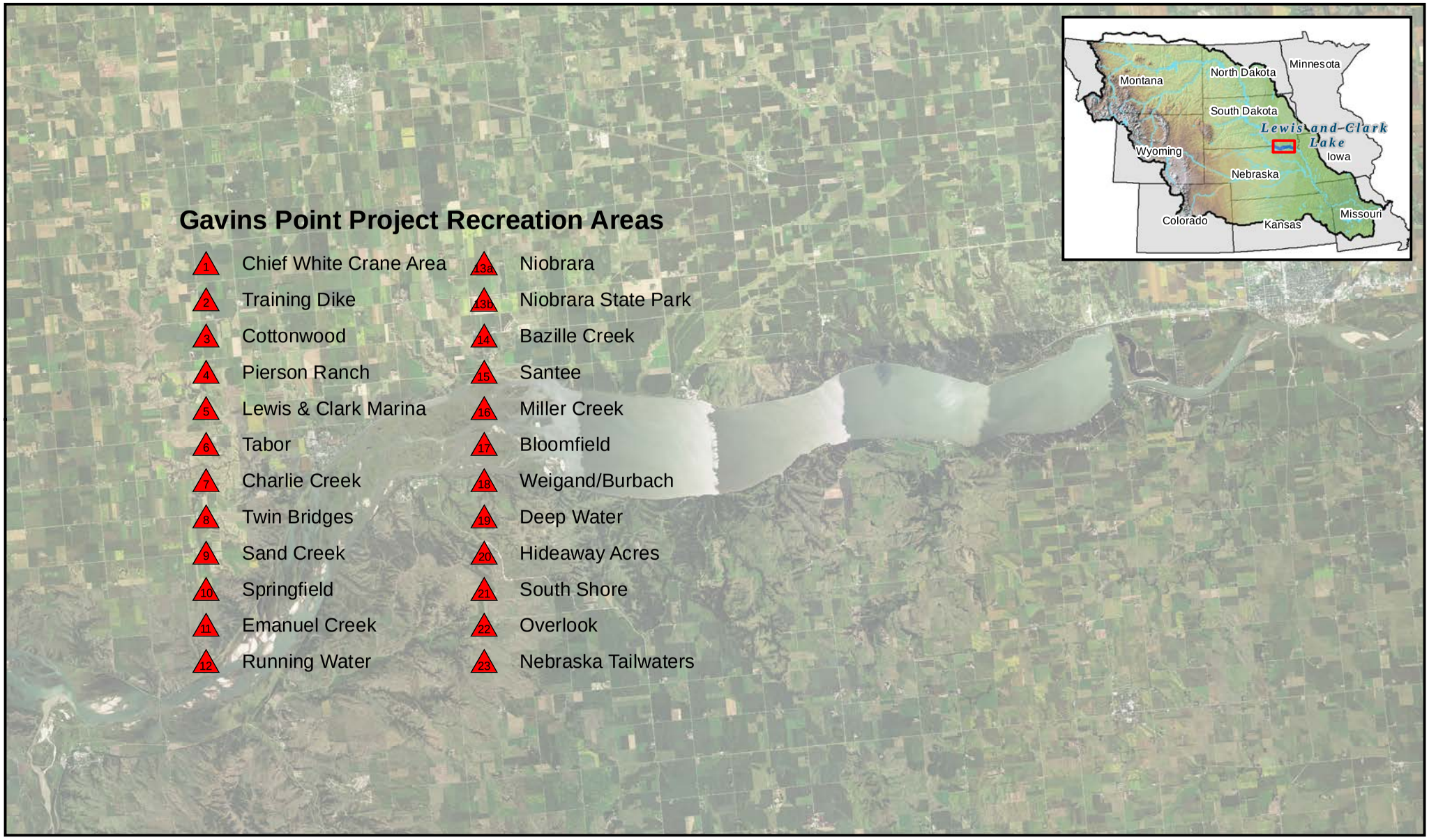

Plate IV-11

US Army Corps of Engineers®
Northwestern Division

0 2.5 5 10 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

N W E S

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Missouri River Basin
GAVINS POINT PROJECT
RECREATION AREA INDEX
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

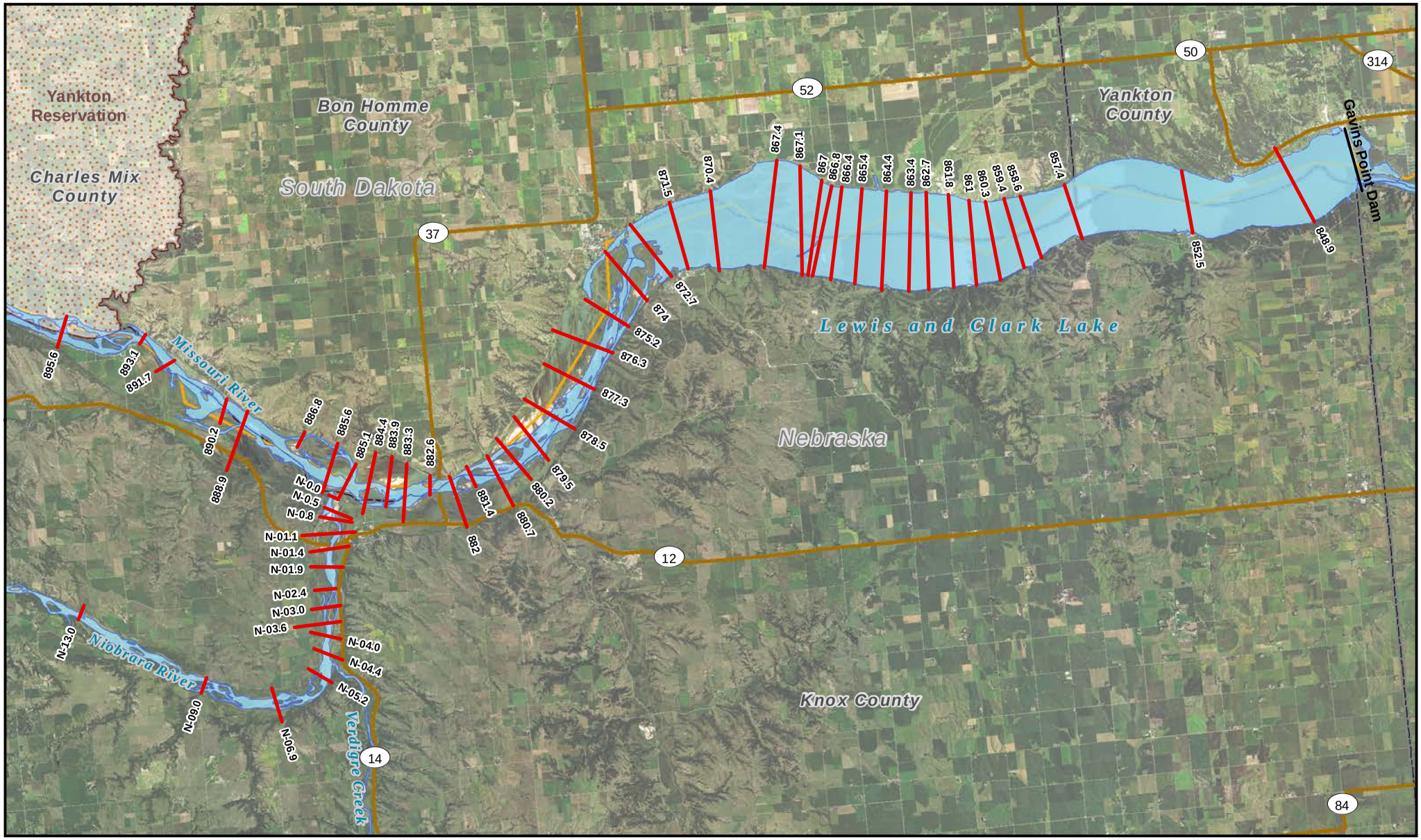

Plate IV-12

US Army Corps of Engineers®
Northwestern Division

Cities
Aggregation Rangeline
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

0 1 2 4 6 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

N W E S

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Missouri River Basin
GAVINS POINT PROJECT
SEDIMENT RANGE MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

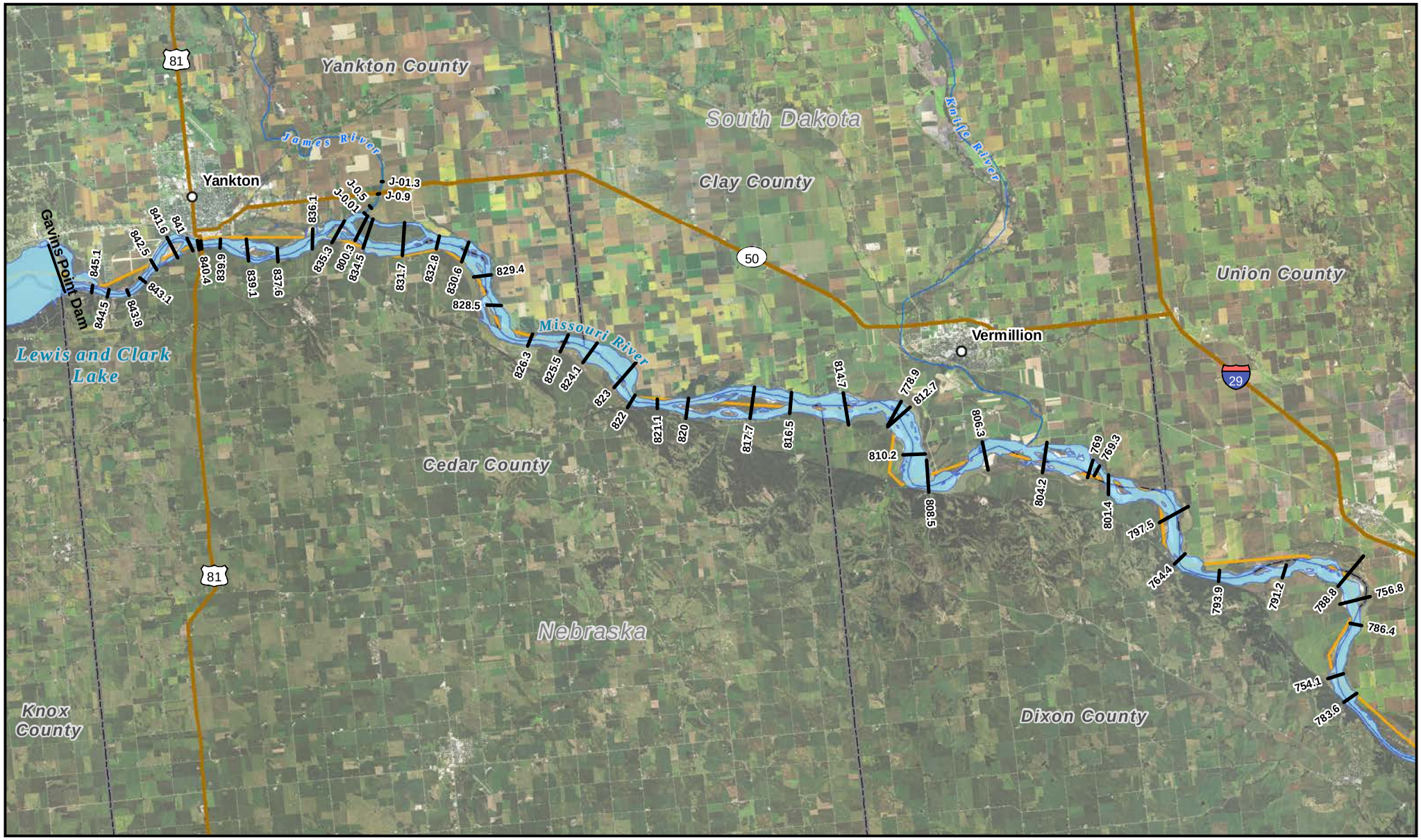

Plate IV-13

US Army Corps of Engineers®
Northwestern Division

Cities
Degradation Reach
Rivers
Roads
Reservations
Reservoirs/Lakes
State Boundaries
County Boundaries

0 2 4 8 12 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

N W E S

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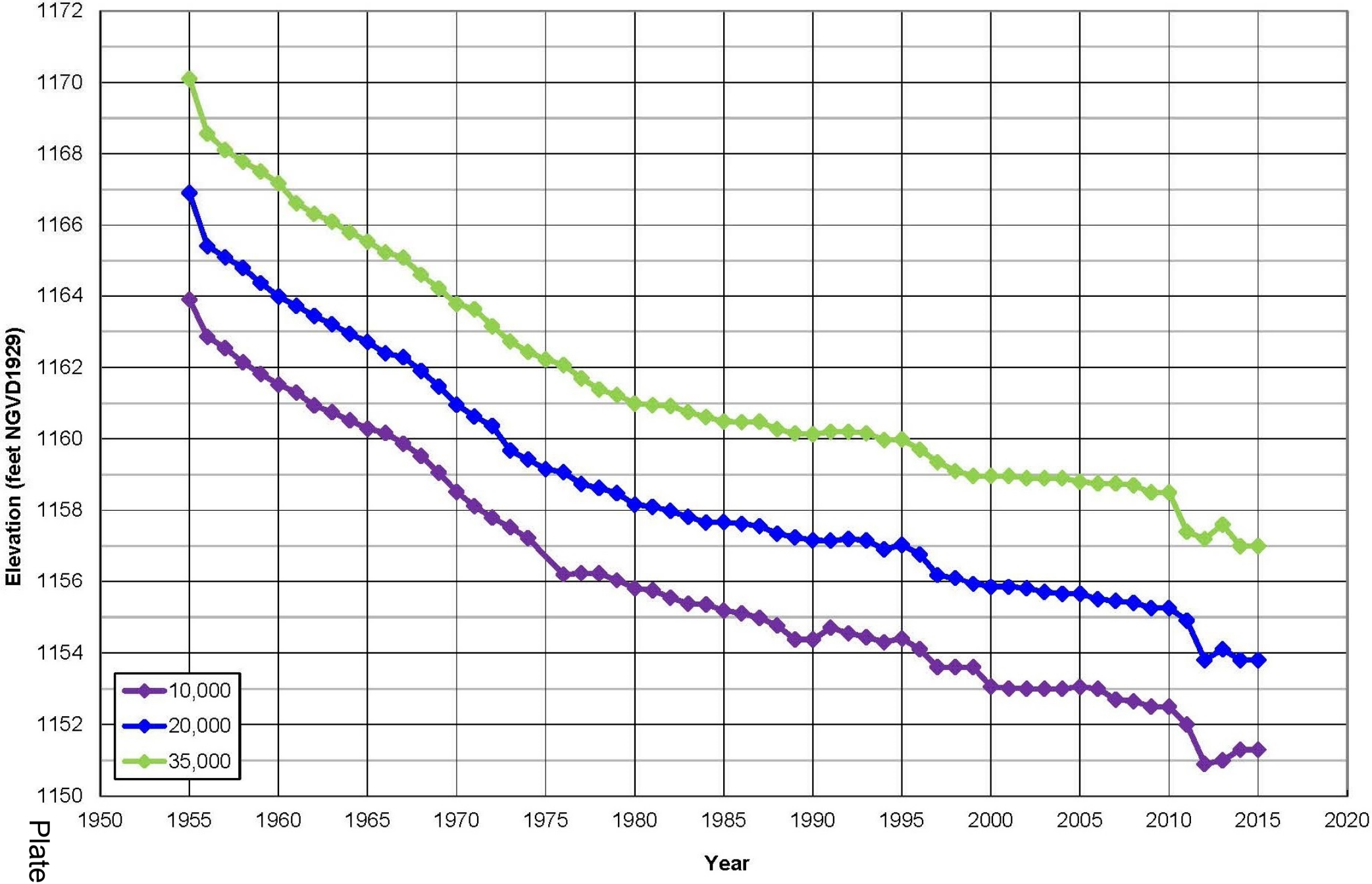
Missouri River Basin
GAVINS POINT PROJECT
SEDIMENT RANGE MAP
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Source: Omaha District, January 2016

Missouri River Basin

Gavins Point Water Control Manual

Tailwater Stage Trends

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

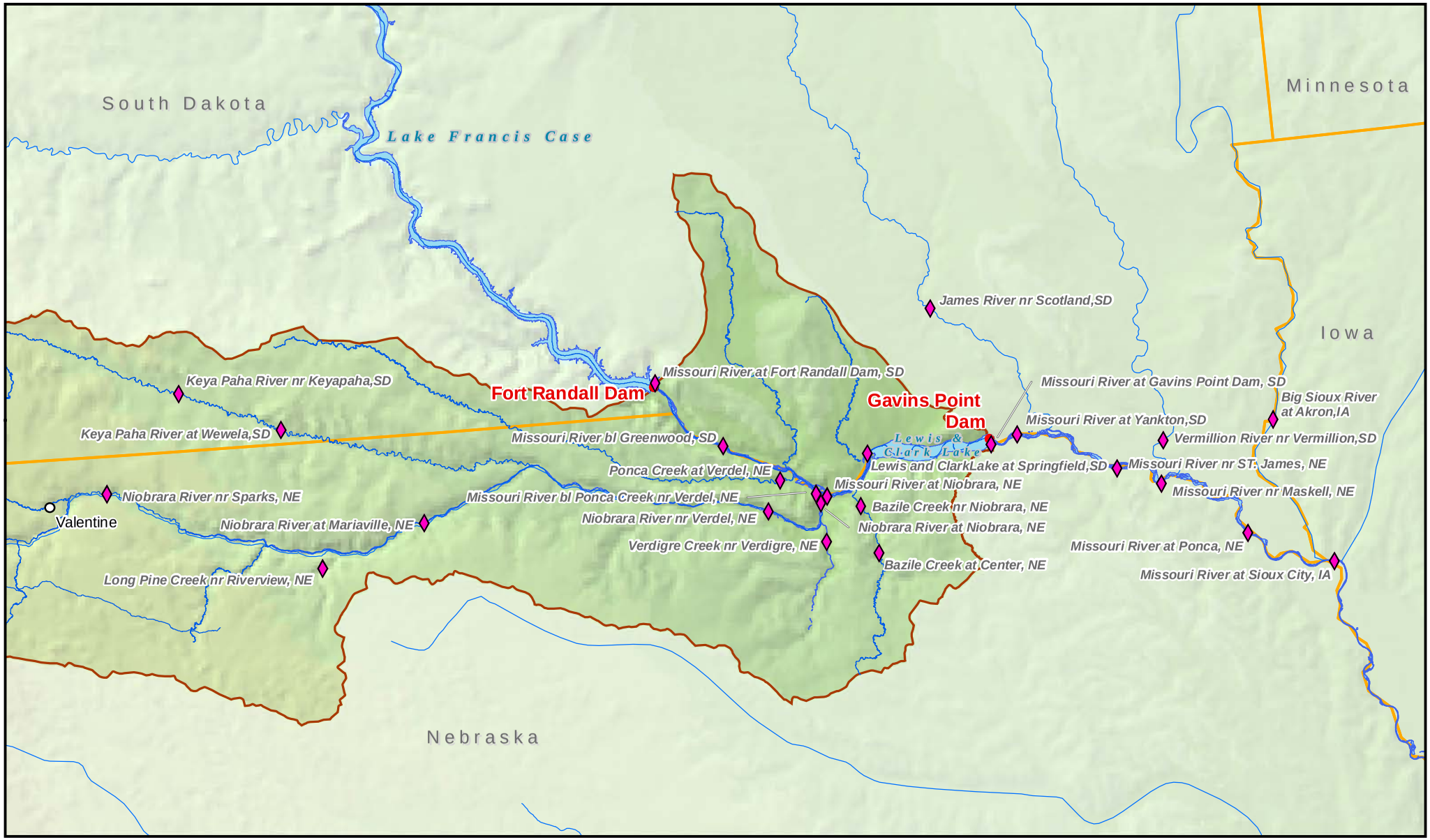


Plate V-1

US Army Corps of Engineers®
Northwestern Division

Streamgaging Station
Mainstem Dam
Cities
Rivers
Reservoirs/Lakes
Gavins Point Drainage Area
Omaha/Kansas City District Boundaries
State Boundaries

0 10 20 40 Miles

Imagery Source:
U.S. Department of Agriculture,
Farm Service Agency 2014

N W E S

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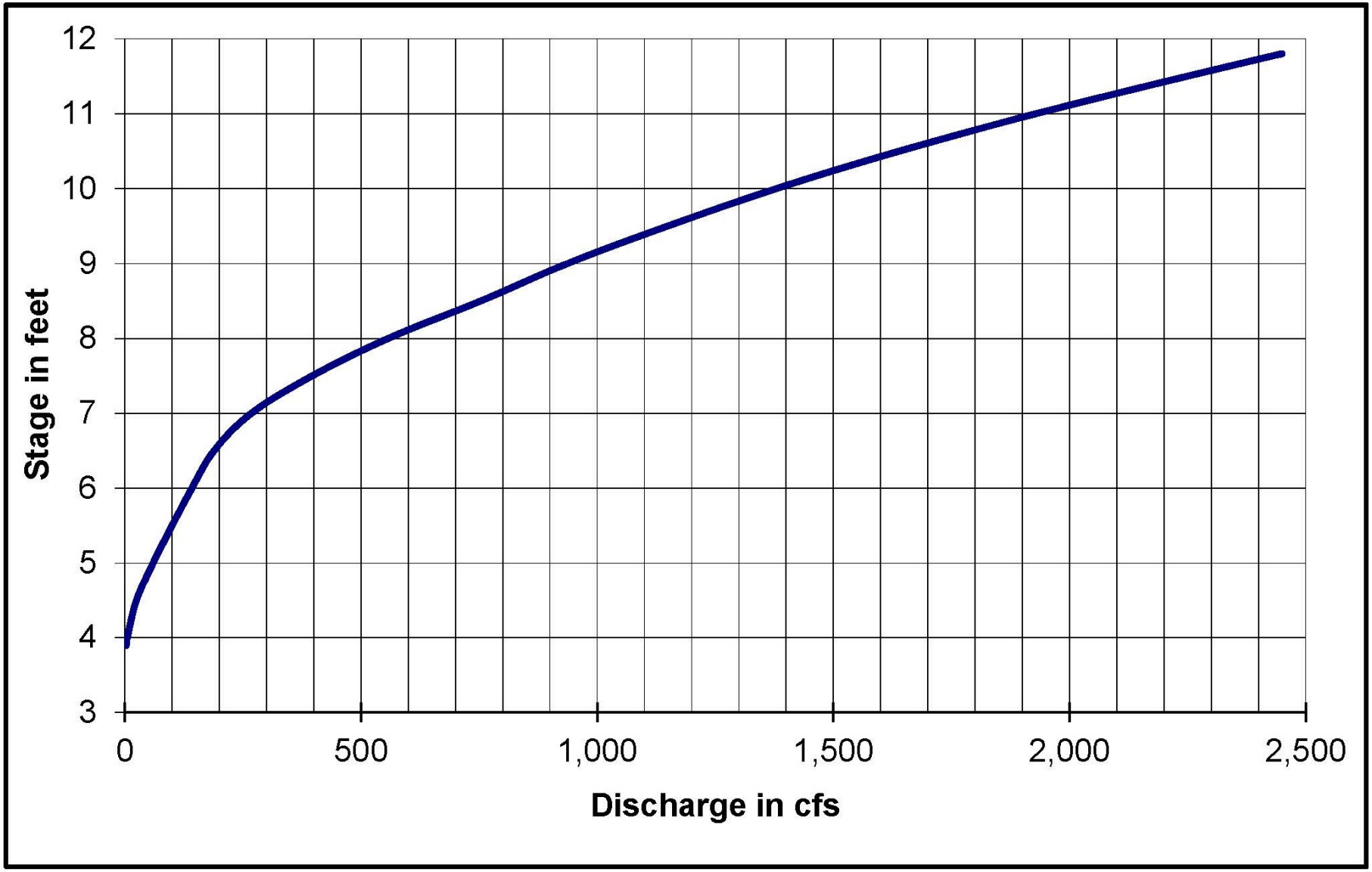
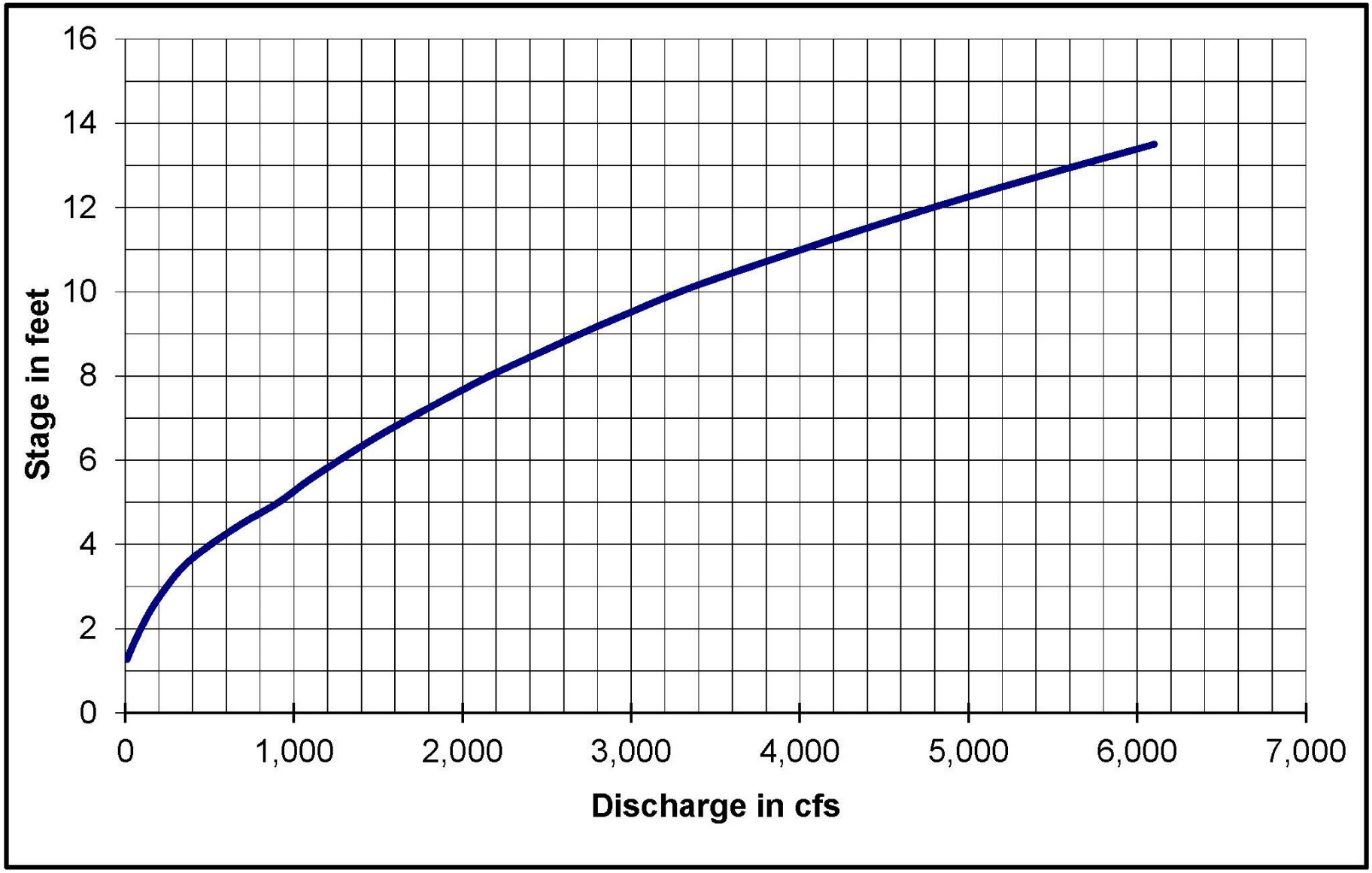
Missouri River Basin
GAVINS POINT DRAINAGE AREA
KEY STREAMGAGING STATIONS
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



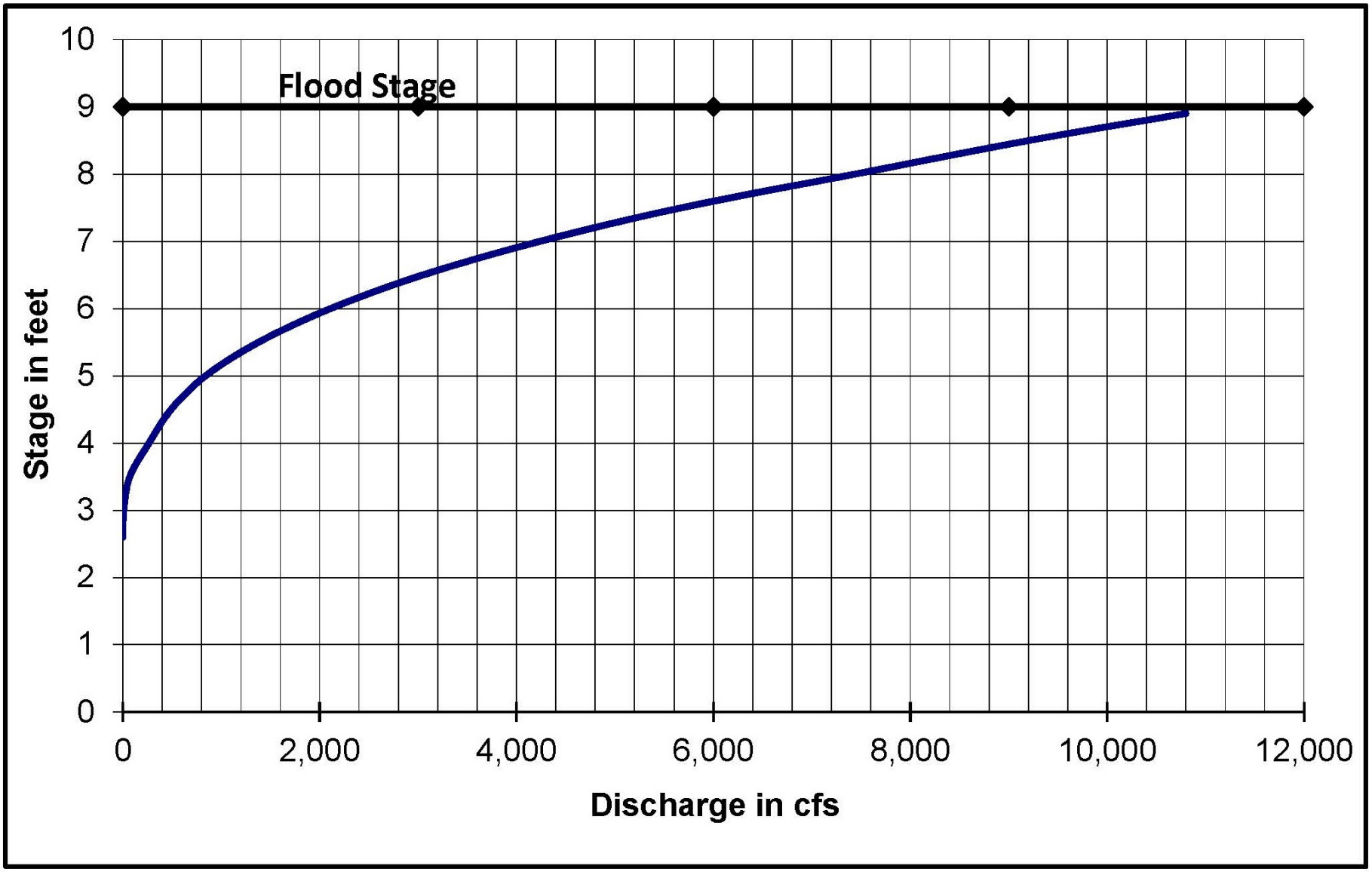
Note: Datum of gage is 2,230.00 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Keya Paha River near Keyapaha, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



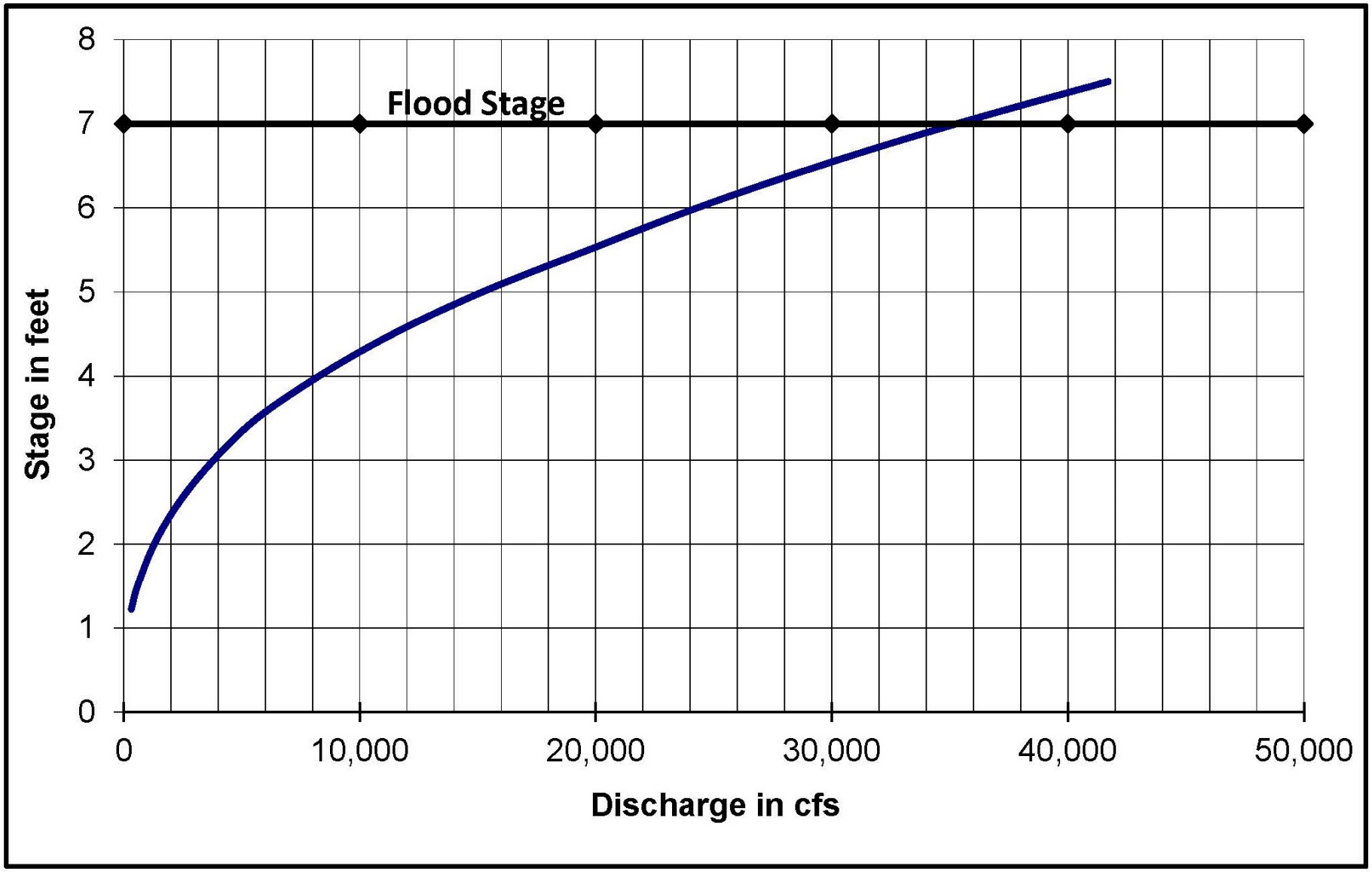
Note: Datum of gage is 2,049.78 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Keya Paha River at Wewela, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



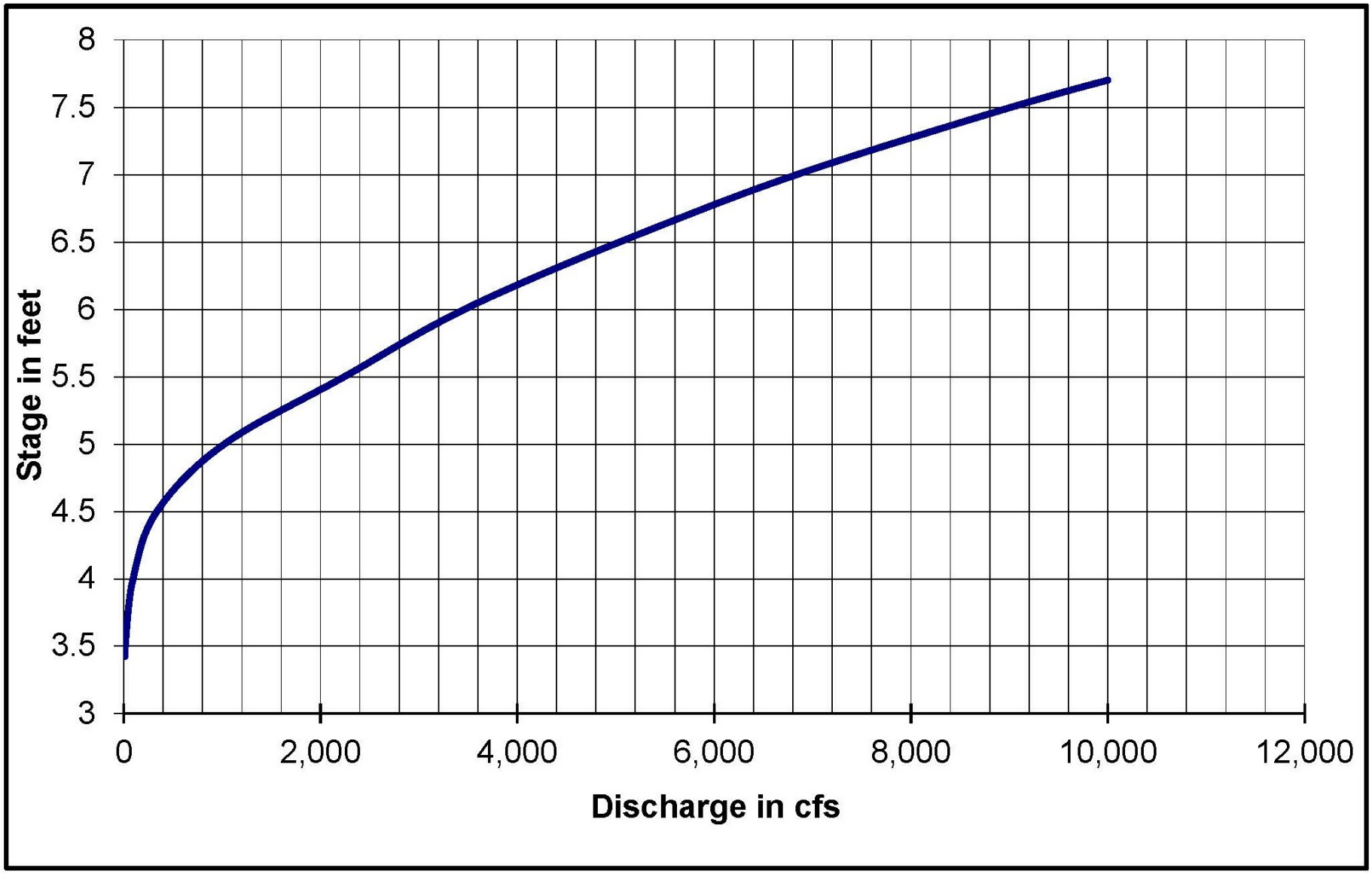
Note: Datum of gage is 1,243.32 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Bazile Creek near Niobrara, NE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



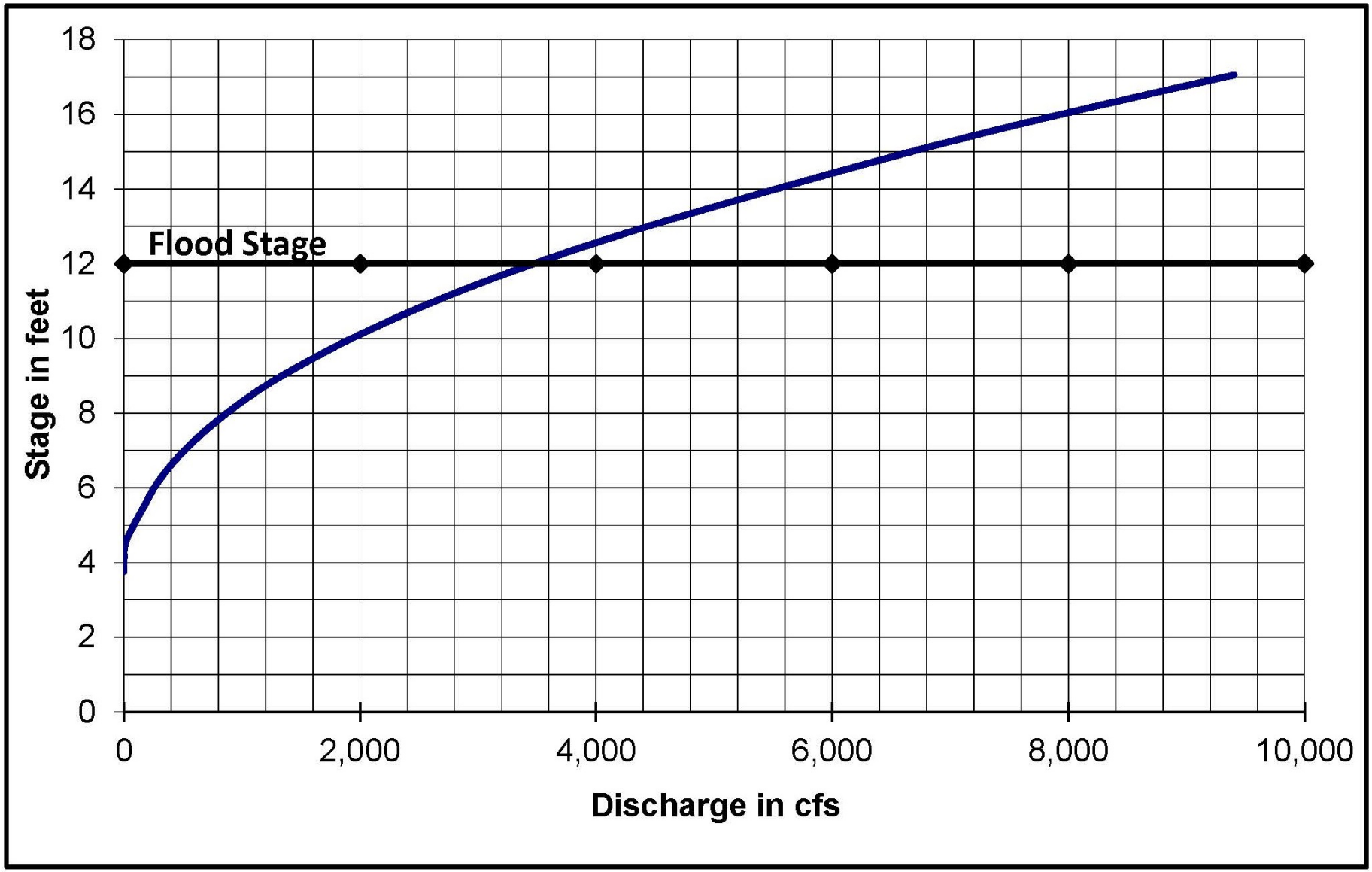
Note: Datum of gage is 1,312.12 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Niobrara River near Verdel, NE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



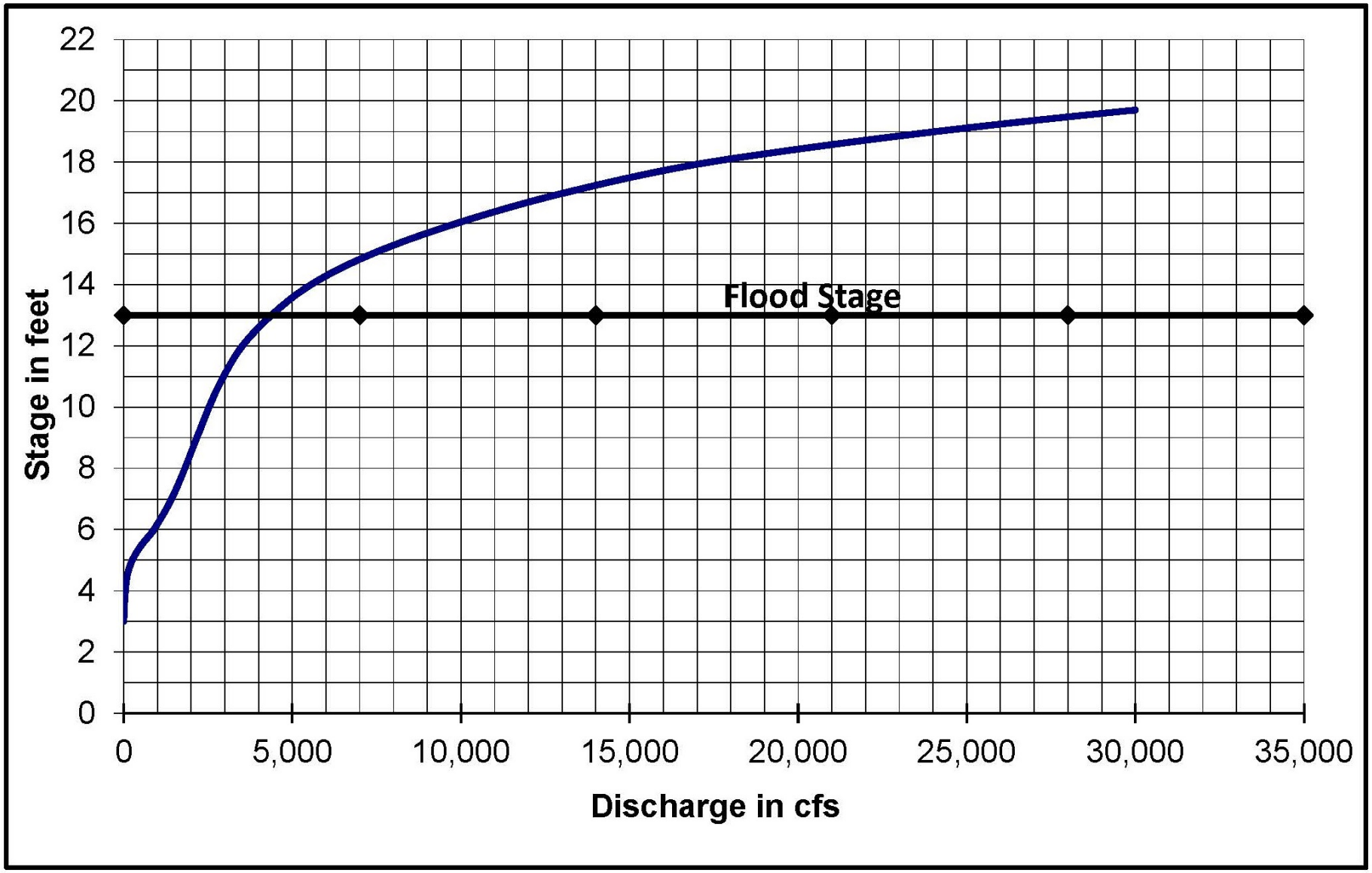
Note: Datum of gage is 1,290 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Verdigre Creek near Verdigre, NE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



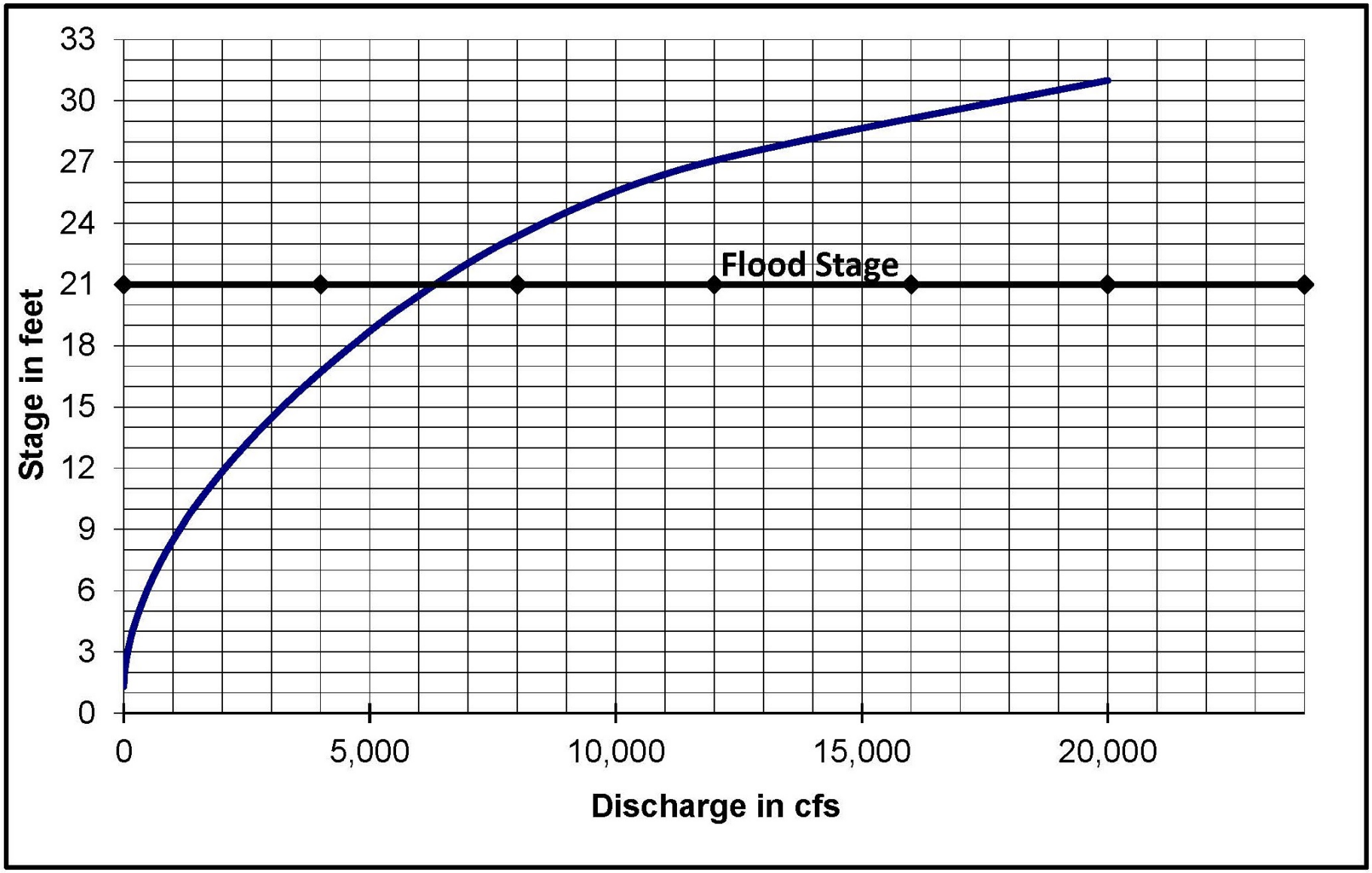
Note: Datum of gage is 1,232.92 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Ponca Creek at Verdel, NE
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



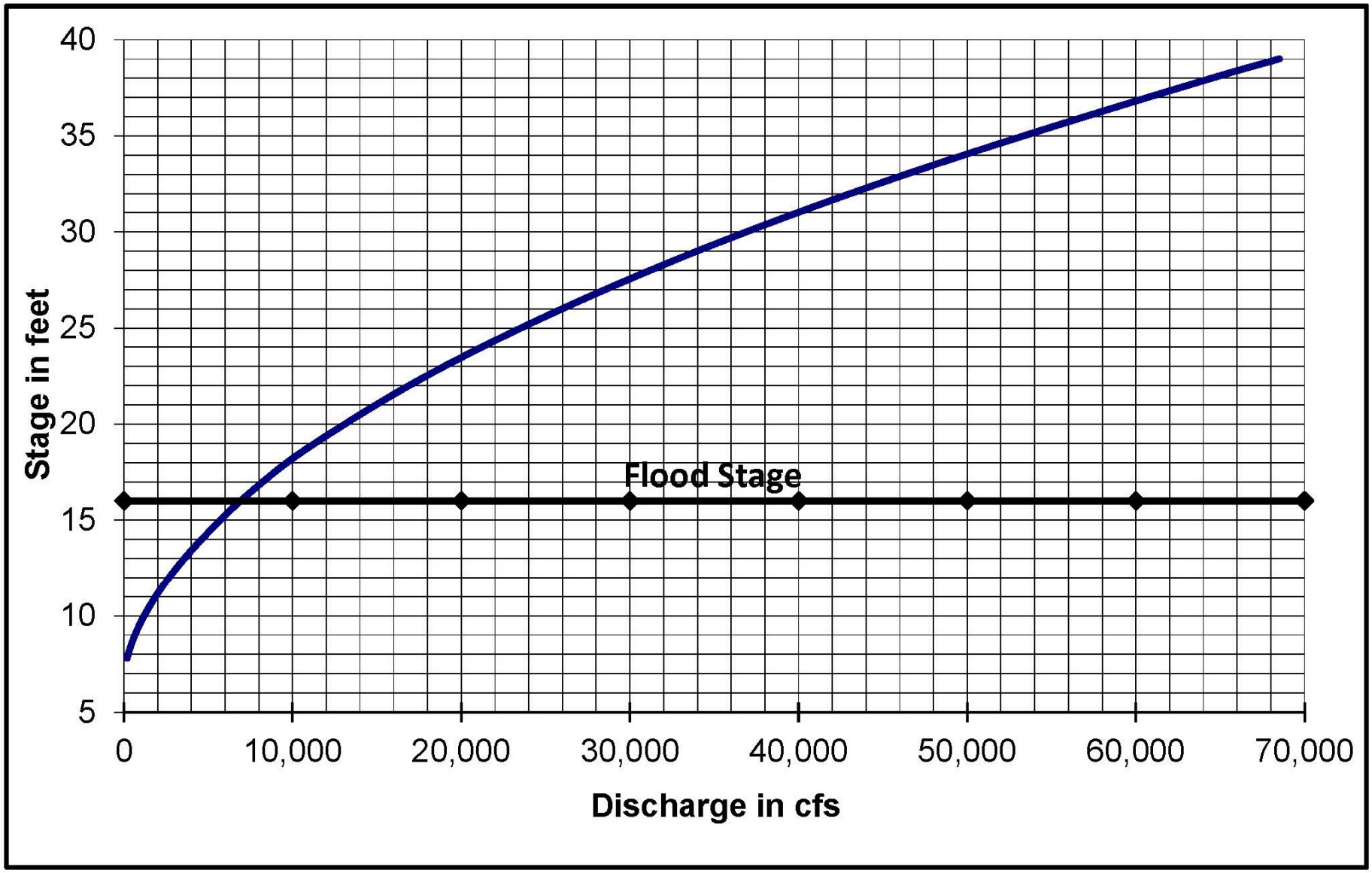
Note: Datum of gage is 1,168.02 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
James River near Scotland, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



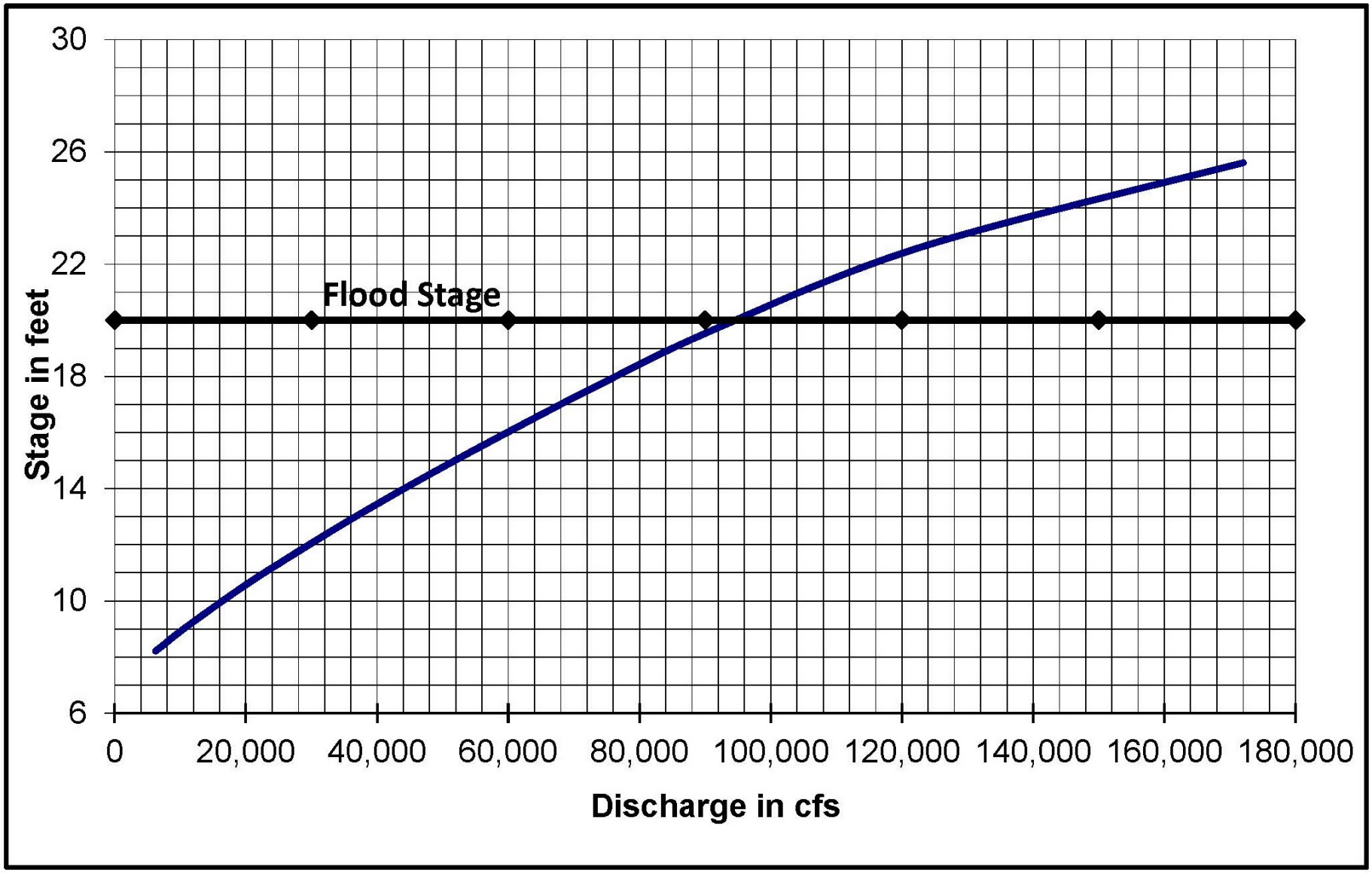
Note: Datum of gage is 1,121.65 feet above NAVD88.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Vermillion River near Vermillion, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



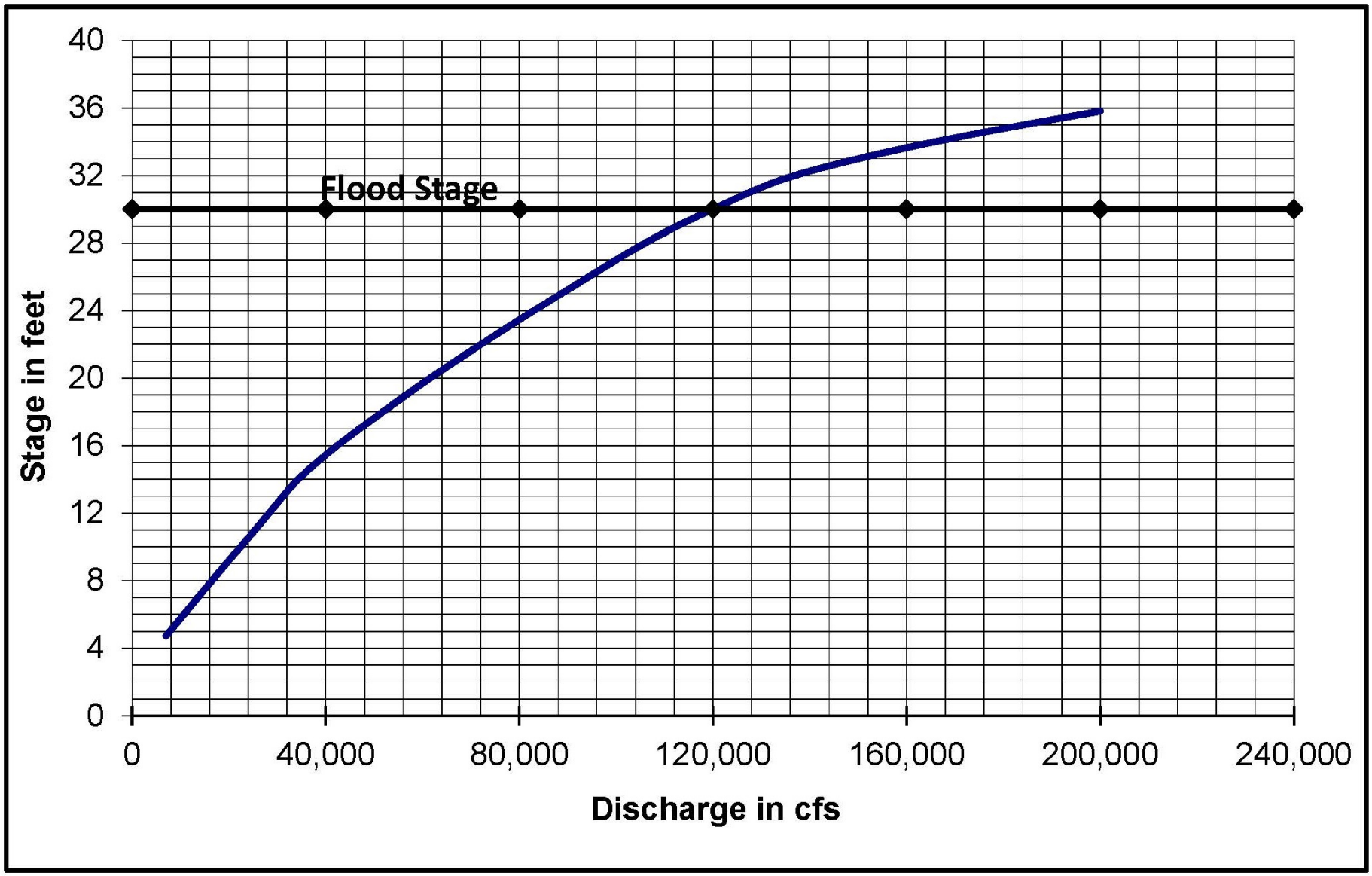
Note: Datum of gage is 1,118.90 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Big Sioux River at Akron, IA
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Note: Datum of gage is 1,140.20 feet above NAVD88.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Missouri River at Yankton, SD
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Note: Datum of gage is 1,056.98 feet above NGVD29.

Missouri River Basin
Gavins Point Water Control Manual
Rating Curve
Missouri River at Sioux City, IA
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Gavins Point to Allow for Wind Effects

Reservoir Elevation at 1195 feet msl

(True Elevation = Reported Pool Elevation* + Correction)

Wind Direction	Wind Speed in Miles Per Hour														
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.3	+0.4	+0.5	+0.6	+0.7	+0.9	+1.0
10	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.8	+1.0	+1.2	+1.4	+1.6	+1.8
20	+0.0	+0.0	+0.1	+0.1	+0.2	+0.4	+0.5	+0.7	+0.9	+1.1	+1.4	+1.7	+2.0	+2.4	+2.8
30	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.8	+2.2	+2.6	+3.1	+3.6
40	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.1	+2.6	+3.1	+3.7	+4.3
50	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.9	+2.4	+3.0	+3.6	+4.2	+4.9
60	+0.0	+0.0	+0.1	+0.2	+.05	+0.7	+1.0	+1.3	+1.7	+2.1	+2.6	+3.2	+3.9	+4.6	+5.4
70	+0.0	+0.0	+0.1	+0.3	+.05	+0.7	+1.0	+1.3	+1.7	+2.2	+2.8	+3.4	+4.1	+4.8	+5.7
80	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+1.0	+1.4	+1.8	+2.3	+2.8	+3.4	+4.1	+4.9	+5.8
90	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+1.0	+1.3	+1.7	+2.2	+2.8	+3.4	+4.1	+4.8	+5.7
100	+0.0	+0.0	+0.1	+0.2	+0.5	+0.7	+1.0	+1.3	+1.7	+2.1	+2.6	+3.2	+3.9	+4.6	+5.4
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.9	+2.4	+3.0	+3.6	+4.2	+4.9
120	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.1	+2.6	+3.1	+3.7	+4.3
130	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.8	+2.2	+2.6	+3.1	+3.6
140	+0.0	+0.0	+0.1	+0.1	+0.2	+0.4	+0.5	+0.7	+0.9	+1.1	+1.4	+1.7	+2.0	+2.4	+2.8
150	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.5	+0.6	+0.8	+1.0	+1.2	+1.4	+1.6	+1.8
160	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.3	+0.4	+0.5	+0.6	+0.7	+0.9	+1.0
170	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
180	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-.05	-0.6	-0.7	-0.9
190	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.7	-0.9	-1.0	-1.2	-1.4	-1.6
200	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.0	-1.2	-1.5	-1.7	-1.9	-2.2
210	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.6	-0.8	-1.0	-1.3	-1.5	-1.8	-2.1	-2.4	-2.7
220	-0.0	-0.0	-0.0	-0.1	-0.2	-.04	-0.7	-0.9	-1.2	-1.5	-1.8	-2.1	-2.4	-2.8	-3.1
230	-0.0	-0.0	-0.0	-0.1	-0.3	-0.5	-0.8	-1.1	-1.4	-1.7	-2.0	-2.3	-2.7	-3.0	-3.4
240	-0.0	-0.0	-0.0	-0.1	-0.3	-0.6	-0.8	-1.1	-1.5	-1.8	-2.1	-2.5	-2.8	-3.2	-3.6
250	-0.0	-0.0	-0.0	-0.1	-0.3	-0.6	-0.9	-1.2	-1.5	-1.8	-2.2	-2.6	-3.0	-3.4	-3.8
260	-0.0	-0.0	-0.0	-0.1	-0.3	-0.6	-0.9	-1.2	-1.5	-1.9	-2.2	-2.6	-3.0	-3.4	-3.8
270	-0.0	-0.0	-0.0	-0.1	-0.3	-0.6	-0.9	-1.2	-1.5	-1.8	-2.2	-2.6	-3.0	-3.4	-3.8
280	-0.0	-0.0	-0.0	-0.1	-0.3	-0.6	-0.8	-1.1	-1.5	-1.8	-2.1	-2.5	-2.8	-3.2	-3.6
290	-0.0	-0.0	-0.0	-0.1	-0.3	-0.5	-0.8	-1.1	-1.4	-1.7	-2.0	-2.3	-2.7	-3.0	-3.4
300	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.7	-0.9	-1.2	-1.5	-1.8	-2.1	-2.4	-2.8	-3.1
310	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.6	-0.8	-1.0	-1.3	-1.5	-1.8	-2.1	-2.4	-2.7
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.0	-1.2	-1.5	-1.7	-1.9	-2.2
330	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.7	-0.9	-1.0	-1.2	-1.4	-1.6
340	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.9
350	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0

Reservoir Elevation Wind Corrections in Feet

*** Pool elevation as measured at the dam.**

Missouri River Basin
Gavins Point Water Control Manual
Reservoir Elevation Wind Correction Table
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Reservoir Elevation Corrections at Gavin Point to Allow for Wind Effects

Reservoir Elevation at 1205 feet msl

(True Elevation = Reported Pool Elevation* + Correction)

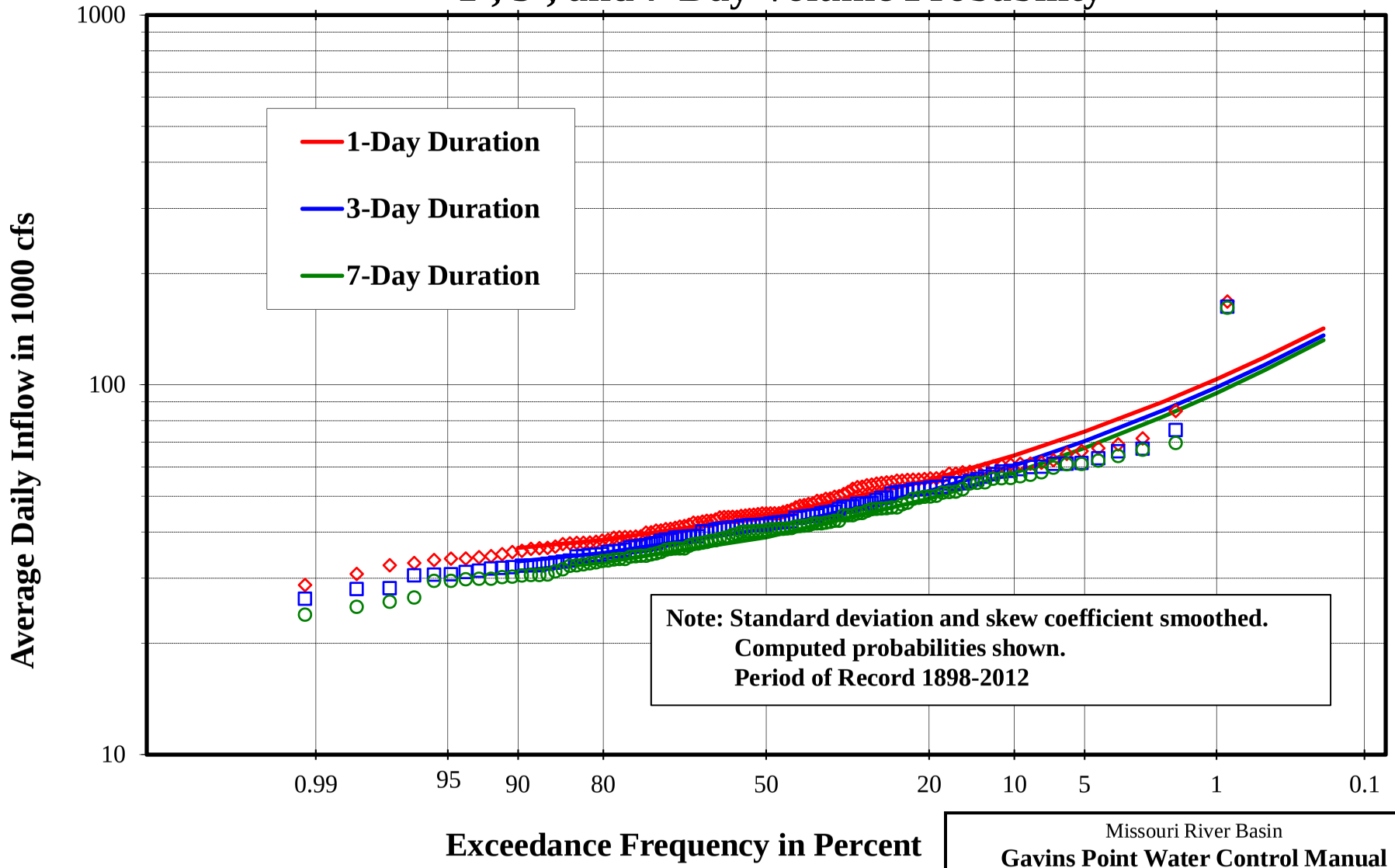
Wind Direction	Wind Speed in Miles Per Hour														
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
10	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.0	+1.2	+1.4	+1.6
20	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.0	+1.2	+1.5	+1.7	+2.0	+2.3
30	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.6	+0.8	+1.0	+1.3	+1.6	+1.9	+2.2	+2.6	+3.0
40	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.5	+1.8	+2.2	+2.6	+3.1	+3.6
50	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.1	+2.5	+3.0	+3.5	+4.1
60	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.8	+2.3	+2.7	+3.2	+3.8	+4.5
70	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.9	+2.3	+2.8	+3.4	+4.0	+4.7
80	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+0.9	+1.2	+1.6	+1.9	+2.4	+2.9	+3.4	+4.1	+4.8
90	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.9	+2.3	+2.8	+3.4	+4.0	+4.7
100	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.5	+1.8	+2.3	+2.7	+3.2	+3.8	+4.5
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.4	+1.7	+2.1	+2.5	+3.0	+3.5	+4.1
120	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.5	+1.8	+2.2	+2.6	+3.1	+3.6
130	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.6	+0.8	+1.0	+1.3	+1.6	+1.9	+2.2	+2.6	+3.0
140	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.0	+1.2	+1.5	+1.7	+2.0	+2.3
150	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.0	+1.2	+1.4	+1.6
160	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.3	+0.4	+0.5	+0.6	+0.7	+0.8	+0.9
170	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
180	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.7
190	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-0.8	-1.1	-1.3	-1.4
200	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.3	-0.4	-0.6	-0.8	-1.1	-1.3	-1.6	-1.8	-2.1
210	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.1	-1.4	-1.7	-2.0	-2.3	-2.6
220	-0.0	-0.0	-0.0	-0.1	-0.1	-0.3	-0.5	-0.8	-1.0	-1.3	-1.7	-2.0	-2.3	-2.7	-3.0
230	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.6	-0.9	-1.2	-1.5	-1.9	-2.2	-2.6	-2.9	-3.3
240	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.7	-1.0	-1.3	-1.6	-2.0	-2.4	-2.8	-3.1	-3.6
250	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.7	-1.0	-1.4	-1.7	-2.1	-2.5	-2.8	-3.3	-3.7
260	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.7	-1.0	-1.4	-1.7	-2.1	-2.5	-2.9	-3.3	-3.7
270	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.7	-1.0	-1.4	-1.7	-2.1	-2.5	-2.8	-3.3	-3.7
280	-0.0	-0.0	-0.0	-0.1	-0.2	-0.4	-0.7	-1.0	-1.3	-1.6	-2.0	-2.4	-2.8	-3.1	-3.6
290	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.6	-0.9	-1.2	-1.5	-1.9	-2.2	-2.6	-2.9	-3.3
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.3	-0.5	-0.8	-1.0	-1.3	-1.7	-2.0	-2.3	-2.7	-3.0
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.1	-1.4	-1.7	-2.0	-2.3	-2.6
320	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.3	-0.4	-0.6	-0.8	-1.1	-1.3	-1.6	-1.8	-2.1
330	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-0.8	-1.1	-1.3	-1.4
340	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.5	-0.7
350	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0

Reservoir Elevation Wind Corrections in Feet

*** Pool elevation as measured at the dam.**

Missouri River Basin
Gavins Point Water Control Manual
Reservoir Elevation Wind Correction Table
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

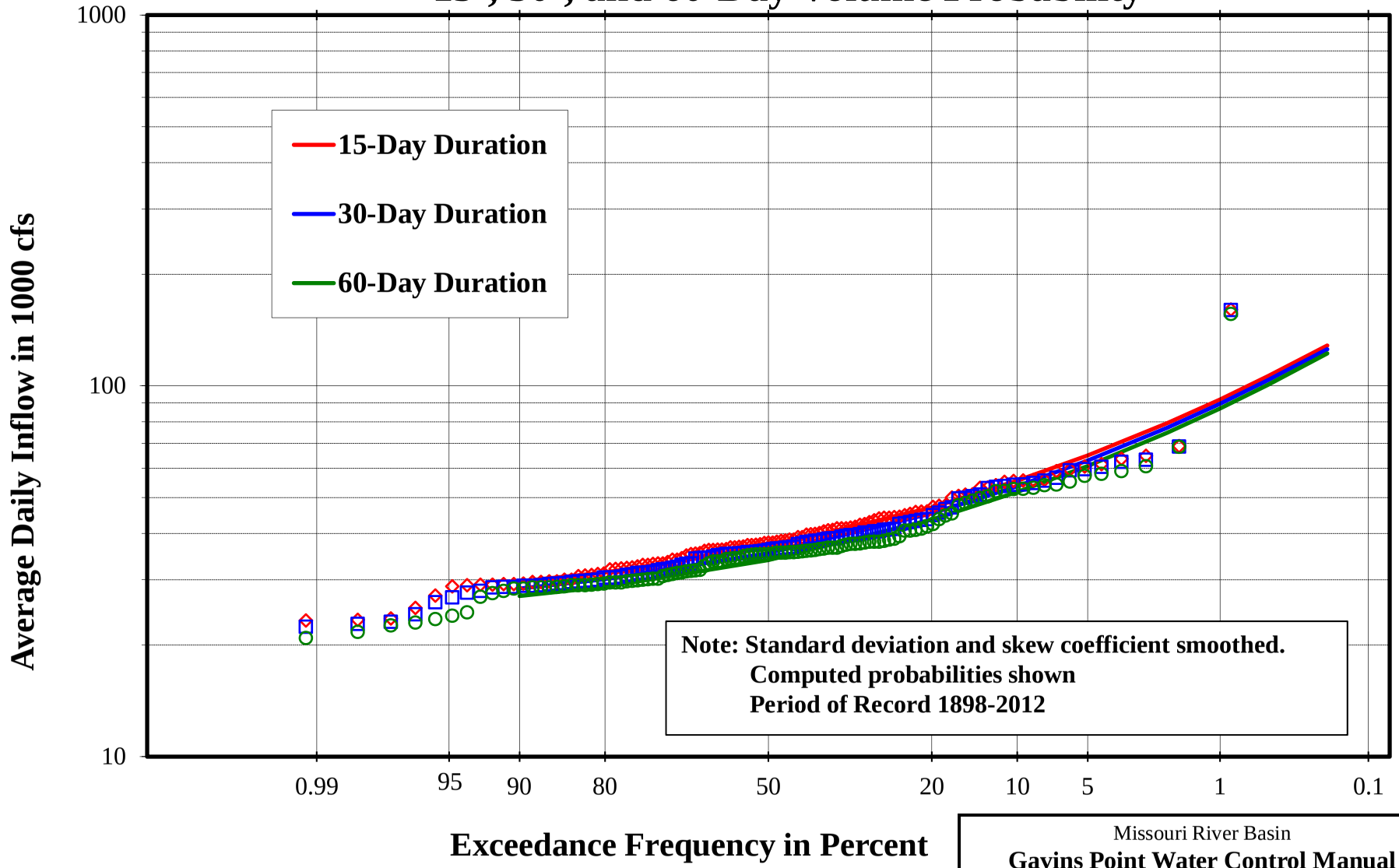
Gavins Point - Regulated Inflow
1-, 3-, and 7-Day Volume Probability



Missouri River Basin
Gavins Point Water Control Manual
Gavins Point Regulated Inflow Probability

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

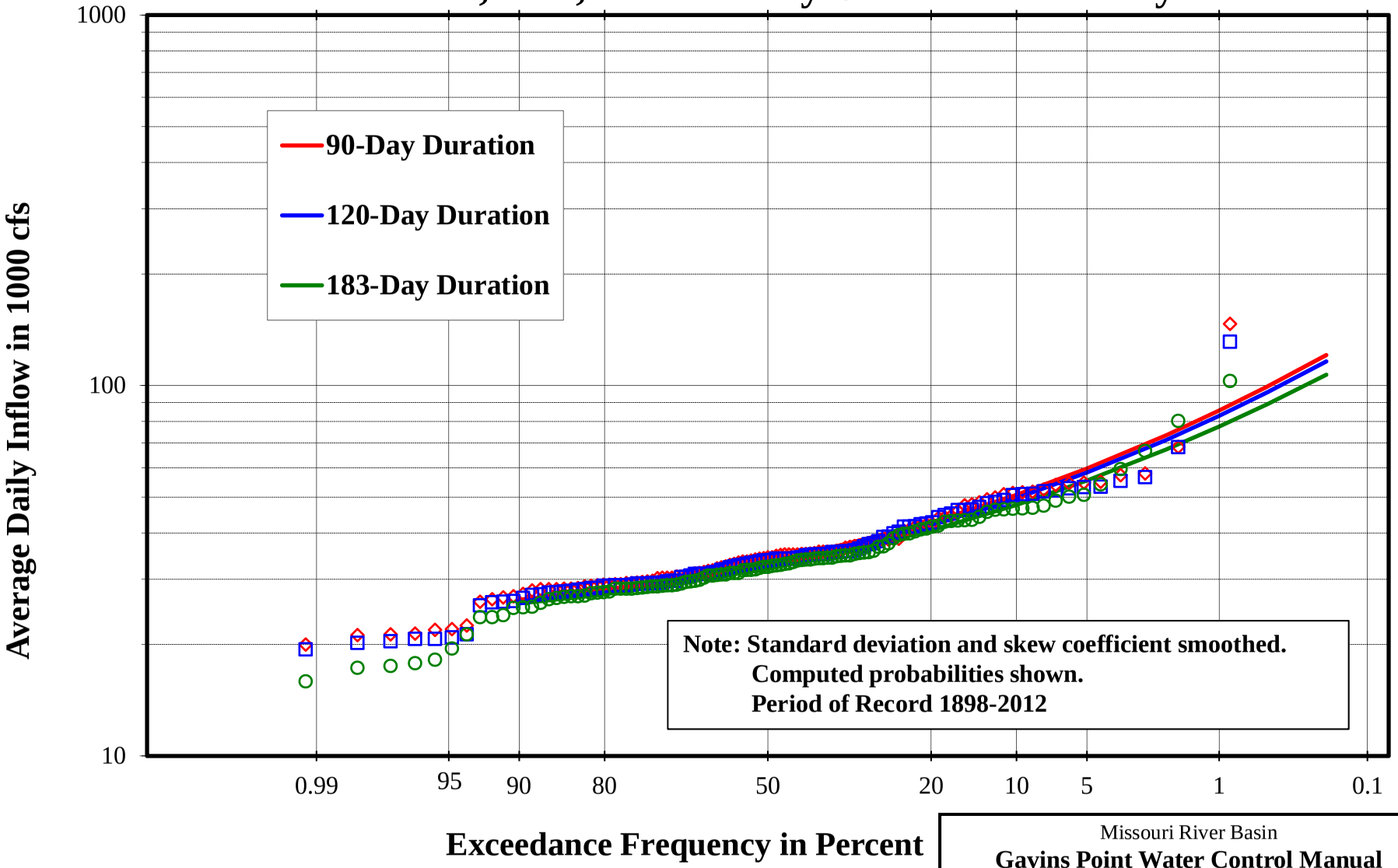
Gavins Point - Regulated Inflow
15-, 30-, and 60-Day Volume Probability



Missouri River Basin
Gavins Point Water Control Manual
Gavins Point Regulated Inflow Probability

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

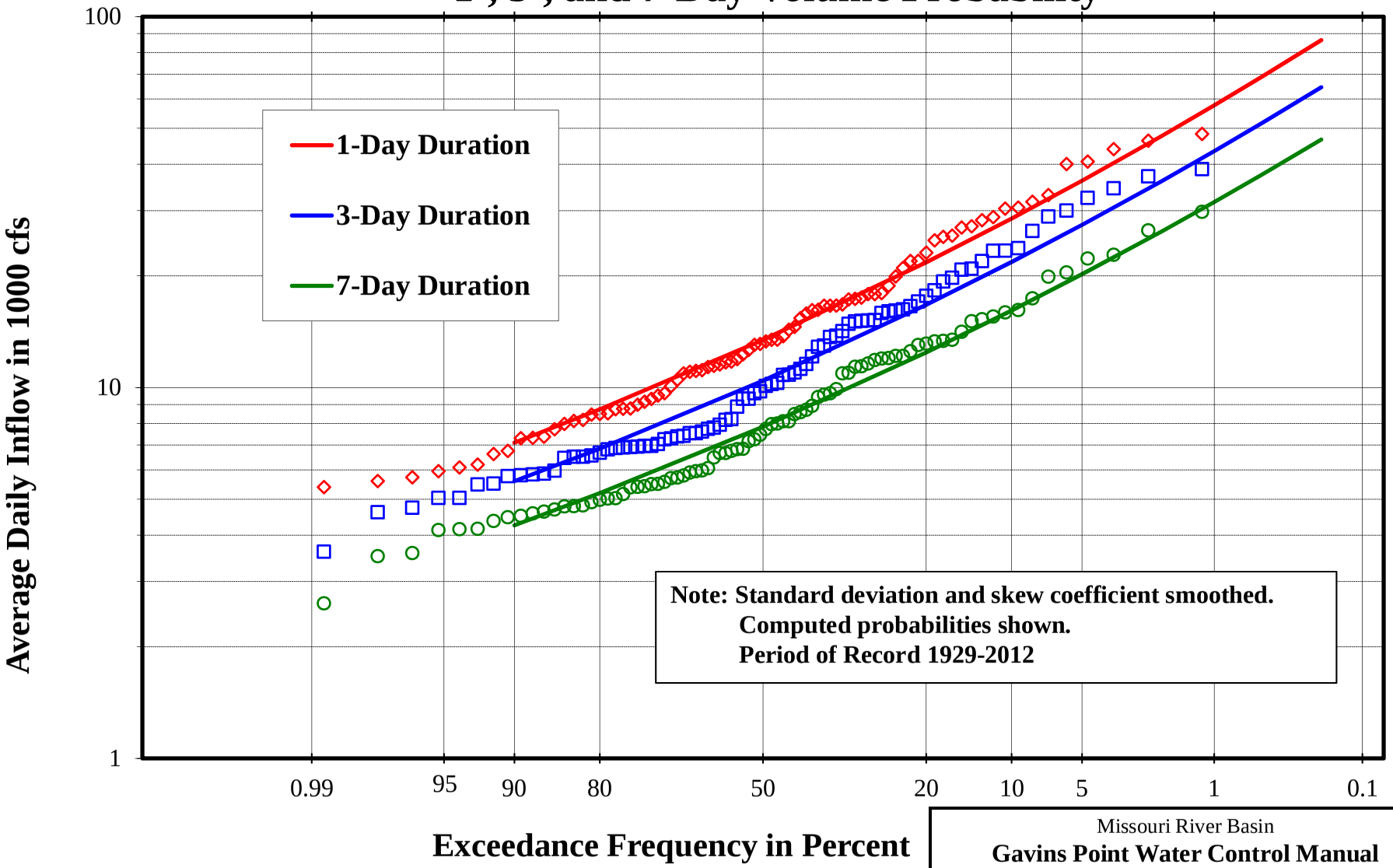
Gavins Point - Regulated Inflow
90-, 120-, and 183-Day Volume Probability



Missouri River Basin
Gavins Point Water Control Manual
Gavins Point Regulated Inflow Probability

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

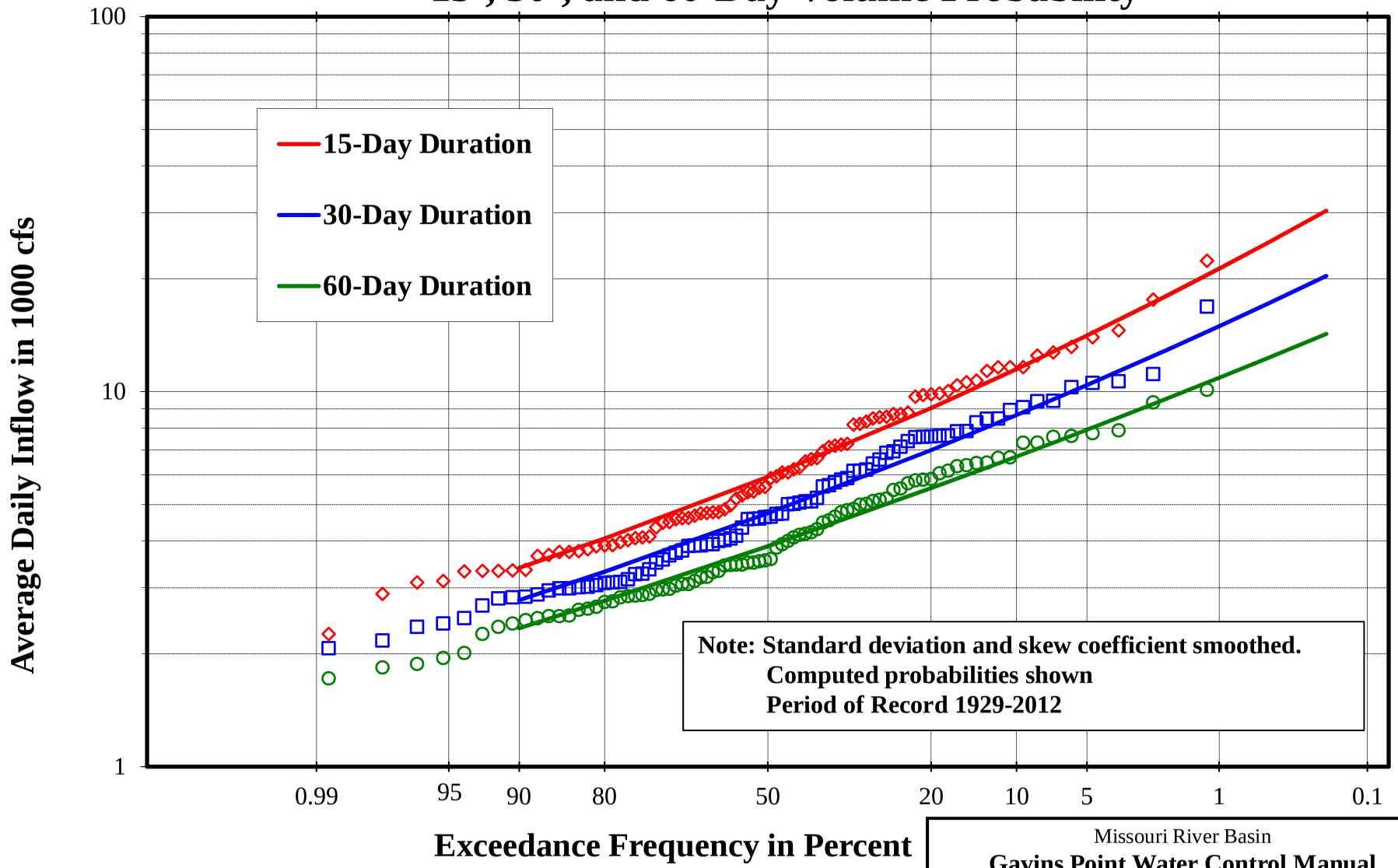
Gavins Point - Incremental Inflow
1-, 3-, and 7-Day Volume Probability



Missouri River Basin
Gavins Point Water Control Manual
Gavins Point Incremental Inflow Probability

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Gavins Point - Incremental Inflow
15-, 30-, and 60-Day Volume Probability



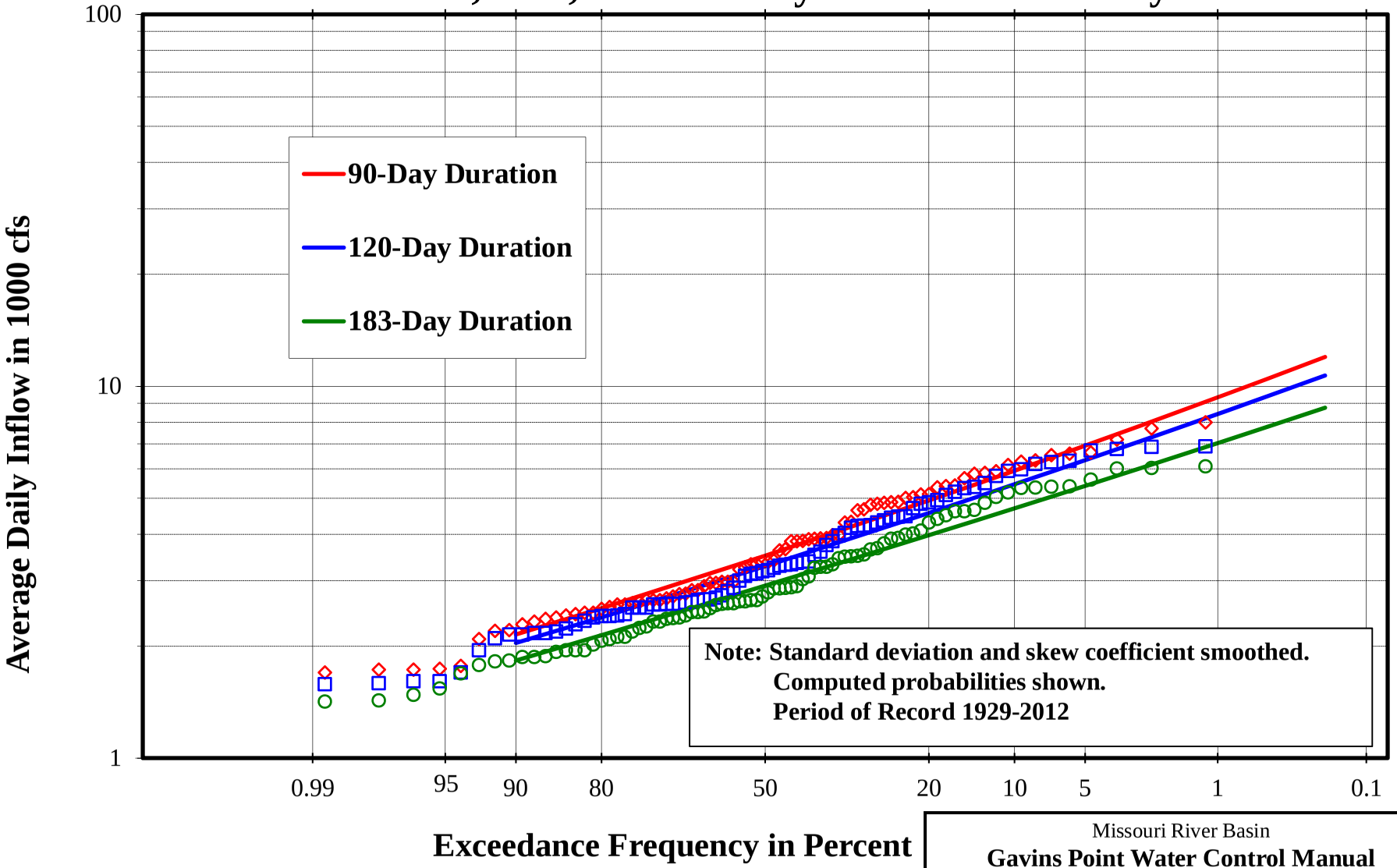
Missouri River Basin

Gavins Point Water Control Manual

Gavins Point Incremental Inflow Probability

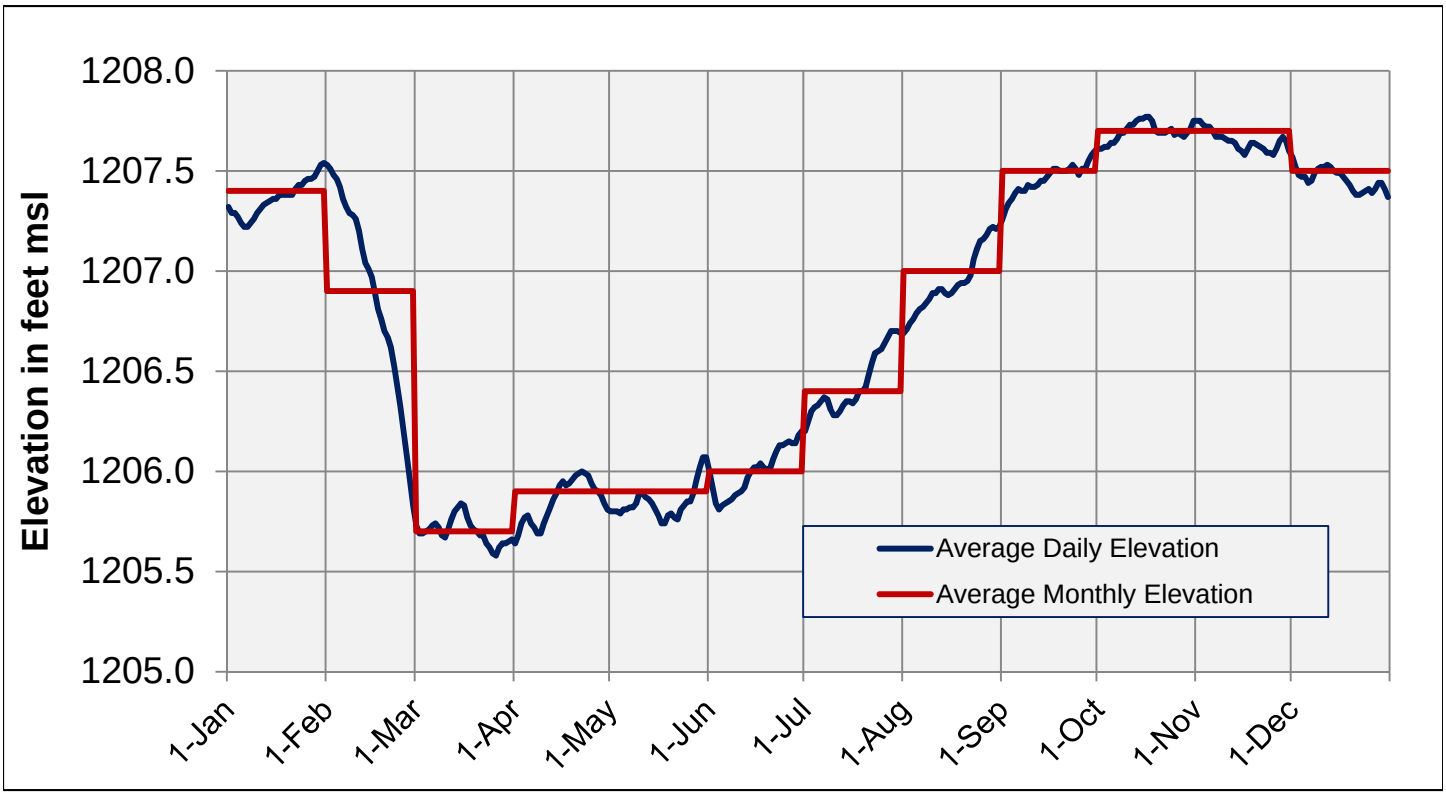
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

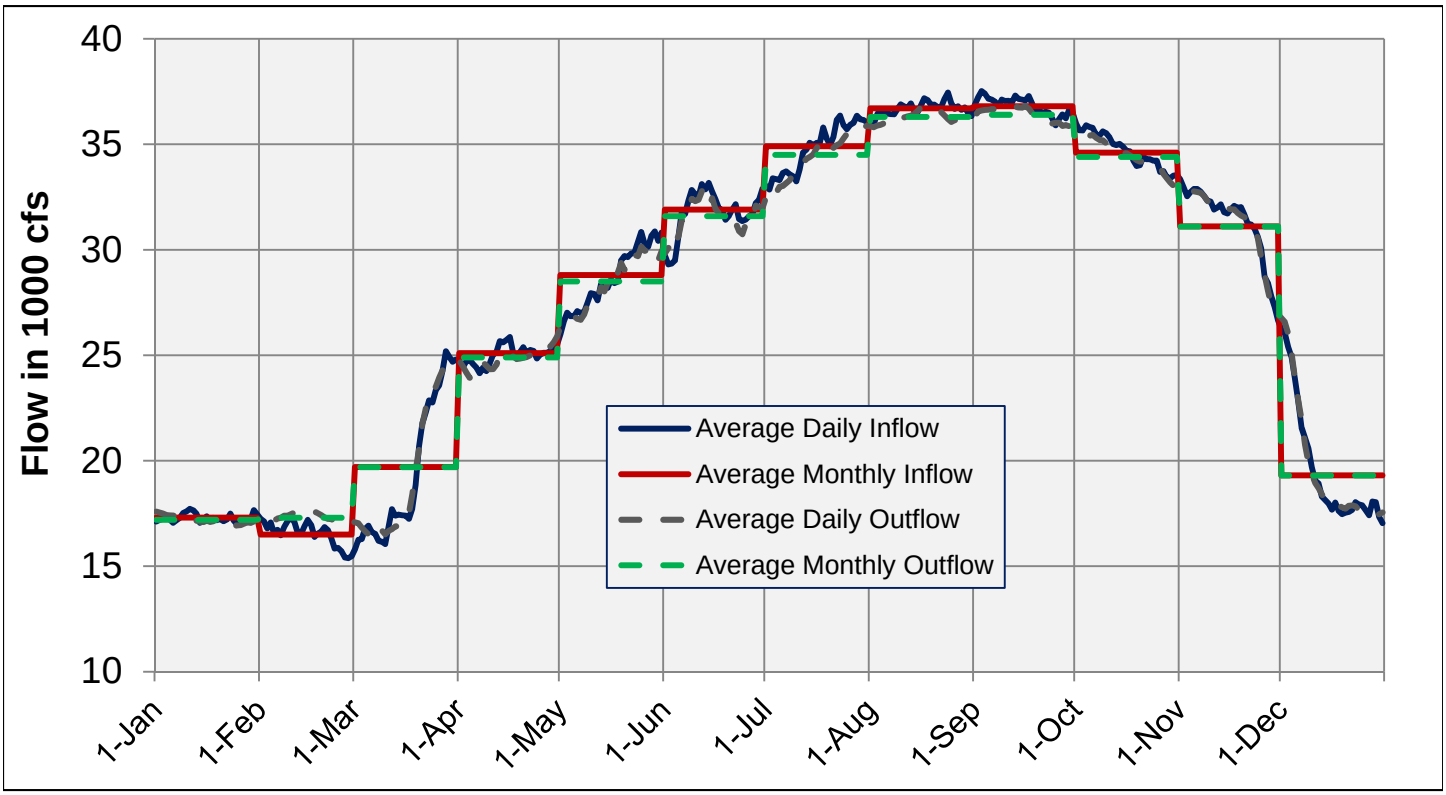
Gavins Point - Incremental Inflow
90-, 120-, and 183-Day Volume Probability



Missouri River Basin
Gavins Point Water Control Manual
Gavins Point Incremental Inflow Probability

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

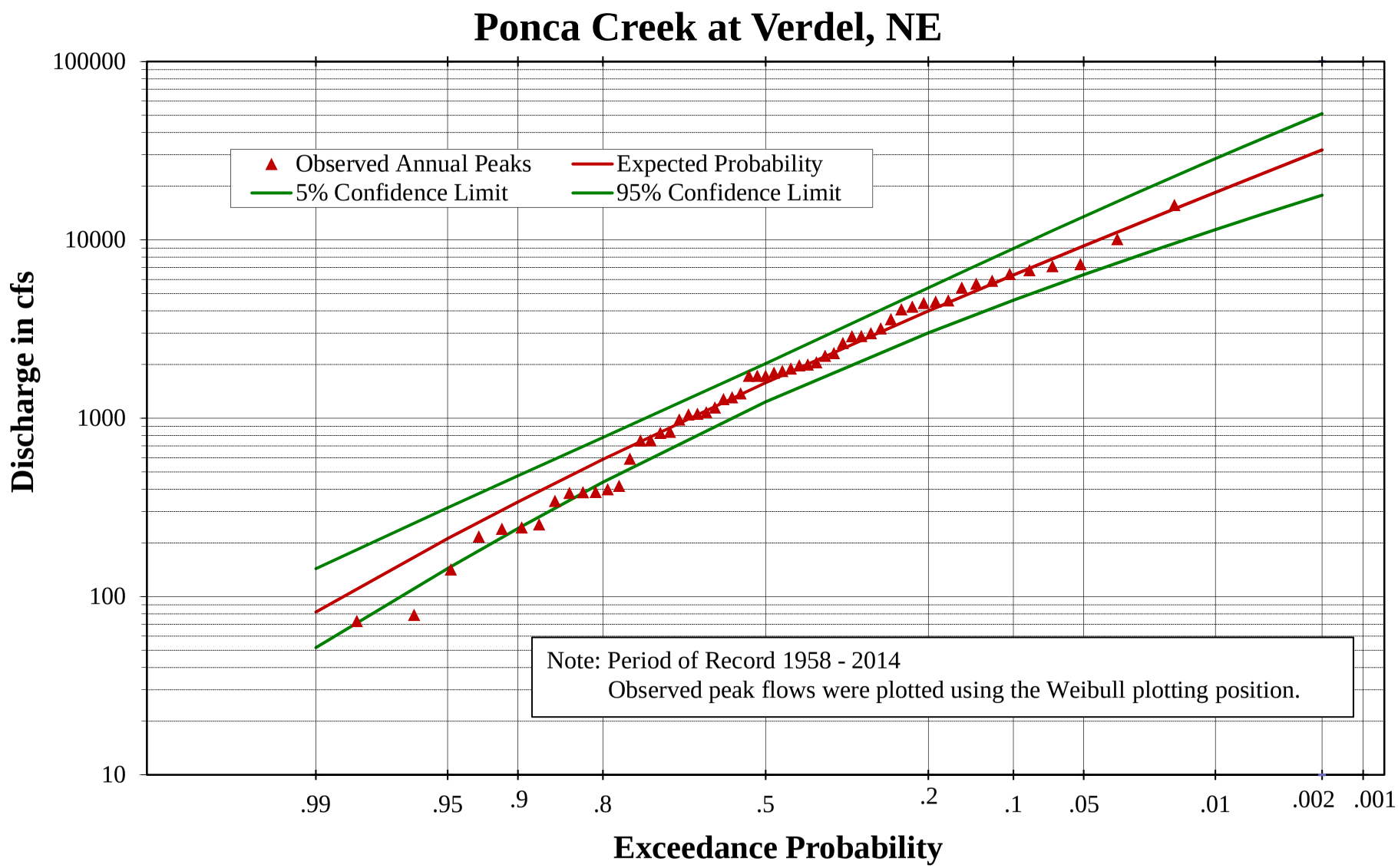




Period of Record: 1967 - 2015

Missouri River Basin
Gavins Point Water Control Manual
Average Daily and Monthly Elevations, Inflow and Outflow

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin

Gavins Point Water Control Manual

Probability Curve – Ponca Creek at Verdel, NE

U.S. Army Engineer Division, Northwestern
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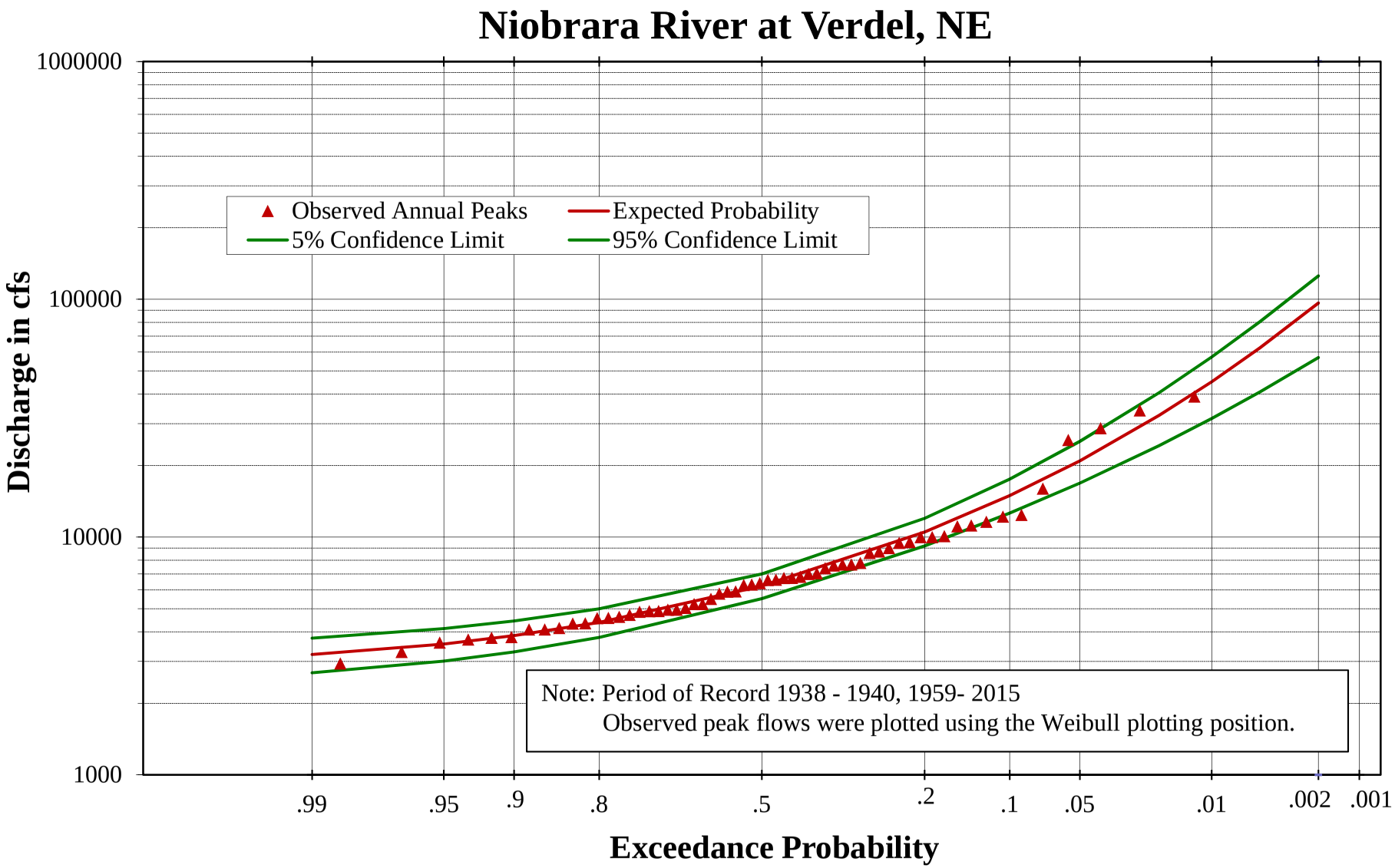
September 2017

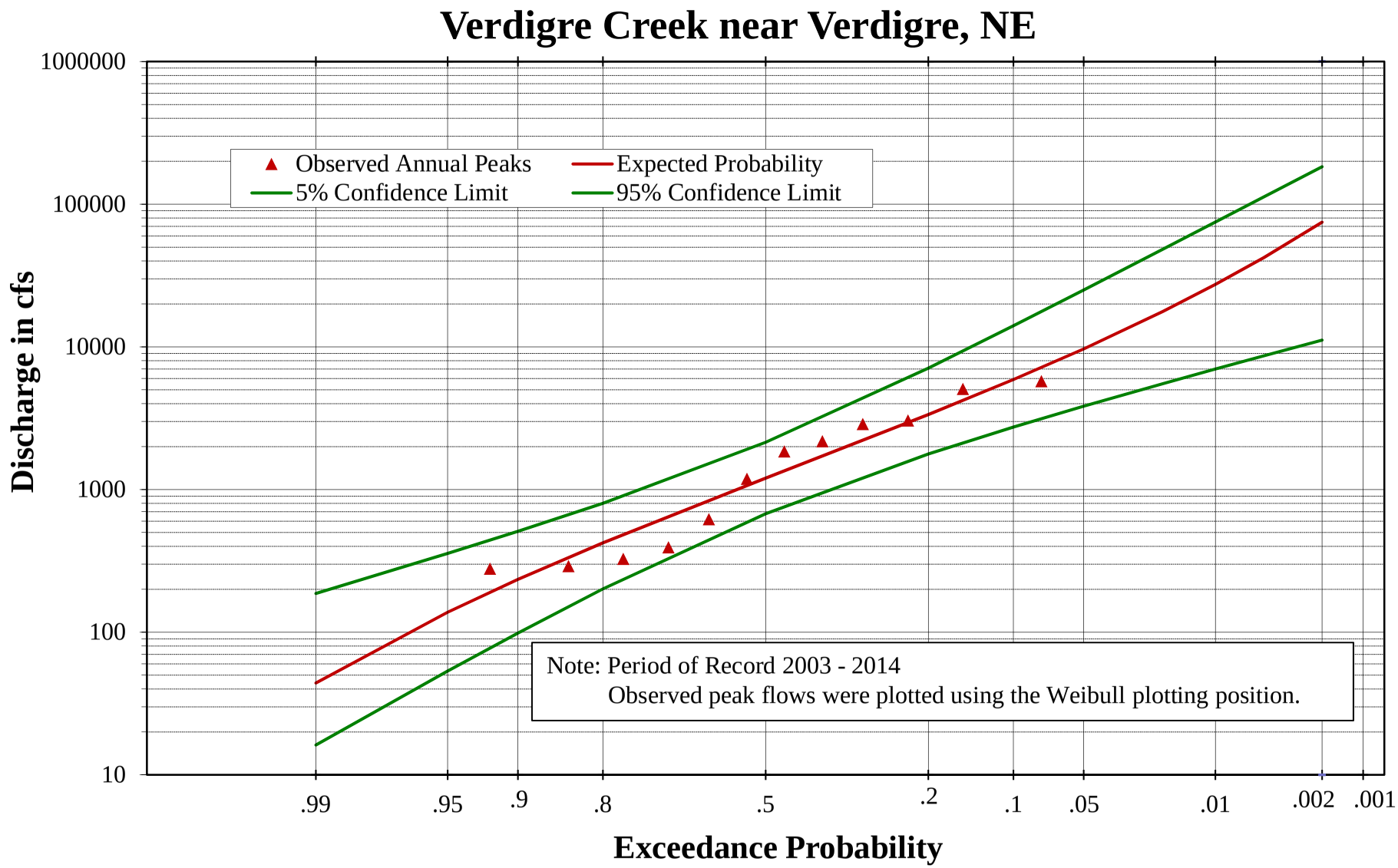


Missouri River Basin

Gavins Point Water Control Manual

Probability Curve – Niobrara River at Verdel, NE

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



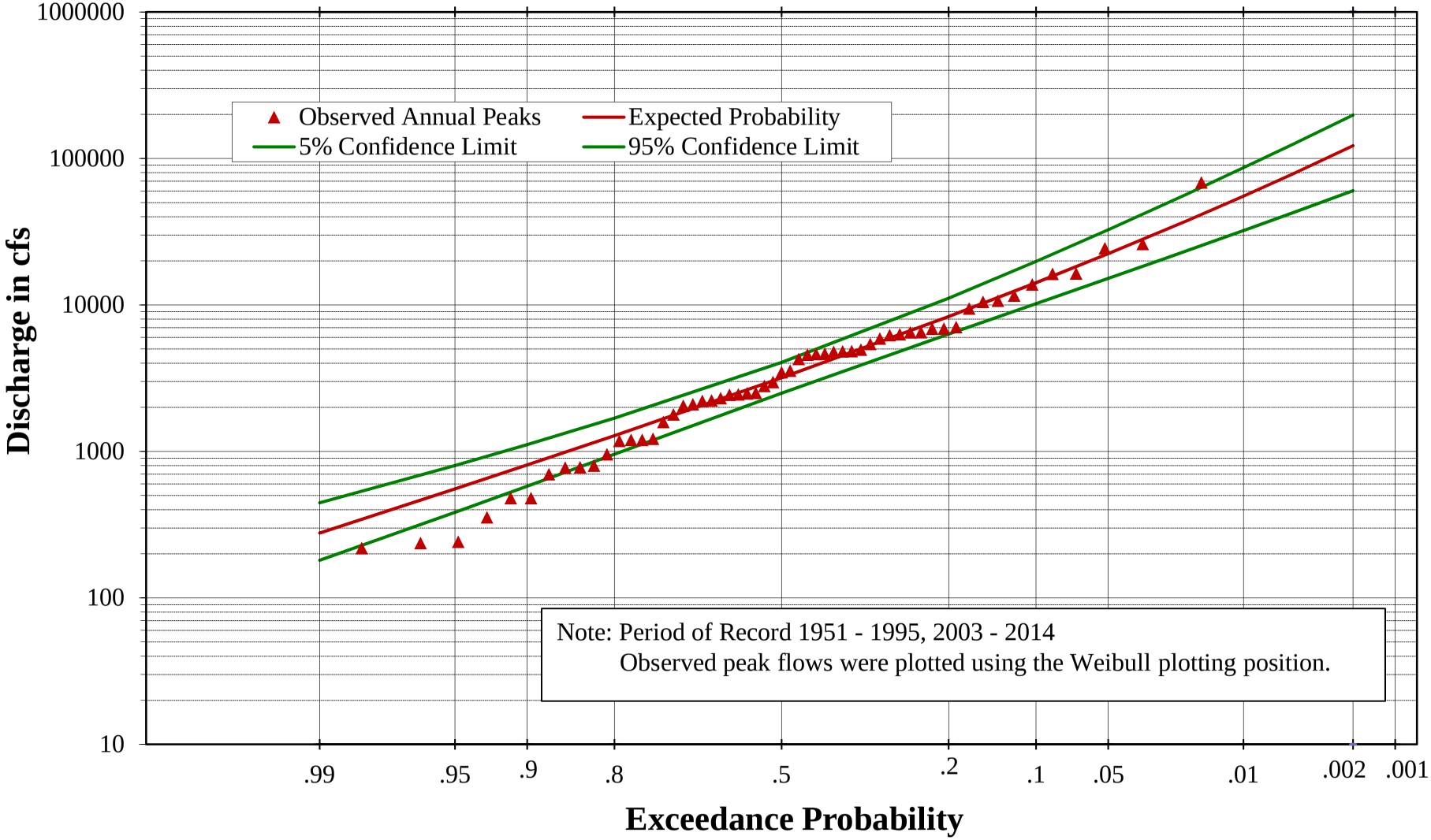
Missouri River Basin

Gavins Point Water Control Manual

Probability Curve – Verdigre Creek near Verdigre, NE

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Bazile Creek near Niobrara, NE



Missouri River Basin

Gavins Point Water Control Manual

Probability Curve – Bazile Creek near Niobrara, NE

U.S. Army Engineer Division, Northwestern
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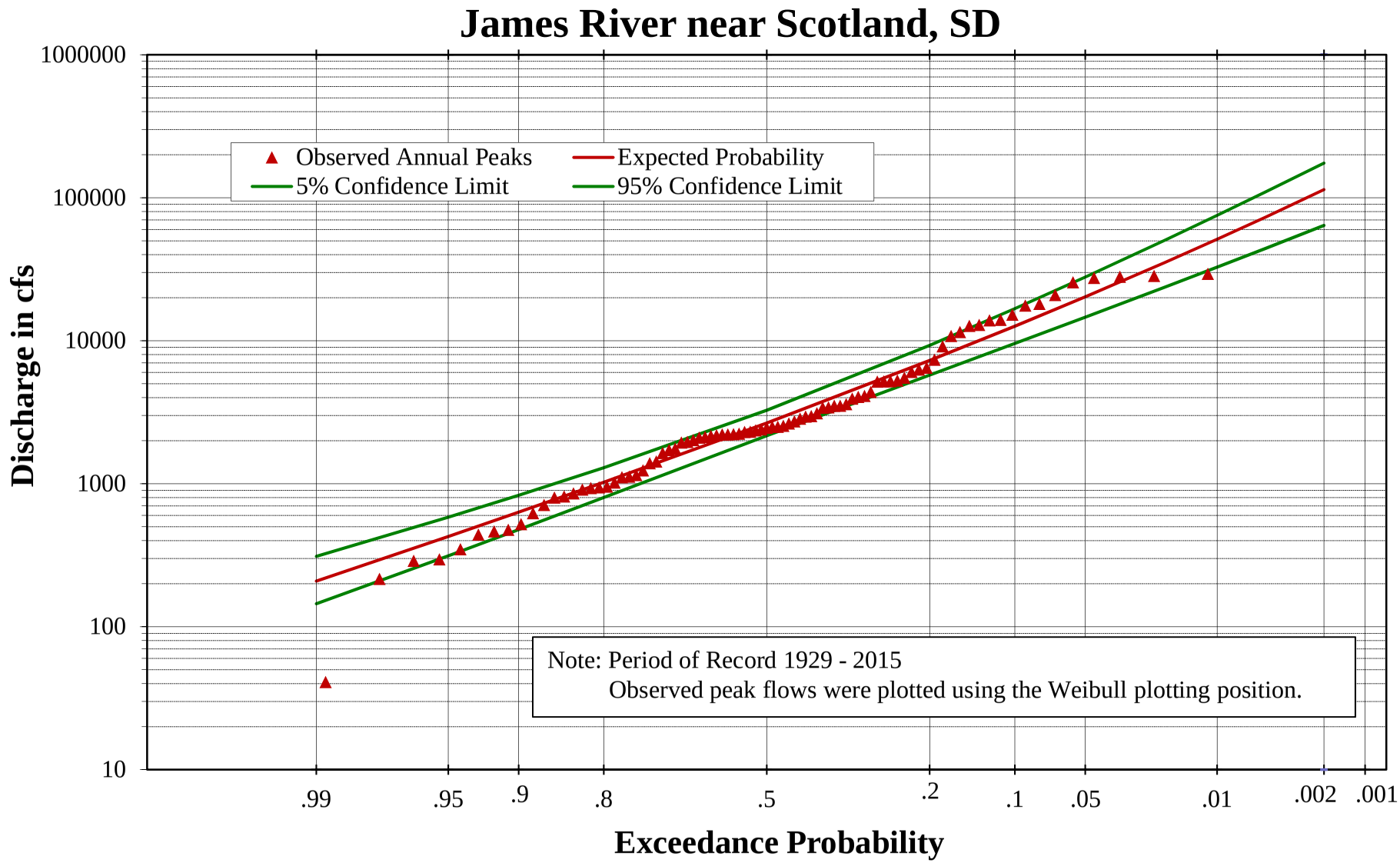
September 2017

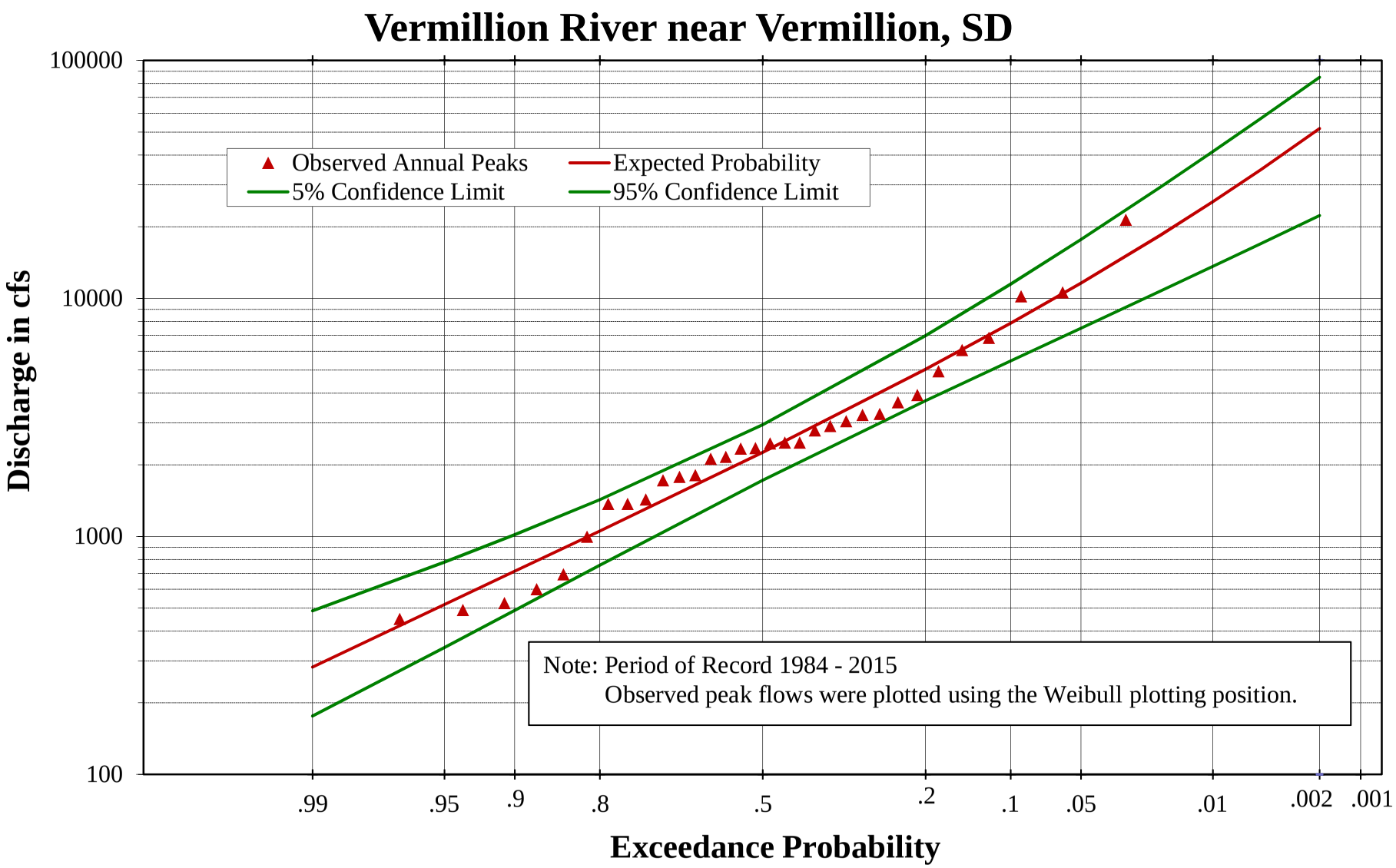


Missouri River Basin

Gavins Point Water Control Manual

Probability Curve – James River near Scotland, SD

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin

Gavins Point Water Control Manual

Probability Curve – Vermillion River near Vermillion, SD

U.S. Army Engineer Division, Northwestern
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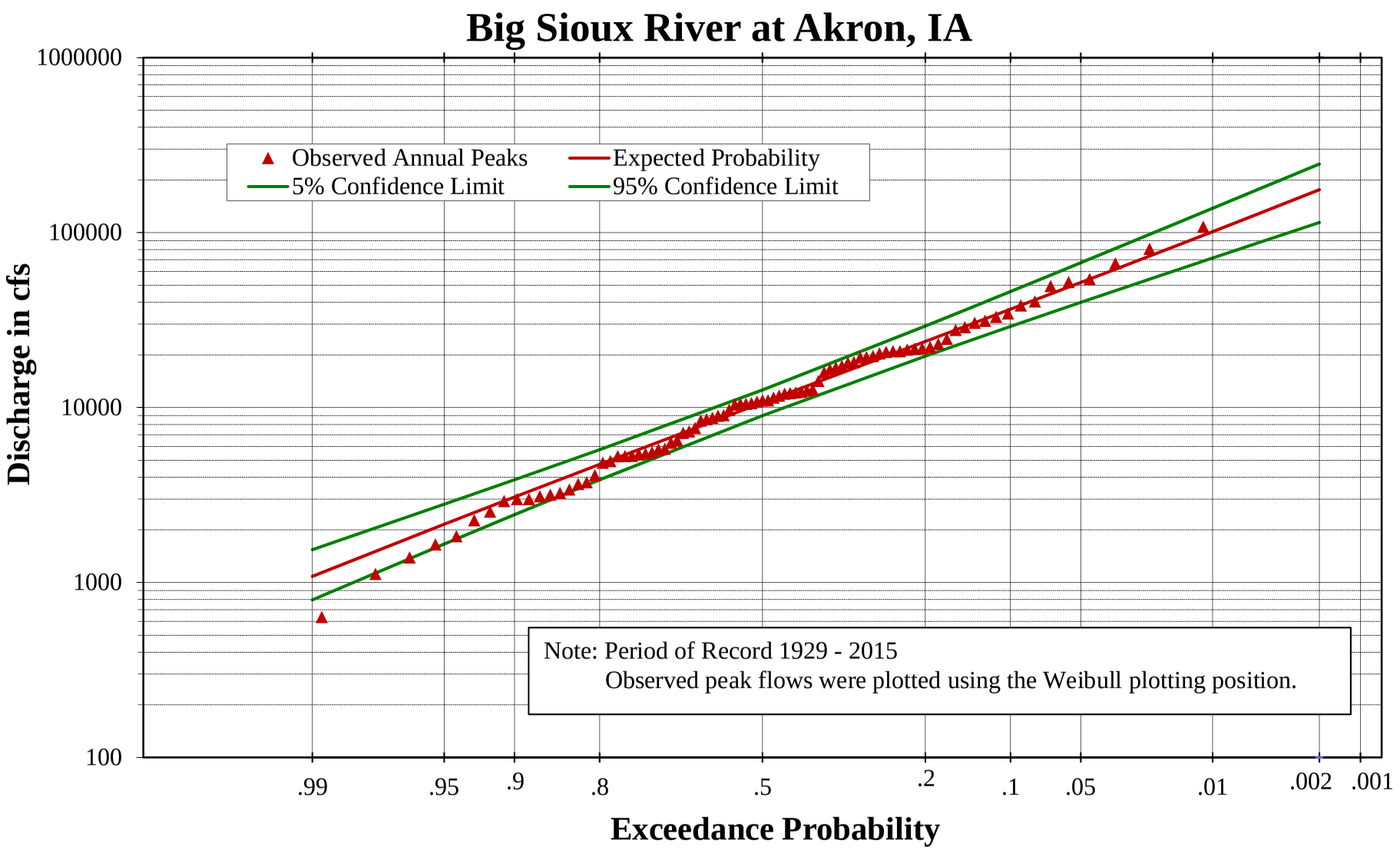

Missouri River Basin

Gavins Point Water Control Manual

Probability Curve – Big Sioux River at Akron, IA

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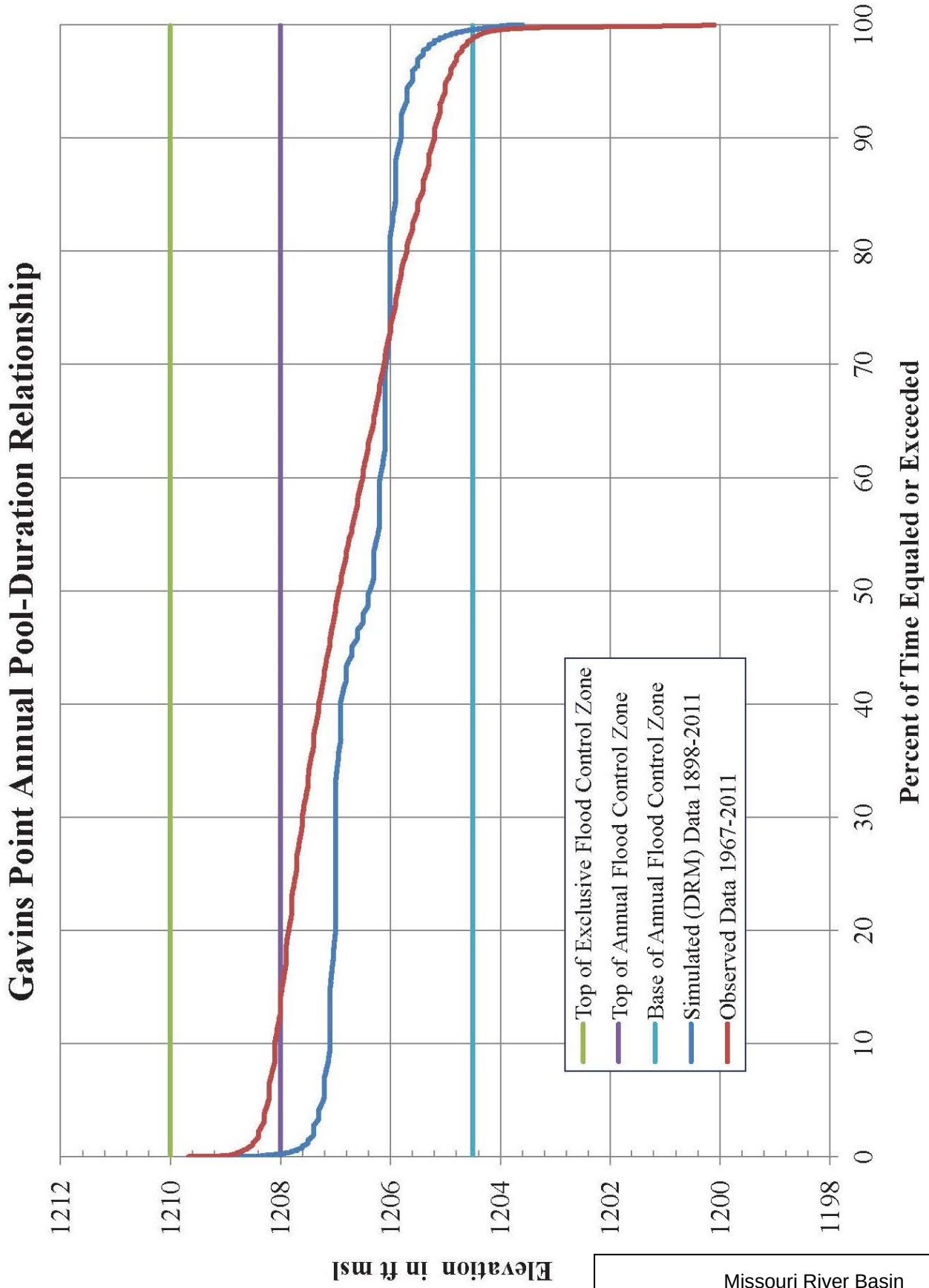
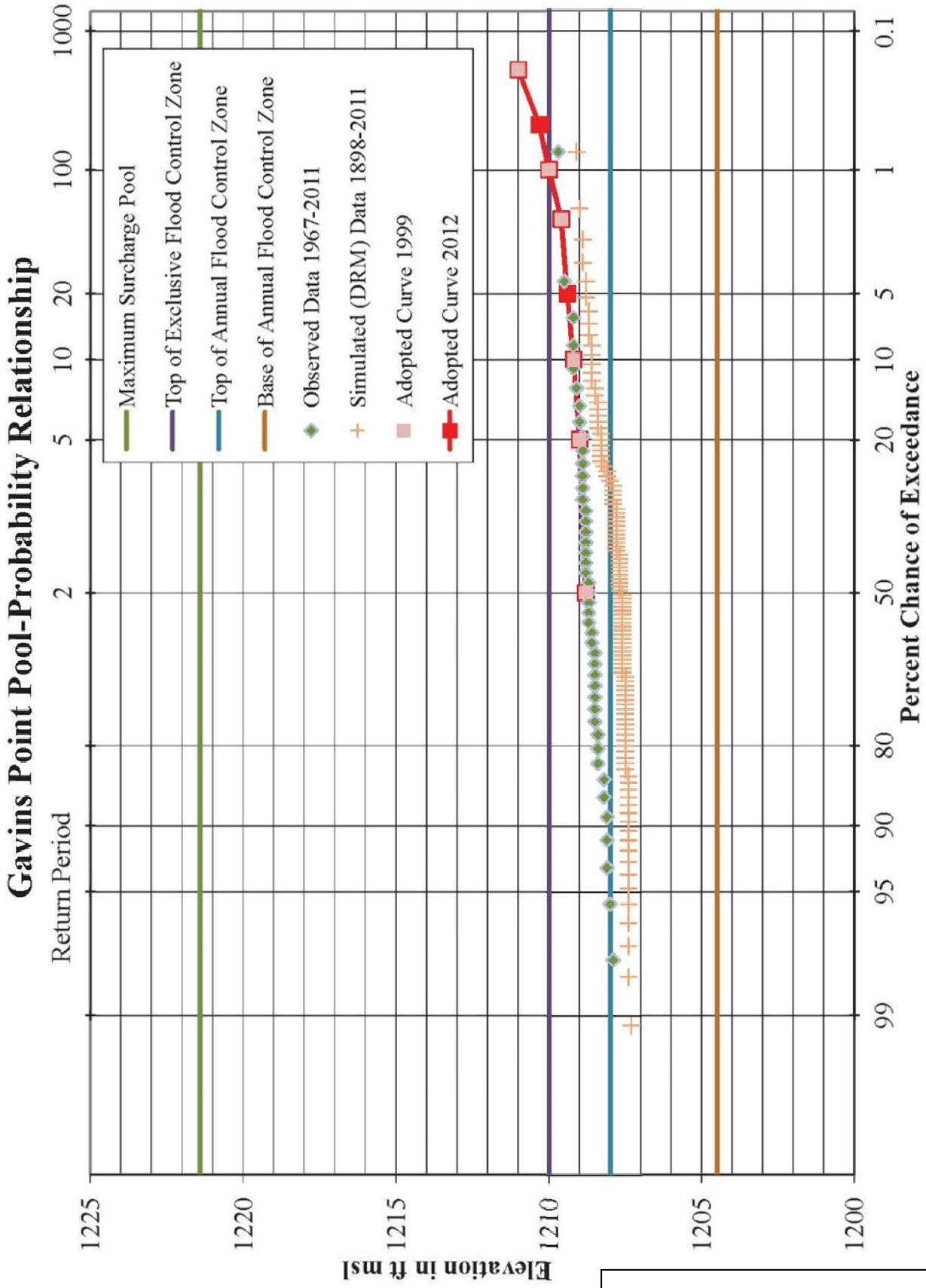


Missouri River Basin

Gavins Point Water Control Manual

Gavins Point Pool-Duration Relationship

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

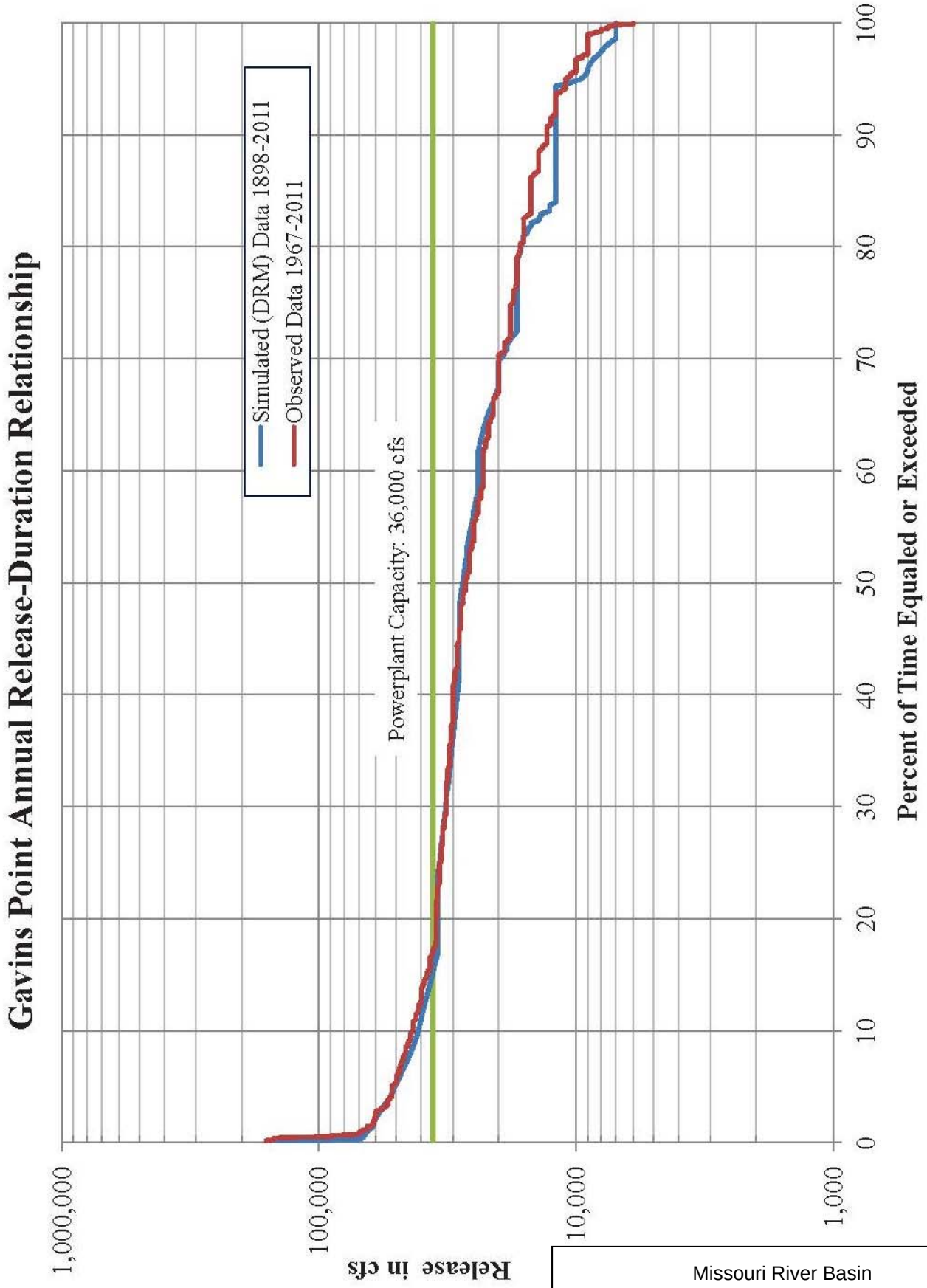


Missouri River Basin

Gavins Point Water Control Manual

Gavins Point Pool-Probability Relationship

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

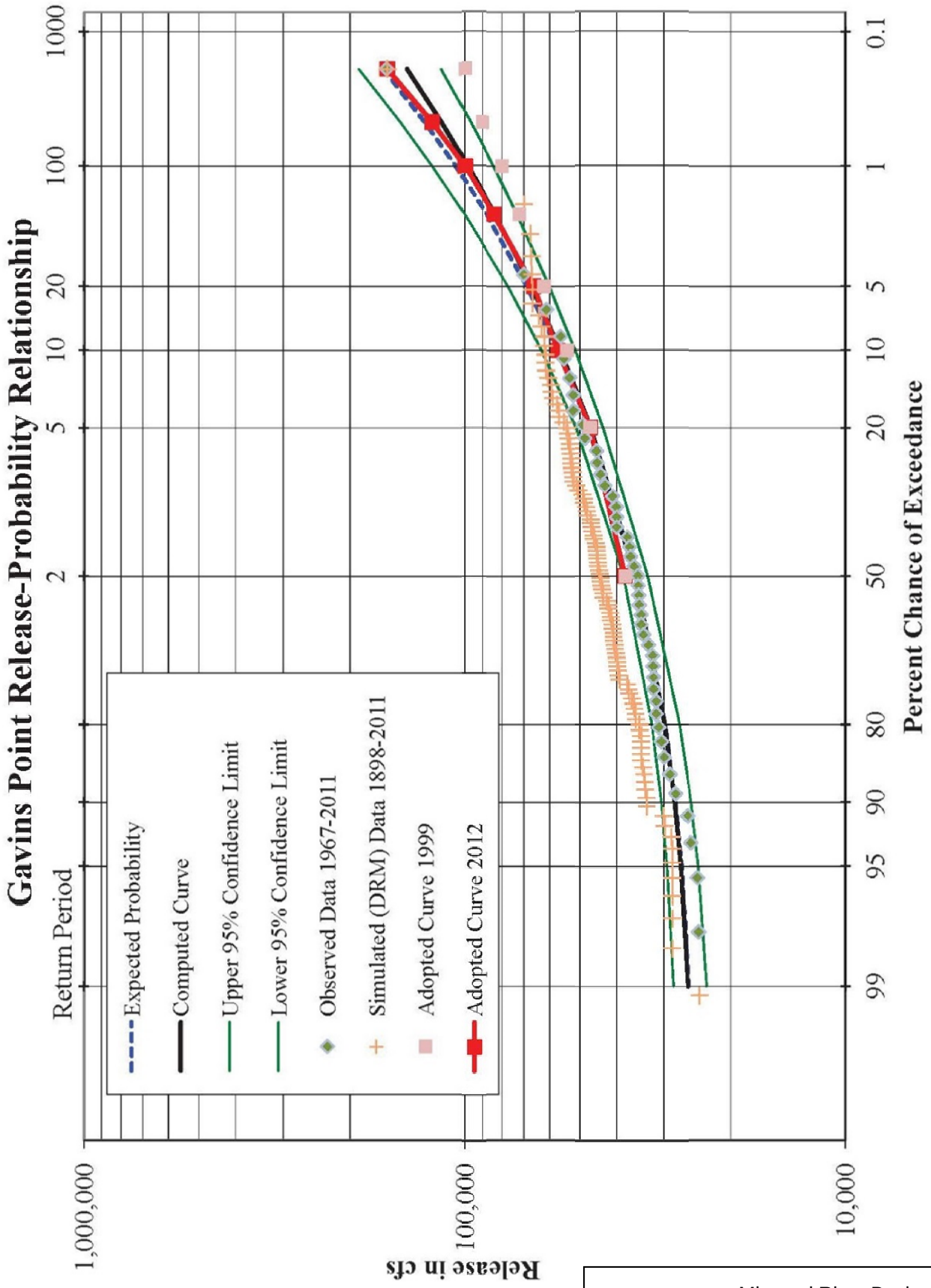


Missouri River Basin

Gavins Point Water Control Manual

Gavins Point Release-Duration Relationship

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017



Missouri River Basin

Gavins Point Water Control Manual

Gavins Point Release-Probability Relationship

U.S. Army Engineer Division, Northwestern
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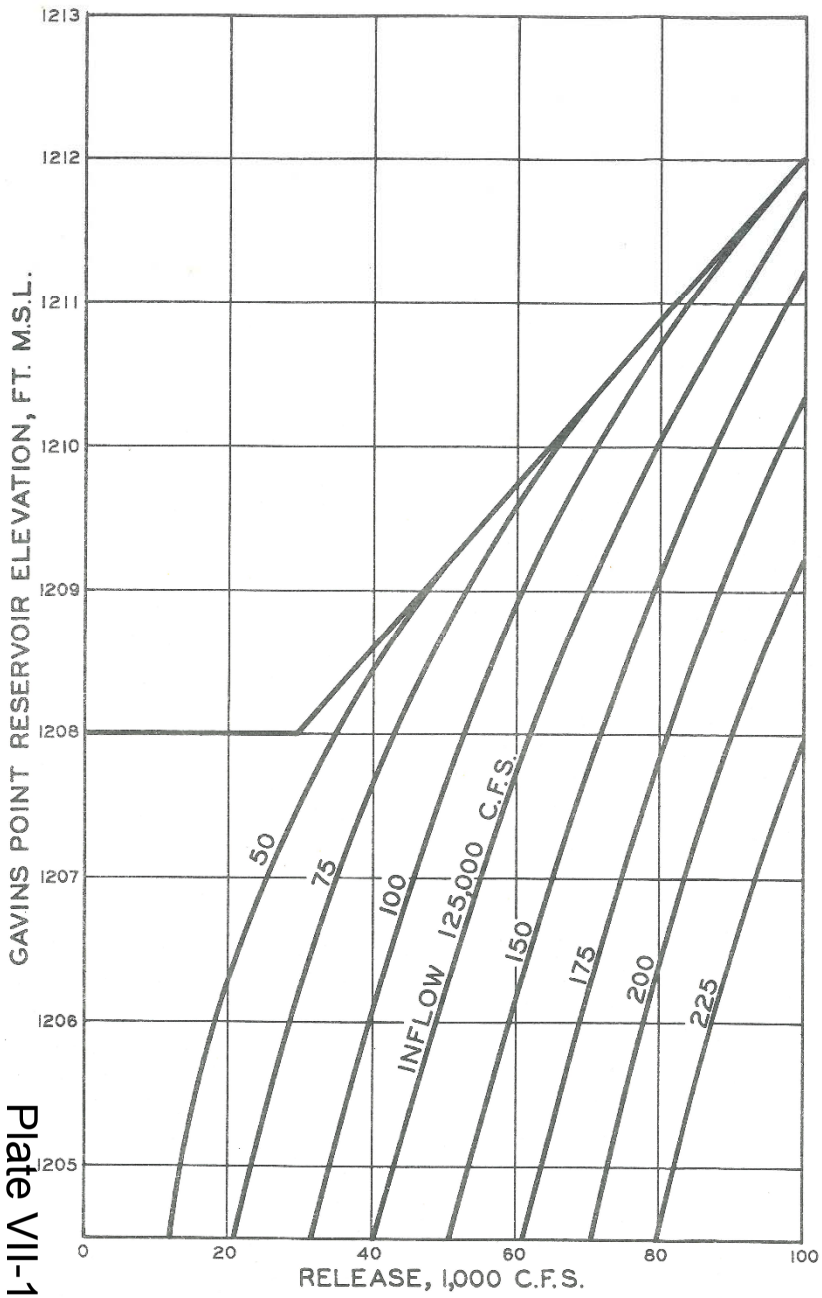
September 2017



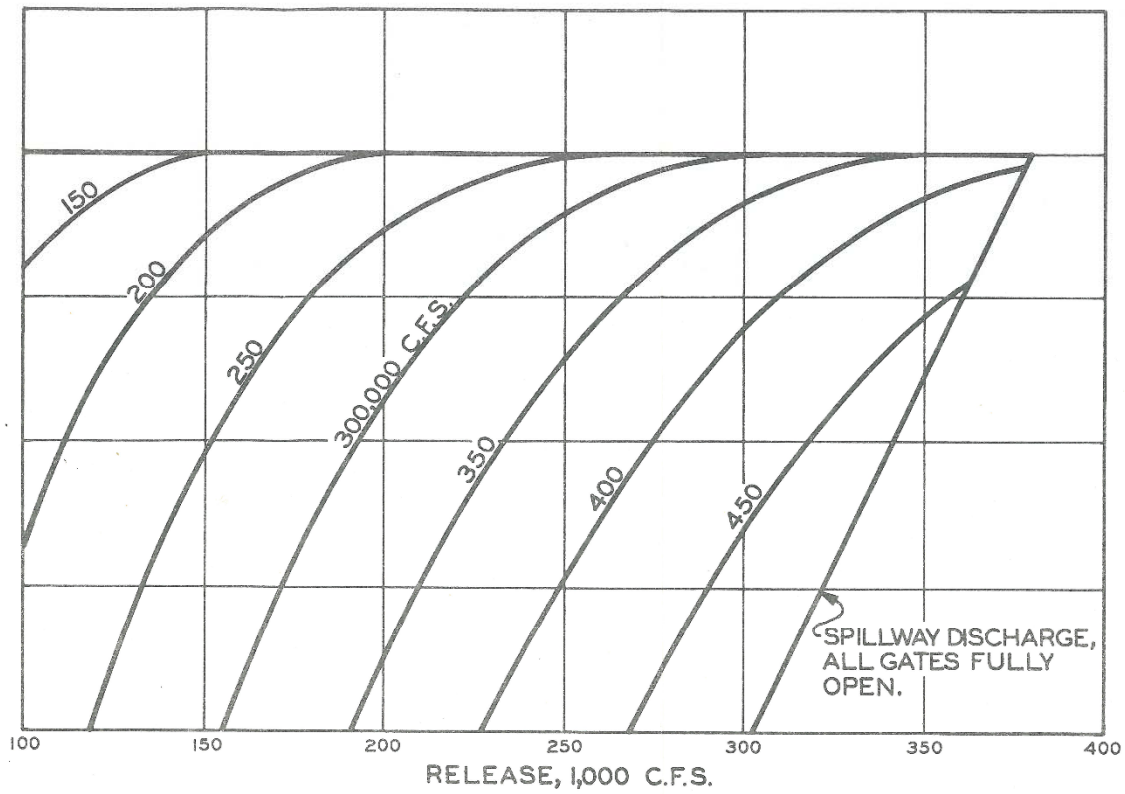


Plate VII-1

Missouri River Basin

Gavins Point Water Control Manual

Emergency Regulation Curves

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
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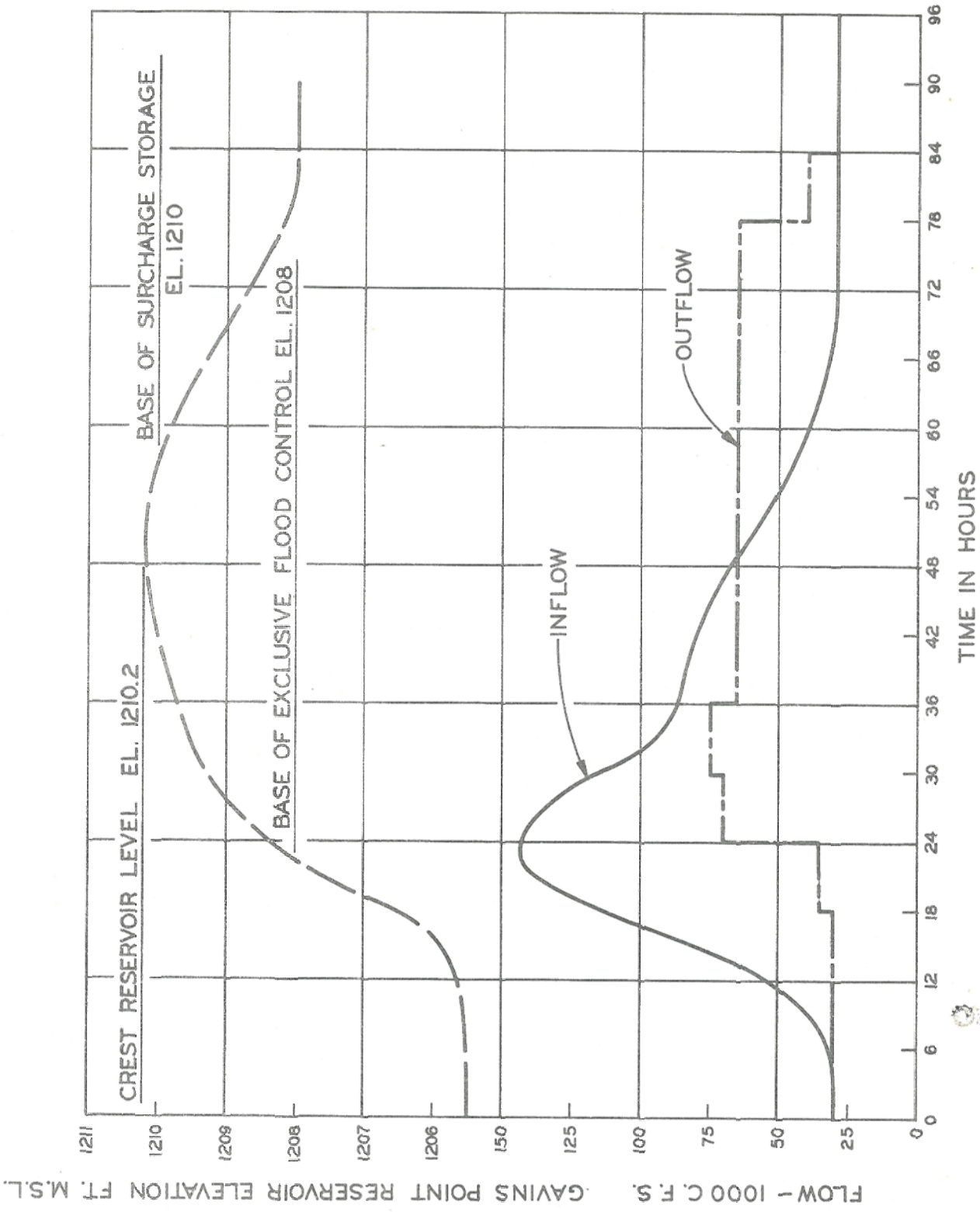

Missouri River Basin

Gavins Point Water Control Manual

Reservoir Design Flood Routing

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
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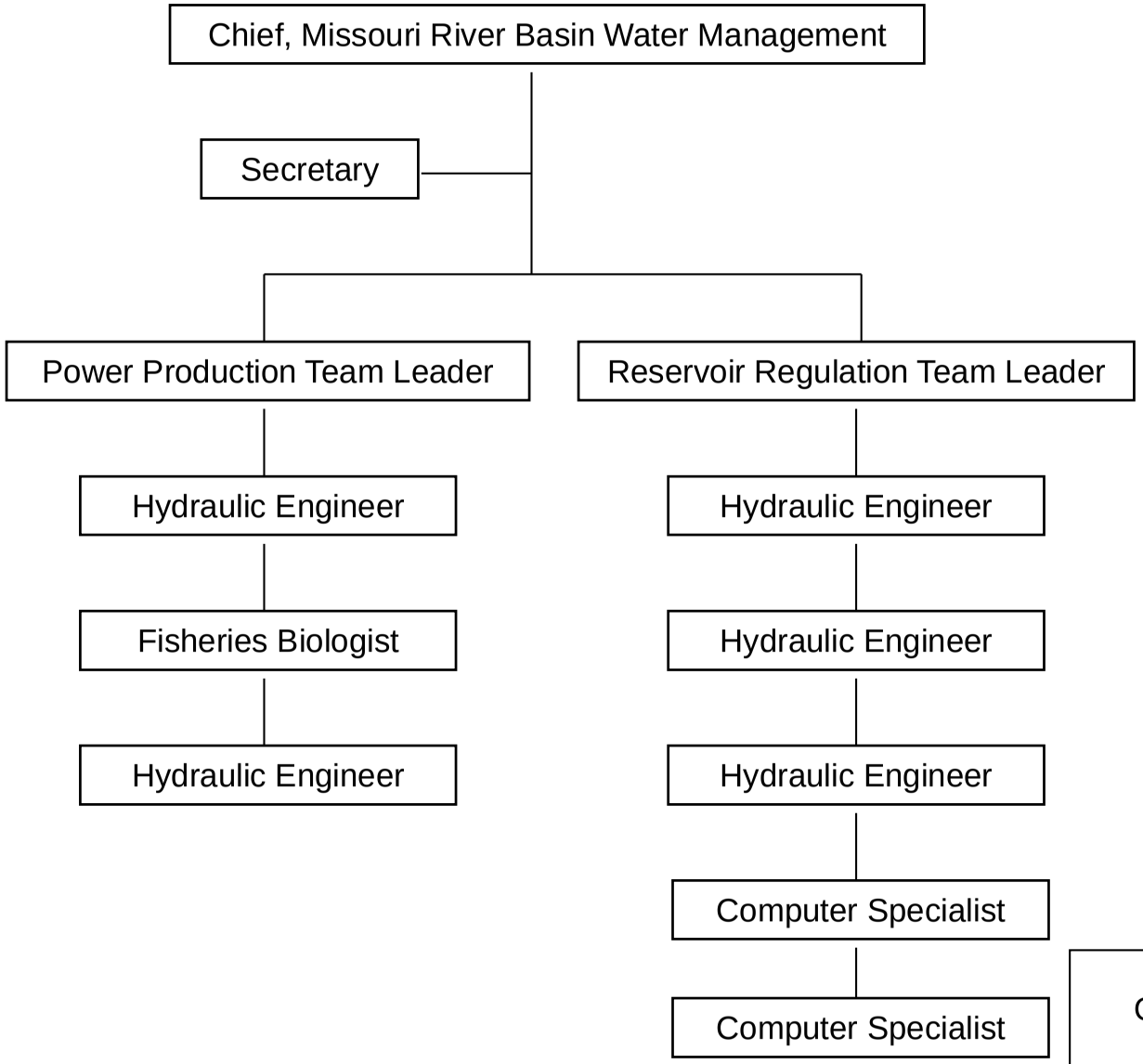
NWD-Omaha

Missouri River Basin Water Management Division



Budget Analyst is shared with Columbia River Basin Water Management

Missouri River Basin
Gavins Point Water Control Manual
MRBWMD Organization Chart

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
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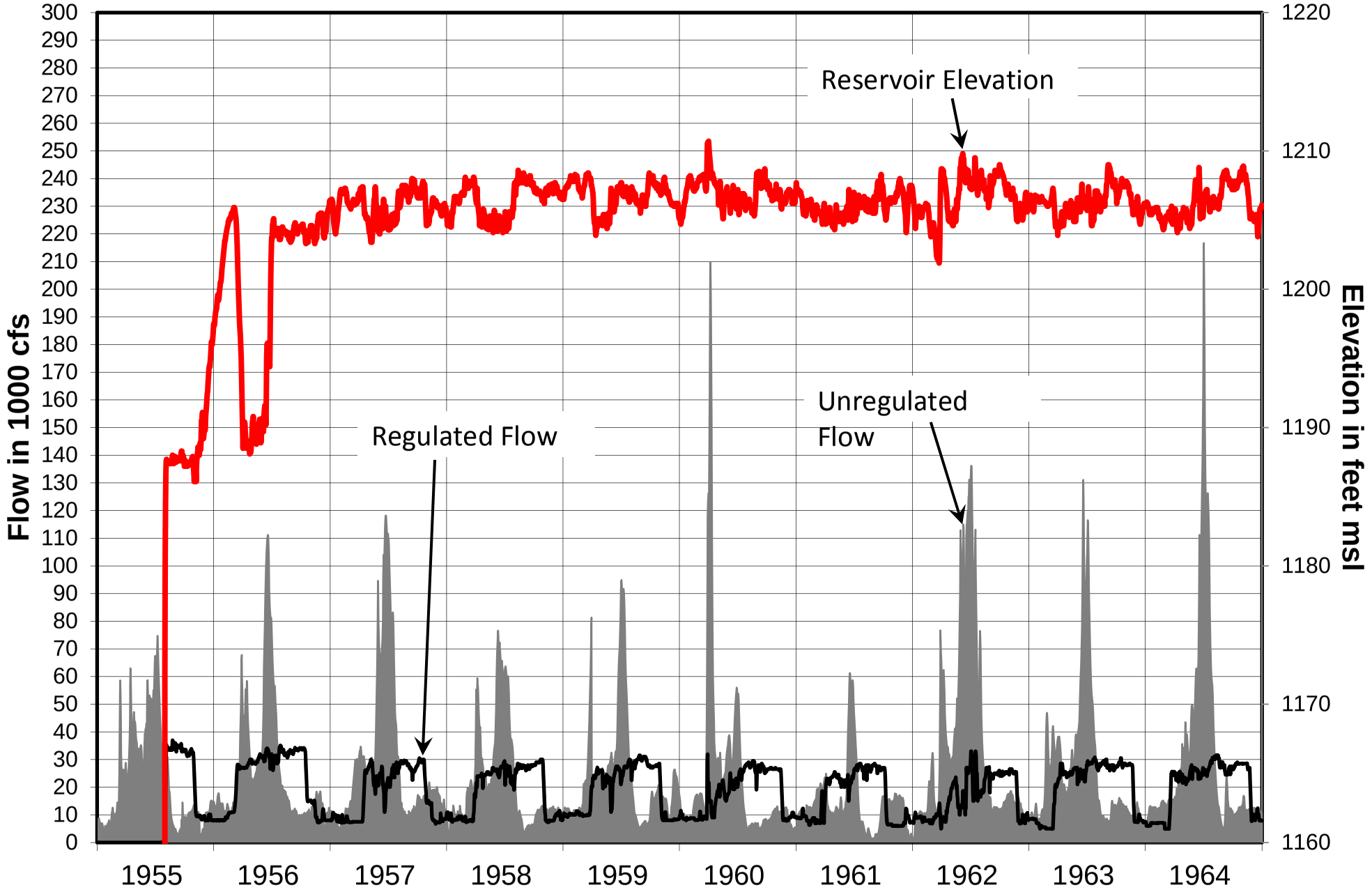

Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1955 - 1964

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
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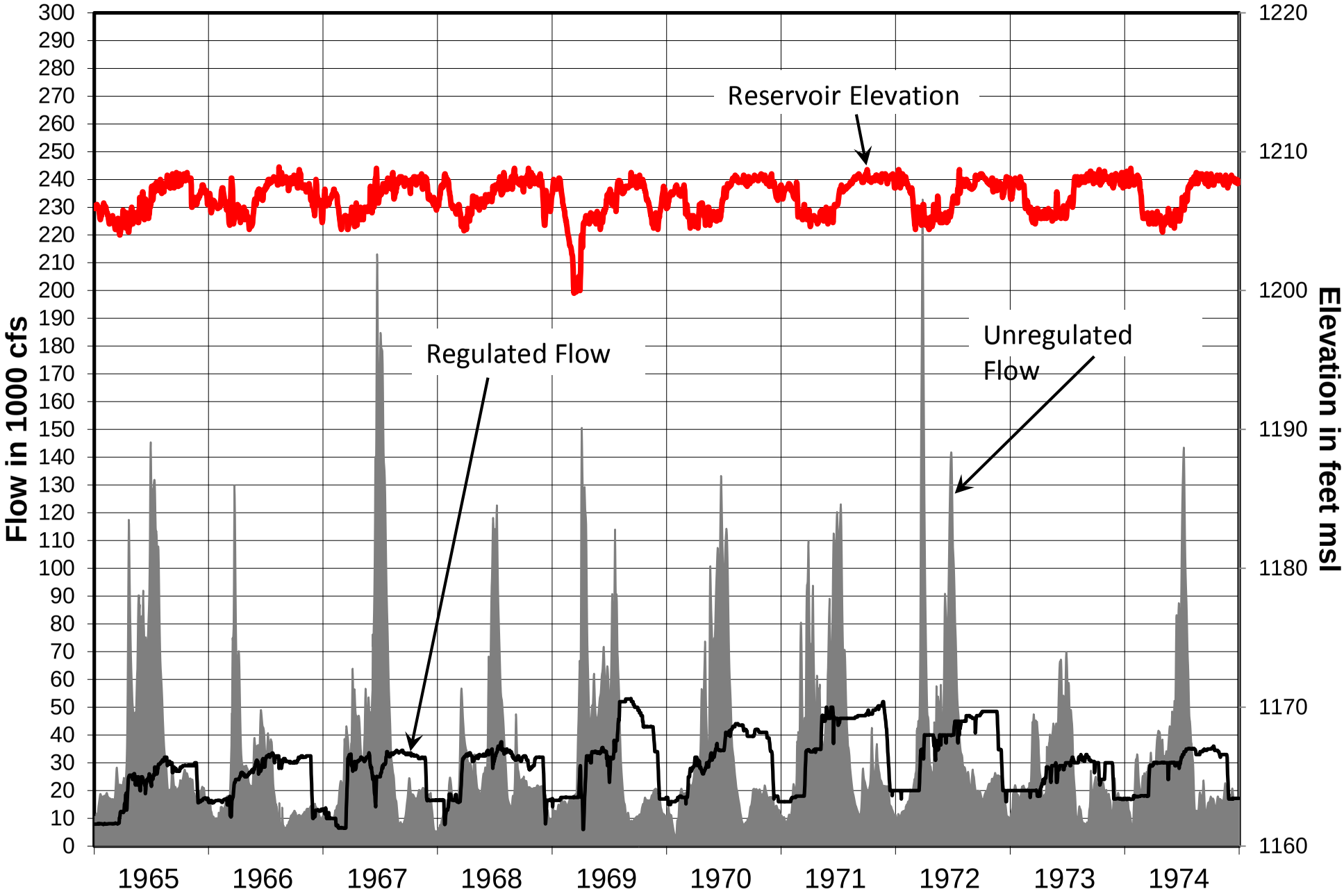

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Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1965 - 1974

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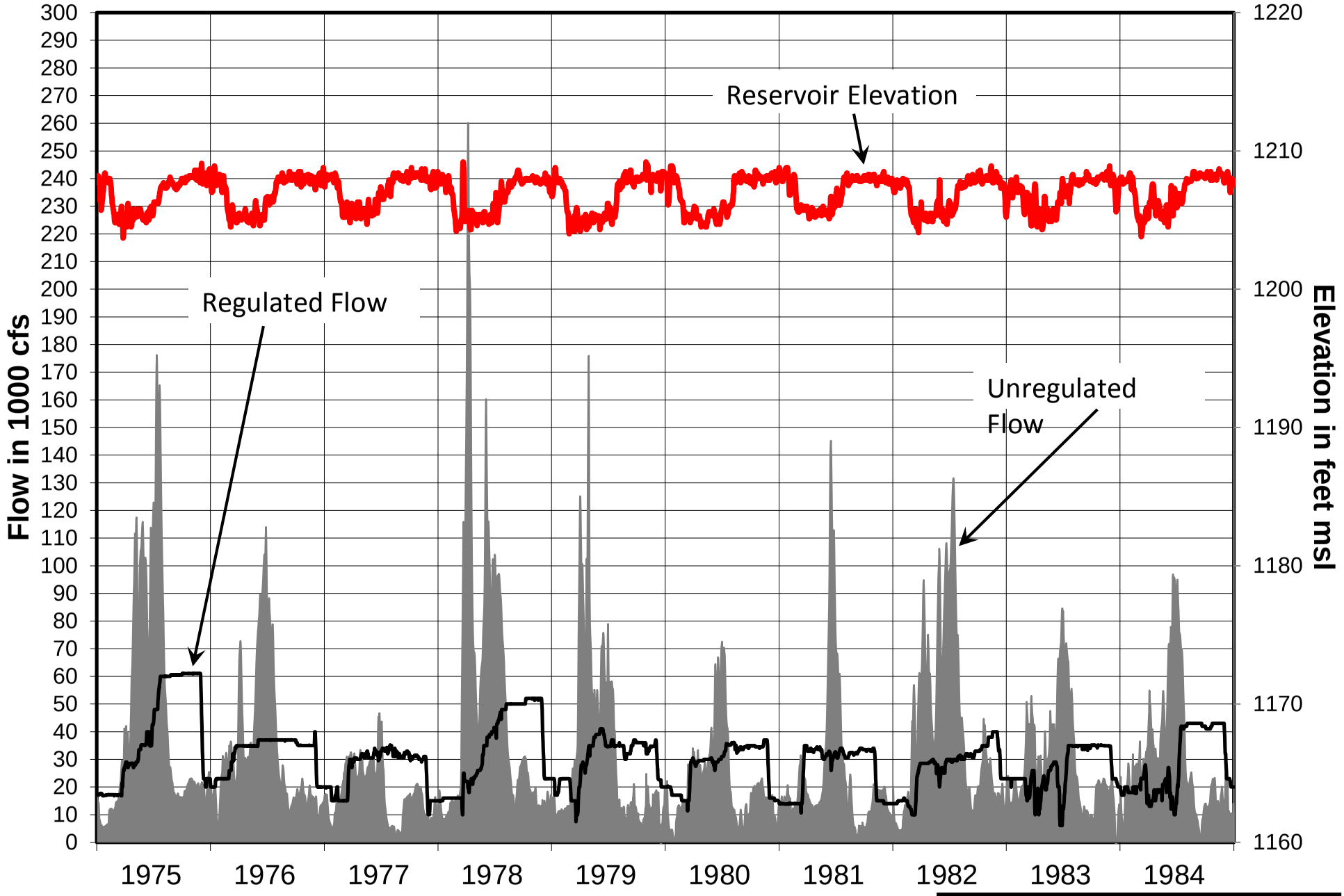

Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1975 - 1984

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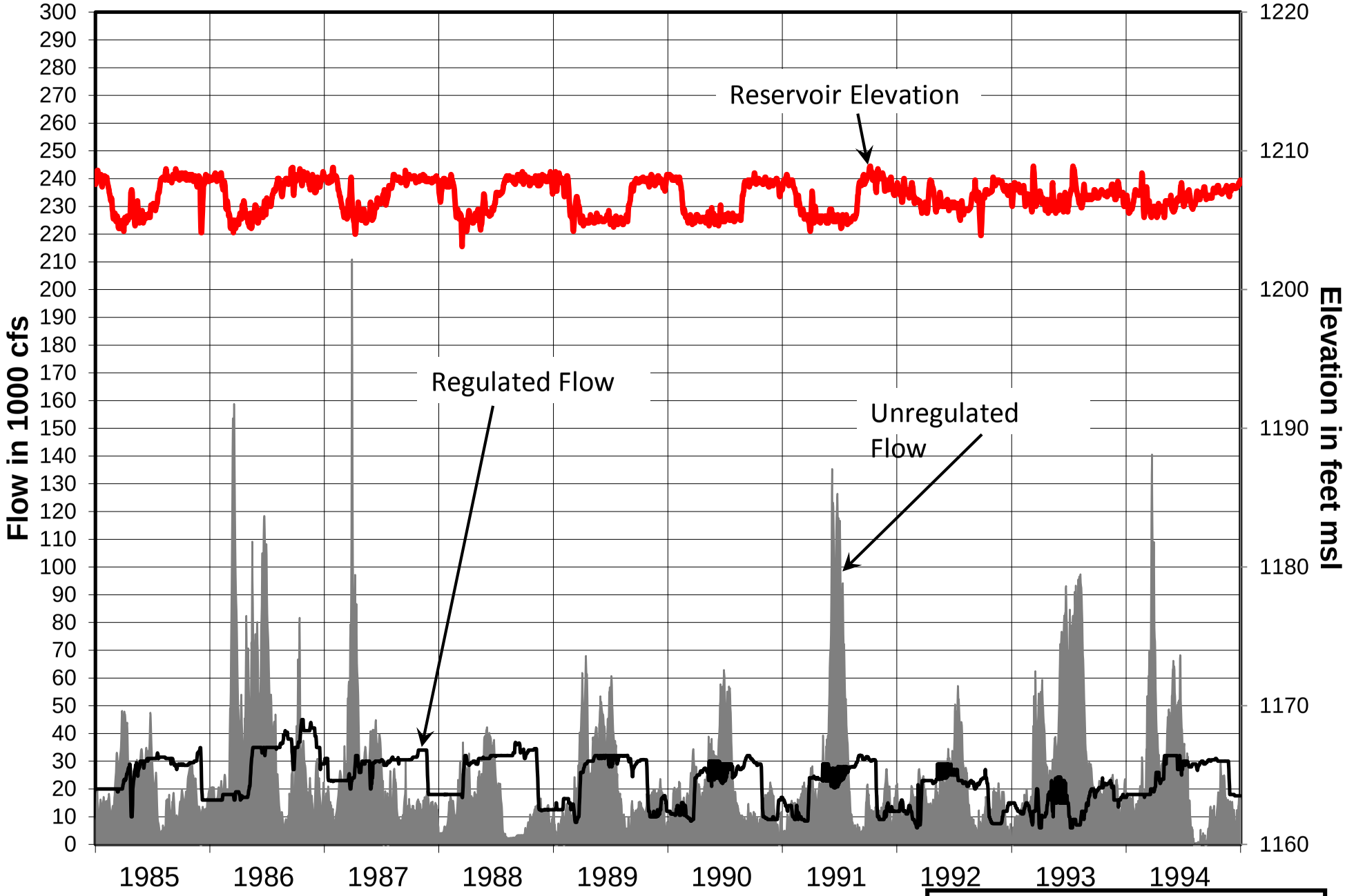

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Reservoir Elevation, Regulated and Unregulated Flows, 1985 - 1994

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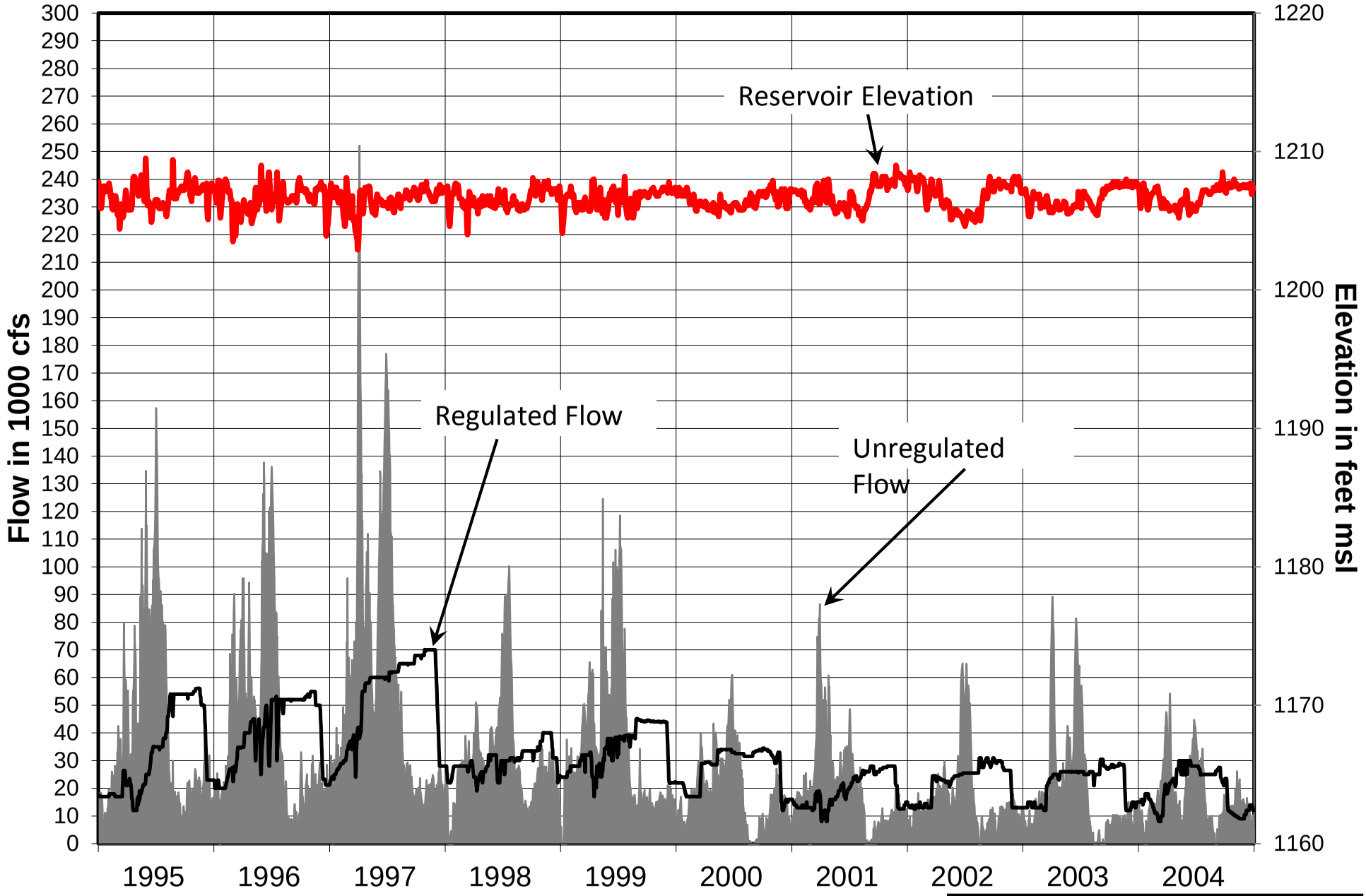

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Reservoir Elevation, Regulated and Unregulated Flows, 1995 - 2004

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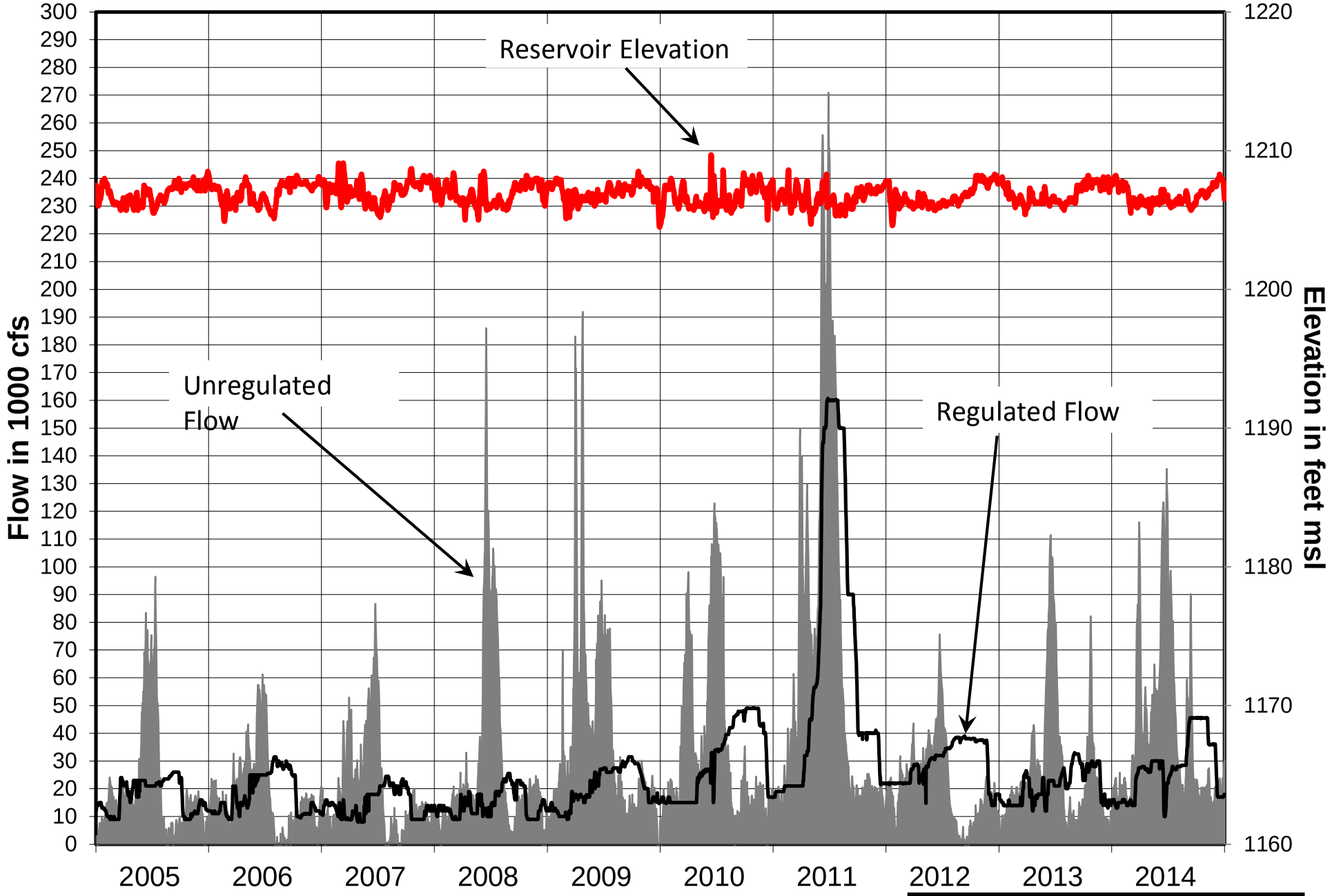

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Reservoir Elevation, Regulated and Unregulated Flows, 2005 - 2014

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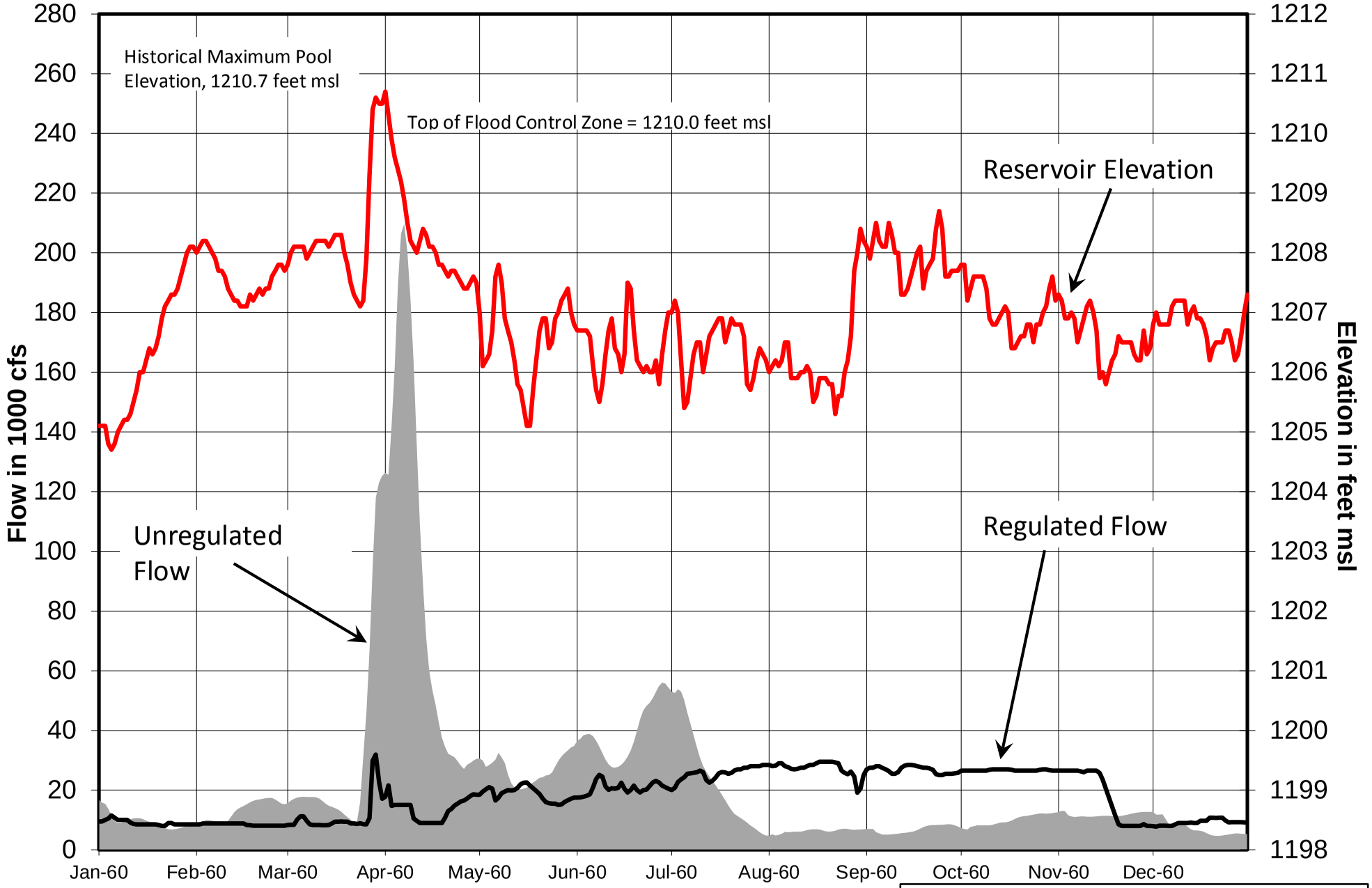

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Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1960

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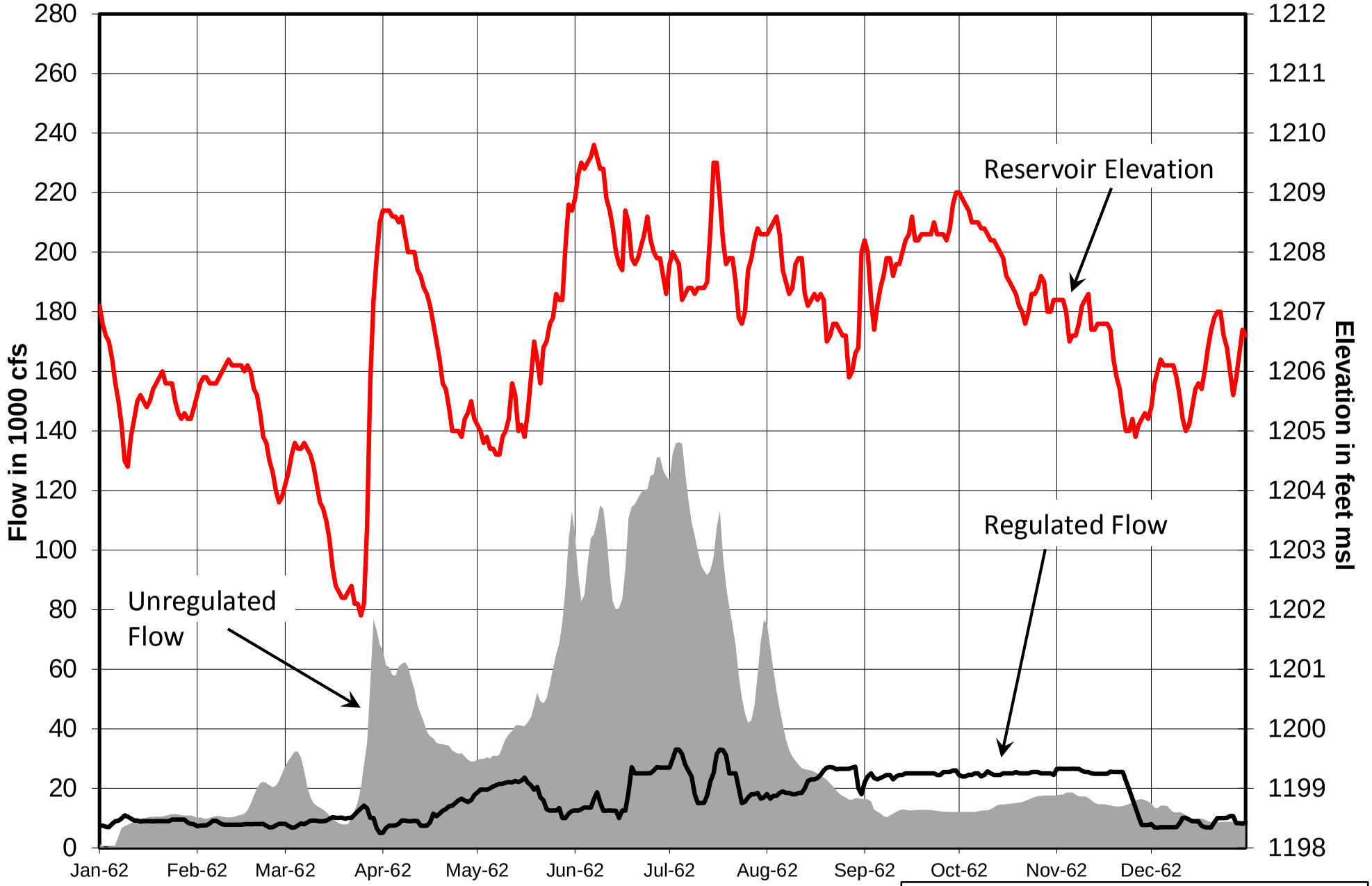

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Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1962

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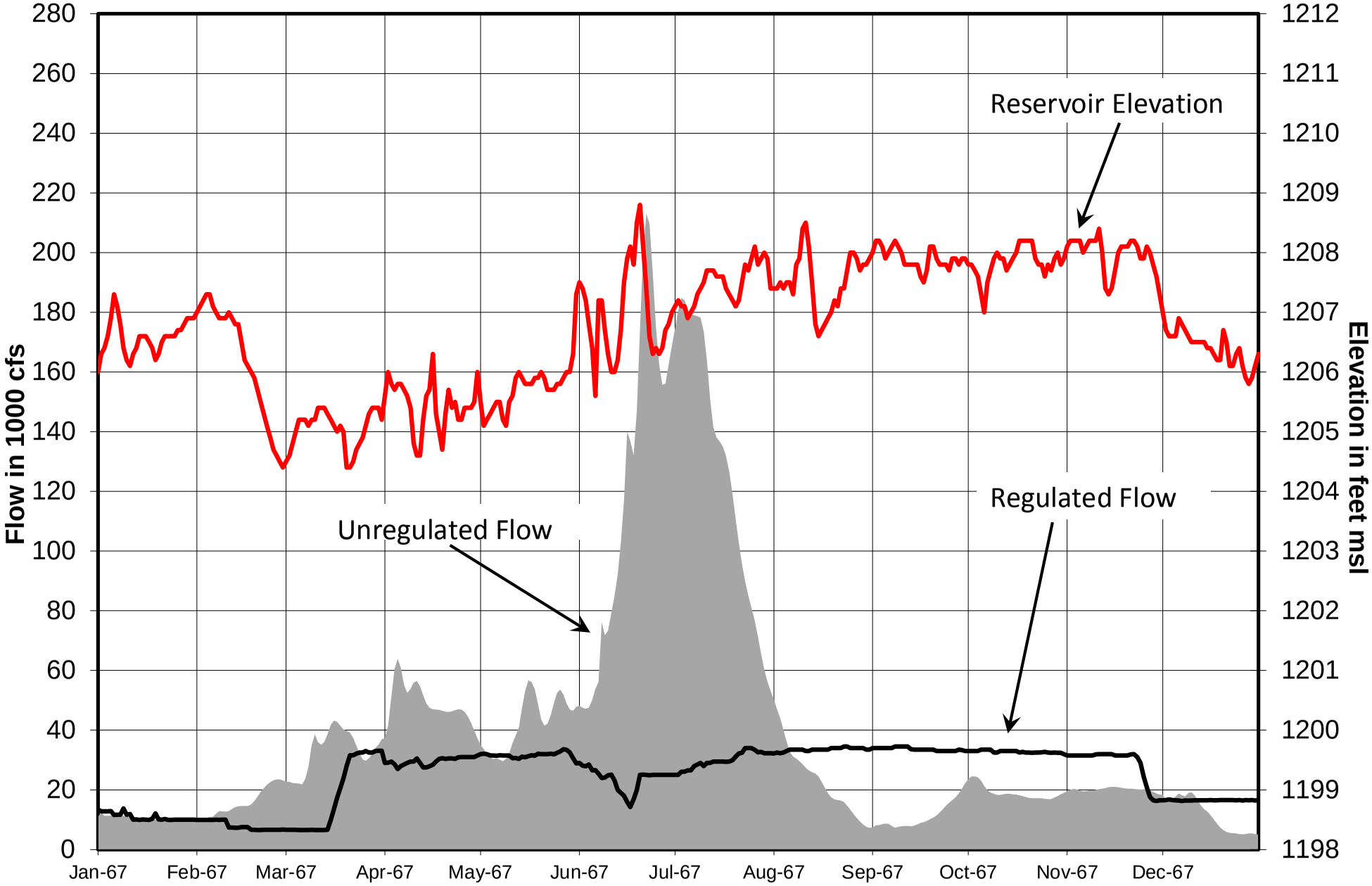

Missouri River Basin

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Reservoir Elevation, Regulated and Unregulated Flows, 1967

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
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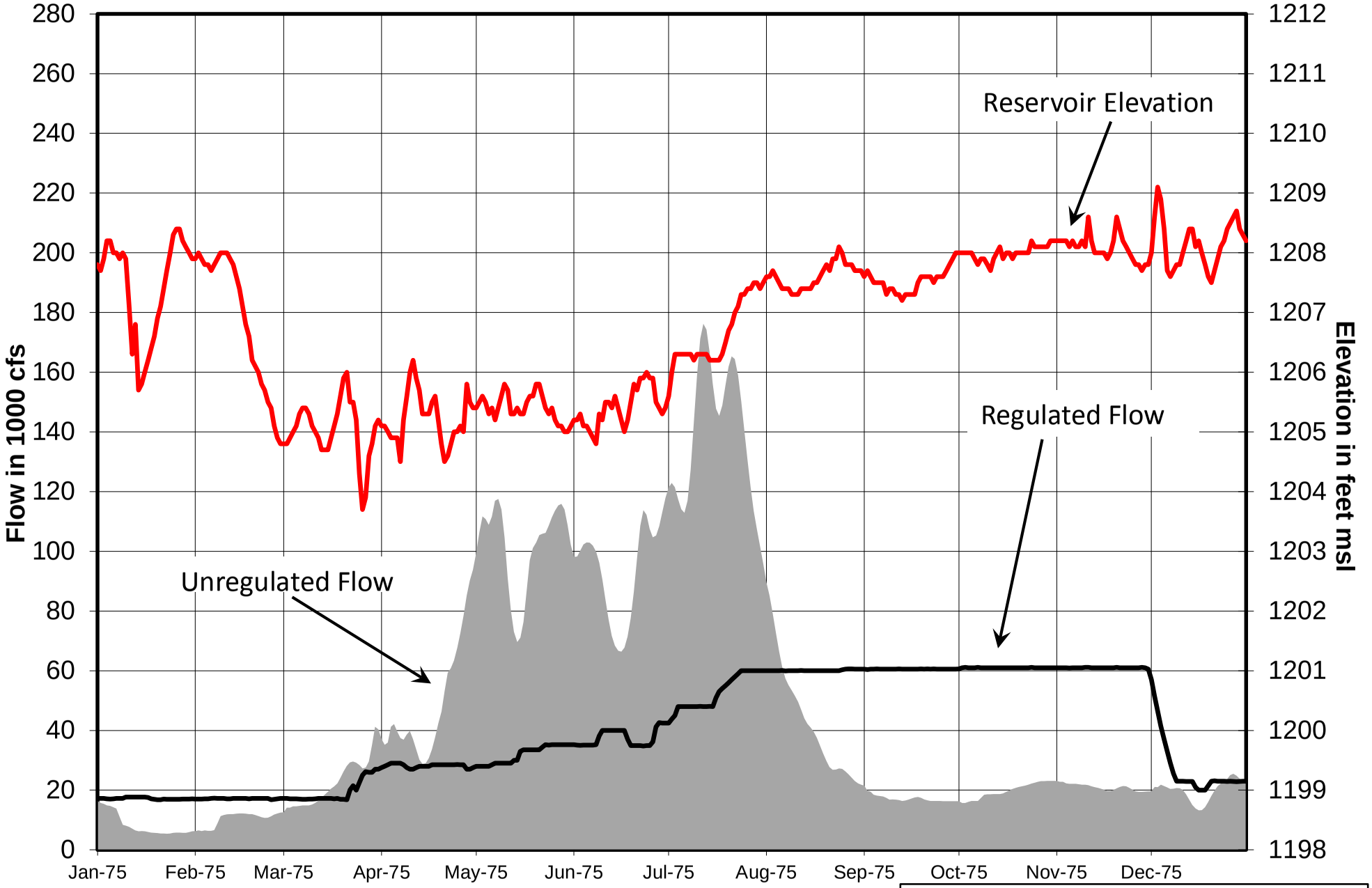

Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1975

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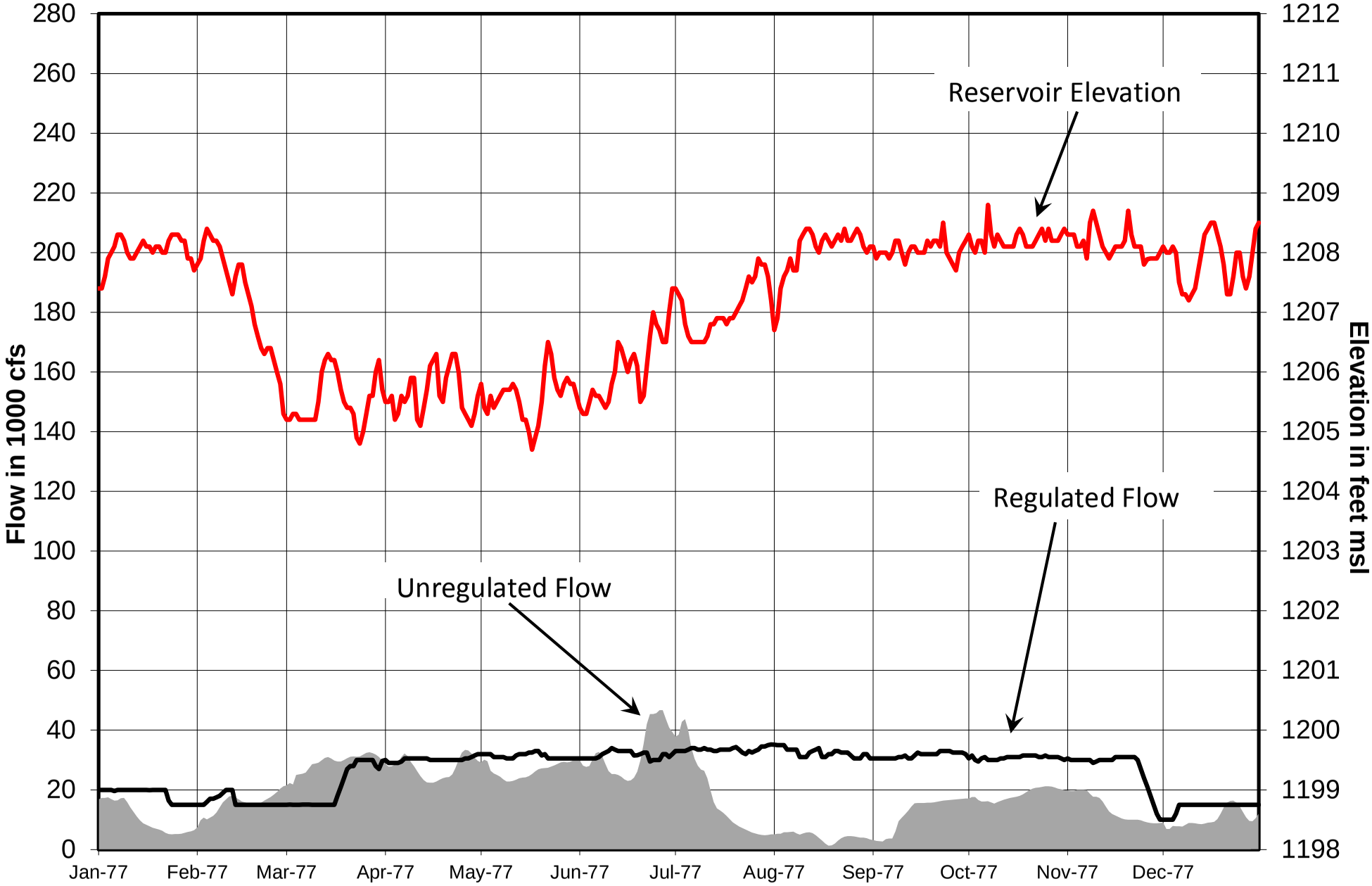
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



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Reservoir Elevation, Regulated and Unregulated Flows, 1977

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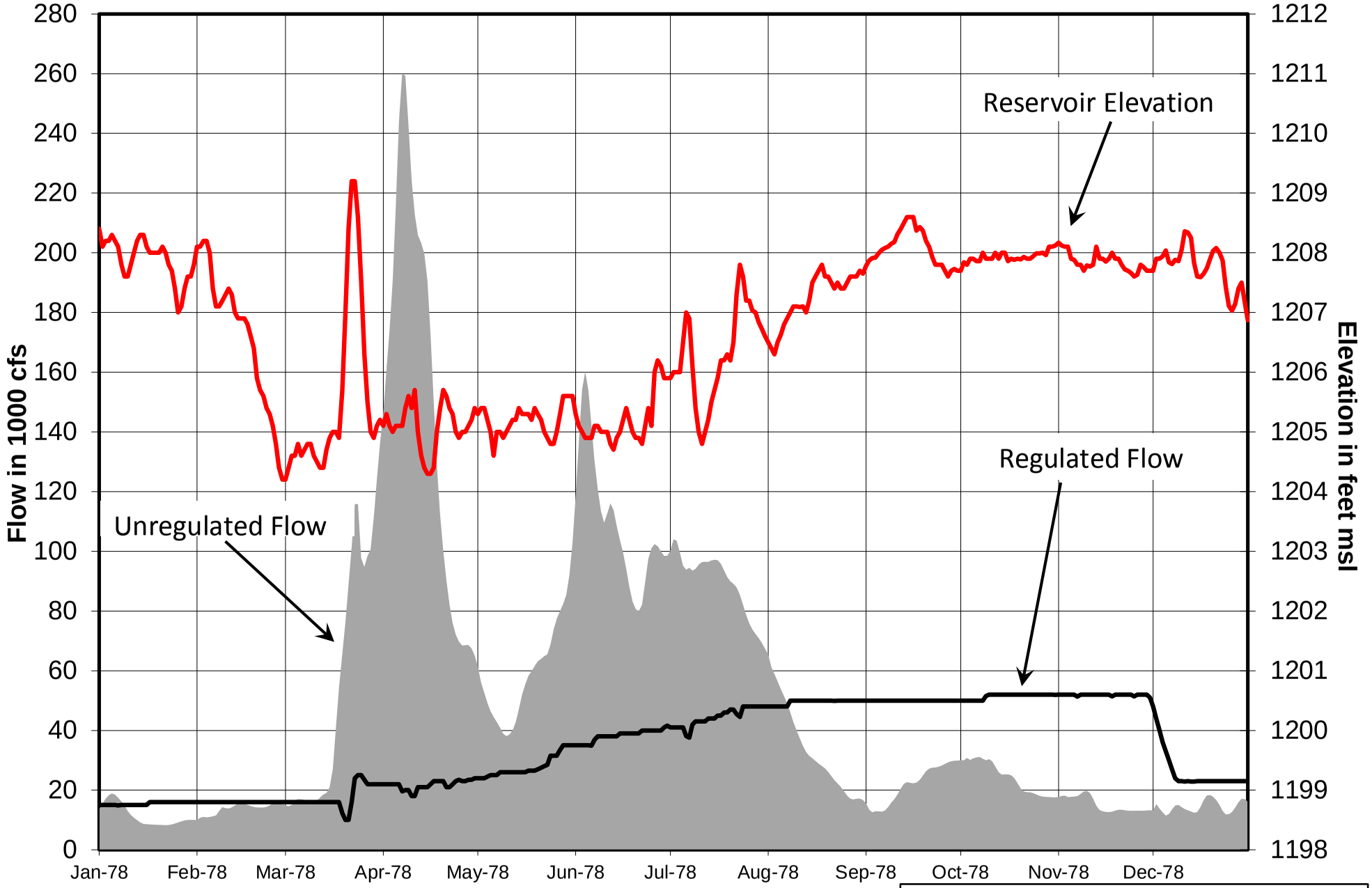
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



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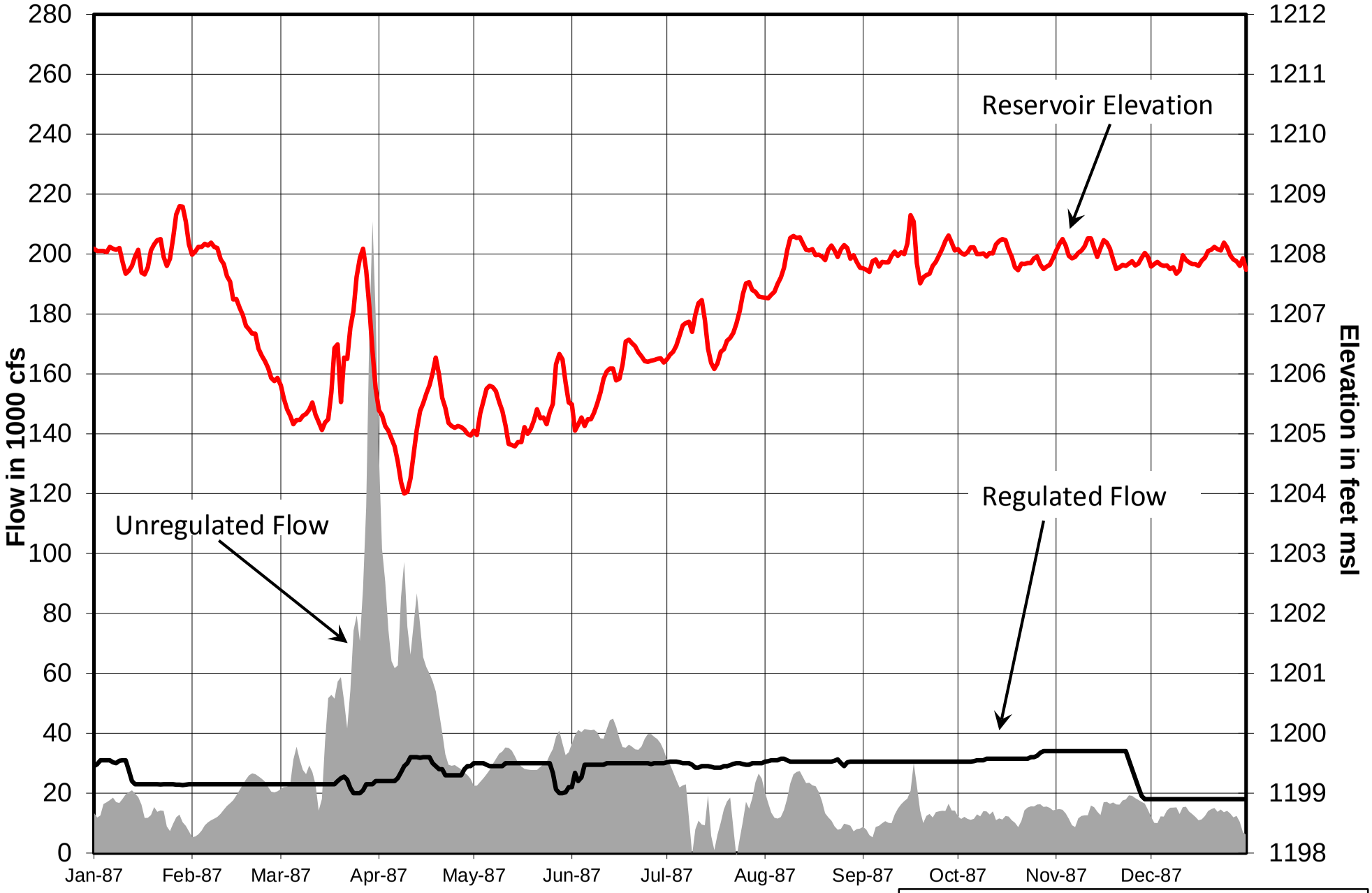
Reservoir Elevation, Regulated and Unregulated Flows, 1978

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1987

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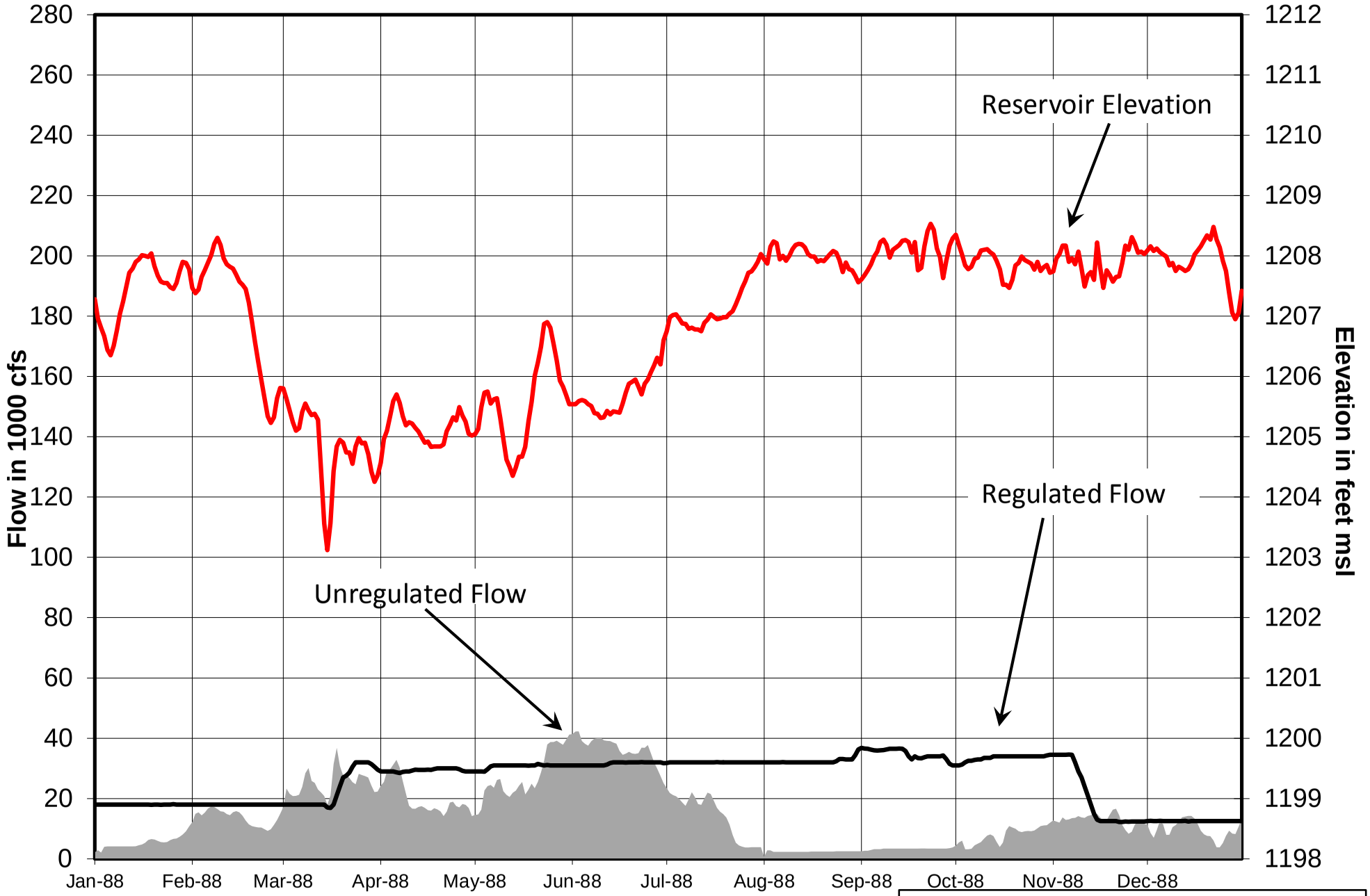
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



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Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1988

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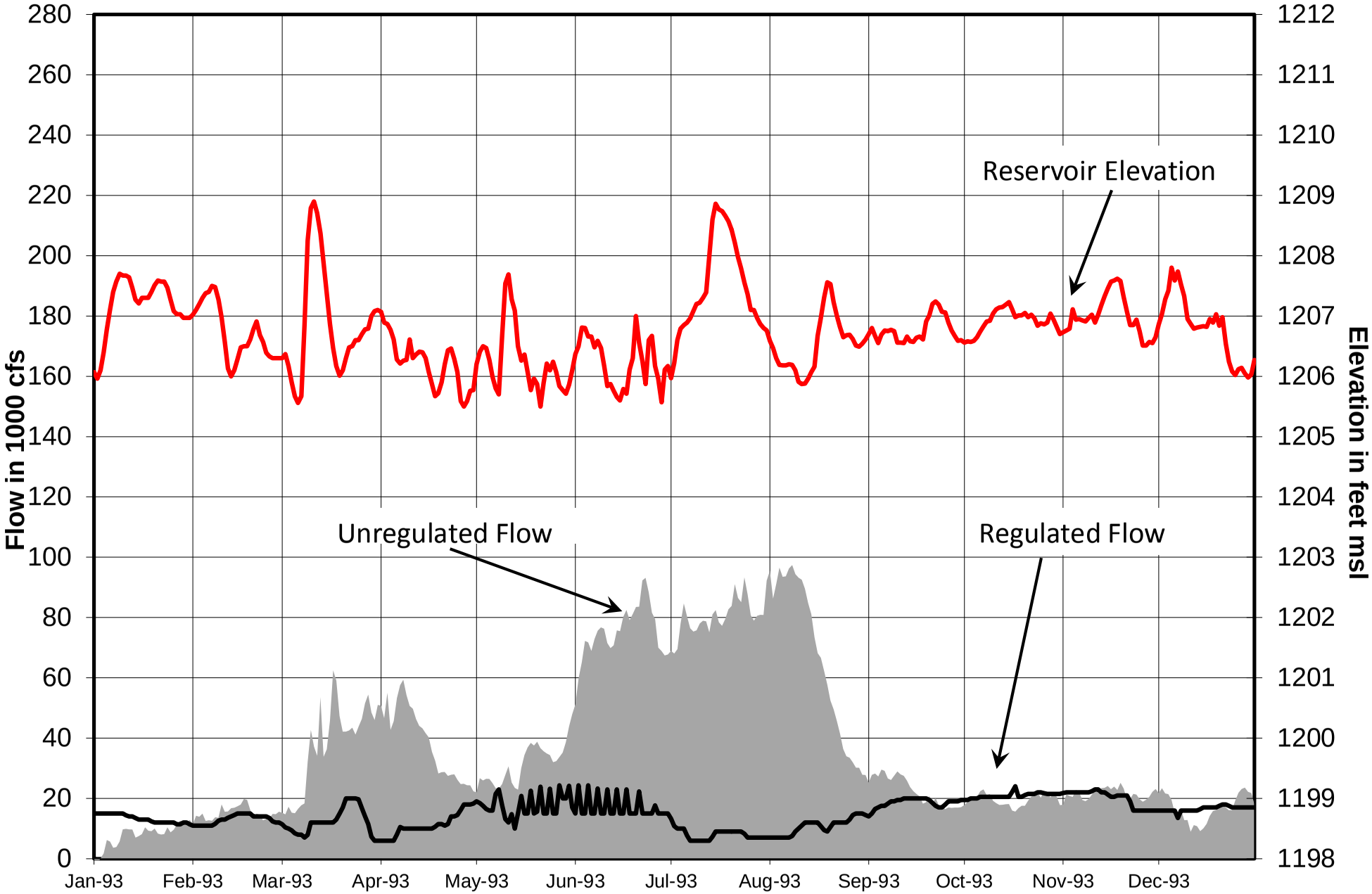
September 2017



Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1993

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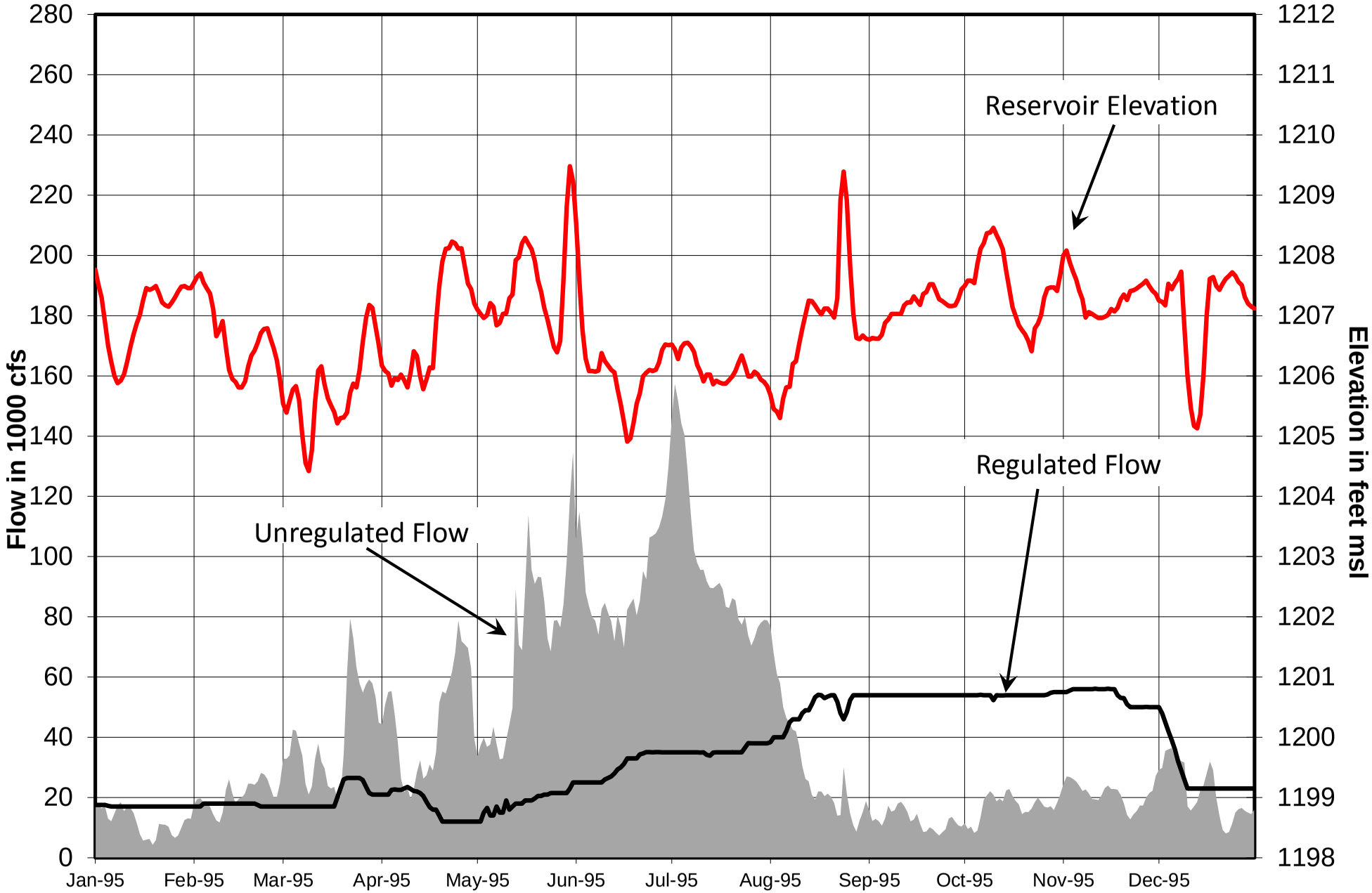
September 2017



Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1995

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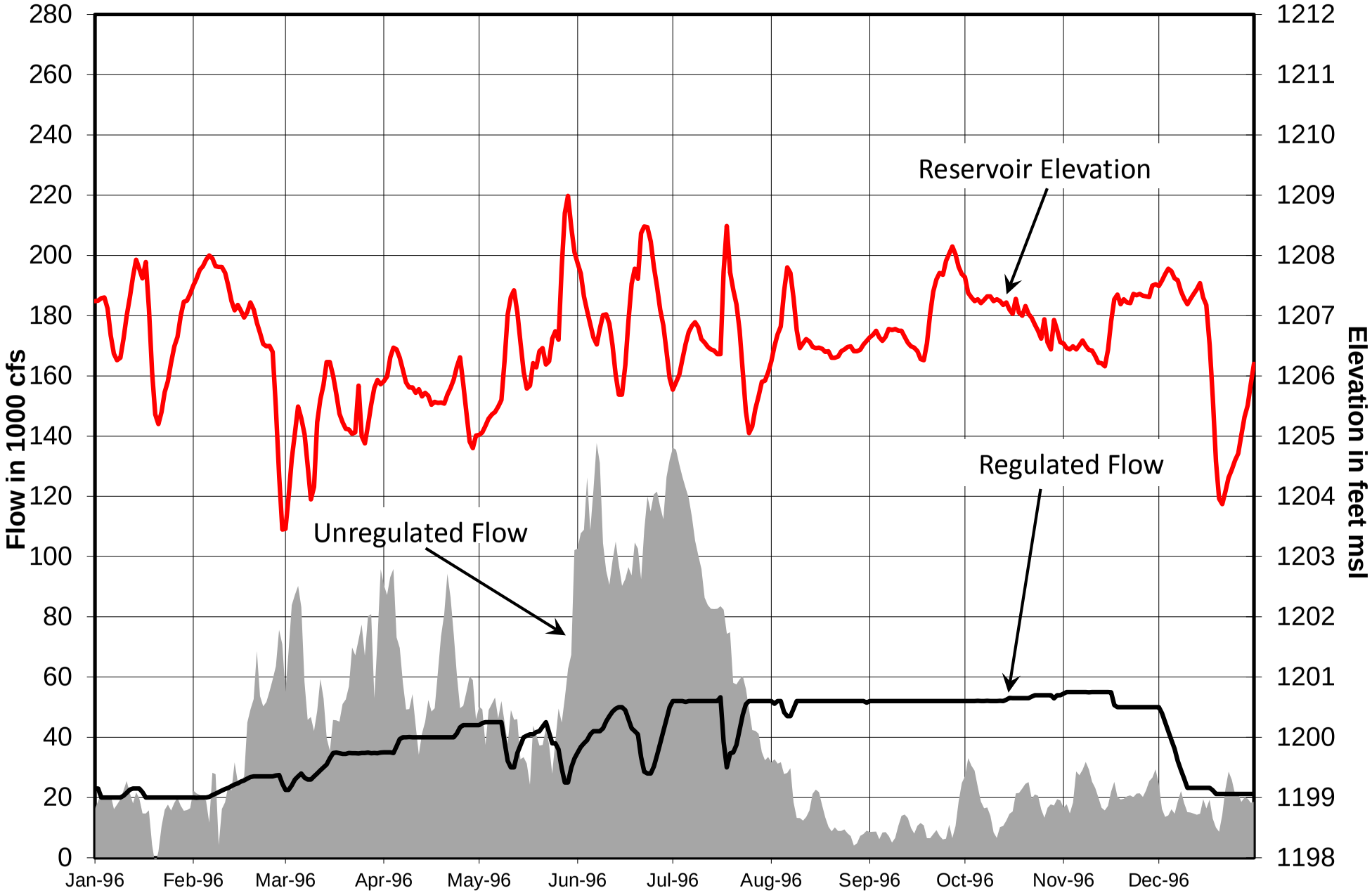
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

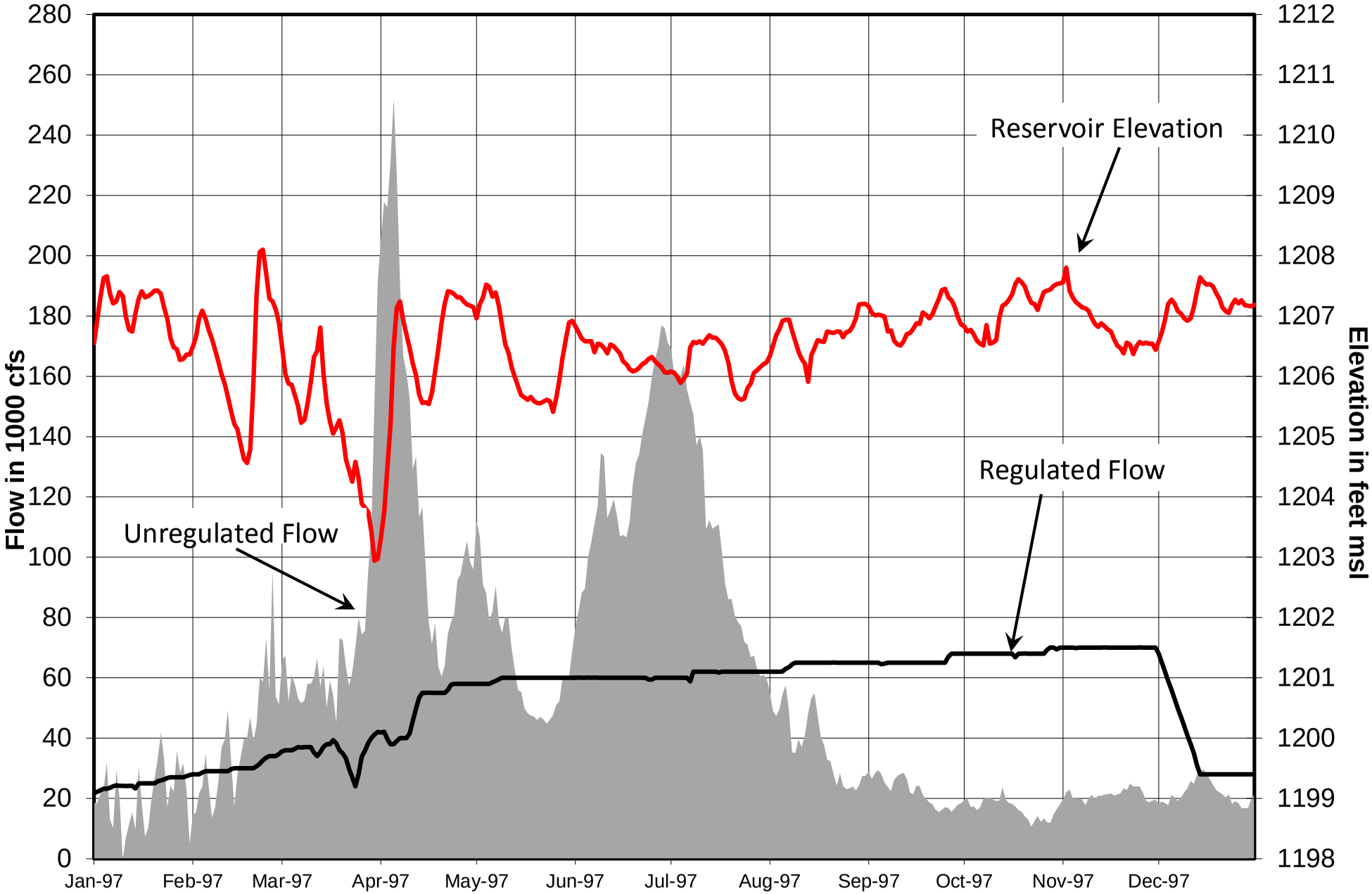


Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1996

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

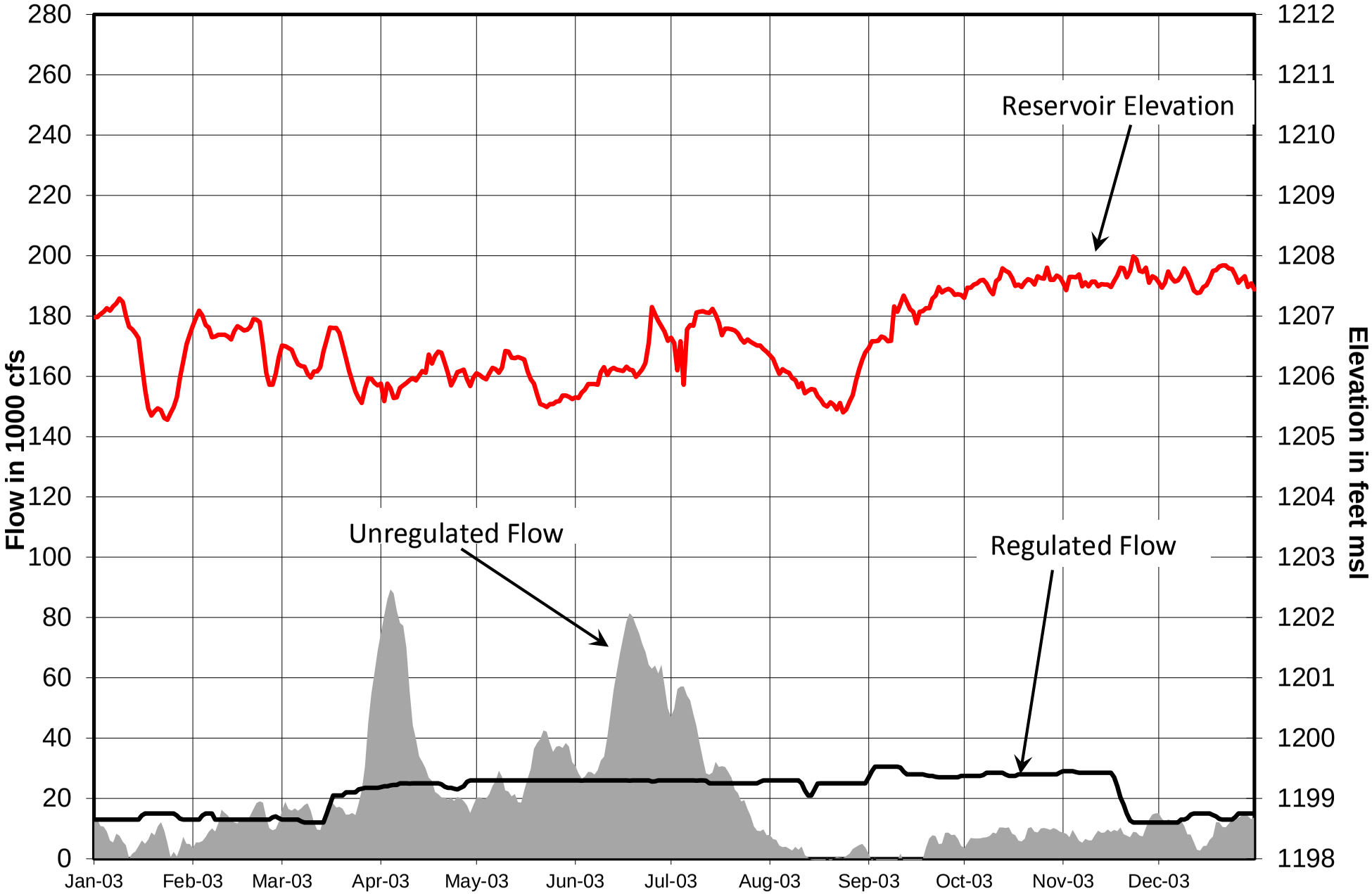


Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 1997

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

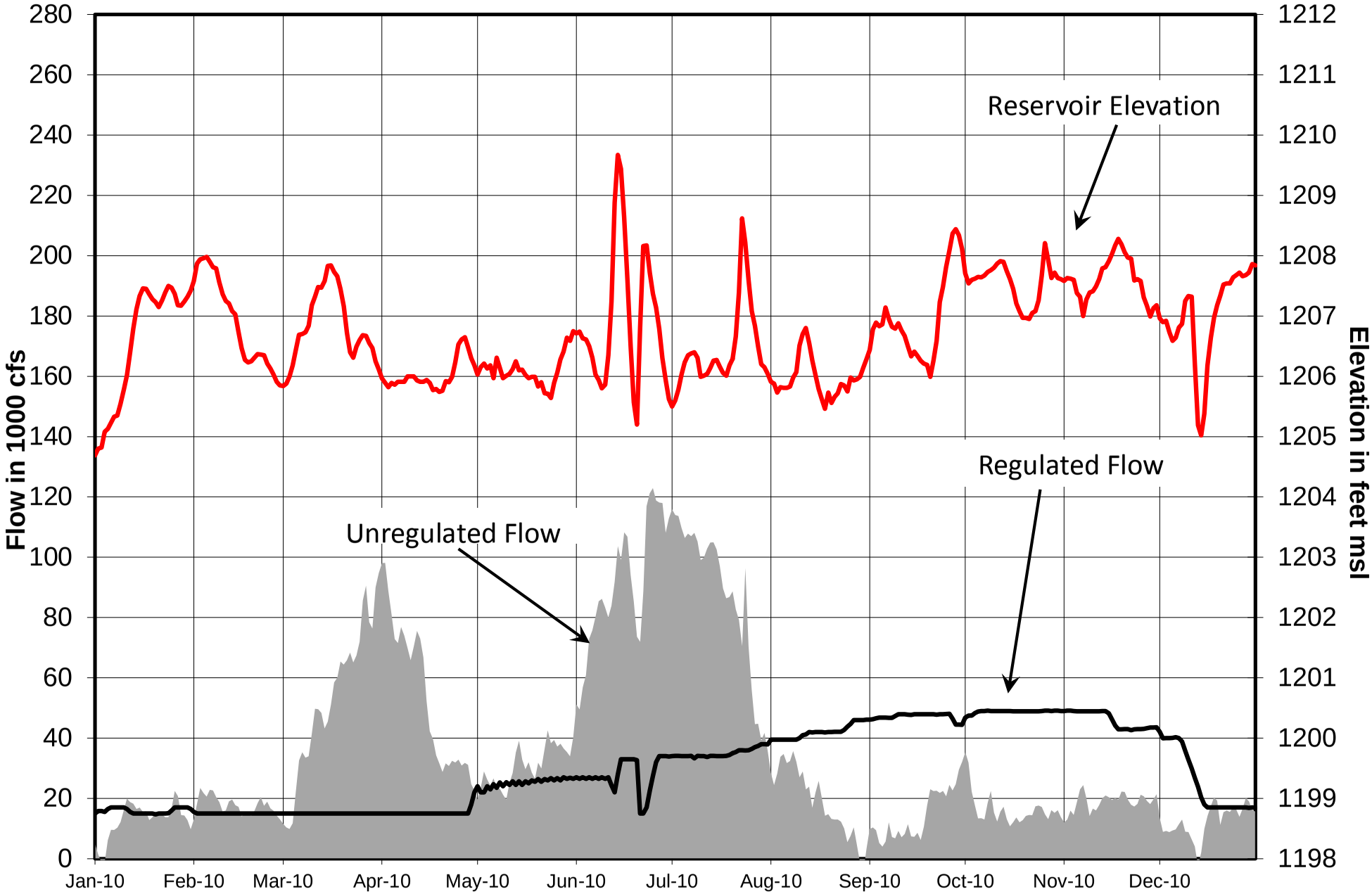


Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 2003

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017



Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 2010

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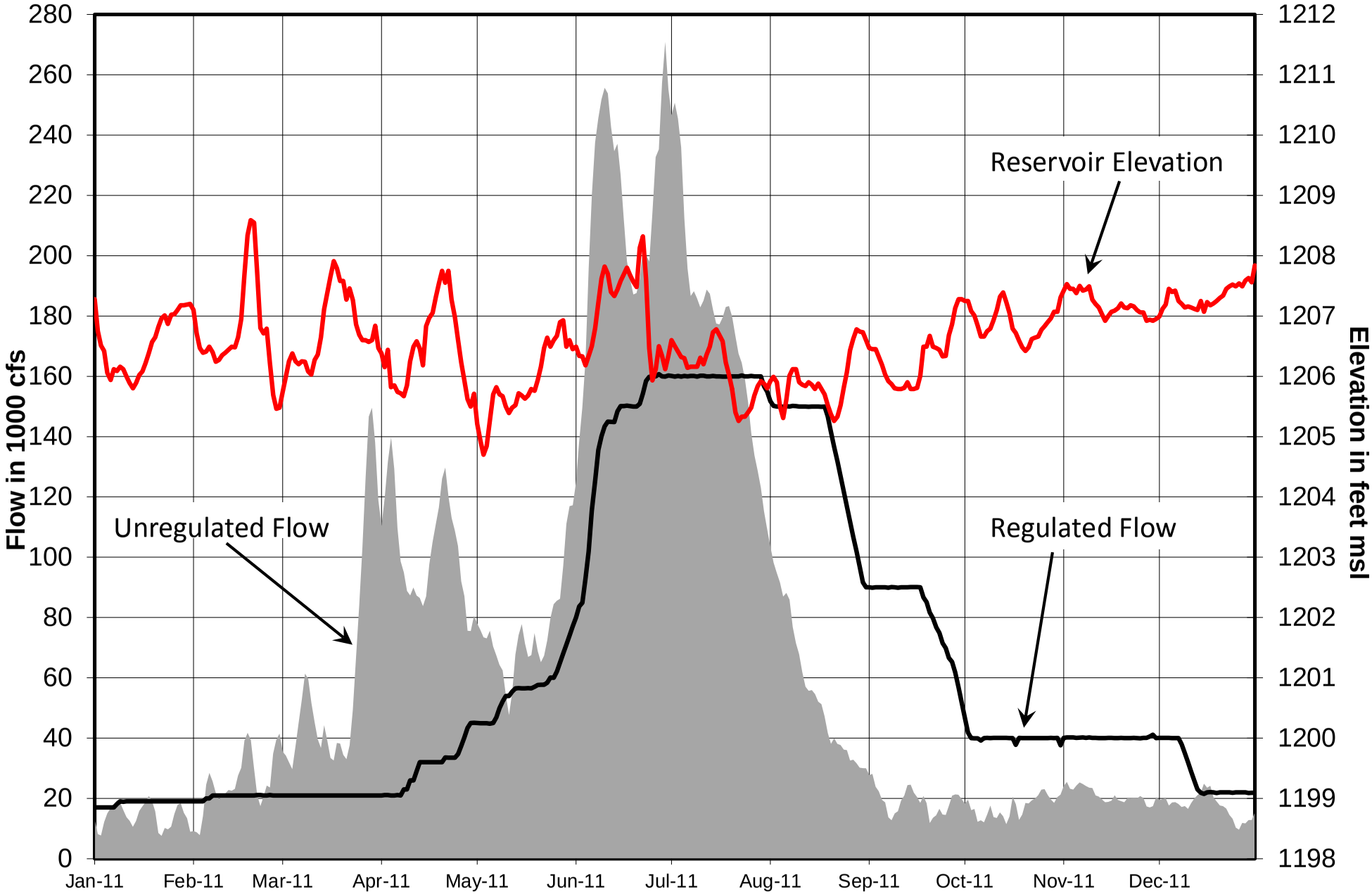

Missouri River Basin

Gavins Point Water Control Manual

Reservoir Elevation, Regulated and Unregulated Flows, 2011

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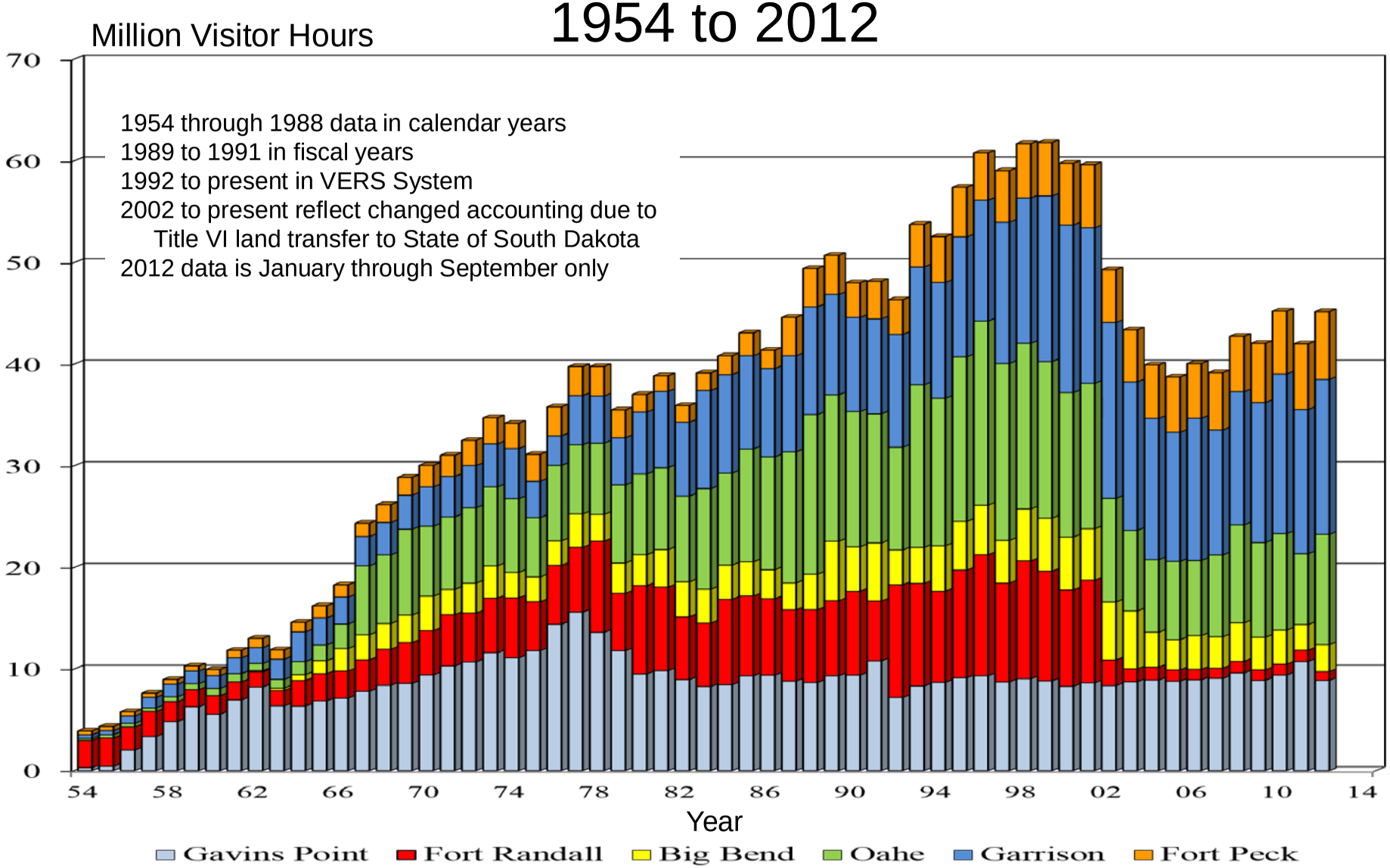
CORPS OF ENGINEERS, OMAHA, NEBRASKA
September 2017

Mainstem Project Visits
1954 to 2012



Missouri River Basin
Gavins Point Water Control Manual
Mainstem Project Visitor Hours
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
December 2016

Year	Season Length* (Months)	Commercial (Tons) (1)	Traffic (Tons) (2)	Total Traffic (1,000 Ton-Miles) (2)
1967 (3)	8	2,562,657	6,659,219	1,179,235
1968	8 (4)	2,254,489	6,724,562	1,047,935
1969	8 (4)	2,123,152	7,001,107	1,053,856
1970	8 (5)	2,462,935	7,519,251	1,190,232
1971	8 (4)	2,791,929	7,483,708	1,329,899
1972	8 (4)	2,665,579	7,182,841	1,280,385
1973	8	1,817,471	6,370,838	844,406
1974	8	2,576,018	7,673,084	1,227,525
1975	8 (4)	2,317,321	6,208,426	1,105,811
1976	8 (4)	3,111,376	6,552,949	1,535,912
1977	8	3,335,780	6,734,850	1,596,284
1978	8 (4)	3,202,822	7,929,184	1,528,614
1979	8 (4)	3,145,902	7,684,738	1,518,549
1980	8	2,909,279	5,914,775	1,335,309
1981	7 1/4 (6)	2,466,619	5,251,952	1,130,787
1982	8 (4)	2,513,166	4,880,527	1,131,249
1983	8 (4)	2,925,384	6,301,465	1,300,000
1984	8 (4)	2,878,720	6,386,205	1,338,939
1985	8 (4) (7)	2,606,461	6,471,418	1,201,854
1986	8 (4) (7)	2,343,899	6,990,778	1,044,299
1987	8	2,405,212	6,735,968	1,057,526
1988	7 1/2	2,156,387	6,680,878	949,356
1989	6 3/4	1,906,508	5,352,282	796,799
1990	6 3/4	1,329,000	5,841,000	552,509
1991	6 3/4	1,563,000	5,729,000	537,498
1992	6 3/4	1,403,000	5,783,000	593,790
1993	8 (8)	1,570,000	5,631,000	615,541
1994	8	1,800,000	8,501,000	774,491
1995	8 (4)	1,439,000	6,884,000	604,171
1996	8 (4)	1,547,000	8,165,000	680,872
1997	8 (4)	1,651,000	8,172,000	725,268
1998	8 (4)	1,735,000	8,379,000	777,727
1999	8 (4)	1,576,000	9,252,000	699,744
2000	8	1,344,000	8,733,000	628,575
2001	8	1,288,000	9,732,000	566,150
2002	8 (9)	1,009,000	8,266,000	409,980
2003	8 (10)	667,000	8,050,000	256,788
2004	6 1/2 (11)	525,498	8,192,219	181,995
2005	6 1/2 (11)	284,641	7,935,747	129,882
2006	6 1/2 (11)	195,290	8,295,226	84,483
2007	6 3/4 (11)	302,769	6,684,625	119,177
2008	7 (11)	174,800	5,670,968	86,203
2009	8	269,563	5,035,744	114,865
2010	8(4)	379,492	4,829,714	132,747
2011	8(4)	230,439	3,831,925	62,253
2012	8	197,000	3,906,000	56,631
2013	8	244,576	4,104,505	110,280
2014	8(4)	293,125	4,670,661	89,932
2015	8	275,000(12)	4,409,000(12)	95,000(12)

* Mainstem System flow-supported season length; the Missouri River is open for use year-round.

(1) Includes commercial tonnage except for sand and gravel or waterway materials. Tonnage compiled by Waterborne Commerce Statistics Center (WCSC).
(2) Includes commodities; sand, gravel, and crushed rock; and waterway improvement materials. Tonnage by WCSC.
(3) Mainstem Reservoir System first reached normal operating storage level in 1967.
(4) 10-day extension of season provided.
(5) 10-day extension and 10-day early opening provided.
(6) Full service flows for shortened season in preference to reduced service.
(7) 10-day extension provided for 1985 season in trade for 10-day delayed support of 1986 season.
(8) Lower Missouri River closed: 57 days in 1993, 20 days in 1995, and 18 days in 1999.
(9) To protect endangered shore birds below Gavins Point Dam, the Corps did not support navigation from July 3 to August 14, 2002. Average days towing industry off the river was 23 days.
(10) 6-day shortening of season to follow CWCP. From Aug 11 to Sep 1 Corps did not support navigation flows to comply with lawsuit to follow 2000 Biological Opinion. Navigation industry left the river during this period.
(11) Season shortening; 47-days, 2004; 48-days, 2005; 44-days, 2006; 35-days, 2007; 30-days, 2008
(12) Estimated using boat report barge counts.

Missouri River Basin
Gavins Point Water Control Manual
Missouri River Navigation
Tonnage and Season Length
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017

Year	Months	Sioux City	Omaha	Nebraska City	Kansas City
1967	Apr-Jun	28	28	34	38
	Jul-Nov	31	31	37	41
1968	Apr-Nov	31	31	37	41
1969	Apr-Jun(1)	35-40	35-40	41-46	45-50
	Jul(1)	36	36	42	46
	Aug-Sep(1)	50-55	50-55	55-60	55-60
	Oct-Nov(1)	40-45	40-45	45-50	50-55
1970	Apr-May	31	31	37	41
	May-Sep(1)	36	36	42	46
	Oct-Nov(1)	40	40	46	50
1971	Apr-May(1)	36	36	42	46
	May-Nov(1)	45-50	45-50	50-55	55-60
1972	Apr-Nov(1)	40-50	40-50	45-55	50-60
1973-74	Apr-Nov	31	31	37	41
1975	Apr	31	31	37	41
	May-Nov(1)	35-60	35-60	41-66	45-70
1976	Apr-Jul(1)	34-38	34-38	40-44	44-48
	Aug-Dec(1)	31-34	31-34	37-40	41-44
1977	Apr-Nov	31	31	37	41
1978	Apr	31	31	37	41
	May-Jul(1)	35-46	35-46	41-52	45-56
	Aug-Nov(1)	46-51	46-51	52-57	56-61
1979	Apr-Jul(1)	36-42	36-42	42-48	46-52
	Aug-Nov(1)	31-36	31-36	37-42	41-46
1980	Apr-Nov	31	31	37	41
1981	Apr-Nov(2)	31	31	37	41
1982	Apr-Sep	31	31	37	41
	Oct	31-36	31-36	37-42	41-46
	Nov-Dec(1)	36-46	36-46	42-52	46-56
1983	Apr-Jun	31	31	37	41
	Jul	31-36	31-36	37-42	41-46
	Aug-Nov(1)	36	36	42	46
1984	Apr-Jun	31	31	37	41
	Jul-Dec(1)	31-44	31-44	37-50	41-54
1985	Apr-Dec	31	31	37	41
1986	Apr(1)	36-41	36-41	42-47	46-51
	May-Dec(1)	41-46	41-46	47-52	51-56
1987	Apr-Nov	31	31	37	41
1988	Apr-Nov(2)	31	31	37	41
1989	Apr-Aug(3)	28	28	34	38
	Sep-Oct(3)	28	28	34	35
1990-93	Apr-Oct(4)	25	25	31	35
1994	Apr-Dec	31	31	37	41
1995	Apr-May	31	31	37	41
	Jun-Dec(1)	46-56	46-56	52-62	56-66
1996	Apr(1)	41	41	47	51
	May(1)	41-51	41-51	47-57	51-61
	Jun-Dec(1)	56	56	62	66
1997	Apr-Dec(5)	*	*	*	*
1998	Apr-Dec(5)	31	31	37	41
1999	Apr-Dec(1)	31-43	31-43	37-49	41-53
2000	Apr-Jun	31	31	37	41
	Jul-Dec(3)	29.5	29.5	35.5	39.5
2001	Apr-Dec(3)	28	28	34	38
2002	Apr-Jun(3)	27	27	33	37
	Jul-Dec(3)	25	25	31	35
2003	Apr-Nov(4)	25	25	31	35
2004-08	Apr-Oct(6)	25	25	31	35
2009	Apr-Nov(7)	25/31	25/31	31/37	35/41
2010	Apr-Dec(1)	31-43	31-43	37-49	41-53
2011	Apr(1)	31-41	31-41	37-47	41-51
	mid-Apr(1)	41-46	41-46	47-52	51-56
	May(1)	46-56	46-56	52-62	56-66
	mid-May(5)	*	*	*	*
2012	Apr-Dec	31	31	37	41
2013	Apr-Jun(6)	25	25	31	35
	Jul-Dec(3)	28	28	34	38
2014	Apr-Jun(3)	28	28	34	38
	Jul-Dec(1)	31-46	31-46	37-52	41-56
2015	Apr-Dec	31	31	37	41

(1) Downstream flow targets above full-service navigation level as a flood control storage evacuation measure
(2) Full service flows provided for shortened season
(3) Navigation targets below full service as a water conservation measure
(4) Navigation targets at minimum service as a water conservation measure.
(5) Releases determined by flood control storage evacuation critiera and not adjusted to meet specific navigation targets.
(6) Minimum service targets at Sioux City and Omaha not met during periods when there was no navigation in those reaches.
(7) Minimum service targets at Sioux City were not met during periods when there was no navigation in those reaches.

Missouri River Basin
Gavins Point Water Control Manual
Missouri River Navigation Service Level Flow Targets in 1000 cfs
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
September 2017