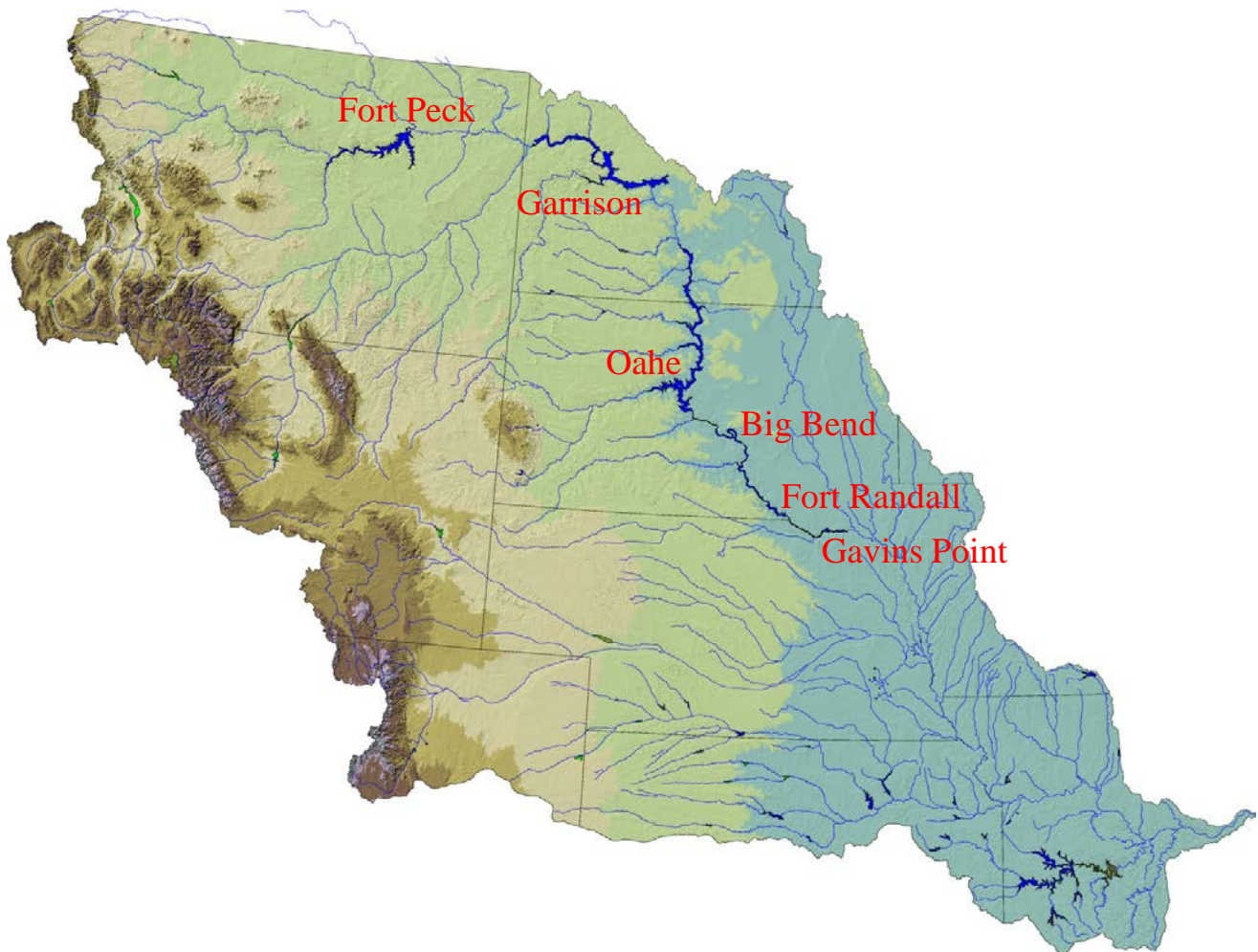




**US Army Corps  
of Engineers** ®  
Northwestern Division



# Missouri River Mainstem Reservoir System Water Control Manual Garrison Dam – Lake Sakakawea



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 3

**GARRISON PROJECT**

Volume 1	Master Manual
Volume 2	Fort Peck (Fort Peck Reservoir)
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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## ABBREVIATIONS

AF	-	acre-feet
AOP	-	Annual Operating Plan
BIA	-	U.S. Bureau of Indian Affairs
cfs	-	cubic feet per second
Corps	-	U.S. Army Corps of Engineers
CRREL	-	Cold Regions Research and Engineering Laboratory
DCP	-	Data Collection Platform
DPR	-	Definite Project Report
DRM	-	Daily Routing Model
EM	-	Corps' Engineering Manual
EPA	-	Environmental Protection Agency
ER	-	Corps' Engineering Regulation
ESA	-	Endangered Species Act
°F	-	Degrees Fahrenheit
GDU	-	Garrison Diversion Unit
kAF	-	1,000 acre-feet
kcfs	-	1,000 cubic feet per second
kV	-	kilovolt
kVA	-	kilovolt-amp
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
NRCS	-	Natural Resources Conservation Service
NWCC	-	NRCS National Water and Climate Center
NWD	-	Northwestern Division
NWDR	-	Northwestern Division Regulation
NWS	-	National Weather Service
O&M	-	Operation and Maintenance
QPE	-	Quantitative Precipitation Estimate
PPCS	-	Powerplant Control System
RCC	-	Reservoir Control Center
RM	-	River Mile (1960 mileage)

SNOTEL	-	SNOwpack TELemetry
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
USDA	-	U.S. Department of Agriculture
USFWS	-	U.S. Fish and Wildlife Service
USGS	-	United States Geological Survey
WCM	-	water control manual
Western	-	Western Area Power Administration
WMS	-	Water Management System

**Missouri River Basin  
Garrison Dam – Lake Sakakawea  
Water Control Manual**

**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 Garrison, 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 Garrison 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 Garrison. 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 manual 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 for total System regulation (Master Manual):

<u>Volume</u>	<u>Project</u>
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 Garrison is part of the System, any discussions regarding the regulation of Garrison 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 Garrison WCM supplements the Master Manual by discussing the factors pertinent to the regulation of Garrison. The regulation of major tributary reservoirs located within the Missouri River basin affecting the regulation of Garrison 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 Garrison and serves as a supplement to the Master Manual.

**1-04. Project Owner.** Garrison 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 Garrison. 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 Garrison, 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 Garrison 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) process, 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 Garrison. These are provided for reference only and should not be used for construction or other purposes.

**Table I-1  
Garrison Datums (in feet)**

Local project datum	NGVD29	NAVD88
0.0	-0.095	+1.215
(ex.) 1837.5	1837.405	1838.715

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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 Garrison, as it exists today, was not included in the document, the report proposed 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. House Document 475 (78th Congress, 2nd Session, 1944) presented the Corps' plan for the overall development of the main stem of the Missouri River. This document proposed a dam at the Garrison site, together with other projects along the main stem of the Missouri River with such modifications as the Secretary of War and the Chief of Engineers might find advisable. The U.S. Bureau of Reclamation's (USBR) plans for Missouri River development, as contained in Senate Document 191, 78th Congress, also proposed a series of dams along the main stem of the Missouri River, differing in some extent from those envisioned by the Corps. The differences between the two plans were adjusted in an interdepartmental conference and the coordinated plan, including Garrison near its present site, was presented to Congress in Senate Document 247, otherwise known as the "Pick-Sloan Plan." Legislative history of the System and individual projects are described in greater detail in Chapter II of the Master Manual.

2-01.2. Garrison 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."

2-01.3. The Garrison reservoir was designated as Lake Sakakawea by Public Law 90-46, 93rd Congress, 1st Session and approved July 4, 1967.

2-01.4. Prior to 1927, local interests proposed to divert water from the Missouri River for developing irrigation, improvement of water supply, raising the slowly receding level of Devils Lake and increasing low flows of the James River and the Sheyenne River in the eastern part of North Dakota. A damsite in the general vicinity of the present location of Garrison Dam was considered in the plan.

2-01.5. The 69th Congress, 1st Session, in House Document No. 308, authorized a survey by the Corps of navigable streams in the United States (with certain exceptions) to formulate general

plans for the most effective improvement of such streams. The purpose contemplated was navigation with the most efficient development of potential water power, control of floods and irrigation. A damsite near Garrison, ND was considered in the reports covering the James River and the Missouri River investigations.

2-01.6. The “308” report of the James River was printed as House Document No. 83, 73rd Congress, 1st Session. This report contained as appendices reports by the State Engineer of North Dakota and a report by the State Geologist of North Dakota, which had been submitted to the State Governor. The State Engineer suggested a hydraulic fill dam 173 feet high with concrete overflow spillway at approximately the site of the present Garrison Dam. From the reservoir created by the dam, water was to be supplied through a system of conduits to the headwaters of the James and Sheyenne Rivers and to Devils Lake. The purpose of the diversion was to raise lake levels and to furnish water for irrigation and domestic water supply. Flood control, navigation improvement, erosion control and power were incidental benefits. The State Geologist, in his report, stated that the foundation at that site was unsatisfactory for the high dam proposed by the State Engineer. The “308” report for the James River states “. . . all available data strongly indicate that the foundation conditions obtaining at the site are inadequate . . .”

2-01.7. The “308” report of the Missouri River was printed as House Document No. 238, 73rd Congress, 2nd Session. The “308” report considered a dam at the Garrison site and states “. . . borings indicate that the foundation materials at that point do not have sufficient crushing strength to support a high dam. The site was accordingly abandoned in favor of other sites on the main stem above the mouth of the Yellowstone River.”

2-01.8. Advances in the fields of soil mechanics and foundation engineering caused renewed interest in the proposed dam and reservoir near Garrison, ND. In 1933, a firm of consulting engineers submitted a report to the State Engineer of North Dakota, recommending that an improvement similar to that previously proposed by the State Engineer be initiated. This report recommended a main dam of the rolled fill type, rather than the type proposed by the State Engineer. A board of consultants inspected the Garrison damsite and by letter to the Missouri River Diversion Board on July 31, 1943 concluded that a safe high dam at the proposed site was reasonably feasible and that the proposed location appeared generally satisfactory.

2-01.9. House Document 475, 78th Congress, 2nd Session, presented the U.S. Engineer Department plan for the overall development of the main stem of the Missouri River. A dam at the Garrison site was recommended in the plan. Because of previous uncertainties of the foundation condition, investigations for this report were as comprehensive as those ordinarily considered appropriate for a Definite Project Report (DPR).

2-01.10. The 78th Congress, 2nd Session, considered the Missouri River development plans submitted by the U.S. Engineer Department in H.D. 475 and by the USBR in S.D. 191. The differences between the two plans were adjusted at an inter-departmental conference and the coordinated plan of which the Garrison project is a feature is contained in S.D. 247 and was approved by the 1944 Flood Control Act (Public Law 534, 78th Congress, 2nd Session). Definite project planning was begun as a result of this authorization. The DPR for the Garrison project was completed and dated January 1946. Surveys and investigations for this report were made in more complete detail than usually required in view of the tremendous size of the project,

the unfavorable conclusions of earlier investigations for Garrison and the possibility that it might be desirable to undertake construction at an early date as a part of the overall post-war planning requirements for the Nation.

2-01.11. The investigation program for Garrison inaugurated prior to completion of the DPR was continued and served as a basis for the final design. A board of consultants was appointed to advise on the design and construction of the project. Details of design studies made by the Corps, private consultants and the board of consultants are contained in the record documents on file.

**2-02. Project Development.** Early studies and investigations for construction of a dam near Garrison, ND were made by the Corps' Kansas City District under supervision of the Upper Mississippi Valley Division. Additional investigations, studies, preliminary design and the preparation of the DPR for the Garrison project were accomplished by the Corps' Omaha District under the supervision of the Missouri River Division (MRD) and the Office of the Chief of Engineers. The Garrison District, with headquarters at Bismarck, ND, was established on July 1, 1946 and moved to Riverdale, ND, near the damsite, in December 1953. Final design and supervision of construction of Garrison was the responsibility of the Garrison District until April 1, 1960 when the Garrison District became an Area Office under the Omaha District. Construction of the project was initiated in 1946, closure of the dam was made in April 1953, and in December 1953 the project was placed in operation for flood control, as an aid to navigation on the Missouri River and for storage. Power generation began in January 1956 when the first unit came on line. Since 1956 Garrison has been operating as an integral unit of the System.

2-02.1. The tentative spillway design as shown in the DPR provided for a chute-type spillway with a low flat weir surmounted by 29 tainter gates, each 40 feet wide by 29 feet high and a discharge capacity of 600,000 cubic feet per second (cfs) with the reservoir at elevation 1858.0 feet. Final spillway design flood studies for the Garrison reservoir were based on hydrometeorological estimates supplied by the U.S. Weather Bureau and supplemented by detailed meteorologic, hydrologic and hydraulic studies by the Corps. The flood adopted for the final design of the Garrison spillway represents the maximum runoff from the maximum possible winter's snowpack accumulation, combined with the maximum possible early-spring snowstorm over the plains region above the damsite. The final design of the Garrison spillway provides for a chute-type spillway with an ogee weir surmounted by 28 tainter gates, each 40 feet wide by 29 feet high and a discharge capacity of 827,000 cfs with the reservoir at elevation 1858.5 feet.

2-02.2. The DPR provided for eight power conduits, 24 feet wide by 24 feet high, with semi-circular tops and five rectangular sluices, 11 feet wide by 18 feet high, to be constructed by cut-and-cover methods. Steel penstocks, 18 feet in diameter, were planned for erection within the power conduits. Gates planned for the tunnels included 21 service gates of the self-closing type and five crane-operated emergency gates. All gates were to be identical in size, 11 feet wide and 18 feet high and interchangeable. The overall dimensions of the intake structure as shown in the DPR were 110 feet wide, 430 feet long and 230 feet high with the operating deck at elevation 1880.0 feet. Further investigations and studies resulted in adoption of tunneling in lieu of cut-and-cover methods. This resulted in large savings both in time and costs. Other major changes in the outlet works included the size of the tunnels and size of the penstocks; the type, number

and size of control and emergency gates and the dimensions of the intake structure. The final design of the outlet works provided for five power conduits, 29 feet in diameter and three flood control tunnels, one 26 feet in diameter and two 22 feet in diameter. Penstocks, with an inside diameter of 24 feet, were installed in the power conduits. One 18-foot by 24.5-foot tainter gate was provided for each flood control tunnel for fine regulation. Two vertical-lift caterpillar gates, each 26 feet high by 12 feet wide, were provided for each of the power tunnels. Tractor-type vertical life emergency gates were provided for the three flood control tunnels and four sliding vertical-lift bulkhead gates were installed ahead of any pair of penstock gates. The final design also provided an intake structure with a base 170 feet wide and 540 feet long and a height of 203 feet from the foundation to the operating deck at elevation 1865.0 feet.

2-02.3. The DPR provided for an initial power installation of 80,000 kilowatts (kW) and an ultimate installation of 320,000 kW. The proposed installation included a total of eight 40,000 kW units with 18-foot diameter penstocks. Station service hydroelectric units were also proposed in the DPR. The final design of the powerplant provided for a 400,000 kW power installation consisting of five 80,000 kW power units with 29-foot diameter penstocks and ten surge tanks (two for each power unit), 65 feet in diameter. The station service units were not included in the final design.

2-02.4. In the DPR, all main power transformers were located in the switchyard with leads from each main generator being carried from the plant to the switchyard in a power cable tunnel which is separated from the tunnel carrying control cable. The DPR also provided for the switchyard to have initial circuits for three 115 kilovolt (kV) lines with positions for a fourth 115 kV line and two 230 kV lines to be installed in the future. The final design provided for the main power transformer for each unit to be located on a transformer deck on the downstream side of the powerhouse. The main power circuits consist of 13.8 kV isolated busses from the generator terminals to the main power transformer and high tension cables in oil-filled pipes from the main power transformer to the switchyard. The switchyard as constructed provides for termination facilities for the main generators and for four 115 kV and three 230 kV outgoing lines.

2-02.5. The DPR included plans for the protection of Williston, ND and two irrigation projects at the head of the Garrison reservoir. The irrigated land to be protected included the Lewis and Clark Project comprising about 8,100 acres and Unit Nos. 1, 2 and 3 of the Buford-Trenton Project comprising about 15,700 acres. Plans for protection from backwater from the reservoir during floods by means of levees and pumping facilities were included for Williston, the Lewis and Clark Project and for the east portion of the Buford-Trenton Project. The balance of the land in the Buford-Trenton Project was not expected to require protection until such time that aggradation caused high backwater stages during floods. In order to conform to the desires of local interests and for economic reasons, actual project development resulted in federal purchase of all land in the Lewis and Clark Project and in the east bottom portion of the Buford-Trenton Project. The Williston area was protected by construction of levees designed for initial aggradation additions.

**2-03. Construction History.** Construction of the rolled fill embankment began in October 1947 and was completed in 1956. Material for the embankment was obtained primarily from the excavations, which were necessary for the intake structure and powerhouse foundations, intake and outlet channels, spillway construction and spillway pilot channel.

2-03.1. Construction of spillway facilities began in June 1952, with the crest structures completed in 1955. Work on the spillway stilling basin continued into 1957.

2-03.2. Construction of the eight outlet and power tunnels and associated intake structure and stilling basin began in 1949. Tunnels were completed in 1951 and the intake structure was completed in 1954. Installation of emergency gates, penstock gates, regulating gates, stop logs, gate hoists and associated mechanical and electrical equipment was completed in June 1955.

2-03.3. Construction of the powerhouse foundation began in 1949 and work continued on power generation and distribution facilities into 1962. The first power unit was placed on line in February 1956. Succeeding units came on line in March 1956, August 1956, December 1959 and May 1960. Terminal facilities and switchyards were completed in July 1962.

2-03.4. 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.** The relocations required for the Garrison project included two federal highways, five state highways, several county roads and Bureau of Indian Affairs (BIA) roads, two railroads, numerous power transmission lines, telegraph and telephone lines, gas lines, two towns, the Fort Berthold Indian Reservation and several small cemeteries. A complete new town (New Town, ND) was constructed to replace Sanish and Van Hook, ND, which were inundated by the reservoir. Portions of U.S. Highways 82 and 85 and ND State Highways 2, 8, 22, 23 and 28 were relocated. A new highway bridge (Four Bears Bridge) was constructed across the Garrison reservoir on State Highway 23 near New Town. Lost Bridge over the Little Missouri River arm of the reservoir on ND State Highway 22 and county road bridges over Little Muddy Creek and Stoney Creek east of Williston were raised. U.S. Highway 83 and the Minneapolis, St. Paul and Sault Ste. Marie Railway (SOO Line) were rerouted across the Snake Creek embankment. The branch line of the SOO Line, located in the vicinity of Sanish and Van Hook, was relocated to a terminus at New Town. The Great Northern Railway required relocation east of Williston. Detailed descriptions of the relocations are contained in Appendix VII to Volume II of the DPR for Garrison Dam and Reservoir dated January 1946. Relocations were started early in 1949 and were essentially complete in 1962.

**2-05. Real Estate Acquisitions.** Lands required for Garrison totaled almost 500,000 acres. Most of this area was acquired in fee, with easements totaling less than 3,000 acres. The basis for real estate acquisition was a guide-taking line of elevation 1855.0 feet over a major portion of the reservoir area. In upstream areas, the guide-taking line was as high as elevation 1860.0 feet, recognizing backwater and aggradation that was likely to occur. While most of this real estate has been acquired, there are numerous small parcels of land below these elevations that were not acquired due to faulty surveys or inadequate blocking out and acquisition of these parcels.

**2-06. Regulation History.** Closure of Garrison Dam and the first impoundment of water in the reservoir occurred April 15, 1953. In early operation the reservoir was utilized for flood control and the accumulation of storage that was subsequently released to help support navigation on the lower Missouri River. As power units came on line and additional storage was accumulated, service to all authorized functions began. While the project has been fully operational since

1960, initial fill of the reservoir to normal operating levels was not completed until 1966. As of the writing of this WCM, storage in the Exclusive Flood Control Zone (elevation 1850.0 to 1854.0 feet) has been utilized on a number of occasions: July-August 1969, June-August 1975, July-August 1995, July-September 1997, July-September 2010, May-August 2011 and June-August 2018. Further information concerning historical regulation is contained in Appendix A of this WCM. Detailed descriptions of each year's project regulation are detailed in that year's AOP and annual Summary of Actual Regulation Report, both published by the MRBWM office.

**Missouri River Basin  
Garrison Dam – Lake Sakakawea  
Water Control Manual**

**III - Basin Description and Characteristics**

**3-01. General Characteristics.** The Missouri River basin drainage area upstream of Garrison includes northwestern North Dakota, all of Montana east of the Continental Divide, the central portion of northern Wyoming, a small part of South Dakota and portions of southern Canada lying in the tributary Milk River basin. The total drainage area above Garrison Dam is 181,400 square miles, which includes the 57,500 square miles upstream from Fort Peck Dam. The Missouri River basin above Fort Peck Dam is described in detail in the Fort Peck WCM. The portion of the Missouri River basin described in this WCM consists of the 123,900 square mile drainage area between Fort Peck and Garrison dams and that portion of the basin below Garrison Dam draining to the Missouri River above the headwaters of the Oahe reservoir. Plate III-1 is a general map of the Missouri River basin. The incremental drainage area between Fort Peck and Garrison is shown on Plate III-2.

3-01.1. The major portion of the drainage area described in this WCM is drained by a single tributary stream, the Yellowstone River, which enters the Missouri River in the headwaters region of the Garrison reservoir. The Yellowstone River contributes by far the largest amount of runoff to the Missouri River reach under consideration in this WCM and is also the major contributor of inflow to the entire System.

**3-02. Topography.** The Rocky Mountains form the western boundary of the Yellowstone River basin. They have an exceptionally rugged topography, with many peaks surpassing 14,000 feet in elevation. Within the basin, the mountains extend over an area of about 30,000 square miles. While the mountains contain many valleys, peaks and mountain spurs are the major characteristics.

3-02.1. Sloping eastward from the Rocky Mountains, the Great Plains form the remaining portion of the Missouri River basin under consideration in this WCM. The western boundary of these plains at the foot of the Rockies averages about 5,500 feet in elevation. West-to-east slopes of the plains average about 10 feet per mile. Through a major portion of the drainage area, the surface mantle and topography have been developed largely by erosion of the fluvial plain extending eastward from the mountains. However, particularly in those portions of North Dakota north and east of the Missouri River, the Great Plains have been affected by continental glaciation. In these areas the topography was shaped primarily by erosion of the glacial drift and till.

**3-03. Land Use.** Agriculture represents the primary use of the land in this portion of the Missouri River basin, estimated to extend over 95 percent of the total area. The remainder is devoted to recreation, fish and wildlife, transportation and built-up areas. Pasture and range is the primary agricultural pursuit, utilizing about 80 percent of the total area. Cropland comprises only 8 percent of the Yellowstone River basin but makes up about 20 percent of the remaining drainage area. Forests and woodland amount to 14 percent of the Yellowstone River basin and less than 5 percent of the remaining drainage area. Irrigation is practiced on about one-third of

all cropland in the Yellowstone River basin but on only about 2 percent of cropland in the remainder of the drainage area under consideration. Water areas in this incremental drainage area 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. Land use in counties adjacent to Lake Sakakawea has undergone change in the last several years. Oil well development in the Bakken/Three Forks formations has created an oil boom in western North Dakota. These developments have transformed some sparsely populated, predominantly agricultural areas and brought changes to the patterns of land use, including population density. Refer to Plate III-3 for a graphical representation of land use in the Garrison 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 Garrison are the large areas of the upper Missouri River controlled by the Fort Peck reservoir. The Milk River, the first major tributary below Fort Peck Dam, drains a 23,000 square mile area that is predominantly of the plains region and includes a portion of Canada. The most significant tributary stream in this reach of the Missouri River is the Yellowstone River, which originates on the western slopes of the Absaroka mountain range in Yellowstone National Park and drains an area of about 70,000 square miles. Essentially all of the mountainous drainage area in the Fort Peck to Garrison incremental area is within the Yellowstone River basin. Streams tributary to the Yellowstone River are of major importance, with regard to both contributing drainage area and water supply within the upper Missouri River basin. The other major Missouri River tributary in this area is the Little Missouri River with a drainage basin consisting of about 9,500 square miles, entirely in the plains region of the basin. In the reach between Garrison Dam and the Oahe reservoir, the major tributaries are the Knife and Heart Rivers, which flow into the Missouri River from the west and have drainage areas of 2,300 and 3,400 square miles, respectively. The drainage area between Fort Peck Dam and Bismarck, ND is well defined except for portions of North Dakota and northeastern Montana, north and east of the Missouri River, where numerous depressions and potholes occur.

3-04.1. The most prominent feature of the drainage pattern in this area is that every major tributary (except the Milk River) is a right bank tributary and flows in a north to east direction. 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 that time in the headwaters regions are significantly higher than at the tributary mouths, resulting in an aggravation to ice jamming near their mouths during the ice break-up period.

**3-05. Stream Slopes.** The total fall of the Missouri River from Fort Peck to Garrison is approximately 365 feet and averages about one foot per mile along the river's thalweg. Slopes of the Yellowstone River and its tributaries in their mountainous headwater areas are very steep, ranging up to several hundred feet per mile. All tributary slopes progressively flatten as they approach their confluence with the Missouri River. The lower reach of the Milk River is exceptionally flat with a slope of less than 0.5 foot per mile. Most other major tributary streams have slopes ranging upward from 5 feet per mile, significantly steeper than the Missouri River, throughout their length.

**3-06. Climate.** The climate of the drainage area above Garrison is predominantly semi-arid, except for small humid areas in the mountains along the Continental Divide. The climate of the drainage area is influenced by the barrier effect of the mountain ranges to the west and south of the upper Missouri River basin, the differences in elevations, the interior location on the North American continent, the latitude and the movement of air masses and storms. These factors result in large variations in annual and daily temperatures and relatively low amounts of precipitation within the drainage area.

3-06.1. Annual Precipitation. Principal moisture-bearing air masses approach the upper Missouri River drainage basin from the Pacific Coast. However, a large portion of their moisture is lost as precipitation in crossing the more western mountain ranges of the continent. Crossing the main range of the Northern Rockies results in further uplift of the air masses and precipitation over the western part of Montana. These losses, together with the warming and drying of the air during its descent over the eastern slope of the mountains, largely account for the small amount of precipitation in the lower elevation areas of the incremental drainage basin between Fort Peck and Garrison. In the mountainous regions of the basin the amount of precipitation tends to increase with elevation. There are also orographic barriers south and southeast of the Yellowstone River basin that limit the amount of precipitable moisture entering the basin from these directions. Moisture-bearing air must rise to at least 8,000 feet to reach the portion of the Yellowstone River basin west of the Absaroka Range. It must rise almost 7,000 feet to enter the Bighorn River basin and about 3,500 feet to reach the lower Yellowstone River basin in southeastern Montana. Average annual precipitation varies widely throughout the drainage area. Annual precipitation in the plains area varies from less than 6 inches in the upper Bighorn River basin to about 16 inches at the lower end of the drainage area near Garrison Dam. The mean annual precipitation increases to about 26 inches in the vicinity of Yellowstone National Park and to more than 40 inches in the high mountainous areas. The pattern of average annual precipitation throughout the Missouri River basin, including the incremental drainage area emphasized in this WCM, is presented in Plate III-4. Monthly precipitation patterns are presented in the Master Manual (Plates III-4 through III-15).

3-06.2. Seasonal Precipitation. Approximately 70 percent of the precipitation that falls on the plains drainage area between Fort Peck and Garrison occurs during the months of April through September. Most of the spring and summer rainfall occurs in frequent showers or thunderstorms, however, steady rains lasting for several hours or days may occasionally occur. Excessive rainfall is unusual in the drainage basin above Garrison Dam. May and June are normally the wettest months in the Missouri River basin in Montana and Wyoming with May, June and July the wettest in North Dakota. Winter precipitation over the plains is generally light and falls as snow. In the mountainous portions of the drainage area, precipitation is more evenly distributed throughout the year. Large amounts of winter precipitation in the form of snow frequently occur at the higher elevations.

3-06.3. Snow. Normal annual snowfall varies from less than 20 inches over portions of the plains area to over 200 inches in mountain regions. Over the plains area, snow does not usually progressively accumulate through the winter season but is melted by intermittent thaws. However, there have been notable exceptions when snow accumulations containing as much as 6 inches or more of water content have blanketed large areas of the plains prior to a significant melt period. Mountain areas usually progressively accumulate snow through the winter and

early spring season, up to a maximum accumulation in April or early May with a water content ranging upward to 24 inches or more at the higher elevations. Plates III-5 and III-6 present mean annual snowfall and maximum annual snowfall, respectively, across the Missouri River basin.

3-06.4. Temperature. Due to its mid-continent location, the plains area in this region experiences temperatures noted for fluctuations and extremes. Extreme recorded temperatures have varied from -65 degrees Fahrenheit (°F) to almost 120°F. Winters are long and cold; however, cold temperatures may be frequently interrupted during periods of downslope or “Chinook” winds when relatively mild temperatures prevail. Summers are normally relatively mild, particularly in higher elevations, but may be interrupted by short periods of extremely warm temperatures over all of the plains area. 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 Garrison reservoir is normally slightly less than 3 feet. This evaporation loss equates to 882,000 acre-feet (AF) of volume (refer to Plates III-9 through III-12). Studies made by the MRBWM office conclude that with average net evaporation, which is evaporation adjusted for precipitation on the reservoir surface, runoff that would have occurred from land area now inundated and the original channel surface area now inundated by the reservoir amounts to about 20 inches annually. Due to seasonal precipitation patterns and to the lag in normal reservoir surface temperatures from corresponding air temperatures, most of the annual net evaporation from the Garrison reservoir can be expected to occur during the 5-month period from August through December.

3-06.6. Storm Potentialities. The source of moisture for all major storms in the high 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 charges. 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 runoff 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 mountains and portions of the plains area. Usually the highest annual flows experienced in the region result from melt of these snow accumulations. Severe flooding will only occasionally occur over portions of the drainage area due to an individual major storm event.

**3-07. Streamflow Records.** With the exception of a few stations, records of runoff from the incremental area considered in this WCM exist only from the early 1930s to date. The main exception is a record near the mouth of the Yellowstone River extending back almost to the turn of the century. 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 streamgaging 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 Peck to Garrison 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, prior to recent accelerated resource development, was selected. 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 mountainous drainage area of the Yellowstone River basin is normally the major runoff source in the incremental drainage area between Fort Peck and Garrison. However, on occasion rainfall or a particularly large winter snowpack accumulation will result in a very substantial runoff contribution from the plains area. Normal contributions to runoff from various drainage basins through this region are presented in Table III-1.

3-08.1. Seasonal Runoff Pattern. Runoff from the drainage area between Fort Peck and Garrison usually follows a characteristic seasonal pattern:

1. Winter is characterized by frozen streams, progressive accumulation of snow in the mountain areas and intermittent snowfall and thaws in the plains area where the season usually ends with a “spotty” snowpack 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 quite low.
2. Early spring is marked by a rapid melting of snow and ice on frozen ground, usually in March or April, in the plains area as temperatures rise rapidly, usually accompanied by very little rainfall. This causes a characteristic early spring ice break-up and increases in tributary streamflow. Due to the tendency of temperatures to rise above freezing first to the south and west and the northerly or easterly course of the tributaries through this region, ice jams are frequently experienced on the lower Yellowstone River and along other tributary streams during this period. The rapid release of water from melting snow and ice jams results in a flashy “March” rise in flow. Peak stages and flows usually occur at this time along lower Yellowstone River tributaries and other streams tributary to the Missouri River through the region. On tributary streams other than the Yellowstone River, a major portion of annual runoff frequently occurs during this period. Snowmelt in the mountains also usually begins in this period but contributes little to runoff until later in the year.
3. Late spring consists generally of the months of May, June and early July. During this period extensive general rains may occasionally occur, sometimes accompanied by severe local rainstorms. Plains area runoff is usually quite low unless these rains occur. This is the season of rapid melting of the mountain snow accumulations and

results in the highest flows of the year over headwater tributaries of the Yellowstone River. Since this headwater area is normally the major contributing area to the Fort Peck to Garrison reach of the Missouri River, incremental flow volume during this period normally exceeds that occurring during any other period of the year.

Occasionally, runoff from severe rainstorms synchronizes with the high runoff from mountain snowmelt and general rainfall during this period.

4. Summer and autumn are generally characterized by a lack of general rainfall and frequent widely scattered intense local rainstorms and occasional severe storms. Runoff in the Fort Peck to Garrison incremental drainage area is usually quite low from late July through the remainder of the calendar year. However, occasionally an intense local storm will result in significant runoff amounts.

3-08.2. Total unregulated Missouri River runoff originating above Garrison usually follows a definite and characteristic annual pattern. Plate III-13 lists the Missouri River basin monthly runoff above Garrison for the period from 1898 to 2014. Total monthly runoff above Garrison (maximum, minimum and average) for each month is shown on Plate III-14. Normal monthly runoff shows a general increase from January through June and then decreases through December. As would be expected, the variations in maximum and minimum monthly runoff amounts that have been observed generally follow the trend established by normal monthly amounts as shown on Plate III-14. Monthly runoff distribution in the Fort Peck to Garrison incremental area is shown on Plate III-15. A pattern very similar to the total Garrison drainage area pattern is evident. The effect of reservoir regulation on these runoff patterns and regulation of various flood events is discussed in Appendix A of this WCM.

3-08.3. The MRBWM Technical Report, *Hydrologic Statistics on Inflows*, dated July 2015, details the development of inflow volume probability relationships for various durations for both regulated and unregulated flows in the Fort Peck to Garrison reach. See Section 6-15 and Plates VI-3 through VI-8 for regulated and incremental inflow volume probability relationships for various durations.

**3-09. Effects on Basin-Wide Floods.** Regulation provided by the Fort Peck and Garrison projects, augmented by upstream tributary reservoir storage, has greatly reduced, but not eliminated, flooding along the portion of the Missouri River extending from Fort Peck to the mouth of the Yellowstone River and the portion extending from Garrison to the headwaters of the Oahe reservoir below Bismarck, ND. Many instances of above-bankfull flows were experienced through these reaches prior to construction of the System projects and would be continuing if the projects were not in operation. All floods experienced in this portion of the Missouri River, except one, have occurred in the March-July season with snowmelt as an important flood component. The one exception occurred in September 1923 when a large rainstorm over portions of southern Montana and northern Wyoming resulted in an October flood on the Missouri River. Basin-wide floods are described in Appendix A of the Master Manual.

**Table III-1**  
**Missouri River Basin – Normal Annual Runoff**  
**Between Fort Peck Dam and Bismarck, North Dakota**

Contributing Area	Drainage Area (square miles)	Average Annual Runoff(1)	
		(kAF)	(inches)
Milk River			
Nashua	22,332	480	0.40
Yellowstone River			
Corwin Springs	2,623	2,256	16.12
Billings	11,795	5,046	8.02
Miles City	48,253	8,158	3.17
Sidney	69,103	8,993	2.44
Corwin Springs to Billings	9,172	2,790	5.70
Miles City to Sidney	20,850	1,153	0.75
Little Missouri River			
Watford City	8,310	551	0.90
Knife River			
Hazen	2,240	172	1.04
Heart River			
Mandan	3,310	272	1.12
Missouri River(2)			
Above Fort Peck	57,500	7,231	2.36
Total above Garrison	181,400	17,973	1.86
Fort Peck to Garrison	123,900	10,742	1.63
Local Drainage			
Fort Peck to Garrison(3)	24,155	871	0.68

(1) Based on available record at each location.

(2) Missouri River runoff at the 1949 depletion level of water resource development.

(3) Incremental drainage area between Fort Peck and Garrison dams is less Milk River at Nashua, Yellowstone River at Sidney and Little Missouri River at Watford City.

**3-10. Effects of Garrison on Flood Inflows.** Studies conducted by the MRBWM office indicate that regulation of Garrison, in conjunction with other upstream System reservoir projects would greatly reduce, but not eliminate significant flood damages in the reach extending from Garrison into Oahe 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 to the Garrison Reservoir.** Plate III-16 shows the graphical representation of travel times for the major tributaries in the Fort Peck to Garrison drainage area. See Plate IV-1 of the Master Manual for travel times for the entire Missouri River basin. Table III-2 presents the approximate time involved for changes in flow at upstream locations in the Fort Peck to Garrison drainage area to be reflected in Garrison reservoir inflows.

**Table III-2  
Water Travel Time to the Garrison Reservoir**

Stream	Location	Approx. Travel Time in Days
Missouri River	Fort Peck Dam	4
	Wolf Point	3
	Culbertson	2
Milk River	Vandalia	6
	Nashua	4
Yellowstone River	Corwin Springs	7
	Livingston	6
	Billings	5
	Yellowtail Dam	5
	Miles City	3
	Sidney	1
Little Missouri River	Marmarth	3
	Watford City	1

**3-12. Water Quality.** The Omaha District Water Control and Water Quality Section is responsible for the water quality monitoring of the System projects and Missouri River, including the Garrison reservoir and the Missouri River downstream of Garrison. Omaha District conducts long-term fixed-station ambient water quality monitoring at the System reservoirs and on the lower Missouri River. Water quality conditions of the water discharged through each of the mainstem dams is continuously monitored. 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.** The upstream Fort Peck project acts as a sediment trap to all sediment above Fort Peck. The headwaters of the Garrison reservoir are near Williston, ND. The confluence of the Yellowstone and Missouri Rivers is 35 miles upstream of Williston. Both rivers combine to contribute roughly 38 million tons of sediment annually. Of this annual total, the Yellowstone River contributes four to five times more sediment than the Missouri River. Another relatively big contributor of sediment is the Little Missouri River, which transports about 6.9 million tons of sediment into the Garrison reservoir. Other sources of sediment are the many other tributaries and shoreline erosion. The average annual sediment depletion rate for the Garrison reservoir, from 1953 to 2012, is estimated to be 21,600 AF/year. At this rate the estimated sediment life of

the reservoir is 1,086 years. See Plates III-17, III-18 and III-19 for the location of sediment rangelines in the Garrison reservoir and for the reach below Garrison to the Oahe headwaters.

**3-14. Missouri River Channel below Garrison Dam.** The physical characteristics of the Missouri River channel below Garrison Dam constrain releases made from the project. Release scheduling must consider these constraints, which are determined by channel dimensions, the degree of encroachment on the floodplain, and the type of floodplain development involved.

3-14.1. Real estate has been acquired as a part of the Oahe project below River Mile (RM) 1303.4 (1960 mileage). This results in a reach of 86.5 river miles extending below Garrison that can be affected by Garrison releases. Problems associated with high river stages through this reach have mostly been confined to the Bismarck/Mandan area downstream to the headwaters of the Oahe reservoir. However, on-going development in areas north of Bismarck, such as Hoge Island, which was affected during the 2011 flood, is becoming more of a concern. The river valley immediately above the Oahe guide-taking line is known as the Sibley Island area. This low-lying area has experienced flooding during times when a Missouri River ice cover has formed through the reach.

3-14.2. Aggradation has been occurring in the headwaters region of the Oahe reservoir and is expected to influence Missouri River stages downstream of Bismarck. At RM 1303.4, which is the upper limit of the Oahe guide-taking line, with an Oahe reservoir level in the Exclusive Flood Control Zone range of elevations 1617.0 feet to 1620.0 feet and Missouri River flows of 60,000 cfs and 120,000 cfs, the Missouri River elevations were estimated to be 1624.2 feet and 1628.7 feet, respectively, prior to aggradation. As noted in the most recent stage trends report, from the late 1920s to 2010, the Missouri River stages for the 20,000 to 40,000 cfs flows increased 1 to 3 feet, respectively. Record discharges in 2011 lowered the stages for these flows 1 and 2 feet, returning the stage close to levels experienced in the 1920s. Currently, it is still too early to determine long-term effects from the record Garrison releases, but it is anticipated that future aggradation will continue.

3-14.3. Channel Description. The Missouri River in the reach from Garrison to the headwaters of the Oahe reservoir is an alluvial stream contained in a relatively wide valley. With an average channel width of about 1,000 feet, the river meanders through numerous sandbars and sloping sand banks between near-vertical loam banks deposited by previous flood flows. Due to the river meandering process, erosion of these vertical banks is quite common. In previous years, bank stabilization has been accomplished in several areas and the river has been partially confined, particularly in the Bismarck, ND area.

3-14.4. Channel Deterioration. As is typically experienced following construction of a dam, there has been a deterioration in the flood-carrying capacity of the Missouri River channel below Garrison, in addition to the Oahe aggradation effects discussed in Section 3-14.2 of this WCM. This deterioration is partially due to the absence of flood flows, with their scouring effects, since dam construction. Channel encroachment, encouraged by the control afforded by the Garrison reservoir and bank stabilization measures, are believed to contribute to this loss of flood-carrying capacity. Deterioration is evident at Bismarck, ND, the principal damage center below Garrison. At the time the Garrison dam was constructed, a stage of 13.0 feet was approximately equivalent to an open water flow of 90,000 cfs. However, in 1975, after 22 years of project operation, flows

of 50,000 cfs resulted in a similar stage. With the scouring effects of flood flows in 2011, recent trends show a flow of 63,000 cfs at a stage of 13.0 feet. The stage trends at the Missouri River at Bismarck gage, located approximately 75 miles downstream of Garrison, are shown on Plate III-20.

3-14.5. Floodplain Encroachment. Construction of the System reservoirs has encouraged encroachment upon the floodplain adjacent to the Missouri River channel. Adverse effects to extensive new developments in the vicinity of Bismarck begins at river levels as much as 1.5 feet lower than the current Bismarck flood stage of 14.5 feet. A similar problem exists with the irrigation intake facilities adjacent to the channel throughout the reach of the river from Garrison to Bismarck. These facilities are usually designed to function at a near-constant river stage and complaints have been made relative to both low and high releases, as well as to release changes. Other water intakes serving powerplants and municipalities in the reach must also receive consideration during the regulation process. This change in land use along the river was instrumental in the decision by the National Weather Service (NWS) to lower the flood stage at Bismarck from the long-established level of 19.0 feet to 16.0 feet in 1976. The flood stage was lowered again in 2012 to 14.5 feet.

**3-15. River Ice.** The Missouri River and its tributaries in the incremental drainage basin between Fort Peck and Bismarck, ND are at least partially ice covered for several months of the year. The period usually extends from late November or early December to March or early April. Ice thickness on the Garrison reservoir has reached 41 inches. Ice thickness on the streams in the Garrison drainage basin has been measured in excess of 36 inches. The MRBWM office keeps records of the Garrison reservoir ice cover. From these records it may be noted that an ice cover has formed on the reservoir as early as November 23 (1955) and remained as late as May 8 (1956).

3-15.1. Construction of Garrison Dam has materially altered the ice experience along the Missouri River below the dam from that occurring prior to the project. Immediately below the dam a complete ice cover is now seldom experienced. The extent of open water in this reach during the winter period is primarily dependent on air temperatures and release water temperatures. In recent years there has usually been at least several miles of open water downstream from the project, although this may be materially reduced during extremely cold temperature periods. Formation of an ice cover in the entire reach below Garrison has also been materially delayed from pre-project expectations. Release water temperatures during the normal ice formation period are significantly higher than previously experienced river water temperatures. This tends to maintain the Missouri River in a relatively ice-free condition beyond the time that contributing tributaries are frozen.

3-15.2. Regulation of Garrison also influences the downstream ice break-up. Ice loss on the Missouri River downstream of Garrison now results almost entirely from melting, with this melt progressing downstream from Garrison. This contrasts with the pre-project mechanical break-up of the Missouri River ice by the higher flows from earlier break-up on the northward flowing tributaries. The Garrison reservoir also acts as a trap to ice contributed from the upstream river and tributaries. Experience to date has also indicated that, in combination with the effects of Garrison releases, ice contributions from tributary streams between Garrison and the Oahe reservoir do not present a significant threat for ice jamming along the main stem channel in most

years. However, ice jamming can still be a concern, particularly when combined with snowmelt or rainfall runoff events, which occurred in 1997 and 2009.

3-15.3. Channel Capacity. The main damage center along the Missouri River in the reach immediately below Garrison is Bismarck, the capital city of North Dakota. If Bismarck stages are below 13 feet, few complaints relating to high Garrison releases can be expected. As noted earlier in the manual, this stage presently indicates an open water flow of about 63,000 cfs, although at the time the Garrison project closed open water flows of 90,000 cfs resulted in a stage of this magnitude. Further channel deterioration is a distinct possibility. During periods of ice cover in the Bismarck vicinity, flows resulting in a stage of 13 feet will vary. At the time an initial ice cover forms, the stage typically increases 4 to 6 feet and a stage of 13 feet may be reached at a flow of about 20,000 cfs. As the ice cover remains in place a gradual adjustment occurs and increasing flows can be accommodated with a 13-foot stage or lower. The adjustment is due primarily to the gradual smoothing out of the ice cover under the surface and the bed of the river. After about one month of continual ice cover the discharge capacity of the channel can be expected to increase, allowing for gradual increases in Garrison releases without materially exceeding a target stage of 13 feet at Bismarck, provided significant inflows are not occurring in the reach.

3-15.4. Stage-Discharge Relationship. The relationship between river stages and corresponding discharges on the Missouri River below Garrison are illustrated by the rating curve for the Missouri River at Bismarck, ND, on Plate VI-1. The current open water rating curve indicates that, if an ice cover is not present, a change in river flow of about 6,000 cfs will result in a corresponding stage change of one foot when stages are near the maximum non-damaging level of 13 feet. If an ice cover is present, the stage-discharge relationship is warped materially. Due to continuing adjustments after an ice cover first forms, there is no single rating curve applicable for ice conditions at Bismarck. However, in general, the ice-covered stage is noticeably higher than the open water stage, as shown on Plate III-21. More information on recent (2001 to 2012) ice conditions in the Bismarck area can be found in the report *Review of Ice Formation on the Missouri River at Bismarck, ND* prepared by the Corps' Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL).

3-15.5. Travel Time from Garrison Dam. The effects of Garrison release changes generally travel downstream at a rate of about three river miles per hour if an ice cover is not present. As a consequence, any change in an average release rate on one day is usually reflected by a changed Bismarck stage on the following day provided there is not a significant ice cover upstream from Bismarck. An ice cover over most of the reach has the effect of slowing travel times to such an extent that two days may be required before the effects of release modifications become apparent on the Bismarck gage. Plate III-22 relates water travel time to specific locations in the reach extending from Garrison to the headwaters of the Oahe reservoir.

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**Missouri River Basin  
Garrison Dam – Lake Sakakawea  
Water Control Manual**

**IV - Project Description and History**

**4-01. Location.** Garrison Dam is located at RM 1389.86 in McLean and Mercer counties, North Dakota, approximately 75 river miles upstream from Bismarck, the capital city of North Dakota. The project is second in downstream order of the six Missouri River mainstem projects constructed by the Corps. The Garrison reservoir (Lake Sakakawea) extends in a generally northwest direction to near Williston, ND. A project photo is shown as Plate IV-1.

**4-02. Embankment.** The dam consists of a rolled earthfill embankment 11,300 feet in length at the crest with a crest at elevation 1875.0 feet, over 200 feet above the old riverbed. The upstream portion of the embankment is composed of dense impervious material and the downstream portion is semi-pervious with a pervious drainage blanket over the old streambed. The maximum width of the base is about 2,600 feet with an impervious blanket extending an additional 1,250 feet upstream from the upstream toe of the dam. The crest width is 60 feet and side slopes range from 1 vertical (V) on 8 horizontal (H) and 1V on 10H in the lower portions of the embankment to 1V on 3H and 1V on 2.5H in the upper portions. Seepage control is addressed with a combination of the upstream impervious blanket, steel sheet piling cutoff walls, impervious-filled cutoff trenches, grout curtains at the abutments and a toe drain in the downstream section of the embankment. A system of relief wells located about 175 feet downstream from the toe of the dam also facilitates drainage of seepage water and reduces hydrostatic pressures in the foundation material downstream from the cutoff walls. The upstream face of the dam is protected from wave action by riprap placed above elevation 1800.0 feet. A gravel blanket extends from the bottom of the riprap to elevation 1770.0 feet. Detailed description of the embankment is contained in the Operation and Maintenance (O&M) Manual for the Garrison Dam Embankment. Refer to Plate IV-I for an aerial photo that shows the Garrison embankment, intakes, powerhouse, outlet tunnels, spillway and reservoir. Plan and cross 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 reservoir level at elevation 1859.0 feet. A wind tide allowance of 1.8 feet and wave height plus ride-up allowance of 6.3 feet was developed in design studies. An additional safety factor of 7.9 feet resulted in the total freeboard allowance of 16.0 feet, establishing the embankment crest at elevation 1875.0 feet.

**4-03. Spillway.** The spillway is located in the left abutment and separated from the main embankment by about 800 feet of natural ground. The spillway is of the conventional concrete chute-type with crest gates at the upper end and consists of the approach channel, control gate structure, lined chute, stilling basin and unlined discharge channel. The bottom of the approach channel is at elevation 1810.0 feet with an upstream width of 2,200 feet narrowing to 1,356 feet at the spillway crest structure. The spillway crest consists of an ogee-type weir, divided into 28 bays, with a crest elevation of 1825.0 feet. Each bay contains a tainter gate 40 feet wide by 29 feet high. The gates are electrically operated and can be individually controlled from the service

bridge. Refer to Plates IV-3 and IV-4 for photos of the Garrison spillway gates and spillway, respectively.

4-03.1. A concrete-lined spillway discharge chute extends from the crest structure 2,605 feet downstream to the stilling basin. The stilling basin is 800 feet wide and over 200 feet long with a floor at elevation 1620.5 feet. The lower portion of the stilling basin contains baffles 10 feet high and 8 feet wide spaced on 10-foot centers. An unlined pilot discharge channel was constructed downstream of the stilling basin to guide flows to the Missouri River channel. The pilot channel was expected to erode and adjust itself to the flow conditions. Plan, profiles and sections of the spillway structure are shown on Plate IV-2. Spillway discharge rating curves are shown on Plate IV-5.

4-03.2. The spillway was used for regulation purposes for the first time in 2011. The spillway pilot channel was excavated to an elevation of 1696.0 feet with a 5-foot bottom width for approximately 8,900 feet. Excavated material was wasted along the channel to be carried away by water discharge in the process of channel development. As anticipated, preliminary releases caused backwater effects to inundate much of the downstream campground and threatened to back into the relief well channel and maintenance facility area. A temporary earthen levee was constructed adjacent to the fish hatchery ponds and tied into high ground. Water approached the top of the structure but eventually receded as the pilot channel gained efficiency. The existing road embankment and culverts were removed to permit water to be released through the spillway. Scour depths along the embankment were estimated to be upwards of 30 feet, making repair of the road impractical. Spillway flows cut a very uniform channel downstream from the old railroad embankment to the river channel. Measurements showed the channel to be approximately 370 feet wide, with a depth ranging from 25-30 feet, and a length of roughly 2.5 miles downstream of the spillway. The channel banks were relatively stable once spillway discharges stabilized. More information can be found in the 2011 Garrison flood surveillance report. Additional guidance regarding best practices and/or special considerations and restrictions for use of the spillway at Garrison can be found in Exhibit A of this WCM.

**4-04. Outlet Works.** The outlet works and power tunnels include an approach channel, an intake structure, eight concrete lined tunnels, of which three are for flood control and five for water supply to power units, a stilling basin at the downstream end of the flood control tunnels and a discharge channel leading to the old river channel. The approach channel to the intake structure served to carry Missouri River flows at the time of embankment closure. It consisted of a channel excavated to near elevation 1670.0 feet about 500 feet wide and 2.5 miles long along the right (west) bank of the Missouri River channel that lies upstream from the dam prior to closure. It is now continuously submerged and ends at the intake structure.

4-04.1. Tunnels through the dam are approximately 1,320 feet long with invert elevations of 1672.0 feet at the upstream end and 1662.0 feet at the downstream exit. The easterly five tunnels, Nos. 1 through 5, serve as conduits for the penstocks supplying the power units. The remaining three tunnels, Nos. 6, 7 and 8, are for flood control and discharge into a stilling basin. The five power tunnels have an inside diameter of 29 feet, except for a short distance of Tunnel No. 4, which has a 30-foot inside diameter. Tunnel No. 6 has an inside diameter of 26 feet and Tunnel Nos. 7 and 8 have inside diameters of 22 feet. A stilling basin extends below the three flood control tunnels. Stop log slots, designed to be used for basin dewatering, are located 40

feet downstream of each tunnel portal. Below the stop log slots is a 250-foot long chute section, followed by a level stilling basin section about 165 feet long with a bottom at elevation 1619.0 feet. The level stilling basin section leads into a paved slab section that slopes upward to elevation 1650.0 feet at the entrance to the unpaved discharge channel. The discharge channel extends from the downstream edge of the tailrace and stilling basin to the Missouri River channel, a distance of almost 4,000 feet. Sloping sides of the discharge channel are protected by riprap. A more detailed description of the outlet works is contained in the Garrison O&M Manual. Plan and profiles of the outlet works are shown on Plate IV-2. The discharge rating curves for the flood control tunnels are shown on Plate IV-6. Additional guidance regarding best practices and/or special considerations and restrictions for use of the outlet works can be found in Exhibit A of this WCM.

**4-05. Powerplant and Switchyard.** Principal features of Garrison's power production facilities include penstocks and surge tanks, the powerhouse that houses the generators, turbines, a control room and related equipment, the tailrace and the outdoor switchyard. Water is supplied to the turbines by five 24-foot diameter steel penstocks contained in the 29-foot diameter power tunnels. Two surge tanks, each 65 feet in diameter and almost 140 feet in height extending upward to elevation 1885.7 feet, are provided for each penstock. A bubbler system is provided to prevent a solid ice cover from forming on the water surface in the surge tanks during freezing weather. The surge tanks and switchyards can be seen on Plates IV-7 and IV-8, respectively.

**4-06. Intake Structure.** The intake structure houses gate-controlled inlets to all eight tunnels. The intake structure is a massive reinforced-concrete structure, having overall dimensions 540 feet in length, 170 feet in width at the base, and 203 feet in height from the foundation to the operating deck at elevation 1865.0 feet. A superstructure extends upward another 65 feet. Gates housed in the structure include an 18-foot by 24.5-foot tainter gate for each of the three flood control tunnels and two 12-foot by 26-foot vertical lift gates for each of the five power tunnels. Emergency gates are provided for closure ahead of any of the regulating gates described above. The intake structure is shown on Plate IV-9.

**4-07. Powerhouse.** The powerhouse structure, which encloses five generating bays, an erection bay, and a control and office bay, is located in the right abutment of the dam. The structure is oriented so that the water flow through the powerhouse is approximately north to south. The common centerline of the units runs east to west. Generator Bay No. 5 is located on the west end and the control and office bay is on the east end of the structure. The substructure of each generating unit is of the conventional monolith-type, 75 feet wide by 111 feet long. The erection bay substructure is 79 feet wide by 118 feet long. The control and office substructure is 72 feet wide by 85 feet long and consists of a rigid reinforced concrete box. The generator floor is at elevation 1703.0 feet. The turbine floor is at elevation 1684.0 feet.

4-07.1. Five hydraulic turbines of the vertical shaft single-runner Francis-type, with riveted plate steel scroll casings and elbow-type draft tubes, are installed in the powerhouse. Each turbine has a rated capacity of 149,500 horsepower at the rated speed of 90 revolutions per minute (rpm) and 163 feet net head. Each turbine is supplied water by an individual steel penstock extending from the intake structure to the spiral case extension at the upstream face of the powerhouse. Two surge tanks are provided with each unit. Penstocks are provided with vertical lift gates in the intake structure. The turbines rotate counterclockwise when viewed from the top and looking

down on the unit. Each turbine is controlled by a digital hydraulic governor, which adjusts the wicket gate openings through the servomotors and gate mechanisms.

4-07.2. The generators are vertical shaft, water-wheel driven synchronous generators with static excitation systems. Each generator is equipped with a bearing oil and generator air cooling system, a braking and jacking system, metering and protective relaying and a carbon dioxide fire protection system. The generators for Unit Nos. 1, 2 and 3 are each rated at 128,000 kilovolt-amps (kVA) at a 0.95 power factor (121.6 megawatts (MW)) and Unit Nos. 4 and 5 are each rated at 115,000 kVA at 0.95 power factor (109.25 MW). All units generate power at 13.8 kV between phases. Refer to Plate IV-10 for a photo of the generators.

4-07.3. The generator step-up transformers are located on the transformer deck on the south side of the powerhouse. Each 3-phase transformer for Unit Nos. 1, 2 and 3 is rated at 128,000 kVA and raises the voltage from 13.8 kV to 230 kV. Each 3-phase transformer for Unit Nos. 4 and 5 is rated at 128,000 kVA and raises the voltage from 13.8 kV to 115 kV. Each transformer is cooled using oil-directed, forced-air coolers.

4-07.4. The generation switchyard is adjacent to the east bank of the tailrace, which is southeast of the powerhouse. The generator unit breakers, exterior 13.8 kV station service switchgear and black-start generator are located in the generation switchyard.

4-07.5. The transmission switchyard is located southeast of the generation switchyard. The transmission switchyard has a 115 kV switchyard and a 230 kV switchyard which are connected together by an auto-transformer. Three generation lines (Unit Nos. 1, 2 and 3) and three transmission lines are connected to the 230 kV switchyard. Two generation lines (Unit Nos. 4 and 5) and four transmission lines are connected to the 115 kV switchyard. The main high voltage busses, circuit breakers, disconnects, lightning arresters and instrument transformers are located in the transmission switchyard.

4-07.6. The tailrace extends from the downstream face of the powerhouse about 150 feet to the discharge channel. Tailrace paving slopes upward from elevation 1629.0 feet at the draft tube exit up to elevation 1650.0 feet at the entrance to the discharge channel.

4-07.7. A more detailed description of the power facilities and other structures is contained in the Garrison O&M Manual. Plan and sections of the powerhouse are shown on Plate IV-2. Powerplant tailwater rating curves and powerplant characteristic curves are shown on Plates IV-11 and IV-12, respectively.

**4-08. Reservoir.** The reservoir formed by Garrison Dam, Lake Sakakawea, lies in northwestern North Dakota. At elevation 1837.5 feet, the base of the Annual Flood Control and Multiple Use Zone, the reservoir has a length of 178 miles, shoreline of 1,340 miles, a surface area of 308,000 acres and a maximum depth of about 180 feet. In general, the reservoir is relatively narrow for its length because it is confined to the Missouri River valley. There are three major exceptions to this configuration (see Plate IV-13). The Snake Creek area, which was separated from the Garrison reservoir by construction of an earth embankment, is immediately upstream from Garrison. The reservoir upstream from this secondary embankment is Lake Audubon and is described in more detail in Section 4-15.4 of this WCM. The major Missouri River tributary

entering the Garrison reservoir is the Little Missouri River and the tributary valley forms the Little Missouri Arm of the reservoir. Upstream from the mouth of the Little Missouri River, a large relatively flat bench exists where Shell Creek enters the reservoir and forms an area known as the Van Hook Arm. A map of the reservoir area is shown on Plate IV-13.

4-08.1. Allocation of storage space in the Garrison reservoir was based on System authorized purposes as described in Section 7-03 of the Master Manual. Types of storage space, with associated elevations and storage quantities for each zone, are presented in Table IV-1. The area-capacity table for the Garrison reservoir is on Plate IV-14. Storage volumes in Table IV-1 and Plate IV-14 are exclusive of Lake Audubon.

**Table IV-1  
Garrison Reservoir Storage Space Allocations**

Storage Designation (Zone)	Elevation in feet		Storage Space in AF
	From	To	
Exclusive Flood Control	1850.0	1854.0	1,495,000
Annual Flood Control and Multiple Use	1837.5	1850.0	4,211,000
Carryover Multiple Use	1775.0	1837.5	12,951,000
Permanent	1673.0	1775.0	4,794,000
Total Storage			23,451,000

Note: Storage volumes are based on August 2013 elevation-area-capacity tables (2010-2012 survey data).

**4-09. Recreation Facilities.** Fluctuating reservoir levels can have a major effect on recreational use of the reservoir. 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-15 and IV-16 present the 37 recreational facilities at Garrison. Boat ramps have also been constructed for access to the Missouri River below the dam. While some are considered to be a portion of the Garrison project, others have been constructed by private interests or as a part of other federal, state and private recreational developments. These downstream ramps generally continue to be operable through the normal range of Garrison releases.

**4-10. Leasing of Project Lands.** As indicated previously, essentially all land surrounding the Garrison reservoir below elevation 1855.0 feet has been acquired by the Government for project purposes. Unless inflows to the reservoir are much above average, inundation of lands above elevation 1850.0 feet will usually not occur. Consequently, on an annual basis, the Corps makes tracts of land available for leasing, generally for agricultural purposes, as a part of their land management program. The extent of leased lands is based on land management considerations. A major portion of the revenue from this leasing program is returned to the counties within which the leased land lies. All such leases are subject to possible flooding of land, if needed for

operational purposes, and do not serve as constraints upon regulation of the reservoir for authorized purposes.

**4-11. Reservoir Aggradation and Backwater.** Aggradation, or delta formation, occurs at the mouths of all streams entering the reservoir. As mentioned in Section 3-13 of this WCM, the long-term sediment deposition rate in the Garrison reservoir is estimated to be 21,600 AF per year. A major portion of the average annual sediment inflow into the reservoir is contributed by the Yellowstone and Missouri Rivers into the upstream end of the reservoir. Since the reservoir approached normal operating levels in 1965, a delta has been forming and now extends from about the mouth of the Yellowstone River downstream well into the reservoir. A significant effect of this delta formation has been the reduction in channel capacity in the Missouri River above the reservoir, thereby resulting in increased stages. At the mouth of the Yellowstone River, the Missouri River stage for a 40,000 cfs flow increased about 2 feet from 1965 to 1990. For the same time period, an increase in Missouri River stage of about 8 feet occurred about 11 river miles below the mouth of the Yellowstone River, adjacent to the Middle Bottom of the Buford-Trenton Irrigation District, though this stage is somewhat dependent upon the coincident level of the Garrison reservoir. At both locations the Missouri River stage is expected to increase further in future years. The reservoir aggradation ranges are shown on Plates III-17 and III-18.

**4-12. Tailwater Degradation.** Water released from Garrison is clear and sediment-starved, causing degradation of the Missouri River channel from the dam to just above Bismarck, ND. However, the magnitude of the bed-lowering process generally decreases with distance from the dam and time. As shown by the tailwater trends plot shown on Plate IV-17, about 11.5 feet of degradation has occurred below Garrison from 1953 to 2015. By the early to mid-1980s, the tailwater stage for a specific discharge, after lowering about 9 feet since the mid-1950s, appeared to be stabilizing, but high releases in 1996 and 1997 caused a brief period of degradation of about 1 foot. The tailwater trend appeared to stabilize again after 1997, but high releases in 2011 resulted in another period of channel degradation. The Missouri River degradation ranges for the area downstream of Garrison are shown on Plate III-19.

**4-13. History of Water Resources Development.** Due to the generally arid climate as well as the lack of transportation facilities, development of water resources in that portion of the Missouri River basin extending from Fort Peck downstream to the headwaters of the Oahe reservoir began soon after westward expansion in the early 1800s. Initial development was concerned with navigation, as a means of transportation in the region and irrigation. In later years, as population increased, the development of hydroelectric power facilities, generally in connection with irrigation projects, received emphasis. Control of floods became a major concern in the 1940s. In recent years, municipal and industrial (M&I) water supply, recreation, water quality enhancement as well as fish and wildlife and other matters related to the 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 the Master Manual, the Flood Control Act of 1944 is of primary importance through this portion of the basin. This act authorized the construction of Garrison, 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 projects and emphasized the multiple-purpose aspects of water resource development for the region.

4-13.2. The most important water resource development in this section of the Missouri River basin has been construction of dams and development of the associated reservoirs. In addition to the Garrison reservoir and the associated Lake Audubon, a number of tributary reservoir projects have been constructed in the incremental drainage area between Fort Peck and the Oahe reservoir. While initially these tributary projects may have been constructed for a single purpose, they all now serve several functions, although service to some functions may be incidental to the primary purpose. The USBR, irrigation districts, Montana State Water Conservation Board, BIA and various private organizations have numerous reservoirs in this incremental drainage area that were constructed primarily for irrigation purposes. Most of these are located in the Yellowstone and Milk River basins. The USBR-owned Yellowtail and Boysen reservoirs contain storage dedicated to flood control and assist the mainstem System in controlling Missouri River floods. Reservoirs in the incremental drainage basin having a usable storage capability of 5,000 AF or more are shown in Table IV-2. Many additional reservoirs with a storage capacity of less than 5,000 AF are used for irrigation and other conservation purposes and numerous small stock ponds have been constructed in the arid regions of the incremental drainage area.

4-13.3. The upstream tributary reservoirs stabilize flows and affect the regulation of Garrison usually by reducing the peak inflows, provided the significant runoff contributing to the peak flows originates above these reservoirs. In certain instances a reservoir may increase the size of the peak below the project over that which would be observed naturally either by the speed-up of travel time through the length of the reservoir or by delaying a portion of the runoff from a sub-area to more nearly coincide with the peak on the main stream. However, with the storage space provided and the large number of reservoirs tributary to the mainstem, the possibility of the aggregate effect increasing Missouri River peak flows is very remote. Tributary projects in this region also store significant volumes of flood season runoff and some contribute inflows to the Garrison reservoir during subsequent low water periods.

**4-14. Flood Control.** In addition to the flood control storage space provided in Garrison, reservoir storage space allocated to this purpose has been provided in the Boysen and Yellowtail projects in the Bighorn River basin and in the Heart Butte reservoir on the Heart River. Respective flood control storage allocations in these projects are 300,000 AF, 509,000 AF and 150,000 AF. While no additional tributary reservoir storage space is allocated to flood control, regulation for other purposes frequently provides flood reductions through the river reaches below reservoir projects. This is particularly true for irrigation storage space provided in reservoirs within the Yellowstone River basin. Fill of the storage space is accomplished at times flood inflows are occurring and this storage often reduces downstream flooding.

**Table IV-2  
Reservoirs in the Incremental Drainage Basin  
Between Fort Peck Dam and the Oahe Reservoir Headwaters  
(Over 5,000 AF storage capacity)**

Reservoir	Basin	Usable Storage AF <sup>1</sup>	Year Completed	Owner or Operator <sup>2</sup>
Anchor	Bighorn River	17,205	1961	USBR
Park	Tongue River	7,350	1933	Park Reservoir Co.
Boysen	Bighorn River	522,420	1952	USBR
Buffalo Bill	Bighorn River	604,820	1909	USBR
Bull Lake	Bighorn River	151,740	1936	USBR
Cooney	Clarks Fork	24,200	1936	Rock Cr. Water Users Assn.
Fresno	Milk River	127,200	1939	USBR
Lake Adam	Yellowstone River	5,720	1912	Big Timber Land Co.
Lake DeSmet	Powder River	25,000	1921	Lake DeSmet Counties Coalition
Lake Walvoord	Yellowstone River	9,710	1912	Big Timber Land
Mystic Lake	Yellowstone River	20,800	1925	Montana Power Co.
Nelson	Milk River	60,810	1922	USBR
Pilot Butte	Yellowstone River	31,600	1928	USBR
Ray Lake	Little Wind River	7,500	1906	US BIA
Shoshone Lake	Bighorn River	9,740		State of Wyoming
Tongue River	Yellowstone River	68,000	1939	MT Dept. of Natural Resources
Upper Sunshine	Bighorn River	53,000	1939	Greybull Valley Irrigation Dist.
Willow Creek	Bighorn River	31,850	1942	US BIA
Yellowtail	Bighorn River	808,990	1966	USBR
Dickinson	Heart River	8,040	1950	USBR
Heart Butte	Heart River	65,090	1949	USBR

<sup>1</sup> Storage available for release below the maximum controllable level.

4-14.1. The overall effect of upstream tributary reservoir regulation is generally beneficial to Garrison regulation. Storage accumulated during the flood season represents a volume of water that will not appear as flood inflow to the Garrison reservoir, allowing the available space in this project to be used for a firmer degree of control of the total water supply. In actual practice, Garrison regulation is geared to recognize the vacant storage space available in the major upstream tributary projects, space that would be utilized for storage of flood inflows should they occur.

4-14.2. There are no local flood protection projects that affect, or are affected by, Garrison operations. Levees have been constructed along the Missouri River adjacent to Williston, ND, in the headwater's region of the Garrison reservoir. These levees are considered to be an integral

portion of the Garrison project, provided to permit normal operation of the project, rather than a separate protection project.

**4-15. Irrigation.** The drainage area between Fort Peck and the Garrison reservoir contains a total of about 1,211,100 acres of irrigated land: 992,600 acres in the Yellowstone River basin, 129,000 acres in the Milk River basin, 8,100 acres in the Little Missouri River basin and 81,400 acres along the main stem of the Missouri River and its minor tributaries between Fort Peck and Garrison. Irrigation is the primary purpose of most major tributary reservoirs that have been constructed within the incremental drainage area discussed in this WCM. Refer to Appendix E of this WCM or Appendix E of the Master Manual for additional information regarding irrigation.

4-15.1. Irrigation development between Garrison and Bismarck, ND includes the Fort Clark Unit of the North Dakota Pumping Division developed by the USBR and privately-owned irrigation developments along the bottomlands of the Missouri River. The Fort Clark Unit is located between the Fort Clark historic site and the town of Stanton, ND in Oliver and Mercer Counties. Facilities of the unit provide full water supply for the irrigation of 1,929 acres of bench land and bottomland bordering the Missouri River. The privately-owned irrigation developments vary from 30 to 1,500 acres in size and include a total of about 5,000 acres of irrigated land supplied with water from the Missouri River by individual pumping units.

4-15.2. Buford-Trenton and Lewis and Clark Irrigation Districts. Prior to development of the Garrison project there were two irrigation districts along the Missouri River at and immediately below the confluence of the Yellowstone River. Since these would be in the headwater area of the Garrison reservoir, problems associated with continued operation of these districts were anticipated. The downstream Lewis and Clark District, located on the right bank of the river, was purchased to form a portion of project lands. However, the Buford-Trenton District, located on the left bank, was at a higher elevation and continued operation of at least a portion of this district appeared feasible through the early years of the Garrison project life.

4-15.3. The Buford-Trenton Irrigation District was developed by the USBR in the early 1940s and is divided by bends in the Missouri River into four areas: Zero, West, Middle and East Bottom. These areas extend downstream for about 35 miles along the Missouri River from immediately above the Yellowstone-Missouri River confluence to near Williston, ND. The project consisted of about 16,800 acres of which 10,000 acres were irrigable. The East Bottom area was purchased by the Corps in 1958 in recognition of the probable flooding and groundwater problems that would occur when the Garrison reservoir reached normal operating levels, which would reduce the area of the District from 16,800 acres to 10,100 acres, of which about 7,100 acres would be irrigated rather than 10,000 acres. The East Bottom lands and the downstream Lewis and Clark Project lands were leased to former owners for continued agricultural use until these lands were needed for project purposes. The Buford-Trenton project currently supplies water to about 10,600 acres of irrigable land by pumping directly from the Missouri River into a main canal and laterals.

4-15.4. In 1965 Congress authorized the Garrison Diversion Unit (GDU) as part of irrigation projects to be developed by the USBR and construction was started in 1967. The GDU project was designed to divert Missouri River water to central and eastern North Dakota for M&I water,

and recreational and fish and wildlife purposes, as well as provide irrigation for 250,000 acres. The Snake Creek Embankment, constructed across Snake Creek about 10 miles northeast of Garrison Dam, serves as a highway (U.S. 83) and a railroad (SOO Line) relocation and also forms Lake Audubon, a separate impoundment. Lake Audubon has a total storage capacity of 396,000 AF at elevation 1850.0 feet. The Snake Creek Pumping Plant pumps water from the Garrison reservoir into Lake Audubon. The Snake Creek Pumping Plant, McClusky Canal and New Rockford Canal are components of the authorized GDU, however, not all features are yet to be considered fully in service.

4-15.5. The 1986 Garrison Diversion Unit Reformulation Act reduced irrigation emphasis of the GDU and increased the emphasis on meeting municipal, rural and industrial water needs throughout North Dakota. The Act authorized a Sheyenne River water supply and release feature and water treatment plant. Appraisal level studies were conducted from 1994 to 2000. The Dakota Water Resources Act of 2000 (Public Law 89-108) authorized the Secretary of the Interior to develop irrigation for 13,700 acres in the Turtle Lake service area, 10,000 acres in the McClusky Canal service area, 1,200 acres in the New Rockford Canal service area, 15,200 acres within the boundaries of the Fort Berthold Indian Reservation and 2,380 acres within the Standing Rock Indian Reservation.

4-15.6. Although the USBR's originally envisioned federal mainstem irrigation projects have not developed as initially planned, numerous irrigators withdraw water directly from the reservoirs and downstream river reaches.

**4-16. Navigation.** Although navigation on the Missouri River through North Dakota and eastern Montana opened up this region for initial westward settlement, there is currently no commercial navigation through this reach of the river. No tributary reservoir storage space has been allocated for this purpose. Storage has been provided in the Garrison reservoir to serve multiple purposes, including Missouri River navigation; however, storage and releases from the Garrison project serve navigation only indirectly. A description of the Missouri River navigation project is contained in Chapter VII and Appendix G of the Master Manual.

**4-17. Hydroelectric Power.** At the present time there are eight hydroelectric powerplants in operation in the Garrison incremental drainage basin. These include the Garrison powerplant, constructed by the Corps and seven plants in the Yellowstone River basin; six constructed and operated by the USBR and the other by NorthWestern Energy (formerly owned by the Montana Power Company). The installed capacity of these Yellowstone River basin plants totals 688,000 kW, whereas the installed capacity at Garrison is 583,000 kW. All power generated by federal facilities in the Missouri River basin is marketed by Western and Garrison power generation is integrated with the generation provided from other System projects and other federal and private facilities throughout Western's power marketing area. Further details concerning Western's 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 Missouri River between Garrison and the Oahe reservoir is the source of water supply for the North Dakota municipalities of Washburn, Bismarck and Mandan. Industrial water intakes in this reach of the river include the Tesoro Mandan refinery near Mandan, the Basin Electric and Great River Energy coal-fired powerplants

near Stanton, Ottertail Power Company plant at Washburn and the Montana-Dakota Utilities powerplant at Mandan.

4-18.1. Several municipalities withdraw water from the reservoir for water supply. A 12-inch water line supplies the water treatment facility located in Riverdale, ND. The treated water is distributed to the Corps' maintenance facility, downstream campgrounds, powerplant, Garrison National Fish Hatchery, Sakakawea State Park, and the cities of Riverdale, Underwood, and Pick City, ND. The Southwest Pipeline Project is a regional water supply system that draws water from the Garrison reservoir. In the future, as noted in Section 4-15.6 of this WCM, the GDU may furnish additional M&I water supply for towns and cities by pumping from the Garrison reservoir. Utilization of water from the reservoir requires a water right from the State of North Dakota in addition to Corps permits.

4-18.2. There are two water projects being developed by the State of North Dakota that will provide Missouri River water to rural water systems and municipalities: the Western Area Water Supply Project and the Southwest Pipeline Project. In addition, the Northwest Area Water Supply project is a rural water supply project, which is currently under development.

**4-19. Land Treatment.** In response to the program administered by the U.S. Department of Agriculture (USDA), land treatment measures designed to reduce erosion and local floods and to increase the local surface water supply are in operation throughout the incremental drainage area discussed in this WCM. 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 water supply to the Missouri River and provide a degree of local flood protection, their effect on Missouri River flows is minimal.

**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 developments. To the degree practicable, fish and wildlife interests are considered prior to regulation of projects. Recreational use of the Garrison reservoir continues to increase through the years. Appendix B of this WCM presents additional information regarding recreation.

**4-21. Streambank Stabilization.** Streambank erosion is a continuing process along the Missouri River below Garrison Dam and also along the tributaries in the region. Prior to construction of Garrison Dam, accretions comparable to the eroded area could be expected to occur; however, the Garrison reservoir now acts as a sediment trap, interfering with the accretion process. Based on studies made in 1968, pre-project (1938-1954) erosion totaled about 225 acres per year in the Garrison-Oahe headwaters reach, compared to about 85 acres per year during the 1954-1968 period. Subsequent erosion data have been clouded somewhat by construction of bank protection projects in the reach. These bank stabilization structures have been constructed at scattered locations between Garrison Dam and the Oahe reservoir where erosion has been most active or threatens concentrated shoreline development, such as in the Bismarck vicinity. While these measures are effective in restricted reaches, there remain large lengths of unprotected banks that are subject to future erosion. There is also some evidence that the structures built for this purpose have had the effect of reducing the capacity of the downstream

channel. Nevertheless, land owners adjacent to the river channel frequently request operational constraints, in the belief that these would minimize erosion below the dam. Adoption of these constraints on release fluctuations from Garrison could seriously affect the primary functions of the project, with no assurance that they would be effective for erosion control.

**4-22. Streamflow Depletions.** Water resource developments in the incremental drainage between the Fort Peck and Garrison Dams have two major effects on the regulation of the Garrison reservoir, a depletion in the available water supply and a partial redistribution of inflows. 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 would generally have adverse effects on other functions 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. As these uses increased, they began to have a significant effect upon streamflow. By 1910, it is estimated that the average annual Missouri River depletion above Sioux City, IA totaled about 2.7 million acre-feet (MAF) with approximately half of this total occurring in the drainage area under consideration in this WCM. Between 1910 and 1949, water use increased at a moderate rate with the resulting increase in the average annual depletion to streamflow amounting to about 300,000 AF from this drainage area. Table IV-3 lists results of the 2005 USBR analysis of the historical and estimated future depletions in the Fort Peck to Garrison reach. Depletions are based on irrigation and as well as M&I uses. Future depletions are primarily based on projected population changes.

**Table IV-3  
Depletions in the Fort Peck to Garrison Reach**

Time Period	Average Annual Depletions in kAF
1929 – 1940	3,834
1941 – 1950	3,657
1951 – 1960	3,997
1961 – 1970	3,873
1971 – 1980	3,889
1981 – 1990	4,035
1991 – 2002	3,900
Future (Estimated)	
2002 – 2010	4,115
2010 – 2015	4,117
2015 – 2020	4,161
2020 - 2025	4,205
2025 – 2030	4,209
2030 – 2050	4,219
2050 – 2070	4,227
2070 - 2090	4,227
2090 - 2110	4,227

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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. Garrison Project Data.** Hourly data are automatically transmitted from the Garrison 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 northwest of the dam, between the powerhouse and Pick City, near the radio building. In the event the automatic data collection and transfer is not working, Garrison personnel fax or email hourly and daily project powerplant data to the MRBWM office and the MRBWM staff manually input the information into the Missouri River Region's (MRR) Corps Water Management System Oracle database. The Garrison monthly summary is faxed or emailed to the MRBWM office and is used to verify daily data.

5-02.1. During the winter season the data described in Section 5-02 may be supplemented by occasional reports of ice thickness on the reservoir and on Lake Audubon. When there is a significant snow accumulation, reports of the depth and water content of the existing snow cover in the vicinity of the damsite may be furnished, along with frost penetration depths. Reservoir ice-in and ice-free conditions and dates are reported to the MRBWM office. Reconnaissance of the reach of the Missouri River extending from Garrison Dam to the headwaters of the Oahe reservoir may be made by local Corps personnel, the NWS and, in some cases, the North Dakota State Water Commission, through the winter season, with particular emphasis during the time an ice cover is forming within this reach. Pertinent observations include location of the head of ice cover, ice conditions, available freeboard at critical locations and river stages at established intermediate locations not normally available on a routine basis. Reconnaissance observations are provided to the MRBWM office. The USGS also maintains a webcam at the Missouri River at Bismarck streamgaging station. Images from that webcam are available on the internet to allow visual observation of the ice conditions at that location.

5-02.2. Throughout the year Garrison project personnel investigate requests and complaints that occur as a result of Garrison regulation and report their findings to the MRBWM office. The MRBWM office keeps the Garrison 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 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 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. During periods of ice formation below Garrison, the temperature data from Bismarck, ND is particularly important for Garrison regulation. 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 snowpack are received from numerous stations located throughout the Missouri River basin. The USDA's Natural Resources Conservation Service (NRCS) installs, operates and maintains an extensive, automated system to collect mountain snowpack and related climatic data in the Western United States called SNOTEL (SNOWpack TELemetry). SNOTEL uses meteor-burst communication technology to collect and communicate data in near real-time. The sites are generally located in remote high-mountain watersheds where access is often difficult or restricted. Basic SNOTEL sites have a pressure sensing snow pillow, storage precipitation gage and air temperature sensor. Data for the Missouri River basin are transmitted and stored in the Snow Survey and Water Supply Forecasting Program database in Kansas City, MO. The MRBWM office accesses the data via the National Water and Climate Center (NWCC) homepage and internet. The SNOTEL stations used by the MRBWM office are shown on Plates V-1 and V-2. Refer to Chapter V of the Master Manual and Sections 6-06 and 6-07 of this WCM for 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-3 and Table V-1 for key locations within the incremental drainage area and in the reach directly below Garrison to near the Oahe headwaters 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.

The Omaha District Water Control and Water Quality office keeps the MRBWM office apprised of Boysen, Buffalo Bill and Yellowtail reservoirs conditions and operations pertinent to regulation of the System.

**Table V-1  
Key Data Collection Platforms**

<b>Corps ID</b>	<b>Location</b>	<b>USGS ID</b>	<b>DCP ID</b>	<b>NWS ID</b>
SACO	Milk River at Juneberg Br near Saco, MT	06164510	CE78D5B0	SACM8
NAMT	Milk River at Nashua, MT	06174500	CE512C54	NSHM8
WPMT	Missouri River near Wolf Point, MT	06177000	CE5119CE	WPTM8
PLRM8	Poplar River near Poplar, MT	06181000	163A2386	PLRM8
CBMM8	Big Muddy Creek near Culbertson, MT	06185110	DD0F77B2	BGCM8
CLMT	Missouri River near Culbertson, MT	06185500	CE51171C	CLBM8
CSMT	Yellowstone River at Corwin Springs, MT	06191500	CE3091C0	CORM8
LVMT	Yellowstone River near Livingston, MT	06192500	DDE53060	LIVM8
BIL	Yellowstone River at Billings, MT	06214500	CE51B936	BILM8
MIMT	Tongue River at Miles City, MT	06308500	CE5DB8AA	MICM8
MLS	Yellowstone River at Miles City, MT	06309000	CE5DB678	MILM8
LOMT	Powder River Near Locate, MT	06326500	CE78DB62	LOCM8
GVMT	Yellowstone River at Glendive, MT	06327500	DD580754	GLNM8
SIMT	Yellowstone River near Sidney, MT	06329500	CE78A320	SIDM8
WSN	Missouri River near Williston, ND	06330000	1636B9AA	WLTN8
WCND	Little Missouri River nr Watford City, ND	06337000	DE0FF340	WTFN8
HAND	Knife River at Hazen, ND	06340500	CE50CD5C	HZZN8
STND	Missouri River near Stanton, ND	06340700	CE127628	STNN8
WSND	Missouri River at Washburn, ND	06341000	CE12E34A	WSBN8
PRND	Missouri River at Price, ND	06342020	CE12D6D0	PRCN8
BIS	Missouri River at Bismarck, ND	06342500	CE50C38E	BIWN8
MAND	Heart River near Mandan, ND	06349000	CE50D0F8	MDNN8
SHND	Missouri River near Schmidt, ND	06349700	CE1200B8	MANN8

**5-06. Communication during Normal Regulation.** Garrison 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 Garrison

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. Garrison personnel are expected to furnish the MRBWM office all 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.

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 Garrison regulation on request by the MRBWM office. The District is also responsible for flood fighting activities and flood control regulation of the USBR Boysen, Yellowtail and Heart Butte reservoir projects in the incremental drainage area between Fort Peck and Garrison. Information that is considered pertinent to the regulation of Garrison, or other System projects, is to be furnished to the MRBWM office.

**5-07. Emergency Regulation.** If emergency conditions develop at Garrison, 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 Garrison 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 Garrison 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 Garrison, have essentially the same degree of importance for all of the other mainstem projects. Analyses considered to be unique or particularly important to Garrison 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. Particularly pertinent to the regulation of Garrison are meteorological forecasts prepared for eastern Montana as well as western and central North Dakota. Temperature forecasts are of particular importance in scheduling Garrison releases during the period an ice cover is forming on the Missouri River below the project and temperature and precipitation forecasts are closely monitored during ice-out. Forecast maximum and minimum temperatures for Bismarck, which are critical to ice conditions in this reach, are available daily for use by the MRBWM office.

**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 Garrison are runoff forecasts prepared for eastern Montana as well as western and central North Dakota. The short-range runoff forecasts, which are discussed in greater detail in Section 6-09 of this WCM, are integral to the day-to-day regulation of Garrison.

**6-04. Precipitation-Runoff Relationships.** As shown on Plate III-4, average annual precipitation in the Fort Peck to Garrison incremental drainage area ranges from less than 8 inches to more than 40 inches. Annual runoff ranges from less than 0.25 inch to more than 20 inches. The runoff-precipitation ratio varies from less than 5 percent over much of the plains area to over 50 percent in the mountainous headwaters of the Yellowstone River and its tributaries. This great variability makes it difficult to generalize in discussing analyses of rainstorm and snowmelt runoff, but past analyses of these factors indicate that utilizing initial loss values from 0.50 to 0.75 inch and infiltration losses from 0.10 to 0.15 inch per hour give reasonably satisfactory results for streamflow estimation purposes. These values are based on relatively few rainfall events because of the rarity of heavy rainfall centers in the area.

Snowmelt infiltration ranges from zero for frozen ground, or ice under snow, to approximately the values noted for rainfall. In actual practice, estimating the rainfall or snowmelt runoff is very imprecise. This is due to the lack of a dense network of precipitation reporting stations, errors in estimating the snowpack and snow water equivalent (SWE) available for melt, errors in estimating the snowmelt rate, as well as 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 largely impractical for the drainage area under consideration in this WCM. Reasons for this include the large size of the drainage area, requiring the division of the area into many sub-areas, the lack of sufficient past rainfall and subsequent runoff events for unit hydrograph definition, the scarcity of rainfall reporting stations needed for both analyses and forecasting purposes and the fact that the greatest amount of runoff that occurs from this drainage area does not result from particular rainfall events but results from progressive plains and mountain snowmelt, making runoff definition in a selected time period very imprecise. Further, with the large amount of storage space available in the Garrison reservoir compared to the volume of runoff from individual rainfall events and the very nature of the regulation process, the effort necessary for a valid and complete analysis by means of unit hydrograph procedures is not believed to be warranted. However, 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 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 annual runoff from the plains contributing area above Garrison is a result of melting the plains snowpack accumulated during the winter months. This melt usually occurs during March or April, but can occur in February and even as early as January, and often results in the annual peak flow from the Fort Peck to Garrison drainage area, even though a major portion of the Yellowstone River basin usually contributes little to peak flows at this time of the year. Basic data pertinent to estimation of plains area snowmelt volumes are: 1) precipitation during the late fall and winter months, 2) winter season 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 the total drainage basin between Fort Peck and Garrison. Forecasts are developed by assuming that the volume of snowmelt runoff from this portion of the Missouri River basin should be similar to that observed in the most analogous year. These estimates are tempered by available ground condition data (e.g., frost depth, soil moisture), 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 volumes during previous years from other areas where snowpack conditions appear similar to the current year's snowpack over the Fort Peck to Garrison 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.

**Table VI-1  
Plains Snow in Major Floods**

<b>Late Winter Plains Snow Moisture in Major Flood Years (SWE in Inches)</b>						
<b>Stream</b>	<b>Location</b>	<b>17-Mar- 1952*</b>	<b>31-Mar- 1969*</b>	<b>18-Mar- 1997*</b>	<b>4-Mar- 2010**</b>	<b>11-Feb- 2011**</b>
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 River	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 River	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 River	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.

6-06.2. Improvement in the techniques of forecasting the runoff resulting from plains snowmelt is an ongoing process 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.

**6-07. Mountain Snow.** A large portion of the annual runoff entering the Fort Peck to Garrison reach of the Missouri River occurs during the May-July period of which snowmelt runoff from the mountainous portions of the basin is an important component. Over 80 percent of the annual runoff above Garrison originates in mountainous areas (above 6,000 feet). As discussed in Section 5-04, numerous NRCS SNOTEL stations are in operation that collect and transmit snowpack and related climatic data in near real-time. From October 1 to July 1 the MRBWM office regularly determines the amount of SWE in the snowpack, in terms of percent of normal, for the drainage basin between Fort Peck and Garrison. The MRBWM office tracks the amount of SWE in the snowpack throughout this 9-month period. Table VI-2 and Plates V-1 and V-2 present the NRCS SNOTEL stations and corresponding drainage basins used in the mountain snowpack analysis.

6-07.1. The May-July runoff forecasts for Garrison are developed using simple and multiple linear regression equations. The equations predict historical May-July runoff from:

- a. average SWE,
- b. average accumulated May-July precipitation,
- c. average maximum April-June air temperature,
- d. observed May runoff and
- e. observed June runoff.

The methodology for the runoff forecasts are documented in an MRBWM Technical Report, *Long-Term Runoff Forecasting*, dated February 2017. The mountain snowpack peak generally occurs in mid-April. The NRCS daily-reporting SNOTEL stations used in this runoff forecast analysis are listed in Table VI-2. The May-July runoff forecasts are generated on a monthly basis beginning on January 1. Similar runoff forecasts are generated by the NWS and NRCS. The three agencies readily share their forecasts and communicate when conditions warrant.

**6-08. Monthly Reach Inflow (Runoff) Forecasts.** Soon after the first of each month throughout the year a forecast of incremental monthly inflows to the System reservoirs, including those originating between Fort Peck and Garrison, is prepared by the MRBWM office. The Fort Peck to Garrison reach normally generates more annual runoff than any of the other incremental areas defined by the individual mainstem projects. Forecasts of monthly reach inflow or runoff extend from the current date through the remainder of the calendar year to March 1 of the succeeding year. These forecasts are utilized to develop System regulation studies, as described in Section 6-12 of the Master Manual.

6-08.1. 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, accumulated snow over the incremental drainage area and accumulated mountain SWE. In the Fort Peck to Garrison reach, snow contributions include mountain and plains snowmelt. Estimation of this snowmelt runoff is important during the early spring (March-April), the period of plains snowmelt runoff, as well as during the late spring and early summer (May-July), the

period of mountain 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 reach inflow forecasts for periods other than the spring and early summer periods 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.

**Table VI-2  
Mountain Snowpack Fort Peck to Garrison - SNOTEL Stations**

Drainage Basin	SNOTEL Stations
Upper Yellowstone River	Beartooth Lake, Box Canyon, Burnt Mountain, Canyon, Cole Creek, East Boulder Mine, Fisher Creek, Monument Peak, Northeast Entrance, Parker Peak, South Fork Shields, Thumb Divide, Two Ocean Plateau, White Mill, Wolverine
Wind River	Burroughs Creek, Castle Creek, Cold Springs, Deer Park, Hobbs Park, Kirwin, Little Warm, Owl Creek, South Pass, St Lawrence Alt, Togwotee Pass, Townsend Creek
Shoshone River	Blackwater, Evening Star, Marquette, Sylvan Lake, Sylvan Road, Younts Peak
Bighorn River	Bald Mountain, Bone Springs Divide, Grave Springs, Shell Creek, Timber Creek
Tongue River	Big Goose, Burgess Junction, Dome Lake, Little Goose, Sucker Creek, Tie Creek
Powder River	Bear Trap Meadow, Cloud Peak Reservoir, Hansen Sawmill, Middle Power, Power River Pass, Soldier Park

**6-09. Short-Range Forecasts of Daily Inflow.** The MRBWM office develops forecasts of future daily inflows to the Garrison reservoir and the other associated System reservoirs at frequent intervals. Each week daily inflow forecasts extending three weeks or more into the future are developed. Experience has indicated that the most satisfactory method of anticipating Garrison reservoir inflows for periods of up to a week or two beyond the current date is a combination of routing observed flows from upstream and tributary locations and extrapolating incremental inflows above or between observation points. In most cases a simple translation of flows from upstream to downstream points by appropriate travel times, as given in Table VI-3, is as satisfactory as utilizing more sophisticated routing procedures. The extrapolation process includes an allowance for anticipated runoff. In this connection it should be recognized that most of the inflows to the Garrison reservoir are a combination of Fort Peck releases; Yellowstone River flows at Sidney, MT; Milk River flows at Nashua, MT; and Little Missouri River flows at Watford City, ND. Reliable estimates of flows at these locations will result in satisfactory inflow estimates unless unusual runoff circumstances occur. As discussed in the

Master Manual, future runoff modeling efforts include the use of observed gridded precipitation in the Corps' HEC-HMS models.

**Table VI-3 – Lag-Average Routing Coefficients  
Upstream Reservoir to Garrison Dam**

Reservoir	Average Days	Lag Days
Fort Peck	3	6
Fresno	5	10
Bull Lake	3	8
Boysen	5	7
Buffalo Bill	5	7
Yellowtail	3	6
Garrison Inflow	1	3

- Note:
1. Data averaged is at the average daily streamflow rate.
  2. Lag given is the number of days from the last day of average daily values averaged.
  3. Lag rates listed assume non-existence of intervening reservoirs.

**6-10. Stage-Discharge Relationships.** Stage-discharge relationships, sometimes referred to as rating curves, are maintained in the MRBWM office for key tributary streamflow stations in the Fort Peck to Oahe incremental drainage area. These are kept current on the basis of discharge measurements made by the USGS. Plate VI-1 shows the present stage-discharge relationships at key locations for developing short-range inflow forecasts pertinent to Garrison regulation and key stations downstream of Garrison.

**6-11. Forecasts of Downstream Locations.** During a major portion of each year Missouri River flows through the entire reach from Garrison to the headwaters of the Oahe reservoir consist almost entirely of Garrison releases. Only during those relatively short periods when substantial runoff occurs from the intervening tributary area will significant additions to Garrison releases occur. The Knife River is the only major tributary in the Garrison to Oahe reach that enters the Missouri River above Bismarck, ND. For practical purposes, Missouri River flows between the mouth of the Knife River and Bismarck will be equivalent to the sum of Knife River flows at Hazen, ND and Garrison releases. Travel time from the Knife-Missouri River confluence to Bismarck, ND, is about one day under open water conditions. The Heart River enters the Missouri River immediately below Bismarck. Missouri River flows below the mouth of the Heart River are equivalent to the summation of the Heart River flows at Mandan, the previous day's Knife River at Hazen flow and Garrison releases and any ungaged flows. Forecasts of Mandan (Heart River) and Hazen (Knife River) flows are derived by noting observed upstream flows on each tributary together with estimates derived by principles described in earlier sections.

6-11.1. The North Dakota cities of Bismarck and Mandan are the main damage centers between the Garrison and Oahe dams. The two cities are located in the same general area. Bismarck is located on the east side of the Missouri River and Mandan is located on the west side of the Missouri River. The USGS open water stage-discharge relationship for the Missouri River at the Bismarck streamgaging station is shown on Plate VI-1. Ice affected stage-discharge relationships are discussed in Section 3-15. The effect of Garrison release changes on stages at

other locations in the Garrison to Bismarck reach may be estimated from the Bismarck rating curve. In general, an average daily discharge change of 1,000 cfs during the open water season will result in a mean stage change of about 0.25 foot (3 inches).

6-11.2. Garrison powerplant releases can have wide fluctuations during any one day due to varying power loads. While not typical, hourly releases fluctuating from zero to the full powerplant capacity can result in Garrison tailwater elevation changes of more than 8 feet. Normally, the release variations result in tailwater elevation changes ranging from 4 to 6 feet. The elevation range declines as the distance from the dam increases. The diurnal stage fluctuation attenuates quite rapidly. Under open water conditions, a 5-foot diurnal fluctuation in the Garrison tailwater is reduced approximately 25 percent to about 3.75 feet at the Basin Electric and United Power powerplant intakes, located 18 miles downstream of the Garrison dam. At Washburn, which is about 35 miles downstream of the dam, a 5-foot diurnal tailwater fluctuation is reduced approximately 65 percent to about 1.5 feet. Further downstream of the dam at Bismarck, which is located 75 river miles downstream of the dam, a 5-foot diurnal tailwater fluctuation is reduced approximately 90 percent to about 0.5 foot. Flow records indicate that it requires about 6 to 7 hours for tailwater crests and troughs to travel to the powerplant intakes. Corresponding travel time to Washburn and Bismarck are 13.5 and 28.5 hours, respectively, indicating an average travel time of these events to be about 2.7 river miles per hour. These travel times are approximate and are for open water conditions. A substantial ice cover in the reach will result in a marked travel time increase and will also tend to reduce downstream diurnal fluctuations. Estimates of diurnal fluctuations, which will occur at downstream locations for any particular release pattern, can be made with reasonable accuracy by applying the methodology described in this section. When making such estimates consideration should be given to the fact that, with diurnal fluctuations in release rates, the tailwater will normally not have an opportunity to stabilize at either the maximum or minimum level indicated by Garrison releases. The MRBWM office has also used the Corps' UNET and River Analysis System (HEC-RAS) models to estimate stage changes and travel times.

**6-12. Routing Procedures.** For purposes of anticipating inflows to the Garrison reservoir a simple translation of observed or anticipated upstream flows by the approximate travel time from the upstream location, as discussed in a previous section, is an adequate routing procedure for reservoir regulation purposes. This conclusion is based on the relatively slow-moving characteristics of inflow hydrographs to the Garrison reservoir. In addition, the large Garrison storage volumes and the associated regulation procedures do not require precise definition of anticipated inflows. The lack of tributary streamflow information from a considerable portion of the incremental Fort Peck to Garrison drainage area also precludes such precision.

6-12.1. Routing procedures are also utilized to translate the effects of upstream tributary and System reservoirs to the Garrison damsite in order that the total reservoir effects at this location may be determined. These procedures are based on travel time to the Garrison damsite which were appropriate prior to the development of either tributary or System reservoirs. A simple lag-average routing method is used with coefficients as presented in Table VI-3.

**6-13. Evaporation.** Due to its large surface area, evaporation is an important component of the overall water budget of the Garrison reservoir. 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. Initially, observed pan measurements were taken daily at Garrison and then factored by an average monthly pan coefficient to determine the lake evaporation. During those portions of the year when pan data were not available, normal evaporation depths for each month was considered the most practical means of developing evaporation estimates for day-to-day regulation activities. Pan coefficients and monthly evaporation rates were taken from the June 1973 MRD-RCC Technical Report JE-73 titled, *Missouri River Main Stem Reservoir System, Reservoir Evaporation Estimates*. Plates III-9 through III-12 indicate pertinent evaporation information for the six System reservoirs. Garrison personnel have since stopped taking observed pan measurements and the MRBWM office has started using estimated values year round.

6-13.1. The MRBWM office and Omaha District partnered with the Corps' CRREL 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 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 Garrison 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 Garrison reservoir is west-northwest of the damsite where the pool level recorder is located. Winds from this direction result in pool level set-up at the dam while a wind from the opposite direction results in pool level set-down. See Plate VI-2 for wind correction tables. 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 entire 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 Garrison reservoir are made each day for regulation purposes. The steps involved consist of:

- a. plotting hourly pool elevations as reported by the Corps' PPCS at Garrison;

- 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. An additional estimate of reservoir inflows consists of Fort Peck releases and gaged tributary flows routed to the Garrison reservoir combined with estimates of ungaged flow and precipitation on the reservoir surface. Differences in inflow estimates as determined by the previously defined process and the gage tributary flows are reconciled by using experience and engineering judgment. At times it will be necessary to adjust data for previous days on the basis of continuing trends in the reservoir level that were not previously evident. See Plates VI-3 through VI-8 for regulated and incremental inflow volume probability relationships for various durations. More information on the inflow volume probability for the System projects can be found in the MRBWM Technical Report, *Hydrologic Statistics on Inflows*, July 2015.

**6-16. Unregulated Flows.** Construction of the Garrison project, together with the other mainstem and tributary projects in the basin, has materially altered flows downstream from the dam. Flood peaks have been reduced and low flows augmented by reservoir regulation. A quantitative estimate of the effects of regulation upon flows at the damsite and important locations immediately downstream is frequently required. This represents a continuing effort by the MRBWM office and involves such factors as reservoir evaporation, precipitation on the Garrison 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, releases, diversions to the Garrison Irrigation Project (through Lake Audubon) and storage changes. Refer to the MRD-RCC Technical Study S-73, *Upper Missouri River Unregulated Flow Development*, dated September 1973, for additional details of the analysis.

6-16.1. In addition to unregulated flows, development of flows at the 1949 level of basin development prior to construction of Garrison and most other water resource development in the Missouri River basin represents a continuing effort of the MRBWM office. Garrison represents a location where such determinations 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-9 through VI-13 for tributary flow probability curves at the Milk River at Nashua, MT; Yellowstone River at Sidney, MT; Poplar River at Poplar, MT; Big Muddy Creek near Culbertson, MT; and Little Missouri River at Watford City, ND. Flow probability relationships were developed for tributary streams in the Fort Peck to Garrison incremental area and are shown in Table VI-4.

**Table VI-4  
Tributary Flow Probability Relationships**

Tributary	Drainage Area (square miles)	Peak Discharge (in cfs) for Given Return Period (in years)			
		10	50	100	500
Yellowstone River near Sidney, MT	69,103	102,000	142,200	160,200	204,600
Milk River at Nashua, MT	22,332	15,400	27,400	33,500	50,300
Poplar River near Poplar, MT	3,174	13,600	43,600	66,100	155,800
Big Muddy Creek near Culbertson, MT	2,684	1,500	6,800	12,200	43,600
Little Missouri River nr Watford City, ND	8,310	30,000	61,900	81,400	146,800

**6-17. Evaluation of Regulation Effects.** In the evaluation of the effects of regulation on downstream flows in order to obtain flood damage reduction estimates, Garrison 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. Ice Formation below Garrison Dam.** Optimum regulation of Garrison involves careful release scheduling during the winter months. During the winter months power demand from Garrison is high while the downstream channel capacity is materially reduced by the ice cover. Procedures have been developed to determine the extent of the ice cover below Garrison, based on the release rate, release water temperature and air temperature. These procedures are detailed in MRD-RCC Technical Study F-73, *Freezing of the Missouri River below Garrison Dam*, and provide guidance for release scheduling from the project through the winter months and in particular during the most critical times which occur during periods of increasing ice cover. In recent years, rather than using these forecasting procedures, local ice observations are typically provided to the MRBWM office, as discussed in Sections 5-02.1 and 7-18.1 of this WCM. Garrison releases are adjusted prior to the onset of freeze-in, as discussed in Section 7-18 of this WCM.

**6-19. Long-Term Studies.** Simulated regulation of Garrison 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, many long-term examples of Garrison regulation are available. From the examples incorporating the present level of water resource development, conclusions relative to regulation of Garrison can be established, as described in succeeding sections.

**6-20. Long-Range Streamflow Forecasts.** As noted in previous sections in this chapter, forecasts are prepared by the MRBWM office as a guide for making estimates of annual and seasonal water yields and for scheduling of releases for the regulation of Garrison. Forecasts of water supply and extended period runoff for the upper Missouri River basin between Fort Peck and Garrison issued by other agencies are described in Sections 6-20.1 through 6-20.3.

6-20.1. NRCS Water Supply Forecasts. Data are collected and a report titled *Snow Survey and Water Supply Forecasts* is published by the NRCS's NWCC and are available via the internet: <http://www.wcc.nrcs.usda.gov/wsf>. These publications contain forecasts of water supply and data pertaining to mountain snow accumulation.

6-20.2. NWS Water Supply Forecasts. These forecasts are published on the first of the month, January through May, and cover the period of a water year (October through September) and the residual portion of the water year remaining after the forecast date. These forecasts are available via the internet: <http://www.crh.noaa.gov/mbrfc/?n=water>.

6-20.3. USBR Water Supply Forecasts. These forecasts are long-range volume forecasts largely for the operation of their tributary reservoirs located in the upper Missouri River basin. The forecasts are published on the first of each month, February through October. These forecasts are available via the internet: [http://www.usbr.gov/gp/lakes\\_reservoirs/](http://www.usbr.gov/gp/lakes_reservoirs/).

**6-21. Garrison Elevations.** Long-term analyses indicate that Garrison reservoir levels will fluctuate from the minimum pool of elevation 1775.0 feet to above the maximum normal operating pool elevation of 1850.0 feet (base of the Exclusive Flood Control Zone). With the present level of water resource development, the reservoir can be expected to be above the base of the Annual Flood Control and Multiple Use Zone (elevation 1837.5 feet) for a majority of the time. Utilization of the Exclusive Flood Control Zone, elevations 1850.0 to 1854.0 feet, was required in 1969, 1975, 1995, 1997, 2010, 2011 and 2018 for regulation purposes during these high runoff years. The Garrison reservoir entered its Surcharge Zone, above elevation 1854.0 feet, in 1975, 1997 and 2011. Extreme drawdown (below elevation 1800 feet) will occur only in the event of a severe and extended drought.

6-21.1. The Garrison reservoir elevation duration curve shown on Plate VI-14 indicates that a reservoir level at or above elevation 1837.5 feet, the base of the Annual Flood Control and Multiple Use Zone, can be expected about 55 percent of the time. A probability curve of annual maximum Garrison reservoir elevation is shown on Plate VI-15. This curve was developed from the long-range study analysis (Daily Routing Model (DRM) simulation) tempered by actual regulation experience of Garrison. This curve indicates that a maximum annual reservoir level at or above elevation 1837.5 feet can be expected in about 70 percent of the years. Further particulars regarding development of these pool-duration and pool-probability curves are given in MRBWM Technical Report, *Hydrologic Statistics*, dated September 2013.

6-21.2. Average Garrison reservoir levels and normal seasonal variations since 1967 are shown on Plate VI-16. This plate illustrates an average reservoir level rise of 9 feet occurring in the 4-month period, mid-March to mid-July, followed by a corresponding gradual decrease in reservoir level through the remaining eight months of the year. Releases are generally higher in the summer and winter periods to provide better service to authorized purposes such as hydropower

and recreation. Higher releases from Garrison in the winter partially compensate for the reduction of power generation at the downstream projects.

**6-22. Garrison Releases.** Long-term regulation studies indicate that Garrison releases in excess of the powerplant capacity of 41,000 cfs will seldom be required. The release-duration curve, shown on Plate VI-17, indicates that a release rate of 41,000 cfs or less can be expected approximately 98 percent of the time. In 1975, 1997 and 2018, releases in excess of 41,000 cfs were made via the outlet tunnels. In 2011, releases in excess of 41,000 cfs were made via the outlet tunnels and the spillway because the total releases were in excess of the combined capacity of the powerplant and outlet tunnels. As seen on Plate VI-17, a release of at least 20,000 cfs is made approximately 50 percent of the time. The release-probability curve of annual maximum releases, shown on Plate VI-18, was developed from long-term regulation study results (DRM) augmented by data experienced during actual regulation. This curve reflects instantaneous releases at full powerplant capacity to supply peak generation requirements. Further particulars regarding development of these frequency curves are given in MRBWM Technical Report *Hydrologic Statistics*, dated September 2013. Average monthly inflows and releases, based on actual System regulation (since 1967), are shown on Plate VI-16. Higher winter and summer releases correspond to higher energy demand periods. The higher winter releases from Garrison reflects the transfer of power generation to Garrison during the winter non-navigation season when lower System releases limit power generation from the downstream System projects.

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Water Control Manual**

**VII - Current Water Control Plan**

**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 regulation 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 Garrison WCM. Rather, the following sections will be concerned with amplifying the regulation objectives and requirements given in the Master Manual that are pertinent to regulation of Garrison 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 Garrison for flood control is discussed later in this chapter.

**7-02. Basis for Service.** As an introduction to regulation of Garrison, 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 1775.0 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 Carryover Multiple Use Zone extends from elevation 1775.0 to 1837.5 feet. This zone is to be used to provide service to authorized purposes during droughts. The Annual Flood Control and Multiple Use Zone extends from elevation 1837.5 to 1850.0 feet and is the preferred operating zone. Ideally, the runoff year begins with all 12.5 feet available to capture runoff during the wetter late winter, spring and early summer periods. The stored waters in the zone are then evacuated during the drier late summer, fall and early winter periods to meet all authorized purposes. The Exclusive Flood Control Zone extends from elevation 1850.0 to 1854.0 feet. This zone is reserved exclusively for flood control regulation of major floods. The next zone is the Surcharge Zone, which is from elevation 1854.0 feet, the elevation of the top of spillway gates when closed, to elevation 1858.5 feet, the maximum reservoir elevation from the spillway design routing. 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 1858.5 feet to the top of the dam embankment (1875.0 feet).

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

- a. Regulation of Garrison as an individual project must be subordinate to regulation of the entire System as a whole.
- b. Flood control will be provided for by evacuating storage space in the reservoir above elevation 1837.5 feet, to the degree practicable, prior to the start of the runoff season, approximately March of each year.

- c. At all times when an adequate reserve of vacant flood control storage space is available, releases will be made in a manner to not contribute to significant flooding along the Missouri River between Garrison Dam and the Oahe reservoir.
- d. All irrigation and other upstream water uses for beneficial consumptive purposes will be served to the extent reasonably possible.
- e. Releases will be sufficient to serve irrigation, water supply and water quality demands in the reach extending from Garrison Dam to the Oahe reservoir. In this context, the Corps' responsibility is to maintain an adequate flow quantity, with downstream users responsible for providing satisfactory intake facilities to divert the needed water supply.
- f. Within the limits designated above, Garrison will participate in the intra-system adjustment of releases to achieve optimum power generation to the degree consistent with other multiple-purpose uses.
- g. Releases from the System to support Missouri River navigation will be backed up by releases from Garrison as appropriate to maintain storage reserves in the System at a generally balanced level.
- h. Insofar as possible without serious interference with the aforementioned, Garrison will be regulated for maximum benefit to recreation and fish and wildlife, including T&E species.

**7-04. Irrigation.** If the GDU project becomes more fully utilized, additional water will be withdrawn from the Garrison reservoir through the adjacent Lake Audubon. These withdrawals will be controlled entirely by the USBR. Corps regulation responsibilities for Lake Audubon withdrawals will be limited to utilizing the daily withdrawal data in the determination of reservoir inflows and in deriving estimates of the actual available water supply. If other major irrigation withdrawals directly from the Garrison reservoir should occur, similar regulation responsibilities would be involved.

7-04.1. Considerable irrigation is served by withdrawals from the Missouri River in the reach extending from Garrison Dam to the Oahe reservoir. With the exception of the Fort Clark project in the vicinity of Stanton, ND, irrigation intakes are of a portable nature, located on sand bars or along the river bank and are not capable of operating over a wide range of river stages without relocation. Access to water at some intake locations becomes extremely difficult during periods of low Missouri River stages even though the available flow adjacent to the intake location may be many times that needed for irrigation. The Master Manual specifies a minimum average daily Garrison release of 9,000 cfs to avoid excessively low stages at downstream water intakes. However, if resource development proceeds as expected during the next fifty years, maintenance of a 9,000 to 10,000 cfs average daily rate may eventually become impossible during extended periods of well-below-average water supply (i.e., extended droughts). Frequent wide fluctuations in average daily releases should be avoided during the irrigation season since major fluctuations in daily releases may require relocation of the portable intakes, either to maintain access or to prevent pumps from being flooded. When a significant change in the prevailing level of releases becomes necessary, irrigators below Garrison should be given advance notification, normally through press releases and/or postings to the MRBWM website.

**7-05. Water Supply and Water Quality Control.** In addition to the irrigation intakes discussed in the preceding section, there are several intakes serving municipalities, thermal electric plants

and industrial uses in the reach extending from Garrison Dam to the headwaters of the Oahe reservoir. These intakes have reported water access problems in a few instances in past years. These problems have been associated with inadequate intake levels or sandbar formations adjacent to the intake, rather than insufficient flow in the river. In order to minimize intake problems without unduly penalizing the hydropower operation, Garrison minimum releases are established by standing orders that call for a minimum generation over a specified number of hours and, in some cases, are dependent on a range of average daily project releases. An example hourly restriction is listed in Table VII-1.

**Table VII-1  
Example Minimum Garrison Energy Generation for Water Supply**

Duration	Minimum Energy for Period
4 hours	300 MWh
5 hours	400 MWh
6 hours	550 MWh
7 hours	700 MWh
8 hours	850 MWh

7-05.1. Observations and studies for this reach of the Missouri River are continuing. Standing orders may be adjusted seasonally or modified temporarily due to changing river channel conditions. In most years, the minimum hourly generation resulting from release patterns for T&E nesting is higher than the minimum specified in the standing orders. Due to the high quality of the water stored in the Garrison reservoir and the lack of major pollution sources in the reach below the dam, minimum releases required for water supply purposes are also adequate for water quality control.

**7-06. Navigation.** All Garrison releases are re-regulated by downstream System reservoirs prior to serving the navigation function. Consequently, the regulation of Garrison for this function consists primarily of backing up the downstream System projects' navigation releases. This is not a day-by-day regulation consideration, but a long-term operation, approaching an annual water scheduling matter.

**7-07. Power Production.** Hydroelectric power generated by Garrison is integrated with the power generated by the other System projects and many other public and private generation facilities in the Missouri River basin and surrounding areas. To the extent practical, all releases are made through the powerplant. Since the Garrison powerplant came on line in 1960 there has been only four years, 1975, 1997, 2011 and 2018, that any significant release has occurred other than through the powerplant. In the large runoff of 1975, during which flood-season runoff above Garrison was the second greatest in the available record period extending back to 1898, releases bypassing the powerplant were less than 12 percent of the total annual release. In 1997, during which annual runoff above Sioux City was the second greatest on record, releases bypassing the powerplant were also less than 12 percent of the total annual release. In 2018, less than 10 percent of the total annual release bypassed the powerplant. Only in the record runoff of 2011 did a significant portion of the total release occur from supplemental releases (approximately 55 percent). A supplementary release is occasionally required for test and

maintenance purposes during normal operation; however, such releases during any year represent a small portion of total releases.

7-07.1. The Western system power marketer or dispatcher in Watertown, SD schedules hourly loading of the Garrison powerplant. These loadings must be within limits prescribed by the MRBWM office. The limits are developed on the basis of daily, as well as hourly, releases required to serve purposes other than hydropower generation. Due to changing power loads during the day, releases may fluctuate widely between 0 cfs, at times when demand is light, up to the full powerplant capacity in the 35,000 to 41,000 cfs range during the heavy load hours. Further discussion on power scheduling is presented in Section 7-12 of the Master Manual.

7-07.2. During years of normal or below normal water supply there will also be a seasonal variation in Garrison power releases, reflecting the concurrent service being provided to other functions as well as the seasonal nature of power demand. During the navigation season relatively large releases are required from the lowermost System project (Gavin Point) to provide navigation flow support, especially during the drier August-November portion of the navigation season. The Gavins Point releases are normally backed up by correspondingly large releases from the Fort Randall, Big Bend and Oahe projects, since relatively little inflow usually originates from the Oahe to Gavins Point portion of the basin during the navigation season and the lower three projects contain only a small percentage of the total storage in the System. During the navigation season the releases from the lower four projects generate substantial amounts of power and leaves a lesser portion of the firm power load to be served by the upstream Garrison and Fort Peck projects. To avoid generating more power than can be marketed and to provide more winter hydropower, the usual practice during the navigation season 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. During the winter months when navigation is not being supported, releases from the downstream reservoirs are usually restricted to less than half their navigation season level due to the reduced capacity of the ice-covered Missouri River channel. Winter is also a season of peak firm power demands over a large portion of the System's marketing area. Consequently, Garrison releases during the winter season are often at a higher rate consistent with the ice-covered channel capacity from the dam downstream through the Bismarck, ND area.

**7-08. Fish and Wildlife.** Regulation of the Garrison reservoir 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. Steady or rising reservoir levels through the late-March to early-July period are desirable for this purpose. However, the ability to provide steady-to-rising pool levels in the upper three reservoirs in low runoff years is dependent on the volume, timing and distribution of runoff. As part of the overall plan, an effort is made to rotate emphasis among the upper three reservoirs during the low runoff years when it may not be possible to keep all three reservoir levels steady or rising. Typically, Fort Peck and Oahe are scheduled to be favored in the same year while Garrison is favored in the following year if runoff conditions require it. Additionally, some species such as the northern pike require the inundation of terrestrial vegetation during late March and April for a suitable spawning habitat. Since prolonged inundation destroys terrestrial vegetation, it can only be re-established by lowering and maintaining the Garrison reservoir level below the vegetative zone for an extended length of time during the growing season. Since the growing season coincides with the March-July flood

season, maintaining a lowered pool level to establish vegetation becomes practical only when inflows during this period are well below normal. After terrestrial vegetation is established, successful spawning requires that the vegetation be inundated during the late-March through April pike spawning period. In view of the typical Garrison regulation pattern, with pool levels lowered through the fall and winter months after the end of the growing season, inundation of terrestrial vegetation established during the preceding year prior to the end of April is not practical unless well-above-average runoff from plains snowmelt occurs at the time. Due to these challenges, pool level manipulations of the Garrison reservoir specifically designed to enhance spawning of northern pike have not been possible up to this time. However, the possibility of this type of regulation during future years, when runoff conditions are conducive, should be recognized. Refer to Appendix D of the Master Manual and Appendix D of this manual for further discussion of fish and wildlife.

**7-09. Threatened and Endangered Species.** Since 1986 releases from Garrison, Fort Randall and Gavins Point have been modified to accommodate endangered interior least tern and threatened piping plover nesting. Releases from Fort Peck were also modified for several years, but no longer are due to the nesting patterns below that project. Hydropower peaking may be restricted in both magnitude and duration at Garrison and Fort Randall. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. 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.

**7-10. Recreation.** Water-based recreation on the Garrison reservoir is dependent on the constructed access facilities. Boat ramps constructed around the perimeter of the project have top elevations extending from 1816.0 to 1859.0 feet and bottom elevations from 1805.0 to 1844.0 feet. Recreation facilities are also discussed in Section 4-09 of this WCM. Insofar as practicable, consistent with runoff, other project purposes and conditions in the other mainstem projects, Garrison reservoir levels should be scheduled to provide continued access to the reservoir area for recreational use. Boating on the Missouri River below Garrison is a popular recreational activity during the summer months. Diurnal fluctuations in release rates resulting from power peaking operations have not had a reported significant adverse effect on this type of activity. Afternoon and evening power releases are usually high, coinciding with the time most pleasure boating occurs. At Bismarck, where the greatest amount of river boating is concentrated, diurnal power release fluctuations are attenuated to a large extent, as described in Section 6-11.2 of this WCM. Extended low Missouri River flows, particularly during weekend periods, adversely affects pleasure boating. On occasion, the reduction from Garrison summer release levels to fall release levels impacts some of the larger boats in the Bismarck area. Stakeholders may find the MRBWM-developed short-term reservoir forecasts, detailed in Section 7-11.1 of this WCM and posted on the MRBWM website, helpful for their planning purposes.

**7-11. Release Scheduling.** As discussed in the Master Manual, scheduling of releases from Garrison and the other System projects, is normally based on continuing studies by the MRBWM office in which all authorized purposes, including flood control, are considered. These 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 functions receives consideration including current projections of power demands and 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 Garrison releases. For example, during the winter freeze-in period there may be day-to-day adjustments to the release schedule. 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 daily 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 Garrison and Western, are the basis for scheduling average daily releases from Garrison. Since exact daily power demands cannot be anticipated, reservoir regulation/power production orders usually allow a specified variation from this scheduled average daily release rate. Hourly patterning of the Garrison average daily release rate within limits prescribed by the MRBWM office is accomplished by Western's scheduling of daily power production except during the T&E nesting season, where the peaking pattern is prescribed by the MRBWM office.

**7-12. Objectives of Flood Control Regulation.** The flood control regulation objectives of Garrison are to: 1) coordinate regulation of Garrison with the regulation of the other System projects to prevent runoff from the drainage basin above Garrison from contributing to damaging flows through the lower reaches of the Missouri River and 2) utilize available storage space in the best possible manner to prevent or reduce flooding in the reach from Garrison to Oahe. The first objective given is the primary flood control objective 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 are to amplify System regulation procedures as they apply particularly to Garrison and to discuss regulation pertaining to the reduction in flooding along the Missouri River immediately below Garrison.

**7-13. Method of Flood Control Regulation.** In general, the developed method of regulation of Garrison 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 Garrison 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 Garrison 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. Storage space allocated for flood control in the Garrison reservoir totals 5.7 MAF. Of this total, 1.5 MAF of storage space is in the Exclusive Flood Control Zone, to be utilized

only during unusually large flood season inflows. The remainder of the storage space is in the Annual Flood Control and Multiple Use Zone that will be filled seasonally to the extent required by the available water supply and subsequently evacuated in the interest of flood control and other beneficial uses. Surcharge storage space has also been provided in Garrison to ensure the safety of the project during extreme floods. However, utilization of this storage will usually provide some downstream flood reductions during extreme flood events. Storage space in the Carryover Multiple Use Zone, when evacuated, will also serve the flood control function although deliberate evacuation of this space to serve flood control will not be scheduled.

**7-15. Replacement Flood Control Space.** As described in Section 4-15 of this WCM and Section 7-04.4 of the Master Manual, three Missouri River basin USBR tributary reservoirs above Fort Peck – Tiber, Clark Canyon and Canyon Ferry – have a portion of their available storage space allocated to flood control use on a “replacement” basis. Replacement storage is defined as tributary reservoir storage space that is regulated in close coordination with the System and, as a consequence, can replace a portion of the System’s Annual Flood Control and Multiple Use Zone. Due to the relative ease of transferring storage between the mainstem projects, including Fort Peck to Garrison, the availability of existing tributary replacement storage space allows regulation of the Garrison reservoir at higher levels than indicated by storage allocations previously prescribed. Replacement System flood control storage was last utilized in the mid-1980s and is not anticipated to be requested in the near future.

**7-16. Flow Regulation Devices.** Releases from Garrison may be made through the powerplant, outlet works and the spillway. Normally, releases through the powerplant will be used to the fullest extent possible in order to achieve the maximum economic return from the project. The discharge capacity of the powerplant is about 41,000 cfs. When it is necessary to release at rates greater than the powerplant is capable of maintaining, the outlet tunnels, which are capable of passing almost 100,000 cfs, will generally be used. If releases larger than the combined capacity of the powerplant and outlet tunnels are required, such as during 2011, some releases must be made through the spillway, which has a capacity of 827,000 cfs at the maximum level of 1858.5 feet, 4.5 feet into the Surcharge Zone.

**7-17. General Plan of Flood Control Regulation.** Flood control regulation of Garrison to meet the stated objectives is based on consideration of the following factors:

- a. coordination of flood control regulation of Garrison with the regulation of the other System reservoirs and upstream tributary reservoirs as described in Chapter VII of the Master Manual;
- b. channel capacity through the reach of the Missouri River from Garrison to the headwaters of the Oahe reservoir;
- c. observed and anticipated runoff from the incremental drainage area between Garrison and the headwaters of the Oahe reservoir;
- d. observed and anticipated inflows to the Garrison reservoir;
- e. space currently available within Garrison and Fort Peck for storage of future runoff; and
- f. release requirements from Garrison for purposes other than flood control.

7-17.1. The general plan of regulation applicable to most of the System reservoirs, including Garrison, is based on having the flood control storage space evacuated prior to the beginning of the March-July flood season. Flood season inflows that are in excess of the current multiple-use requirements are deliberately stored in the Annual Flood Control and Multiple Use Zone until such time there is reasonable assurance that adequate reserves are stored to satisfy multiple-use requirements to the beginning of the next flood season without drawdown into the Carryover Multiple Use Zone. This deliberate storage for future multiple use also serves the flood control function. Following the time that an adequate supply of multiple-use storage is reasonably assured, releases in excess of multiple-use requirements are made as a storage evacuation measure when they are not anticipated to contribute to significant downstream flooding.

**7-18. Local Flood Control Constraints.** The Bismarck-Mandan area is the principal location where flood damages are likely to occur in the reach from Garrison to Oahe. Prior to 1976, the Missouri River at Bismarck flood stage was 19 feet. However, extensive bottomland development, encouraged in part by the flood protection provided by the System reservoirs, resulted in the NWS lowering the flood stage to 16 feet in 1976. The NWS lowered the flood stage again in 2012 to 14.5 feet. Damage, initially confined to bottomland access, occurs if the Bismarck stage exceeds about 13 feet. Consequently, a primary flood control regulation objective of Garrison is preventing the Bismarck stage from materially exceeding 13 feet at all times when there is a reserve of vacant storage space in Garrison's Annual Flood Control and Multiple Use Zone. When encroachment into Exclusive Flood Control Zone occurs or is anticipated, target Bismarck stages may be increased up to the established flood stage of 14.5 feet, dependent on analyses of probable future runoff above Garrison and storage evacuation requirements. With encroachment into Garrison's Surcharge Zone, Bismarck stages in excess of 14.5 feet may be necessary, with Garrison releases and resultant downstream stages dependent on the degree of encroachment and anticipated future inflows to Garrison.

7-18.1. Open-water channel capacity corresponding to a Bismarck stage of 13 feet is about 63,000 cfs, well above the full Garrison powerplant capacity of 41,000 cfs. Therefore, with an ice-free Missouri River channel, local flood control requirements will restrict Garrison power releases only if unusually heavy runoff should occur in the drainage area between Garrison and the headwaters of Oahe. The ice-covered Missouri River channel capacity at a stage of 13 feet at Bismarck never materially exceeds the Garrison powerplant release capacity and is as low as 18,000 to 20,000 cfs during initial ice formation. The Knife River is the only tributary of consequence entering the Missouri River between Garrison and the primary damage center of Bismarck although high flows from the Heart River could contribute to bottomland flooding along the Missouri River immediately below Bismarck. Flows on these tributaries are monitored during periods of significant runoff so Garrison releases can be adjusted accordingly.

7-18.2. The main period of large inflows between Garrison and Oahe is during the early spring when plains snowmelt and ice break-up on tributaries occur. In exceptionally large snowmelt runoff years, such as 1950 and 1952, incremental flows from the tributaries could exceed the Missouri River channel capacity in the Bismarck vicinity, particularly if the Missouri River channel is ice-covered at the time of tributary runoff. Experience indicates that annual tributary peak flows in this region resulting only from rainfall are usually much smaller than annual peaks resulting from snowmelt. When large tributary peaks do occur as a result of rainfall they attenuate rapidly within the Missouri River channel. For example, the maximum flow of record

from the Knife River occurred in June 1966 when a peak of 35,300 cfs was observed at Hazen, ND. However, coincident average daily flows at Bismarck were 21,000 cfs, with Garrison releases being reduced from approximately 12,000 to 9,400 cfs during the event.

**7-19. Regulation during Missouri River Ice Formation.** Ice formation through the reach from Garrison to the Oahe reservoir occurs every year. As active formation occurs, channel capacities are materially reduced, particularly at the head of the forming ice cover. Experience indicates that during the time an ice cover forms in the Bismarck area, coincident Garrison releases should be at 20,000 cfs or less to prevent Bismarck stages from materially exceeding 13 feet. Releases are typically set at 16,000 to 18,000 cfs prior to the freeze-in. Local lowland flooding has also occurred in other areas of this reach, as a result of ice formation, particularly if the ice formation is proceeding at a rapid rate such as occurs when extremely cold temperatures are accompanied by high winds. During this ice formation, the Missouri River stage increases rapidly, typically rising four to six feet over a one- or two-day period. In most years the ice formation and break-up periods through this reach of the river are the most critical insofar as flood control regulation of Garrison for local conditions is concerned.

7-19.1. Soon after the ice cover forms, it stabilizes. The confined flow causes a smoothing of the ice cover's undersurface and an increase in channel capacity occurs. With a continuing ice cover at Bismarck, Garrison releases can be gradually increased by 500 cfs per day or 1,000 cfs every other day up to the scheduled winter release rate without materially exceeding a stage of 13 feet. Maximum January releases of 34,000 cfs occurred in 1971 and maximum February releases of 36,000 cfs occurred in 1969. In more recent years, releases in January and February have been limited to approximately 25,000 to 27,000 cfs. Before increasing releases, careful observations of Bismarck stages and effects of previous release increases on these stages should be conducted. If deemed necessary, the MRBWM office may request that a field reconnaissance of river and ice conditions throughout the reach be conducted by local Corps or NWS personnel, or in some cases, the North Dakota State Water Commission. These inspections may be made several times a week during the period of active ice formation. Images from the webcam at the Bismarck streamgaging station are also available on the USGS website to allow visual observation of the ice conditions at that location.

7-19.2. Since Garrison has been in operation, ice break-up in the Garrison to Oahe reach has generally been non-eventful, with the exception of 1997 and 2009. Observations indicate that the ice melts from the river progressively downstream from the dam. Garrison release reductions coincident with this melt are typically not necessary. In 1997 and 2009, appreciable plains snowmelt occurred in the Knife and Heart River watersheds while the Missouri River at Bismarck was still ice covered. If this occurs, a reduction in Garrison releases may be necessary to prevent Missouri River stages from materially exceeding 13 feet at Bismarck. In 1997, the Bismarck stage reached 13.7 feet due to ice-jam flooding. Garrison average daily releases were reduced to a low of 4,100 cfs in late March. The Knife and Heart River peak flows were estimated at 20,500 and 22,000 cfs, respectively. In 2009, the Bismarck stage reached 16.1 feet due to ice-jam flooding. Releases at Garrison were reduced to 0 cfs for more than two days, which required coordination with intake owners downstream of Garrison. The Knife and Heart River peak flows during this event were estimated at 20,500 and 27,400 cfs, respectively. See Appendix A for additional information regarding these two ice-jam flooding events.

**7-20. Coordinated System Flood Control Regulation.** The System, of which Garrison is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River. Release scheduling from Garrison 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 the subsequent March 1, when the start of the runoff year 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.

**7-21. Exclusive Flood Control Regulation Techniques.** Garrison will usually be regulated at an elevation of 1850.0 feet or lower. Occasionally flood inflows will be of such magnitude that encroachment into the Exclusive Flood Control Zone, which extends from elevation 1850.0 to 1854.0 feet, will occur. Consequential actions will be dependent on existing or anticipated conditions in the other System reservoirs. If a portion of the Annual Flood Control and Multiple Use Zone is vacant in the Fort Peck reservoir and is expected to remain vacant, one option is to reduce Fort Peck releases to the minimum consistent with all functions being served. If the Exclusive Flood Control Zone is being utilized in all reservoirs, action will be on the basis of the studies described in the preceding sections, with System releases and the balance of exclusive flood control storage scheduled in each reservoir of the System as defined by procedures discussed in the Master Manual. Generally, these procedures recognize the desirability of maintaining somewhat more vacant storage space in the lower reservoirs than in Fort Peck and Garrison, since this storage distribution provides the most flexibility for controlling downstream floods at the major damage centers.

7-21.1. At times, encroachment into Garrison's Exclusive Flood Control Zone will occur or will be anticipated when ample annual flood control storage space remains vacant in the downstream Oahe and Fort Randall projects. Normally when this occurs Garrison releases will be maintained at full powerplant capacity in an effort to transfer the stored water downstream while at the same time obtaining the maximum practical power revenue. However, significant encroachment into the Exclusive Flood Control Zone will require releases in excess of the powerplant capacity in order that a storage space reserve can be maintained for future flood inflows. Regulation curves shown on Plate VII-1 may serve as a guide for defining releases at such times. These curves relate pool elevation and inflows to releases. The curves applicable to plains snowmelt and rainfall floods recognize the relatively sharp hydrographs typical of this type of inflow while the mountain snowmelt curves are based on the relatively long recession characteristics of this type of flood event.

7-21.2. As discussed previously, these curves serve only as a guide for possible regulation, since they are based on typical recession hydrographs for the particular types of floods indicated. Final release selection could be greater or less than indicated by the curves and would be based on anticipated inflows, the effects of release through downstream reaches and the anticipated maximum pool level of the Garrison reservoir as reflected in additional system regulation studies performed at that time. If use of the outlet works or spillway are required, additional guidance

regarding any operational restrictions and best practices for those facilities can be found in Exhibit A of this WCM.

**7-22. Surcharge Regulation Techniques.** During exceptionally large flood inflows all available flood control storage space may be utilized and the Garrison reservoir may rise into the Surcharge Zone above elevation 1854.0 feet. Since the primary reason for providing surcharge space was to ensure the safety of the Garrison project and since real estate surrounding the reservoir has in general not been acquired above elevation 1855.0 feet, significant surcharge encroachment should be allowed only when necessary to prevent extensive downstream damage or if unusually large flood inflows occur. When the Garrison reservoir level approaches or is expected to exceed elevation 1854.0 feet, maintenance of a Missouri River at Bismarck stage of 13 feet or less is no longer the essential criterion. Prior to allowing the reservoir level to exceed elevation 1855.0 feet (one foot of Surcharge Zone storage), releases should be based on maintaining a Bismarck stage at the level of approximately 14.5 feet, the current flood stage. This currently corresponds to a flow of about 75,000 cfs. Therefore, with an allowance for moderate incremental inflows, Garrison outflows of about 70,000 cfs should be scheduled whenever it appears probable that such releases are required to prevent the reservoir level from rising more than one foot into the Surcharge Zone. The Garrison reservoir entered its Surcharge Zone in 1975, 1997 and 2011. See Appendix A of this WCM and Appendix A of the Master Manual for more details on Garrison regulation during these floods.

**7-23. 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 Garrison and the other System projects. Instructions to ensure continuation of Garrison 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.

**7-24. Emergency Regulation.** Reliable and rapid communication is usually available between the MRBWM office and Garrison 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 manual outlines the emergency procedures to be followed. In general, these procedures are written such that service will be continued to multiple-use functions through the period of communications failure at the approximate level prevailing prior to the communications outage if Garrison inflows continue in the range of those previously anticipated. The emergency procedures also allow for increased inflows, up to those occurring in maximum possible floods as developed for spillway design purposes.

7-24.1. Emergency regulation curves, shown on Plates VII-2 and VII-3, were developed by the method described in EM 1110-2-3600. The rainfall and plains snowmelt curves shown on Plate VII-2 assumes a recession constant ( $T_s$  value) of five days, with this time period selected on the basis of the recession curve of the maximum possible early-spring flood. The relatively steep recession rate is believed to be quite characteristic of rainfall floods and plains snowmelt floods that can be expected to result in high inflows during the March-April flood season.

7-24.2. During the May-July period large volumes of inflow to Garrison will usually result from mountain snowmelt, augmented at times by general rains over the contributing area. Such floods

have a slower recession rate than the floods originating from plains area snowmelt or only from an unusually large rainstorm. Consequently, a  $T_s$  value of 15 days, characteristic of mountain snowmelt flood recession, was utilized for the emergency curves applicable during the mountain snowmelt period shown on Plate VII-3 on the basis that this is the most probable flood type occurring at the time. However, mountain snowmelt runoff could, on occasion, be augmented by an unusually heavy rainstorm having a much steeper recession than snowmelt alone. Since, under emergency conditions, such information probably would not be available to project personnel, release rate increases are restricted in a manner that will compensate for an actual recession rate being steeper than the rate assumed in development of the regulation curves.

7-24.3. When unprecedented flood inflows occur, or if reservoir levels exceed or are expected to exceed elevation 1855.0 feet, the regulation curves provided with the emergency instructions, Exhibit B, should be used as a guide for release scheduling. These regulation curves relate reservoir levels and inflows to suggested releases, with the suggested release being based on typical hydrograph recession rates for the season, similar to the exclusive flood control regulation curves previously described.

**7-25. Maximum Possible Early Spring Flood.** As discussed in a previous section, emergency regulation curves are shown on Plates VII-2 and VII-3 and were provided with the emergency regulation procedures in Exhibit B of this manual. Plate VII-2 is the set of curves applicable to the early spring season when substantial inflows to the project result primarily from plains area snowmelt. An example of using emergency procedures as the only criteria for regulation of the Garrison project is shown on Plate VII-4. The flood examined is the maximum possible early spring flood developed for spillway design purposes, with a peak inflow of over 1,000,000 cfs. An initial pool level at elevation 1840.0 feet was assumed. Peak reservoir levels and project releases are 1858.8 feet and 830,000 cfs, respectively, very close to the values determined at the time of the design of the Garrison project.

**7-26. Maximum Possible Late Spring Flood.** The effects of using the late spring emergency regulation procedures as given by Plate VII-3 during the maximum possible late spring flood are shown on Plate VII-5. The flood inflows were as developed during spillway design studies and reflect a combination of mountain snowmelt and heavy rainfall runoff. A peak inflow of 960,000 cfs can be controlled to a maximum outflow of 750,000 cfs with a maximum pool elevation of 1857.6 feet, 3.6 feet into the Surcharge Zone.

**Missouri River Basin  
Garrison Dam – Lake Sakakawea  
Water Control Manual**

**VIII - VIII – Water Management Organization**

**8-01. Responsibilities and Organization.** This chapter describes the personnel and coordination necessary to regulate Garrison. Garrison is regulated as part of the System, which is comprised of six projects on the main stem of the Missouri River. The Corps has the long- and short-term direct responsibility for regulating Garrison as a hydraulically and electrically integrated project. This has been the case since April 1953, when Garrison was closed to begin storing water.

8-01.1. The 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 Garrison in 1946. Garrison 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 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 manual for instructions to the Garrison 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 (or the Omaha District 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](http://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 results 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 snowmelt, 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. The 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 operation requires 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."

**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 (EPA), Western, U.S. Forest Service and the USDA's NRCS. 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 Garrison. 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](http://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**

<b>Frequency</b>	<b>Type of Report</b>	<b>Reporting Requirement<sup>1</sup></b>
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	
Yearly	Monthly Project and System Energy Summary	
	Draft Annual Operating Plan (AOP)	
	Final Annual Operating Plan (AOP)	
	Annual Summary of Actual Regulation	
	Division Annual Report	ER Requirement, includes District Reservoirs
	Flood Damages Prevented Report	ER Requirement – MRBWM office provides holdouts <sup>2</sup> and districts provide estimated damages prevented
	Stage Trends Report	
	Annual Sediment Report	ER Requirement
	Annual Water Quality Report	ER Requirement
Cooperative Stream Gage Program (Co-op)	ER Requirement	

<sup>1</sup> Report required per ER.

<sup>2</sup> Unregulated flows.

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## **Appendix A - Historic Droughts and Floods with Regulation Examples**

**A-01. Floods.** Regulation provided by the Fort Peck and Garrison projects, augmented by upstream tributary reservoir storage, has greatly reduced flooding along the portion of the Missouri River extending from Fort Peck Dam to the mouth of the Yellowstone River and the portion extending from Garrison Dam to the headwaters of the Oahe reservoir below Bismarck, ND. Many instances of above-bankfull flows were experienced through these reaches prior to construction of the System and would be continuing if the projects were not in operation. All floods experienced in this portion of the Missouri River except one have occurred in the March-July period with snowmelt as an important flood component. The one exception occurred in September 1923 when a large rainstorm over portions of southern Montana and northern Wyoming resulted in an October flood on the Missouri River.

A-01.1. Appendix A of 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. Sections that follow present a more detailed description of large flows that have originated in the Fort Peck to Garrison reach of the Missouri River as illustrative of events that could utilize storage space allocated for flood control in the Garrison reservoir. Of necessity, the descriptions are limited to rather recent events for which streamflow data are available.

**A-02. Flood of 1923.** As shown on Plate III-15, the volume of runoff originating between the Fort Peck and Garrison dams during October 1923 was almost four times the volume that normally occurs during October. The maximum runoff recorded for each month, October through December, from this reach occurred in 1923. This above-average runoff for this season of the year was primarily caused from direct runoff and residual flows from an unusually late September rainstorm centered over the Big Horn mountains in southern Montana and northern Wyoming. A peak flow of 134,000 cfs was recorded near the mouth of the Yellowstone River while tributary locations in the Yellowstone River basin established record high flows at that time. This flood illustrates that, although large amounts of runoff from the Yellowstone River will usually occur during the March-July flood season, unusual rain storms with large amounts of runoff can occur during seasons when runoff and flows are normally near seasonal lows.

**A-03. Flood of 1943.** Above-normal precipitation occurred over the Fort Peck to Bismarck drainage area during the 1942-1943 winter season, augmented by a heavy four-day snowstorm in the middle of March over the plains portion of this area in eastern Montana and western North Dakota. Snow accumulations at winter's end over both the plains and mountain portions of the drainage area were well above normal. High temperatures during late March and early April resulted in rapid melt of the plain's snow over ice-sheathed and frozen ground. Sharp increases in plains area tributary flows were augmented by the formation of ice jams on these streams and the subsequent progressive releases of stored water. A peak flow of 132,000 cfs, almost 50,000 cfs greater than the corresponding average daily flow, was observed on the Yellowstone River at Sidney, MT. Maximum average daily flows were 17,300 cfs on the Milk River at Nashua, MT and 25,000 cfs on the Little Missouri River at Watford City, ND. Many of the minor tributaries in this region, such as the Poplar River, also recorded unusually large peak flows at the time of the plains snowmelt. It is estimated that if the System had been in operation at the time, peak

inflows to the Garrison reservoir would have exceeded 200,000 cfs. Runoff originating between Fort Peck and Garrison during the February to April period was about 5.4 MAF, more than twice average. Below Garrison the Knife River at Hazen, ND observed a peak discharge of 26,500 cfs, although average daily flows were less than 11,000 cfs.

**A-04. Flood of 1950.** Flood events during the early spring plains snowmelt period of 1950 were particularly severe over the incremental drainage area extending from Garrison to the headwaters of the Oahe reservoir. Snowfall had progressively accumulated through the preceding winter season, which was much colder than normal with above-normal precipitation. Significant melt in this drainage area did not occur until mid-April at which time severe tributary flooding occurred. A maximum average daily flow of 22,000 cfs occurred on the Knife River at Hazen while the Heart River at Mandan experienced its maximum-of-record peak flow of 30,500 cfs and a corresponding average daily flow of 28,400 cfs. If a similar flood were to occur with the Garrison project in operation and if the ice cover in the vicinity of Bismarck continued in place through the flood period, damaging stages could be expected in this reach due to inflows from the tributaries below Garrison.

**A-05. Flood of 1952.** The most severe early spring snowmelt flood recorded in the upper Missouri River basin occurred in April 1952. April runoff in the incremental drainage area from Fort Peck to Garrison totaled 4.9 MAF, exceeding the space in Garrison’s Annual Flood Control and Multiple Use Zone by about 0.6 MAF. This monthly runoff volume has been exceeded only in June 1909 (5.1 MAF), July 2011 (5.6 MAF) and June 2011 (6.5 MAF). This flood was a result of a wet fall during 1951, well-above-normal precipitation over the plains area during the 1951-1952 winter period, formation of a significant ice-layer over frozen ground during early portions of the winter period and colder-than-normal temperatures during the winter season that resulted in a progressive accumulation of plains snow over the drainage area. Warm temperatures in late March and early April resulted in rapid melt of the snowpack and led to extremely large tributary flows. Recorded peak flows are shown in Table A-1.

**Table A-1  
Peak Tributary Flows – Flood of 1952**

Milk River at Nashua, MT	45,300 cfs
Poplar River near Poplar, MT	27,800 cfs
Yellowstone River at Sidney, MT	138,000 cfs
Little Missouri River at Watford City, ND	42,400 cfs
Knife River at Hazen, ND	20,200 cfs
Heart River at Mandan, ND	30,000 cfs

A-05.1. The Garrison project was not in operation at the time of this flood and a peak flow of 348,000 cfs was observed at the damsite. One day later the peak occurred at Bismarck. The corresponding flow from the observed stage indicated that the peak flow was approximately 500,000 cfs, 152,000 cfs greater than the Garrison damsite peak. However, analysis of the event indicates that most of this increase in peak stage resulted from the severe ice-jamming action occurring along the Missouri River at the time. If a similar flood were to occur at the present

time the Garrison reservoir would act as a trap for upstream ice and a Bismarck peak flow about 25,000 cfs greater than the coincident average daily releases from Garrison would appear likely.

**A-06. Flood of 1967.** Runoff from Fort Peck to Garrison during June and July 1967 was the sixth highest recorded for that 2-month period (1898-2014). Mountain snow accumulations immediately prior to the snowmelt period were some of the largest of record at several locations in the upper Yellowstone River basin. Unusually heavy rains coincided with the melt of this mountain snow. While peak flows along the Yellowstone River were not unusually high, partially due to the regulation of tributary reservoirs on the Bighorn River, a tributary to the Yellowstone River, flood season volumes were exceptionally large. The observed 2-month Yellowstone River volume at Sidney was 6.4 MAF. Regulation of this flood by the Garrison project is discussed in Section A-16.

**A-07. Flood of 1972.** Runoff from the Fort Peck to Garrison drainage area in March 1972 totaled 3.6 MAF, the largest March runoff recorded since record-keeping began in 1898 (1898-2014). For the early spring plains snowmelt period, extending from February through April, the monthly runoff occurring in 1972 was exceeded only four times, including the unprecedented 1952 flood occurrence. Warm temperatures in early March melted a large accumulation of plains snow over western North Dakota and southeastern Montana, resulting in considerable tributary flooding in this region. Observed peak flows are shown in Table A-2. Garrison regulation of this flood is discussed in A-17.

**Table A-2  
Peak Tributary Flows – Flood of 1972**

Milk River at Nashua, MT	6,000 cfs
Yellowstone River at Sidney, MT	52,000 cfs
Little Missouri River at Watford City, ND	52,300 cfs
Knife River at Hazen, ND	19,000 cfs
Heart River at Mandan, ND	30,000 cfs

**A-08. Flood of 1975.** Runoff during the months of May, June and July 1975 from the Fort Peck to Garrison incremental drainage area totaled 9.6 MAF, a 3-month volume that has been exceeded only twice (2011 and 1909) since record-keeping began in 1898. The 1975 flood season runoff was the second largest ever observed for the total drainage area above Garrison (1898-2014). Total May through July runoff above Garrison totaled 18.0 MAF. Total March through July runoff above Garrison was 22.0 MAF.

A-08.1. The extremely large amounts of runoff occurring in 1975 resulted primarily from excess precipitation over the upper Missouri River basin during the March-July period. Prior to March 1975, mountain SWE was less than average. However, higher-than-normal mountain SWE accumulation during March and April resulted in record amounts of mountain SWE levels at several locations at the time that mountain snowmelt began. Unusually heavy precipitation over the plains area through the flood period contributed to direct runoff into the tributaries. The flooding was exacerbated by a mid-June extremely heavy rainstorm in Montana that was centered just east of the Continental Divide. This rainstorm had a center with a rainfall depth in

excess of 15 inches. Average rainfall depths of 10 inches covered a 2,500 square mile area while a 10,000 square mile area had average rainfall exceeding 6 inches. Tributary streamflow in the Fort Peck to Garrison reach was not characterized by particularly high peak flows. Rather, it was an extended period of moderately large flows that resulted in the unusually large runoff volume. Regulation of the 1975 flood is discussed in Appendix A of the Master Manual and Section A-18 of this WCM.

**A-09. Flood of 1997.** Flood season (March-July) runoff from the drainage 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 2011 record 5-month total of 40.9 MAF (1898-2014). 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, sometimes in the 80°F range, which significantly increased the total volume of runoff. Mountain snowpack for both January and February above Fort Peck (181 percent and 155 percent, respectively) and Garrison (169 percent and 159 percent, respectively) were significantly above average. In addition, plains snowpack depths ranged from 6 inches in eastern Montana to as much as 36 inches in eastern North Dakota and eastern 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 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 had 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. Regulation of the 1997 flood is discussed in the Master Manual and Section A-22 of this WCM.

**A-10. Flood of 2009.** A Missouri River ice cover was established in the Bismarck area during December and generally remained through mid-March. In mid-March inflows from the tributaries below Garrison resulted in two large ice jams forming on the Missouri River. One of the jams was located just downstream of the Knife River confluence north of Bismarck. The second ice jam was located just downstream of the Heart River confluence in the Bismarck area. The ice jam located near the Heart River confluence caused water to back up and forced the evacuation of Fox Island and the South Port area in the southern part of Bismarck and Mandan, respectively. The Knife and Heart River peak flows during this event were estimated at 20,500 cfs and 27,400 cfs, respectively. Regulation of Garrison during this event is discussed in Section A-23 of this WCM.

**A-11. 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) had 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 (1898-2010). 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, 10-15 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 reservoirs. System storage peaked at 72.8 MAF on July 1, occupying 98 percent of the allocated flood control storage space (16.0 of 16.3 MAF). As shown on Plate III-15, May, June and July runoff in the reach from Fort Peck to Garrison were record highs. Regulation of this flood is discussed in Section A-24 of this WCM.

**A-12. 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 serving all authorized purposes during an extended drought like that of 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.

A-12.1. Two multi-year droughts have occurred in the upper Missouri River basin since the System was first filled in 1967. The first drought lasted from 1987 to 1992 with the Garrison reservoir level dropping to a low of 1815.0 feet in May 1991. The second drought occurred from 2000 to 2007 with the Garrison reservoir reaching its record low level of 1805.8 feet on May 12, 2005, more than 30 feet below the base of the Annual Flood Control and Multiple Use Zone. During this drought the System storage set a new record low of 33.9 MAF in February 2007, 6.9 MAF below the record of 40.8 MAF set in January 1991 during the previous drought. See Section A-07 in Appendix A of the Master Manual for additional information regarding Missouri River basin droughts and regulation of the mainstem projects during droughts.

**A-13. Historical Regulation and Effects.** Closure of Garrison Dam occurred in April 1953, beginning the accumulation of storage in the reservoir. However, it was not until 1955 that an appreciable volume of water was stored in preparation for the first power unit coming on line in 1956. Runoff originating above Garrison was generally well below average during the 1954-1961 period and continuing initial fill of the Carryover Multiple Use Zone proceeded quite slowly. Plates A-1 through A-6 illustrate the levels of Garrison that have occurred since initial fill of the minimum pool, elevation 1775.0 feet, which occurred in late 1955. These plates show that the Carryover Multiple Use Zone of the reservoir, top elevation of 1837.5 feet, was first filled in 1965. The base of the Exclusive Flood Control Zone, elevation 1850.0 feet, has been exceeded several times since the System first filled in 1967: 1850.8 feet in July 1969; 1854.8 feet in 1975 (historic peak); 1851.7 feet in 1995; 1854.4 feet in 1997; 1851.4 feet in 2010;

1854.6 feet in 2011; and 1853.2 feet in 2018. The Garrison reservoir entered its Surcharge Zone in 1975, 1997 and 2011.

A-13.1. Plates A-1 through A-6 illustrate the annual variation in the levels of the Garrison reservoir since 1955. A minimum level usually occurs in late winter. Throughout most of the March-July flood season, storage accumulates in the reservoir provided upstream runoff is not extremely deficient. From late July through most of the winter season, storage is evacuated to serve multiple-purpose needs and to provide space for the control of runoff that can be expected during the succeeding flood season.

A-13.2. Observed average daily releases from the Garrison project are also shown on Plates A-1 through A-6. With three exceptions, 1975, 1997 and 2011, total releases have been less than 40,000 cfs. Powerplant capacity is approximately 41,000 cfs. In all three years reservoir levels peaked in the Exclusive Flood Control Zone.

A-13.3. Minimum daily releases from Garrison as low as 0 cfs have been recorded only once, in March 2009, during ice jam flooding near Bismarck, ND. The second lowest minimum daily release was 4,100 cfs in March 1997, also during an ice jam event. Average daily releases since 1967 have generally been above 9,000 cfs.

A-13.4. The historical effects of regulation provided by Garrison, combined with effects of regulation of upstream reservoir projects, at Garrison damsite are illustrated on Plates A-1 through A-6 for the 1955-2014 period. Average daily unregulated flows shown on these plates are the computed estimates of flows at the damsite if none of the upstream projects, including Garrison, had been in operation. Regulation has resulted in substantial reductions to all annual peak flows that would have been experienced at the Garrison damsite. Further discussion of the regulation provided at the Garrison damsite during particular years is contained in succeeding sections and in the discussion of System regulation given in the Master Manual. Sections A-14 through A-24 discuss Garrison regulation during significant flooding and drought periods.

**A-14. 1961 Regulation.** Runoff originating from the drainage area above Garrison during 1961 totaled about 9 MAF (1949 level of development), about half of the long-term average. Less annual runoff has been recorded only in 1931 and 1988 since records began in 1898 (1898-2014). Therefore, the regulation provided in 1961 is an example of flow supplementation resulting from the operation of Garrison and other upstream projects. Actual average daily regulated flows and the corresponding unregulated flows at Garrison are shown on Plate A-7. During the late summer season, unregulated flows at the Garrison damsite would have been extremely low except for storage released from upstream reservoirs. Development of water resources has continued since 1961 and, if the runoff experienced in 1961 were to occur at the present time, an extended period of negligible unregulated flows would result. This indicates that water resource development has proceeded to the extent that storage is required to supply resource development requirements as well as maintaining a flowing river below Garrison. The levels of the Garrison reservoir during 1961 are also shown on Plate A-7. Releases from the dam resulted in a lowering of the reservoir level by about 10 feet.

**A-15. 1964 Regulation.** Unregulated average daily flows at the Garrison damsite during 1964 peaked at 214,500 cfs, the second highest unregulated peak that has occurred at this location

since regulation of Garrison began. Were it not for the regulation provided by upstream reservoirs, a Bismarck stage approaching 23 feet, 10 feet higher than the non-damaging target stage now utilized for regulation purposes, could have been expected to occur, with corresponding severe flood damages. Actual average daily Garrison releases at the time of this unregulated peak were about 25,000 to 27,000 cfs, as illustrated on Plate A-8, representing a peak flow reduction of approximately 190,000 cfs and a Bismarck stage reduction of over 14 feet. Garrison reservoir levels during this flood period are also shown on Plate A-8. This flood presented no regulation problems at Garrison. Throughout 1964 Garrison regulation was based on maintaining only minimum releases necessary for downstream water requirements. The 1964 regulation is illustrative of that usually occurring with total flood season runoff volumes not appreciably above the long-term average, even though unusually large peak runoff amounts may occur.

**A-16. 1967 Regulation.** The 2-month runoff occurring from the Fort Peck to Garrison drainage area during the June-July period of 1967 was the third largest since 1930. The large amounts of runoff from this drainage area, combined with well-above-average runoff throughout the remainder of the mainstem drainage area and severe flood inflows to the Missouri River below the System. Damages prevented by Garrison and the other System reservoirs during this flood period approached \$2.1 billion (indexed to 2015). As indicated on Plate A-9, the maximum Garrison reservoir level was below elevation 1850.0 feet, or within the Annual Flood Control and Multiple Use Zone. The effects of regulation during this flood at the Garrison damsite, as illustrated by unregulated flows and actual Garrison releases, are shown on Plate A-9. Garrison releases through the flood period were within the powerplant capacity and eliminated all damage through the immediate downstream area.

**A-17. 1972 Regulation.** As discussed in Section A-07, an unusually large amount of plains snowmelt runoff originated from the Fort Peck to Garrison drainage area during March 1972. By the end of March the level of the Garrison reservoir had risen to elevation 1848.0 feet, 2.0 feet below the base of the Exclusive Flood Control Zone. In anticipation of above-average runoff from above Garrison during succeeding months, Garrison releases were increased to about full powerplant capacity near the end of March, after a marked reduction in releases in mid-March to compensate for the large Knife River flows entering the Missouri River below Garrison. Maintenance of near-full powerplant releases through most of June resulted in a peak reservoir level of elevation 1849.0 feet, 1.0 foot below the base of the Exclusive Flood Control Zone. Effects of reservoir regulation on unregulated flows at the Garrison damsite during 1972 are shown on Plate A-10.

**A-18. 1975 Regulation.** March-July runoff originating in the drainage area above Garrison during 1975 was the second highest experienced since runoff records began in 1898 (1898-2014), as described in Section A-08. While the unregulated peak flow of 175,000 cfs at the Garrison damsite was relatively small in relation to the total volume of runoff that occurred, the unusual aspect was the sustained high unregulated flows extending from late April through July. Also unusual was that most of the well-above-normal precipitation contributing to the record runoff occurred after early April. As a consequence, Garrison releases were not increased above average levels until May. By mid-June it became evident that releases greater than ever previously experienced from Garrison would be necessary. Through late June and July regulation was geared to minimize the total adverse effects resulting from high Garrison

reservoir levels, high tributary flows through the Missouri River reach between Garrison and the Oahe reservoir, high pool levels of downstream reservoirs that re-regulated Garrison releases and high System releases. The maximum release from Garrison was 65,000 cfs and the peak Garrison elevation was a record 1854.8 feet, 0.8 foot into the Surcharge Zone. Reservoir levels and average daily unregulated inflows and releases are shown on Plate A-11. The peak Missouri River stage at Bismarck was 14 feet. Without the control afforded by Garrison and other upstream projects, a peak stage of about 21 feet would have occurred at Bismarck. Further information relating to this flood and regulation afforded by all reservoirs in the System is presented in the Master Manual and in the special MRBWM flood report describing the 1975 flood and accompanying System regulation.

**A-19. 1978 Regulation.** Runoff in 1978 above Garrison was 28.1 MAF, the third highest on record (1898-2014). However, runoff in 1977 above Garrison was 10.4 MAF, less than 60 percent of average, causing the Garrison reservoir to start the 1978 runoff season nearly 12 feet below the base of the Annual Flood Control and Multiple Use Zone. With the large runoff, the reservoir peaked at elevation 1849.5 feet, 0.5 foot below the base of the Exclusive Flood Control Zone. Releases were held near full powerplant capacity from late June through late August. Reservoir levels are shown on Plate A-12 along with average daily unregulated flows and releases. Further information relating to this flood and regulation afforded by all reservoirs in the System is presented in the Master Manual and in the special MRBWM flood report describing the 1978 flood and accompanying System regulation.

**A-20. 1988 Regulation.** The total runoff above Garrison during 1988 of 7.9 MAF is the lowest on record (1898-2014). This was the second year of what later would be referred to as the 6-year drought of 1987-1992, the first extended drought to occur since the System filled in 1967. See Plate A-13 for the average daily regulated and unregulated flows and the Garrison reservoir elevations. As seen on Plate A-13, late summer flows would have been extremely low except for water released from upstream reservoirs. The Garrison reservoir level declined nearly 9 feet during the year as water was released to meet authorized purposes.

**A-21. 1995 Regulation.** Runoff above Garrison during 1995 totaled 19.6 MAF. During June and July, flooding in the lower Missouri River downstream of the System led to reduced releases at the lower System projects. The lower-than-average releases and higher-than-normal inflows resulted in high reservoir elevations at Oahe and Fort Randall. The average June and July releases from Garrison were 11,100 cfs and 13,200 cfs, respectively, the lowest since the System filled in 1967. Due to the low summer releases, the Garrison reservoir level rose into the Exclusive Flood Control Zone on July 17 and remained in that zone until late August. The reservoir peaked at elevation 1851.7 feet, 1.7 feet into the 4-foot Exclusive Flood Control Zone. Releases were increased from 16,000 to 37,000 cfs in early August near the end of the T&E nesting season. See Plate A-14 for the average daily regulated and unregulated flows and the Garrison reservoir elevations.

**A-22. 1997 Regulation.** Runoff above Garrison during 1997 totaled 28.0 MAF, the fourth highest on record (1898-2014). In the Fort Peck to Garrison reach, annual runoff was 17.4 MAF, the second highest since record-keeping began in 1898. The total runoff above Sioux City of 49.0 MAF was the second highest on record and almost two times average. A combination of low releases and high runoff caused the Garrison reservoir level to rise more than 7 feet from

mid-March to the end of April. The April end-of-month reservoir elevation was 1847.5 feet, 10 feet into the 12.5-foot Annual Flood Control and Multiple Use Zone. Releases were increased from 21,000 cfs to near full powerplant (approximately 40,000 cfs) in mid-May. Releases remained at that rate through late June. The reservoir reached elevation 1850.0 feet, the base of the Exclusive Flood Control Zone, on June 14. High inflows continued through June and the reservoir elevation was near 1854.0 feet, the top of the Exclusive Flood Control Zone, by the end of the month. Releases were increased from 40,000 cfs to 50,000 cfs during June. Garrison releases were increased again in early July as additional rainfall added to the already high runoff. Releases were increased to 59,000 cfs by July 10 and held at that rate through July 28. The high releases resulted in near bankfull stages through Bismarck. Releases were reduced to 50,000 cfs by August 2 and then ranged from approximately 46,000 cfs to 50,000 cfs through mid-November. The reservoir level peaked at 1854.4 feet and was above elevation 1854.0 feet, the top of the Exclusive Flood Control Zone, from July 2-13. The reservoir level was in the 4-foot Exclusive Flood Control Zone, or higher, from June 14 to August 30. The total estimate of flood damages prevented by the System during 1997 (indexed to 2015) was \$8.6 billion. Further information describing the 1997 flood and accompanying System regulation is presented in the Master Manual and in the special MRD-RCC Summary Report, *Regulation of the Missouri River Main Stem Reservoir System during the 1997 Flood*. See Plate A-15 for the average daily regulated and unregulated flows and the Garrison reservoir elevations.

**A-23. 2009 Regulation.** As discussed in Section A-10, two large ice jams formed on the Missouri River in mid-March. One of the two jams was located just downstream of the Knife River confluence, north of Bismarck. The second ice jam was located just downstream of the Heart/Missouri River confluence. The ice jam located near the Heart/Missouri River confluence caused water to back up and forced the evacuation of Fox Island and the South Port area in the southern part of Bismarck and Mandan. At the request of the State of North Dakota, releases from Garrison were initially cut from 11,000 to 6,000 cfs on March 23 to help relieve the flooding in Bismarck. On March 24, releases were reduced to 4,000 cfs and then eventually to 0 cfs later that afternoon. Releases from Garrison were increased on March 27 from 0 cfs to 3,000 cfs, to 6,000 cfs and eventually to 9,000 cfs by the afternoon of that same day. This was the longest that releases have been held to 0 cfs since the dam was constructed. Releases were held steady at 9,000 cfs until April 13 when they were again reduced to 5,000 cfs to ease the risk of flooding in the Bismarck-Mandan area caused by high tributary flows from the Knife and Heart Rivers. Garrison releases were increased to 9,000 cfs later in the afternoon on April 16 and held steady until April 21, when all restrictions on releases from Garrison were lifted. See Plate A-16 for the average daily regulated and unregulated flows and the Garrison reservoir elevations.

A-23.1. Initially, thermal powerplants that use the Missouri River for cooling purposes were not affected by the 0 cfs releases due to the large inflows from the Knife River. However, as flows on the Knife River started to recede, two large powerplants, Great River Energy's Stanton and the Basin Electric's Leland Olds, both located downstream of the Knife River, were shut down on March 27. The city of Washburn's water treatment plant intake is located on the Missouri River downstream of the Knife-Missouri River confluence. Without sufficient flows on the Missouri River to dilute the sediment-laden water from the Knife River, Washburn's water treatment facility could not effectively eliminate all bacteria from the water. Therefore, residents were instructed to boil water before drinking.

A-23.2. The winter peak ice-affected Missouri River stage at Bismarck was 16.1 feet on March 24 due to a combination of large inflows from tributaries and ice jams on the Missouri River. This stage of 16.1 feet was 0.1 foot above the Bismarck flood stage (since changed to 14.5 feet) and 3.1 feet above the Corps' winter freeze-in target stage of 13 feet.

**A-24. 2011 Regulation.** The 2011 runoff year of 61.0 MAF, almost 2.5 times average, was the highest runoff year of record (1898-2014) in the upper Missouri River basin since record-keeping began. It also marked the fourth consecutive year of above-average runoff in the upper Missouri River basin, immediately following the 2000-2007 drought. Upper Basin runoff in May (9.2 MAF), June (14.8 MAF) and July (10.2 MAF) were the highest recorded 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 (1898-2010) years. The winter of 2010-2011 marked the third consecutive year of significant plains snowpack and mountain snowpack was much above average. While the mountain snowpack was very substantial, runoff from mountain snowpack normally extends over a 3-month period (May-July) and May 1 regulation studies indicated System evacuation releases of 57,500 cfs. During May, heavy rains fell across eastern Montana, western South Dakota and northern Wyoming. In some isolated areas, 10-15 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 reservoirs. System storage peaked at 72.8 MAF on July 1, occupying 98 percent of the allocated flood control storage space (16.0 of 16.3 MAF).

A-24.1. As shown on Plate A-17, the Garrison reservoir elevation was near the base of the Annual Flood Control and Multiple Use Zone in mid-March. Inflows from plains snowmelt and rainfall runoff resulted in the pool rising to 1847.6 feet by early May. The reservoir continued to rise through May and June due to high inflows from mountain snowmelt and rainfall runoff. The reservoir peaked at elevation 1854.6 feet on July 1, 0.6 foot into the Surcharge Zone. This elevation was the second highest on record (1854.8 feet in 1975). The reservoir level was in, or above, the Exclusive Flood Control Zone from May 22 to August 8. Releases from Garrison reached a maximum of 150,000 cfs on June 17. The previous record of 59,000 cfs was set in July 1997. Supplemental releases were made from both the outlet tunnels and the spillway. This was the first time the spillway was used for regulation purposes. Spillway releases were made from June 1 to August 17, with maximum spillway releases of about 61,600 cfs in late June and early July. See Section 4-03.3 of this WCM for additional discussion of the spillway use in 2011. Outlet tunnel releases were made from May 6 to October 11. Maximum tunnel releases were approximately 84,600 cfs on June 5. Average daily powerplant, spillway and outlet tunnel releases are shown on Plate A-18. Record daily inflows of 190,000 cfs, which included the Fort Peck release, occurred on June 13. Both the spillway and the outlet tunnels required repairs following the record releases in 2011.

A-24.2. To accommodate variations in power demands during the time that the 2011 record releases were being made, powerplant releases at some of the projects, including Garrison, were varied in a day-to-night pattern, with higher powerplant releases occurring during the day. This required adjusting releases from the outlet tunnels or spillway twice per day to maintain the

required total project release. These release adjustments lessened later in the summer as power demands increased and total project releases were reduced.

**A-25. Regulation during Downstream Channel Freeze-up.** On a continuing basis, perhaps the most critical time for scheduling Garrison releases is in the early winter period when an ice-cover is forming on the Missouri River channel from the headwaters of the Oahe reservoir upstream to above Bismarck, ND. At this time the power demand is for high Garrison outflows; however, ice formation near Bismarck reduces the downstream channel capacity to less than half of the Garrison powerplant capability. Reference is made to the MRD-RCC Technical Study *F-73, Freezing of the Missouri River Below Garrison Dam*, where the daily analyses made during the December 1972 ice formation period are described for illustrative purposes. Generally, if winter releases from Garrison are expected to be higher than 16,000 to 18,000 cfs, releases are reduced to 16,000 to 18,000 cfs prior to the river freeze-in and then gradually increased after the ice cover has stabilized. See Sections 3-15, 6-18 and 7-18 of this WCM for more information on river ice and regulation during the winter season.

**A-26. Summary of Historical Regulation.** Historical annual runoff above Garrison (1898-2016) has ranged from the minimum of 7.9 MAF (1988) to the maximum of 39.0 MAF (2011). Based on the extensive experience gained from regulating Garrison in a wide range of conditions and supplemented by analyses of the entire period of hydrologic record, it is believed that the regulation criteria developed for Garrison and for the System as a whole, as presented in the Master Manual, as it affects Garrison regulation, are reasonable and represent a near-optimum utilization and control of the water supply that may be available. Of course, studies will continue through the life of the project in an effort to improve criteria as conditions change. In general, it may be stated that, unless runoff originating upstream from the project is well above average, Garrison releases will be maintained within the capacity of the Garrison powerplant and the reservoir level will not exceed elevation 1854.0 feet, the top of the Exclusive Flood Control Zone. Only in 1975, 1997, 2011 and 2018, the years that unusually high amounts of upstream runoff occurred, were significant supplementary releases made through the outlet tunnels or spillway. Only in 1975, 1997 and 2011 did the pool level exceed 1854.0 feet, the top of the Exclusive Flood Control Zone. Minimum daily releases will generally not be less than 10,000 cfs, the flow necessary for normal functioning of downstream water intakes while the level of the Garrison reservoir should be maintained well above the established minimum level of elevation 1775.0 feet.

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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 recreational 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 are 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 1954-2012. This plate shows that the trend is upward except during extended drought, when the trend levels off or is slightly reversed depending on the year. 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. Garrison Recreation Visitation.** Refer to Table B-1 for a history of Garrison 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 carryover multiple use storage volume 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  
Garrison Recreation Visitation of Corps' Recreation Areas**

Year	Visitation in hours	Year	Visitation in hours
1954	370,000	1984	9,694,185
1955	414,770	1985	9,179,904
1956	721,130	1986	8,692,499
1957	1,045,250	1987	9,452,200
1958	1,238,390	1988	10,592,200
1959	1,242,460	1989	9,892,200
1960	1,260,960	1990	9,262,000
1961	1,542,160	1991	9,341,600
1962	1,559,920	1992	11,098,300
1963	1,981,350	1993	11,584,000
1964	2,920,040	1994	11,350,100
1965	2,672,880	1995	11,751,600
1966	2,654,010	1996	11,943,100
1967	2,874,900	1997	13,887,700
1968	3,184,220	1998	14,314,300
1969	3,349,980	1999	16,312,100
1970	3,864,650	2000	16,485,940
1971	3,978,610	2001	15,318,200
1972	4,155,470	2002	17,303,600
1973	4,237,980	2003	14,636,600
1974	4,926,180	2004	13,894,500
1975	3,570,130	2005	12,698,600
1976	2,910,213	2006	14,016,890
1977	4,832,422	2007	12,306,600
1978	4,642,849	2008	13,121,800
1979	4,636,100	2009	13,773,900
1980	6,094,270	2010	15,698,000
1981	7,513,960	2011	14,190,300
1982	7,278,270	2012*	15,233,400
1983	9,657,000		

\*2012 visitation data is for January to September only.

## 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. 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 improved 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 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 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-02.2. Lower reservoirs levels due to long droughts can cause a decline in coldwater habitat in the Garrison reservoir. To try to limit the volume of cold water released in the most recent drought (2000-2007) plywood barriers were installed on the trash racks on the intakes structures of powerplant Unit Nos. 1, 2 and 3. In addition, hydropower peaking patterns were adjusted to limit the volume of cold water released. Plywood barriers may be installed again if the reservoir

level is forecasted to be below 1825 feet per informal agreement or as requested by the North Dakota Game and Fish Department.

**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. 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. Through biological uptake and transformation, mercury can become toxic to fish and humans in the form of methyl mercury. 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 Water Control and Water Quality Section 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, profluralin, prometon, prometryn, propachlor, propazine, simazine, terbufos, triallate and trifluralin.

C-03.5. Lake Sakakawea is located above one of the Nation's largest oil and natural gas resources, known as the Bakken Shale. The use of horizontal drilling and hydraulic fracturing technologies has made these previously inaccessible oil and gas deposits recoverable, resulting in North Dakota being ranked 2nd in oil production in the Nation. Since 2006, infrastructure development in the region has resulted in new well pads, roads and pipelines for transporting oil, gas and various products necessary for oil and gas development. Production from 2006 to 2018 has increased nearly tenfold to 1.1 million barrels per day. Infrastructure is developed on flowage easements, federally-owned lands and private lands adjacent to and/or beneath the reservoir. The continued development of the Bakken Shale around and beneath Lake Sakakawea has increased water quality concerns from stakeholders around the reservoir. These concerns are related to the potential release or migration of contaminants from existing or vintage well pads, which could impact the water quality of Lake Sakakawea or its tributaries. Potential releases include: crude oil, natural gas, natural gas liquids, produced saltwater (a byproduct of production) and contaminated water used from hydraulic fracturing during completion of the well, also known as “frac water”. There are also concerns regarding accelerated eutrophication of Lake Sakakawea due to the increase in non-point source pollution and associated nutrient loading or surface runoff from oil production activity and the infrastructure development necessary to support it.

C-03.6. 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 undesirable algal blooms.

**C-04. Garrison Reservoir and Tailwater.** Lake Sakakawea is on the State of North Dakota’s 303(d) List of Impaired Waterbodies citing impairment to the use of fish consumption. The identified pollutants and stressors are low dissolved oxygen, water temperature and methyl mercury. Algal blooms occur at times in the reservoir during low reservoir conditions. A toxic algal bloom occurred in the reservoir in 1990 when the reservoir was down to elevation 1815.0 feet during a drought. Organic materials, such as decaying algae and imported organic matter, contribute to the in-reservoir oxygen demand and result in reduced dissolved oxygen levels in the deeper, cooler portion of the reservoir. Dissolved oxygen concentrations may fall below 5 mg/L in the deeper, cooler portion of the reservoir and coldwater habitats may be reduced during drought conditions. Elevated concentrations of arsenic, mercury, copper, iron, lead and pesticides have been detected in Lake Sakakawea (personal communication, F.J. Schwindt, Chief, Environment Health Section, State of North Dakota, 1995). Observed arsenic and mercury levels are below the EPA’s recommended drinking water standards. Atrazine was also detected in Lake Sakakawea; however, state criteria have not yet been developed for this pesticide. The North Dakota Department of Health and Consolidated Laboratories (NDDHCL) has issued an advisory on consumption of fish caught in some streams and reservoirs in North Dakota.

**C-05. Water Quality Monitoring at the Project.** The Corps has collected water quality data at Garrison since the late 1970s. Water quality monitoring locations have included sites on the reservoir and on the Missouri River upstream and downstream of Garrison. 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. A 3-year intensive water quality survey was completed at Garrison in 2005 and the findings of the intensive survey are available in the separate report, *Water Quality Conditions Monitored at the Corps' Garrison Project in North Dakota during the 3-Year period 2003 through 2005*.

**C-06. Summary of Water Quality Conditions.** Table C-1 summarizes the water quality conditions that were monitored in the Garrison reservoir (Lake Sakakawea) near-dam site during 2010-2014. A review of these results indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of coldwater fishery habitat in the hypolimnion of Lake Sakakawea. Monitored water quality conditions in the hypolimnion of Lake Sakakawea regularly exceeded the 15°C coldwater fishery habitat criteria for temperature and fell below the 5 mg/L dissolved oxygen criteria. Table C-2 summarizes the water quality conditions that were monitored in the Missouri River in the tailwater of Garrison during 2010-2014. The monitored water quality conditions do not indicate any significant water quality concerns. Updated information and additional detail can be found in the annual water quality report.

**Table C-1**  
**2010-2014 Water Quality Conditions – Garrison Reservoir**

Parameter	Monitoring Results <sup>(A)</sup>						Water Quality Standards Attainment		
	Detection Limit <sup>(B)</sup>	No. of Obs.	Mean <sup>(C)</sup>	Median	Min.	Max.	State WQS Criteria <sup>(D)</sup>	No. of WQS Exceedances	Percent WQS Exceedance
Pool Elevation (ft-NGVD29)	0.1	25	1841.9	1842.7	1828.3	1854.2	-----	-----	-----
Water Temperature (°C)	0.1	1,245	12.5	11.8	3.3	24.8	29.4 <sup>(1,3)</sup>	0	0%
Hypolimnion Water Temperature (°C) <sup>(E)</sup>	0.1	370	10.6	10.7	5.9	16.9	15.0 <sup>(2,3)</sup>	11	3%
Dissolved Oxygen (mg/L)	0.1	1,241	9.1	8.8	3.9	12.6	5 <sup>(1,4)</sup>	29	2%
Dissolved Oxygen (% Sat.)	0.1	1,241	87.6	91.8	36.8	119.1	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/L) <sup>(E)</sup>	0.1	368	7.7	7.5	3.9	11.3	5 <sup>(1,4)</sup>	29	8%
Specific Conductance (uS/cm)	1	1,245	698	740	561	783	-----	-----	-----
pH (S.U.)	0.1	1,245	8.0	8.0	7.3	8.6	7.0 <sup>(1,4)</sup> , 9.0 <sup>(1,3)</sup>	0	0%
Turbidity (NTUs)	1	1,244	-----	1	n.d.	329	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,245	337	339	181	470	-----	-----	-----
Secchi Depth (M)	0.02	25	2.73	2.44	0.84	5.79	-----	-----	-----
Alkalinity, Total (mg/L)	7	50	157	159	144	170	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	50	3.7	3.6	2.0	5.9	-----	-----	-----
Chemical Oxygen Demand (mg/L)	2	20	9	10	3	13	-----	-----	-----
Chloride (mg/L)	1	20	10	10	10	11	100 <sup>(1,3)</sup>	0	0%
Chlorophyll <i>a</i> (ug/L) – Field Probe	1	1,238	6	4	n.d.	33	-----	-----	-----
Chlorophyll <i>a</i> (ug/L) – Lab Determined	1	25	4	5	n.d.	14	-----	-----	-----
Colorized Dissolved Organic Matter (ug/L)	4	40	25	25	18	48	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	50	503	512	276	708	-----	-----	-----
Hexane Extractable Material (mg/L)	1.4	18	-----	n.d.	n.d.	1.7	-----	-----	-----
Nitrogen, Ammonia Total (mg/L)	0.02	50	-----	n.d.	n.d.	0.08	5.6 <sup>(1,3,5)</sup> , 2.4 <sup>(1,5,6)</sup>	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	50	0.4	0.3	n.d.	2.0	-----	-----	-----
Nitrogen, Nitrate-Nitrite N, Total (mg/L)	0.02	50	-----	0.06	n.d.	0.40	1.0 <sup>(1,3)</sup> , 0.25 <sup>(7)</sup>	0, 1	0%, 2%
Nitrogen, Total (mg/L)	0.1	50	0.5	0.3	n.d.	2.1	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	50	-----	n.d.	n.d.	0.03	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	50	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	50	-----	n.d.	n.d.	0.03	0.02 <sup>(7)</sup>	4	8%
Sulfate (mg/L)	1	50	196	215	135	230	250 <sup>(1,3)</sup>	0	0%
Suspended Solids, Total (mg/L)	4	50	-----	n.d.	n.d.	106	-----	-----	-----
Microcystin, Total (ug/L)	0.1	25	-----	n.d.	n.d.	0.0	-----	-----	-----

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.), Specific Conductance, pH, Oxidation-Reduction Potential 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 nondetects, 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 Class 1 lakes.

(2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.

(3) Daily maximum criterion (monitoring results directly comparable to criterion).

(4) Daily minimum criterion (monitoring results directly comparable to criterion).

(5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(6) 30-day average criterion (monitoring results not directly comparable to criterion).

(7) Nutrient guideline for lake or reservoir improvement or management.

(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.

**Table C-2**  
**2010-2014 Water Quality Conditions – Garrison Tailwater**

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit <sup>(A)</sup>	No. of Obs.	Mean <sup>(B)</sup>	Median	Min.	Max.	State WQS Criteria <sup>(C)</sup>	No. of WQS Exceedances	Percent WQS Exceedance
Dam Discharge, Powerplant (cfs)	1	40	21,921	21,067	8,434	32,913	-----	-----	-----
Dam Discharge, Flood Tunnels (cfs) <sup>(D)</sup>	1	5	38,924	34,177	6,564	73,185	-----	-----	-----
Dam Discharge, Spillway (cfs) <sup>(D)</sup>	1	5	24,416	0	0	61,346	-----	-----	-----
Water Temperature (°C)	0.1	39	9.4	10.0	1.1	16.5	29.4 <sup>(1,2)</sup>	0	0%
Dissolved Oxygen (mg/L)	0.1	39	9.8	9.5	6.0	13.7	5 <sup>(1,3)</sup>	0	0%
Dissolved Oxygen (% Sat.)	0.1	39	87.5	92.1	55.6	112.0	-----	-----	-----
pH (S.U.)	0.1	39	7.9	8.0	6.7	8.8	7.0 <sup>(1,3)</sup> , 9.0 <sup>(1,2)</sup>	2, 0	5%, 0%
Specific Conductance (uS/cm)	1	39	702	744	563	794	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	39	364	360	160	556	-----	-----	-----
Turbidity (NTU)	1	39	5	3	n.d.	45	-----	-----	-----
Alkalinity, Total (mg/L)	7	40	158	159	144	168	-----	-----	-----
Carbon, Total Organic (mg/L)	0.05	40	3.7	3.6	2.7	5.5	-----	-----	-----
Chemical Oxygen Demand (mg/L)	2	10	10	10	4	12	-----	-----	-----
Chloride, Dissolved (mg/L)	1	15	10	11	9	11	100 <sup>(1,2)</sup>	0	0%
Colorized Dissolved Organic Matter (ug/L)	4	31	27	25	19	42	-----	-----	-----
Dissolved Solids, Total (mg/L)	5	40	493	493	300	694	-----	-----	-----
Nitrogen, Ammonia Total (mg/L)	0.02	40	-----	0.02	n.d.	0.08	8.4 <sup>(1,2,4)</sup> , 2.4 <sup>(1,4,5)</sup>	0	0%
Nitrogen, Kjeldahl Total (mg/L)	0.1	40	0.3	0.3	n.d.	1.2	-----	-----	-----
Nitrogen, Nitrate-Nitrite Total(mg/L)	0.02	40	0.08	0.07	n.d.	0.20	1.0 <sup>(1,2)</sup>	0	0%
Nitrogen, Total (mg/L)	0.1	40	0.3	0.4	n.d.	1.3	-----	-----	-----
Phosphorus, Dissolved (mg/L)	0.02	40	-----	n.d.	n.d.	0.03	-----	-----	-----
Phosphorus, Total (mg/L)	0.02	40	-----	n.d.	n.d.	0.06	-----	-----	-----
Phosphorus-Orthophosphate (mg/L)	0.02	40	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/L)	1	40	196	215	135	234	250 <sup>(1,2)</sup>	0	0%
Suspended Solids, Total (mg/L)	4	40	-----	n.d.	n.d.	74	-----	-----	-----

n.d. = Not detected.

<sup>(A)</sup> 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.

<sup>(B)</sup> Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, 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).

<sup>(C)</sup> Criteria given for reference – actual criteria should be verified in appropriate state water quality standards.

<sup>(1)</sup> Criteria for Class 1 streams.

<sup>(2)</sup> Daily maximum criterion (monitoring results directly comparable to criterion).

<sup>(3)</sup> Daily minimum criterion (monitoring results directly comparable to criterion).

<sup>(4)</sup> Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

<sup>(5)</sup> 30-day average criterion (monitoring results not directly comparable to criterion).

<sup>(D)</sup> May through September 2011.

## 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. The least tern and piping plover utilize the shoreline of the Garrison reservoir and the Missouri River reach downstream of Garrison Dam for nesting purposes. 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 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. 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. As a measure to minimize take while maintaining the flexibility to increase releases during the nesting season, hourly releases from Fort Randall and Garrison follow a repetitive daily pattern to limit peak stages below the project for nesting T&E birds. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Average daily releases may be increased every third day to preserve the capability of increasing releases later in the summer with little or no incidental take if drier downstream conditions occur. If higher daily releases are required later in the nesting season, the daily peaking pattern may be adjusted, reduced or eliminated resulting in a steady release to avoid increased stages at downstream nesting sites. 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 water needs 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. Garrison Reservoir.** As shown in Table E-3 of the Master Manual, there are 326 water supply intakes located on the Garrison reservoir (Lake Sakakawea). These include 1 powerplant, 15 municipal water supply facilities, 27 industrial intakes, 44 irrigation intakes, 228 domestic intakes and 11 public intakes. The powerplant has a gross generating capacity of 870 MW. The municipal water supply facilities serve a population of approximately 19,212 persons. Of the 326 water supply intakes and intake facilities, there are 78 water supply intakes and intake facilities that serve the Fort Berthold Reservation. These include 4 municipal water supply facilities, 1 industrial intake, 10 irrigation intakes and 63 domestic intakes. The municipal water supply facilities serve a population of approximately 1,512 persons.

**E-03. Garrison Dam to Oahe Reservoir.** There are 128 water supply intakes located on the Missouri River from Garrison Dam to the upper end of the Oahe reservoir. These include 6 powerplant intakes, 7 municipal water supply facilities, 7 industrial intakes, 77 irrigation intakes, 28 domestic intakes and 3 public intakes. The 3 powerplants served by the 6 intakes have a nameplate generating capacity of 3,444 MW. The municipal water supply facilities serve a population of approximately 70,000 persons.

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## 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 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 3,000 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**

<b>Dam</b>	<b>Generator Capacity (MW)</b>	<b>Energy (million MWh)</b>	<b>Average Annual Energy Plant Factor (%)</b>	<b>Units</b>	<b>Average Gross Head (feet)</b>	<b>Average Flow (kcfs)</b>	<b>Normal Powerhouse** Capacity (kcfs)</b>	<b>Average Annual Flow Plant Factor (%)</b>	<b>Type</b>
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	<u>132</u>	<u>0.7</u>	62	<u>3</u>	48	27.6	36	77	Baseload
<b>Total</b>	<b>2,523</b>	<b>9.3</b>		<b>36</b>					

\*\* 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. Garrison Dam.** Five units operate at Garrison, with a generating capacity of 583 MW. Normal powerhouse flow capacity is 41,000 cfs and the average release is 21,600 cfs. The average annual plant factor is 53 percent. The powerplant produces an average of 2.2 million MWh per year. Power generating units came on line between 1956 and 1960. The Garrison powerplant is a semi-peaking plant.

**F-05. Garrison Dam Releases.** Since 1956, releases from Garrison have generally been through the power facilities, having a maximum capacity of about 41,000 cfs. Exceptions were in 1975, 1997 and 2011 when releases of 65,000 cfs, 59,000 cfs and 150,000 cfs, respectively, were required to evacuate accumulated flood storage. The minimum average daily release since 1956 has been 0 cfs, which occurred in 2009.

**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. 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 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 additional detail for Garrison is found in this WCM.

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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## **Exhibit A**

Missouri River Mainstem Dams  
Operational Restrictions and Best  
Practices for Spillway Gates and  
Outlet Tunnels

## 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

CENWO-ED-DF

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

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

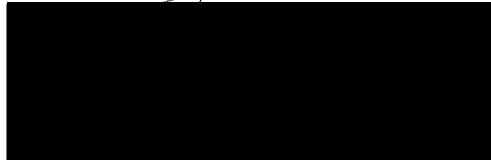
(3) *Fort Peck Outlet Tunnels* - Previous studies have reported damage to the ring gates, shaft, and tunnels during releases through the outlet works. The studies also questioned the ability to place the emergency gates during flow conditions. It is recommended that ring gates should not be used except 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

Garrison 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 Garrison Operations Project Manager

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Garrison

1. Procedures applicable to the regulation of Garrison 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 Garrison. Garrison shall provide to the MRBWM office 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 Garrison on a daily basis. Regulation instructions for the weekend and holidays are contained in the previous normal working day's orders. Garrison 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 MRBWM and Garrison 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 Garrison 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. Hourly powerplant loading will follow the Western loading schedule, if available. If the hourly schedule has not been received from Western, powerplant releases will be made to

CENWD-PDR (11-2-240a)

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Garrison

provide the daily energy schedule specified in the latest regulation order and will be patterned similar to recent experience. 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. Hourly powerplant loading will be as described in 4.b. If requested by Western, and if power emergency conditions have been declared, energy generation may be increased to the maximum allowable limit shown on the latest regulation order. These procedures will continue to be utilized until communications are re-established as long as the Garrison reservoir level remains below elevation 1837.5 feet.

d. If the Garrison reservoir level is above elevation 1837.5 feet, procedures outlined in paragraph 4.c. 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 24 hours will be estimated by computing the storage change during the 24-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 24-hour period. The approximate mean inflow in cfs is equivalent to the mean outflow in cfs plus one-half the storage change in acre-feet during the 24-hour period. Twenty-four hour inflow may also be approximated by the equation:

$$\text{Inflow} = \text{Outflow} + (183,000 \times \text{elevation change in feet})$$

(3) Utilizing the inflow as developed above and the current pool elevation as indicated by the smoothed pool level curve developed in (2), determine the rule curve release by use of the emergency curves shown on Plate VII-2 or Plate VII-3 in the Garrison Water Control Manual (WCM) and as Enclosure 1 and Enclosure 2 to this document, as appropriate to the season.

(4) If the rule curve release developed by (3) is greater than the release given by (1), make release specified by the appropriate rule curve. However, increases in release rates will be limited as specified on the curves.

CENWD-PDR (11-2-240a)

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Garrison

(5) With a Garrison reservoir level below elevation 1850.0, any release adjustments made necessary by use of the rule curve in accordance with (4) should be made once daily. With a reservoir level above elevation 1850.0, the analysis and necessary adjustments should be at intervals of 12 hours or less.

(6) If the release is less than full powerplant capability powerplant loading will be patterned similar to recent experience or as prescribed by Western if communication with their office is possible.

(7) Releases from Garrison shall be made through the powerhouse to the degree feasible.

5. In the event of downstream flooding, as reported to or anticipated by the Garrison Operations Project Manager, releases will be reduced as deemed necessary to alleviate these conditions. However, with a reservoir level above 1837.5 feet, releases will not be reduced below those levels defined by the emergency curves, Plate VII-2 or Plate VII-3 in the Garrison WCM and as enclosures 1 and 2 to this document.

6. The foregoing procedures are not intended to relieve the Garrison Operations Project 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

Encls

Emergency Regulation Curve (Rainfall and Plains Snowmelt)

Emergency Regulation Curve (Mountain Snowmelt Period)

Garrison – Lake Sakakawea

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
<b>Dam and Embankment</b>				
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
<b>Spillway Data</b>				
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
<b>Reservoir Data (6)</b>				
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
<b>Storage allocation &amp; capacity</b>				
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	14,800 a.f./year                      1553 yrs.
<b>Outlet Works Data</b>				
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
<b>Power Facilities and Data</b>				
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.	Remarks
21 miles upstream Chamberlain, SD Mile 987.4 249,330 (1)	5,840	Near Lake Andes, SD Mile 880.0 263,480 (1)	14,150	Near Yankton, SD Mile 811.1 279,480 (1)	16,000		1	(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.
80, ending near Pierre, SD		107, ending at Big Bend Dam		25, ending near Niobrara, NE		755 miles	2	
200 (elevation 1420) 28,900		540 (elevation 1350) 30,000	1,100	90 (elevation 1204.5) 32,000	2,000	5,940 miles	3	
440,000 (April 1952)		447,000 (April 1952)		480,000 (April 1952)			4	
1959		1946		1952			5	
1964		1953		1955			6	
							7	
							8	
							9	
1440 10,570 (including spillway) 78 95 1200, 700		1395 10,700 (including spillway) 140 165 4300, 1250		1234 8,700 (including spillway) 45 74 850, 450		71,596 863 feet	10	(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
Pierre shale & Niobrara chalk		Niobrara chalk		Niobrara chalk & Carlile shale			11	
Rolled earth, shale, chalk fill 17,000,000 540,000 24 July 1963		Rolled earth fill & chalk berms 28,000,000 & 22,000,000 961,000 20 July 1952		Rolled earth & chalk fill 7,000,000 308,000 31 July 1955		358,128,000 cu. yds 5,554,000 cu. yds.	12	
							13	
							14	
							15	
							16	
							17	
							18	
							19	
Left bank - adjacent 1385 376 gated 8 - 40' x 38' Tainter 390,000 at elev 1433.6 270,000		Left bank - adjacent 1346 1000 gated 21 - 40' x 29' Tainter 620,000 at elev 1379.3 508,000		Right bank - adjacent 1180 664 gated 14 - 40' x 30' Tainter 584,000 at elev 1221.4 345,000			20	
							21	
							22	
							23	
							24	
							25	
1423 msl 61,000 acres 1422 msl 60,000 acres 1420 msl 57,000 acres 1415 msl 51,000 acres		1375 msl 102,000 acres 1365 msl 94,000 acres 1350 msl 76,000 acres 1320 msl 36,000 acres		1210 msl 29,000 acres 1208 msl 25,000 acres 1204.5 msl 21,000 acres 1204.5 msl 21,000 acres		1,206,000 acres 1,146,000 acres 984,000 acres 437,000 acres	26	
							27	
							28	
							29	
1423-1422 61,000 a.f. 1422-1420 118,000 a.f.		1375-1365 986,000 a.f. 1365-1350 1,306,000 a.f. 1350-1320 1,532,000 a.f.		1210-1208 54,000 a.f. 1208-1204.5 79,000 a.f.		4,674,000 a.f. 11,626,000 a.f. 38,536,000 a.f.	30	
							31	
							32	
1420-1345 1,631,000 a.f. 1423-1345 1,810,000 a.f.		1320-1240 1,469,000 a.f. 1375-1240 5,293,000 a.f.		1204.5-1160 295,000 a.f. 1210-1160 428,000 a.f.		17,592,000 a.f. 72,428,000 a.f.	33	
							34	
November 1963 25 March 1964 5,300 a.f./year		January 1953 24 November 1953 15,800 a.f./year		August 1955 22 December 1955 2,700 a.f./year			35	
							36	
	430 yrs.		334 yrs.		159 yrs.	77,400	37	
None (7)		Left Bank 4 - 22' diameter		None (7)			38	
							39	
		1013 2 - 11' x 23' per conduit, vertical lift, cable suspension					40	
							41	
1385 (11)		1229 Elev 1375		1180 (11)			42	
							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 None: direct intake		117 8 - 28' dia., 22' penstocks 1,074		48 None: direct intake		764 feet	45	
							46	
None 8 Fixed blade, 81.8 rpm		59' dia, 2 per alternate penstock 8 Francis, 85.7 rpm		None 3 Kaplan, 75 rpm		55,083	47	
							48	
67' 103,000 cfs		112' 44,500 cfs		48' 36,000 cfs		36 units	49	
							50	
3 - 67,276, 5 - 58,500 494,320 497,000 980 October 1964 - July 1966		40,000 320,000 293,000 1,726 March 1954 - January 1956		44,100 132,300 74,000 725 September 1956 - January 1957		2,501,200 kw 1,967,000 kw 9,342 million kWh July 1943 - July 1966	51	
							52	
							53	
							54	
							55	
							56	
\$107,498,000		\$199,066,000		\$49,617,000		\$1,166,404,000		

Corps of Engineers, U.S. Army  
Compiled by  
Northwestern Division  
Missouri River Region  
August 2016

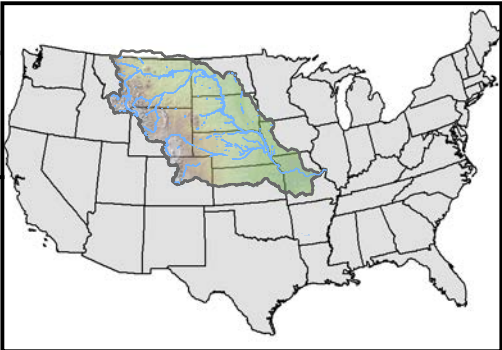


Plate III-1



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



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

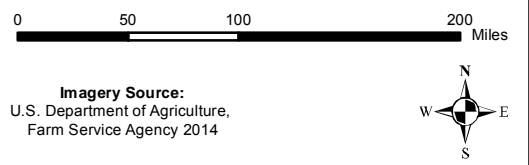


River	Drainage Area (sq.mi.)
Yellowstone River	70000
Milk River	23159
Little Missouri River	8310
Poplar River	3340
Big Muddy Creek	2590
Other	16500
<b>Total</b>	<b>123899</b>

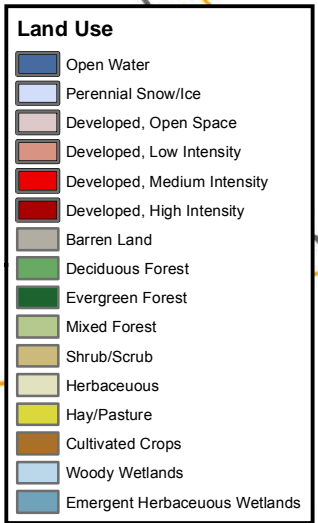
Plate III-2



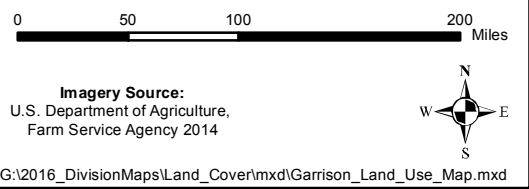
- Mainstem Dam
- Cities
- Rivers
- Reservoirs/Lakes
- Garrison Drainage Area
- Omaha/Kansas City District Boundaries
- State Boundaries



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



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



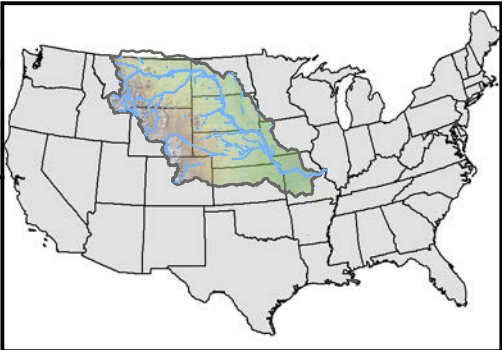


Plate III-4



- 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"

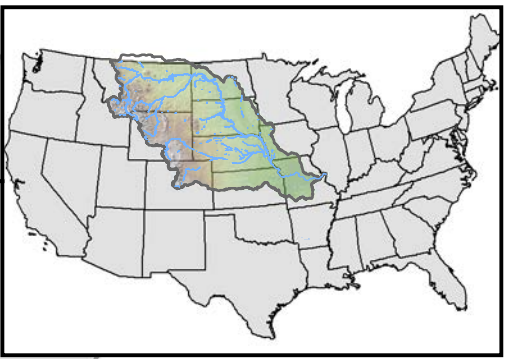
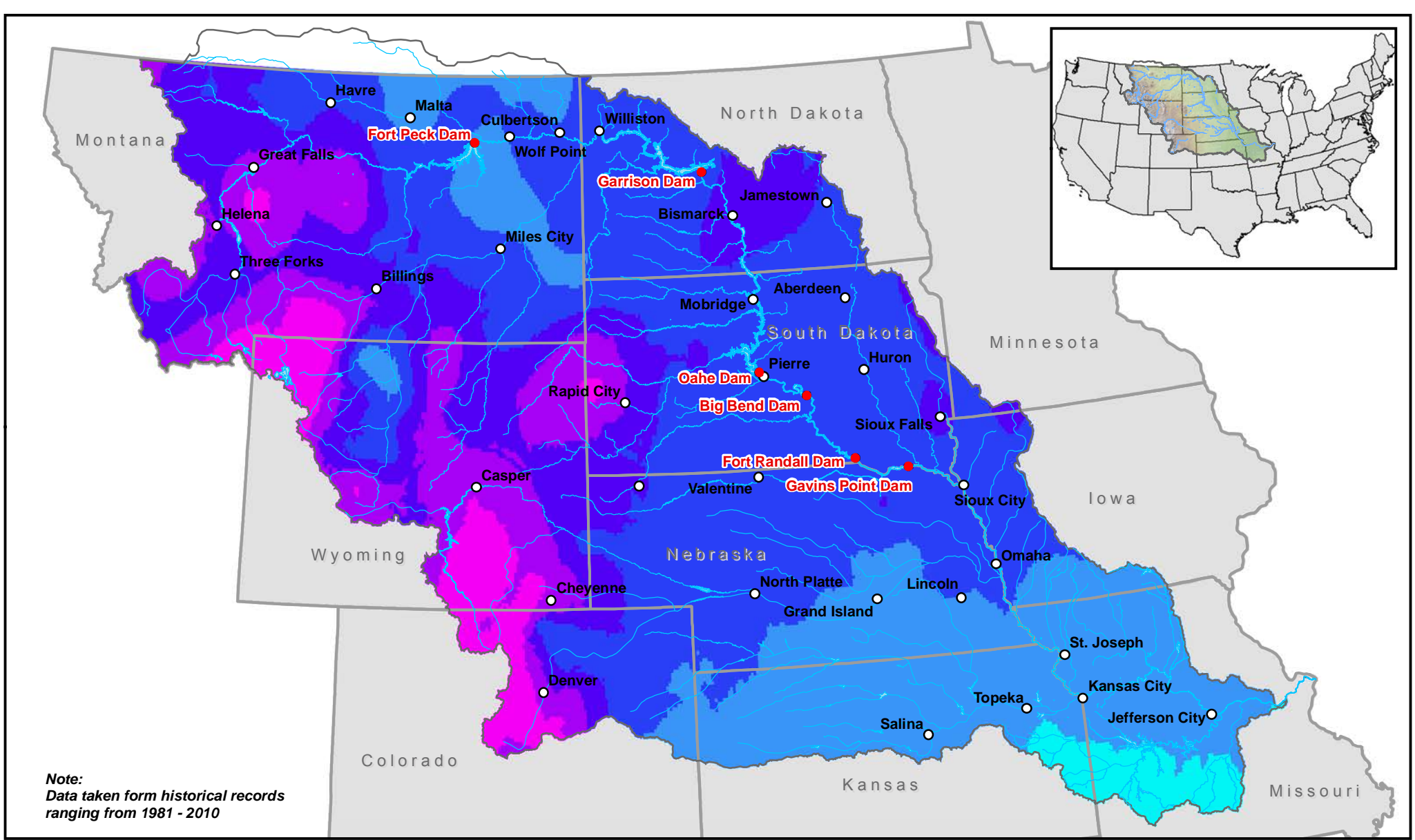
0 50 100 200 300 Miles

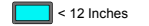
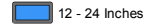
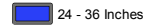
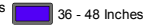
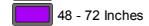
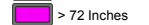
**Data Source:**  
U.S. Department of Agriculture,  
Farm Service Agency 2014

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**Missouri River Basin  
AVERAGE PRECIPITATION  
ANNUAL**


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



● Mainstem Dam	<b>Annual Mean Snowfall</b>
○ Cities	 < 12 Inches
— Rivers	 12 - 24 Inches
— Reservoirs/Lakes	 24 - 36 Inches
— Omaha/Kansas City District Boundaries	 36 - 48 Inches
— State Boundaries	 48 - 72 Inches
	 > 72 Inches

0 50 100 200 300 Miles

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



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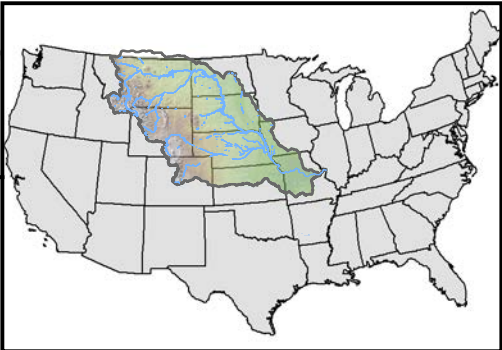
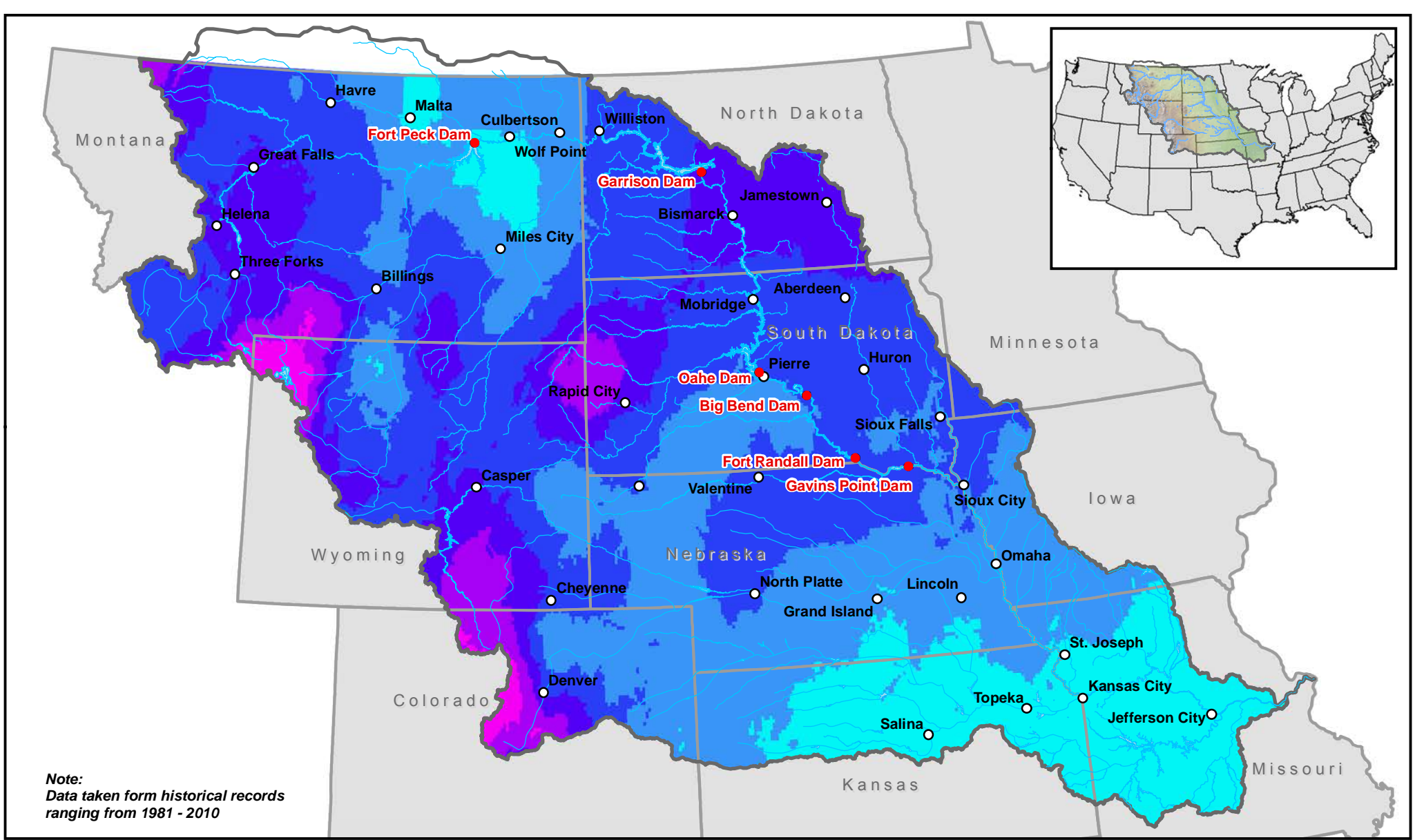


Plate III-6



**US Army Corps of Engineers**  
Northwestern Division

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

**Annual Maximum Snowfall**

Light Blue	< 40 Inches
Blue	40 - 60 Inches
Dark Blue	60 - 80 Inches
Dark Purple	80 - 110 Inches
Medium Purple	110 - 150 Inches
Magenta	> 150 Inches



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



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

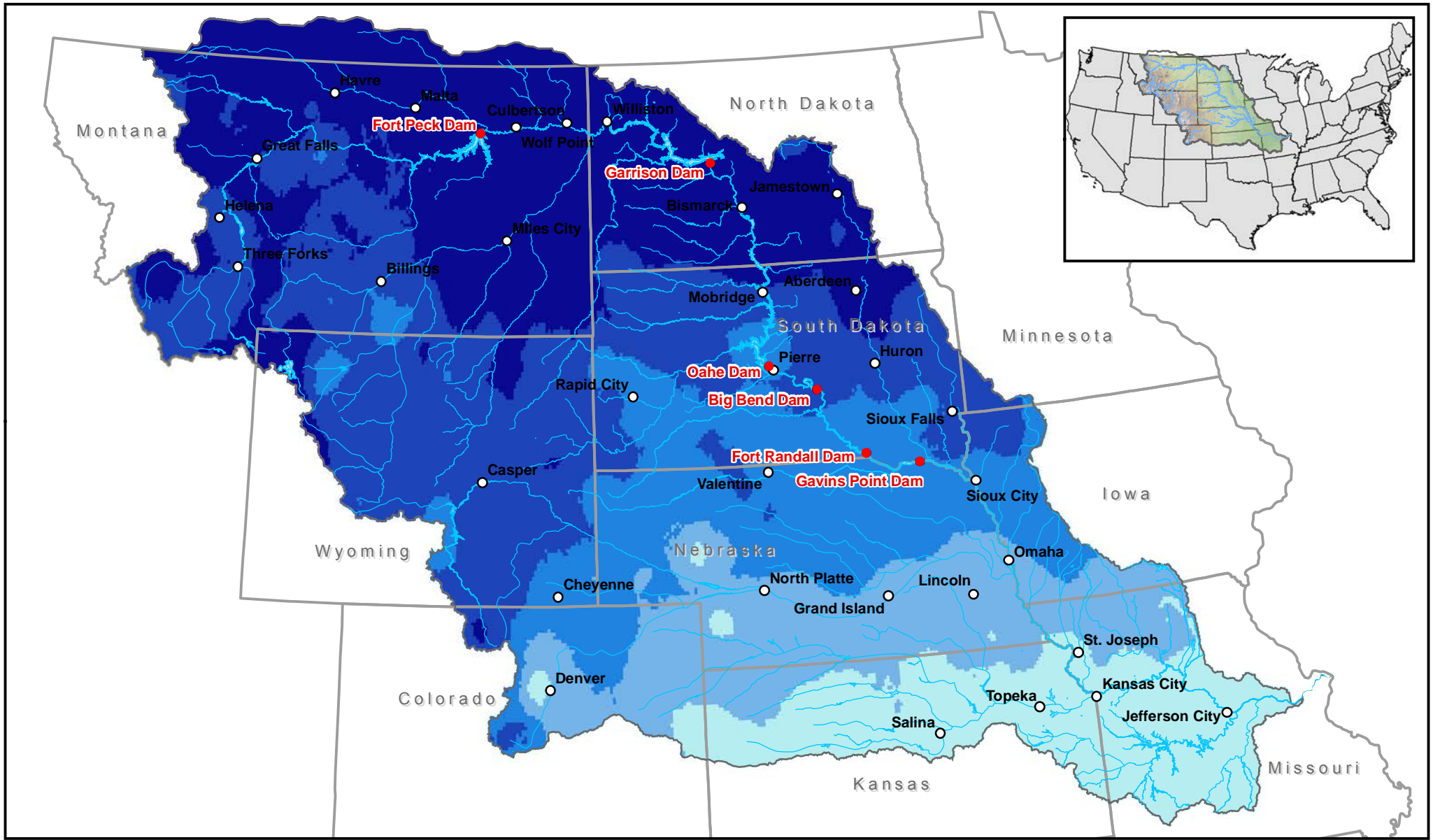


Plate III-7



- 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 -5°F
	-5°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

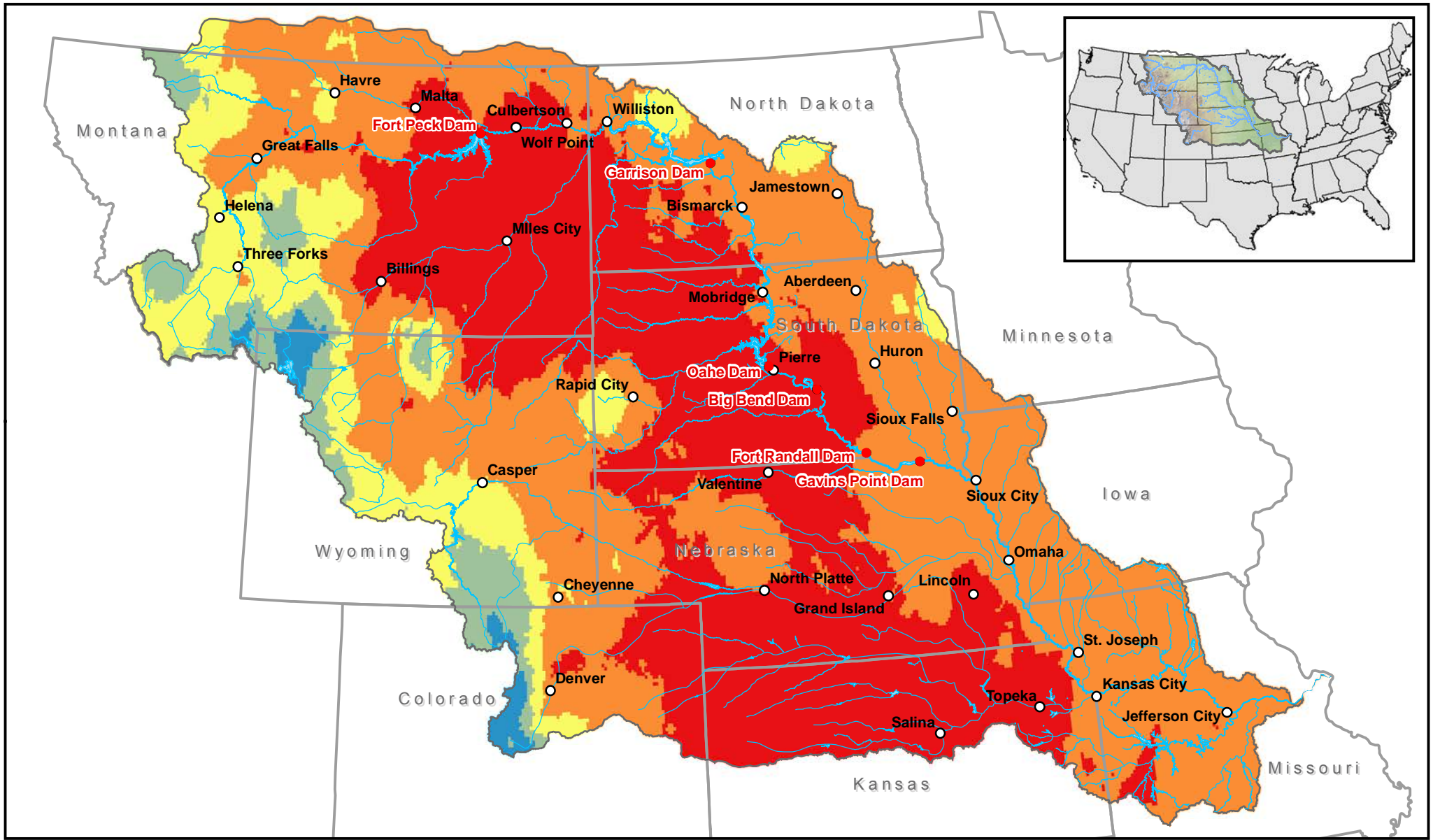


Plate III-8



- 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  
**Garrison 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  
**Garrison 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  
**Garrison 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  
**Garrison 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 Garrison Dam  
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development**

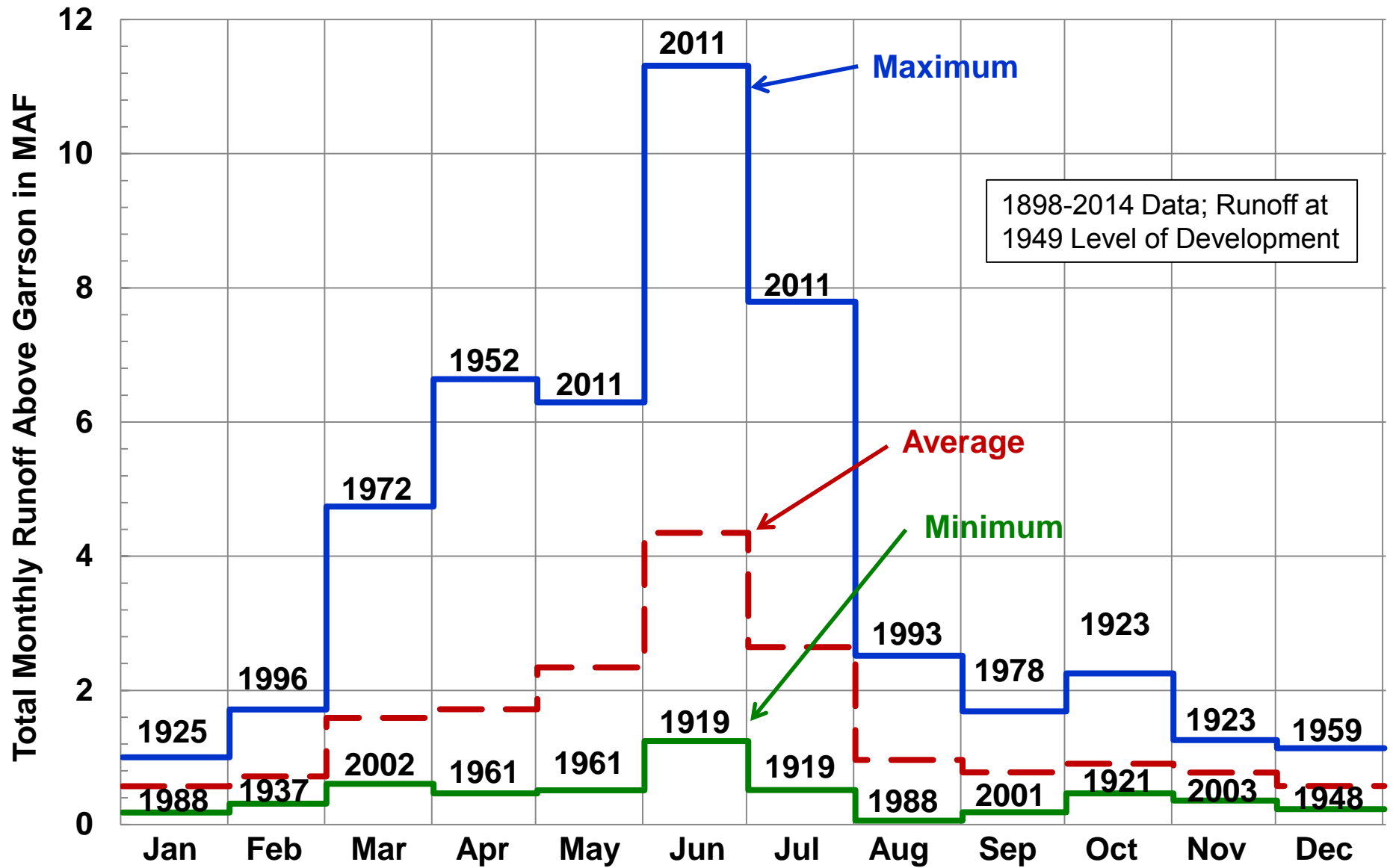
Year	Runoff in 1,000 acre-feet												Annual	Mar-Jul
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Total
1898	551	617	1,137	2,004	3,425	7,048	3,282	892	787	811	648	499	21,701	16,896
1899	504	512	970	4,074	2,676	6,665	5,893	1,244	740	716	821	566	25,381	20,278
1900	646	714	1,898	1,654	3,481	4,380	1,186	396	543	817	623	565	16,903	12,599
1901	498	508	1,478	1,136	4,582	3,957	1,942	601	744	742	691	498	17,377	13,095
1902	502	615	1,678	918	2,328	4,030	2,041	707	705	816	636	490	15,466	10,995
1903	572	710	1,273	1,527	1,664	4,374	2,682	1,059	813	875	726	673	16,948	11,520
1904	674	720	1,319	1,972	3,148	5,292	2,977	1,059	787	710	610	547	19,815	14,708
1905	548	607	1,351	807	1,077	3,884	2,356	790	484	563	599	508	13,574	9,475
1906	566	506	1,270	1,493	2,565	5,474	2,501	1,120	996	732	686	544	18,453	13,303
1907	549	611	1,526	1,432	2,557	6,149	6,314	2,145	1,111	1,105	910	629	25,038	17,978
1908	617	720	1,345	1,591	2,535	8,022	4,624	1,561	996	1,237	948	775	24,971	18,117
1909	710	724	1,561	1,283	2,382	8,024	4,524	1,503	1,343	1,097	819	591	24,561	17,774
1910	672	725	1,975	2,263	3,638	3,439	1,539	819	770	712	696	476	17,724	12,854
1911	405	512	1,444	1,144	1,750	5,570	2,630	1,315	1,333	990	724	529	18,346	12,538
1912	534	605	1,807	3,064	3,030	5,577	3,777	1,827	1,367	1,471	1,192	768	25,019	17,255
1913	669	601	1,232	2,505	3,106	6,718	3,110	1,703	952	1,143	980	700	23,419	16,671
1914	718	708	1,582	1,650	3,456	5,409	2,019	825	813	1,067	972	579	19,798	14,116
1915	579	708	1,656	1,654	2,290	4,726	3,426	1,712	1,375	1,335	904	725	21,090	13,752
1916	696	905	2,741	1,789	2,449	5,736	5,205	1,529	930	958	879	696	24,513	17,920
1917	702	706	1,502	3,228	3,820	6,919	4,822	1,212	976	880	883	701	26,351	20,291
1918	851	805	2,265	2,031	2,337	6,146	2,767	1,230	863	889	769	670	21,623	15,546
1919	770	705	1,479	1,547	1,624	1,244	516	305	365	476	530	541	10,102	6,410
1920	545	718	1,745	1,499	3,261	5,284	3,255	1,033	714	676	756	712	20,198	15,044
1921	574	711	1,475	1,410	2,447	6,221	1,965	609	534	466	569	549	17,530	13,518
1922	552	631	1,627	1,559	2,882	5,484	1,904	912	716	601	718	539	18,125	13,456
1923	544	627	1,269	1,839	2,424	3,688	4,012	1,218	894	2,253	1,259	881	20,908	13,232
1924	971	1,307	1,787	3,382	3,519	3,930	2,226	805	720	948	884	702	21,181	14,844
1925	1,003	1,309	1,968	2,039	3,017	4,956	3,039	1,108	879	1,097	1,000	826	22,241	15,019
1926	827	1,009	1,634	1,995	3,054	2,422	1,860	928	1,019	976	829	720	17,273	10,965
1927	722	918	1,643	1,492	3,739	8,051	3,765	1,843	1,493	1,245	1,073	855	26,839	18,690
1928	769	921	2,089	1,676	4,550	4,334	4,149	1,265	968	903	829	655	23,108	16,798
1929	546	466	1,966	1,642	2,531	4,239	2,245	699	687	841	710	500	17,072	12,623
1930	554	1,045	1,718	2,130	1,902	2,350	1,276	1,101	839	842	713	515	14,985	9,376
1931	438	607	817	772	1,085	2,058	627	563	396	559	403	337	8,662	5,359
1932	394	330	803	1,748	2,325	4,417	2,099	837	672	710	541	444	15,320	11,392
1933	506	424	1,910	1,059	2,540	4,288	1,227	653	837	601	726	308	15,079	11,024
1934	611	886	1,161	1,283	1,547	1,648	536	349	298	486	510	319	9,634	6,175
1935	311	492	706	1,037	1,131	3,378	2,139	631	460	492	394	468	11,639	8,391
1936	356	357	1,432	1,426	1,969	2,366	923	595	440	629	607	454	11,554	8,116
1937	336	312	810	1,032	1,149	2,848	1,724	509	392	669	429	337	10,547	7,563

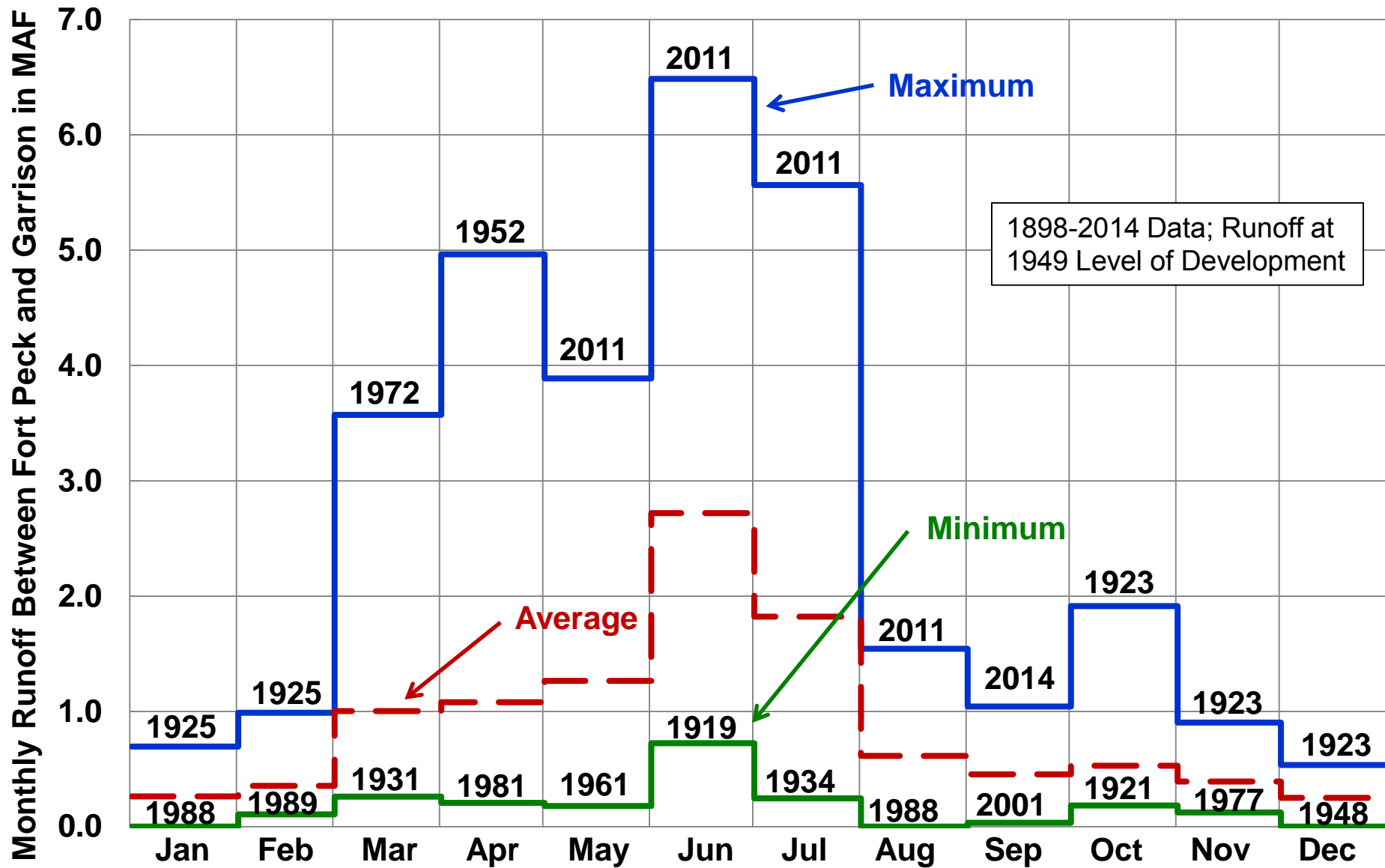
**Monthly Runoff - Missouri River Basin Upstream of Garrison Dam  
For the Years 1898-2014 - Adjusted to 1949 Level of Depletion Development**

Year	Runoff in 1,000 acre-feet												Annual	Mar-Jul
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Total
1938	444	365	1,769	904	1,770	4,871	3,487	782	710	689	593	330	16,714	12,801
1939	595	367	2,944	1,267	2,115	3,108	1,148	517	458	670	609	494	14,292	10,582
1940	343	452	726	1,236	1,619	2,345	871	416	389	863	446	611	10,317	6,797
1941	474	490	750	1,073	1,255	2,719	1,006	952	1,265	1,395	948	791	13,118	6,803
1942	550	659	1,599	1,714	2,541	5,024	2,225	821	625	771	821	551	17,901	13,103
1943	621	1,409	2,509	3,981	2,404	6,540	4,078	1,317	835	974	881	553	26,102	19,512
1944	591	617	1,598	2,519	1,793	6,086	3,383	942	704	799	755	520	20,307	15,379
1945	613	708	2,019	990	1,393	3,637	2,763	962	796	843	621	534	15,879	10,802
1946	766	728	1,539	1,159	1,640	2,991	2,097	649	851	1,075	743	732	14,970	9,426
1947	701	948	2,904	2,678	3,318	4,303	3,003	1,242	837	1,073	778	661	22,446	16,206
1948	657	617	1,460	2,196	2,874	6,766	3,096	1,124	661	825	728	228	21,232	16,392
1949	547	518	2,061	2,477	2,275	3,113	1,477	562	511	833	888	381	15,643	11,403
1950	528	664	1,132	3,242	1,769	4,063	3,199	1,357	1,029	1,229	703	808	19,723	13,405
1951	793	697	1,307	2,993	2,708	3,706	2,691	1,572	1,371	1,356	1,082	506	20,782	13,405
1952	729	1,002	1,096	6,638	3,780	3,611	1,980	1,003	756	772	761	523	22,651	17,105
1953	592	719	945	964	1,692	6,900	2,366	976	693	763	853	587	18,050	12,867
1954	473	1,019	1,024	1,762	1,916	2,390	2,349	1,034	742	689	798	530	14,726	9,441
1955	324	513	763	2,212	2,096	2,994	2,109	802	493	709	477	704	14,196	10,174
1956	763	581	1,275	1,638	2,144	4,654	1,785	917	746	682	853	569	16,607	11,496
1957	466	578	1,256	1,268	2,249	4,872	2,726	795	877	959	991	724	17,761	12,371
1958	599	530	1,062	1,219	1,750	3,314	1,721	750	645	741	717	642	13,690	9,066
1959	547	542	3,022	1,399	1,467	3,403	2,274	654	640	1,037	847	1,139	16,971	11,565
1960	531	826	2,403	2,028	1,525	2,071	772	449	486	547	616	463	12,717	8,799
1961	510	553	820	463	510	2,352	604	365	618	901	854	402	8,952	4,749
1962	507	984	982	1,677	2,436	4,658	3,197	1,159	790	981	820	588	18,779	12,950
1963	421	1,188	1,438	963	1,739	4,850	2,266	704	838	806	693	421	16,327	11,256
1964	527	603	729	972	2,339	6,085	3,858	785	912	790	738	559	18,897	13,983
1965	855	855	1,084	3,094	3,388	5,302	5,096	1,593	1,327	1,436	1,061	776	25,867	17,964
1966	532	613	1,748	1,300	1,591	1,974	1,441	527	628	684	771	581	12,390	8,054
1967	493	885	1,715	2,005	2,412	7,396	4,782	928	965	944	986	464	23,975	18,310
1968	697	816	1,986	1,036	1,449	4,897	2,914	1,414	1,441	1,141	1,126	629	19,546	12,282
1969	648	687	2,295	3,382	2,960	3,072	3,897	943	649	774	907	592	20,806	15,606
1970	354	787	1,166	1,453	3,736	5,689	3,401	899	861	1,061	801	624	20,832	15,445
1971	584	1,703	2,270	2,367	2,718	5,293	3,528	1,146	1,182	1,479	1,038	592	23,900	16,176
1972	579	878	4,740	1,555	2,274	5,242	2,252	1,490	1,088	1,122	1,182	601	23,003	16,063
1973	682	668	1,366	1,112	2,358	3,112	1,652	769	1,181	1,057	854	753	15,564	9,600
1974	707	887	1,194	1,643	2,286	5,402	3,496	1,224	968	788	957	697	20,249	14,021
1975	399	441	1,304	2,670	5,387	6,104	6,515	1,771	1,096	1,163	1,040	949	28,839	21,980
1976	895	1,244	2,049	1,809	3,700	4,866	3,093	1,432	1,049	1,047	902	725	22,811	15,517
1977	349	733	1,017	1,026	1,453	1,817	740	510	782	926	460	631	10,444	6,053

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

Year	Runoff in 1,000 acre-feet												Annual	Mar-Jul
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Total
1978	416	504	3,448	3,923	4,553	5,155	4,475	1,419	1,686	1,187	650	713	28,129	21,554
1979	484	644	3,227	4,435	2,872	3,326	1,784	810	869	640	772	526	20,389	15,644
1980	349	494	1,035	1,305	1,904	3,573	1,795	588	829	1,126	932	487	14,417	9,612
1981	780	642	1,027	680	2,400	5,157	1,788	595	334	843	959	555	15,760	11,052
1982	296	957	1,872	2,277	1,977	4,987	4,563	1,474	961	1,505	1,061	870	22,800	15,676
1983	795	1,049	1,531	992	1,586	3,468	3,091	947	658	1,241	1,141	357	16,856	10,668
1984	762	1,001	1,217	1,160	2,330	3,805	2,779	1,162	706	1,178	1,037	415	17,552	11,291
1985	645	485	1,478	1,407	1,358	1,717	715	825	707	1,342	784	649	12,112	6,675
1986	772	601	3,525	1,240	2,648	4,471	2,168	705	1,571	1,836	890	880	21,307	14,052
1987	488	761	1,278	1,280	1,435	1,750	985	896	771	660	682	369	11,355	6,728
1988	179	503	1,013	733	1,485	1,666	652	59	206	515	485	448	7,944	5,549
1989	276	321	1,556	1,774	2,270	2,549	1,507	614	685	785	914	370	13,621	9,656
1990	751	481	1,291	1,105	1,586	2,682	1,963	699	503	590	793	295	12,739	8,627
1991	425	561	902	820	2,385	5,469	2,772	551	709	744	850	550	16,738	12,348
1992	434	618	935	753	1,128	1,797	2,249	708	516	758	768	270	10,934	6,862
1993	323	564	1,588	1,267	2,179	3,860	3,989	2,516	1,180	1,114	940	854	20,374	12,883
1994	596	556	3,029	1,309	2,625	2,097	743	292	315	824	574	466	13,426	9,803
1995	398	722	1,388	1,024	2,597	5,123	4,190	1,056	646	906	857	668	19,575	14,322
1996	629	1,716	2,460	2,521	2,487	5,719	2,910	688	468	737	608	724	21,667	16,097
1997	779	1,228	2,607	2,605	3,109	7,675	4,148	1,857	1,080	983	1,042	885	27,998	20,144
1998	435	1,066	1,167	1,426	1,687	3,022	3,878	1,286	739	1,254	1,055	567	17,582	11,180
1999	834	924	2,173	1,317	2,195	4,751	2,942	984	824	842	807	611	19,204	13,378
2000	480	661	1,097	784	1,108	2,683	1,611	443	307	826	516	420	10,936	7,283
2001	661	497	1,449	1,046	969	1,864	1,445	501	184	508	462	395	9,981	6,773
2002	390	462	607	1,049	933	3,305	1,987	720	452	679	496	390	11,470	7,881
2003	343	610	1,955	1,188	1,446	3,475	1,530	527	255	521	358	521	12,729	9,594
2004	372	472	1,489	962	768	2,104	1,737	652	503	761	639	361	10,820	7,060
2005	406	705	876	697	1,844	3,649	2,669	693	357	784	626	295	13,601	9,735
2006	853	476	940	1,495	1,873	3,162	1,349	532	288	796	617	370	12,751	8,819
2007	440	573	1,544	1,133	2,265	3,454	1,260	552	290	634	502	362	13,009	9,656
2008	391	457	849	812	1,704	5,400	4,047	1,108	754	895	646	489	17,552	12,812
2009	759	692	1,577	1,866	2,339	4,511	3,242	1,145	845	908	758	547	19,189	13,535
2010	649	604	1,336	1,090	1,872	5,340	3,780	1,075	932	891	548	642	18,759	13,418
2011	729	1,037	2,446	3,557	6,295	11,310	7,794	2,177	945	1,101	784	814	38,989	31,402
2012	580	994	1,362	1,159	1,941	3,305	1,951	744	258	634	700	496	14,124	9,718
2013	477	682	1,035	1,471	1,675	4,870	2,050	905	602	1,149	644	543	16,103	11,101
2014	796	677	2,626	1,785	2,938	5,471	3,515	2,067	1,477	1,086	496	987	23,921	16,335





Missouri River Basin  
**Garrison Water Control Manual**  
 Monthly Runoff Between Fort Peck  
 and Garrison  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

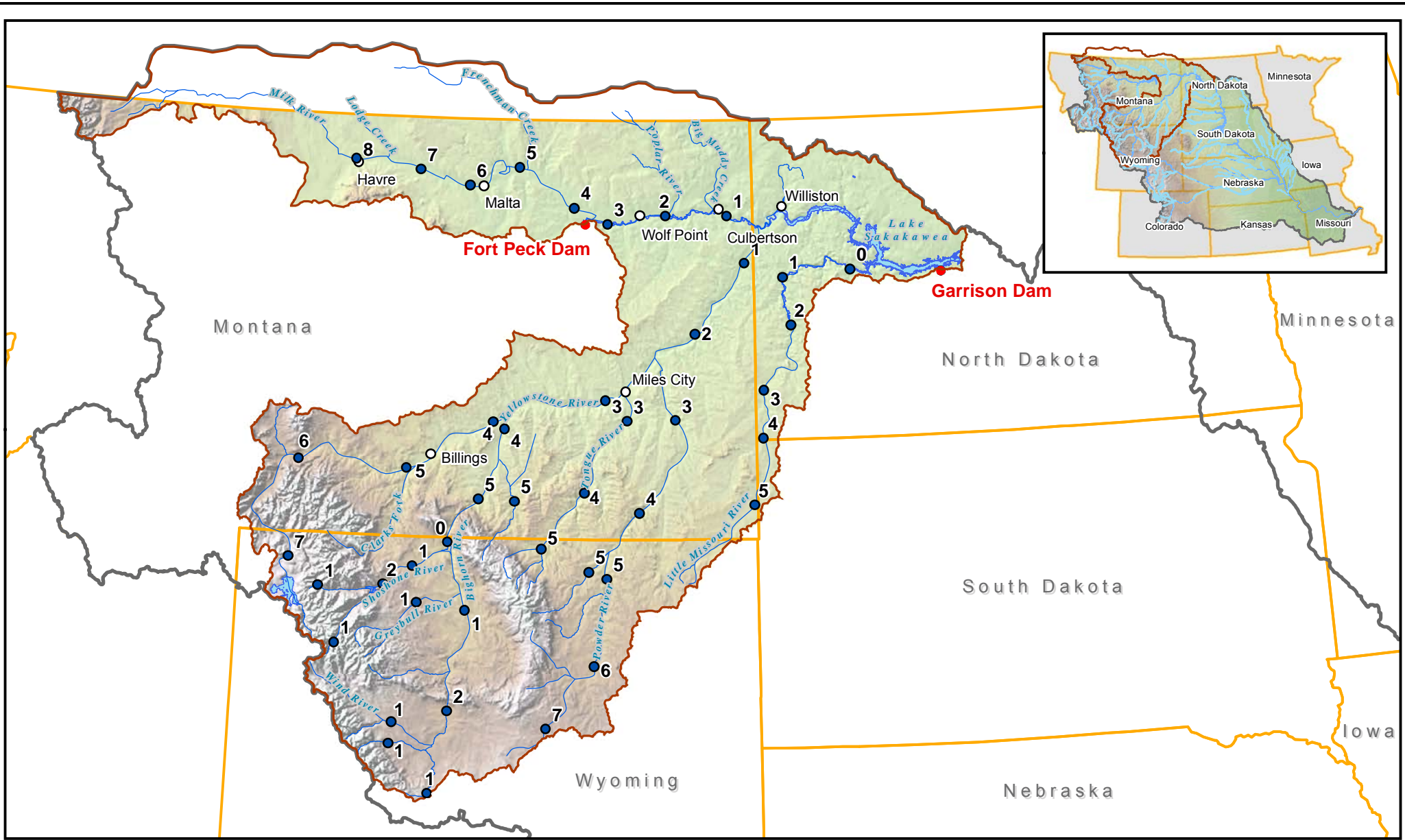


Plate III-16



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

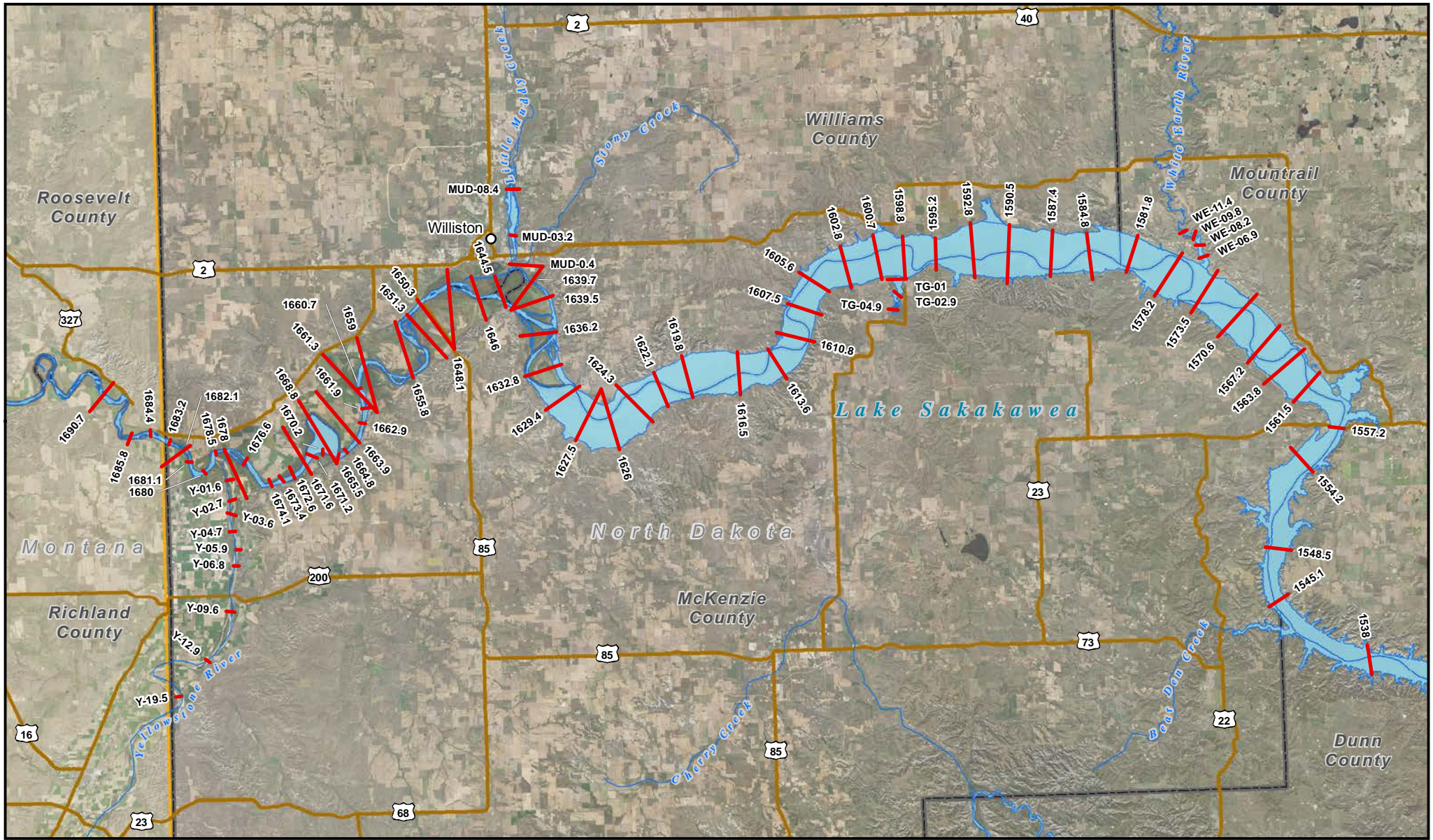
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Imagery Source:  
U.S. Department of Agriculture,  
Farm Service Agency 2014

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**Missouri River Basin  
GARRISON DRAINAGE AREA  
TRAVEL TIMES**









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



**Plate III-17**




**US Army Corps of Engineers**  
Northwestern Division

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

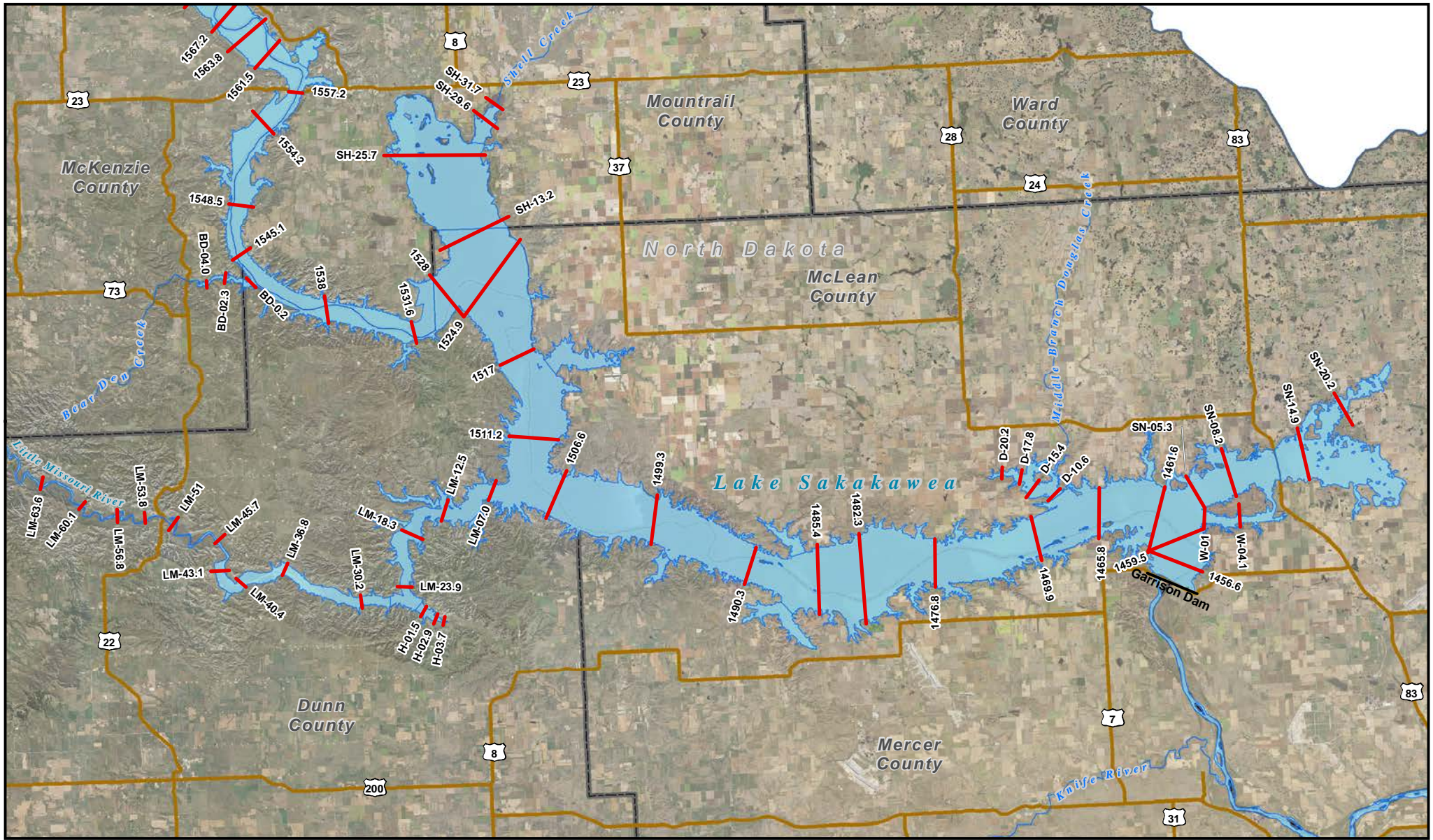
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Imagery Source:  
U.S. Department of Agriculture,  
Farm Service Agency 2015



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



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



Imagery Source:  
 U.S. Department of Agriculture,  
 Farm Service Agency 2015



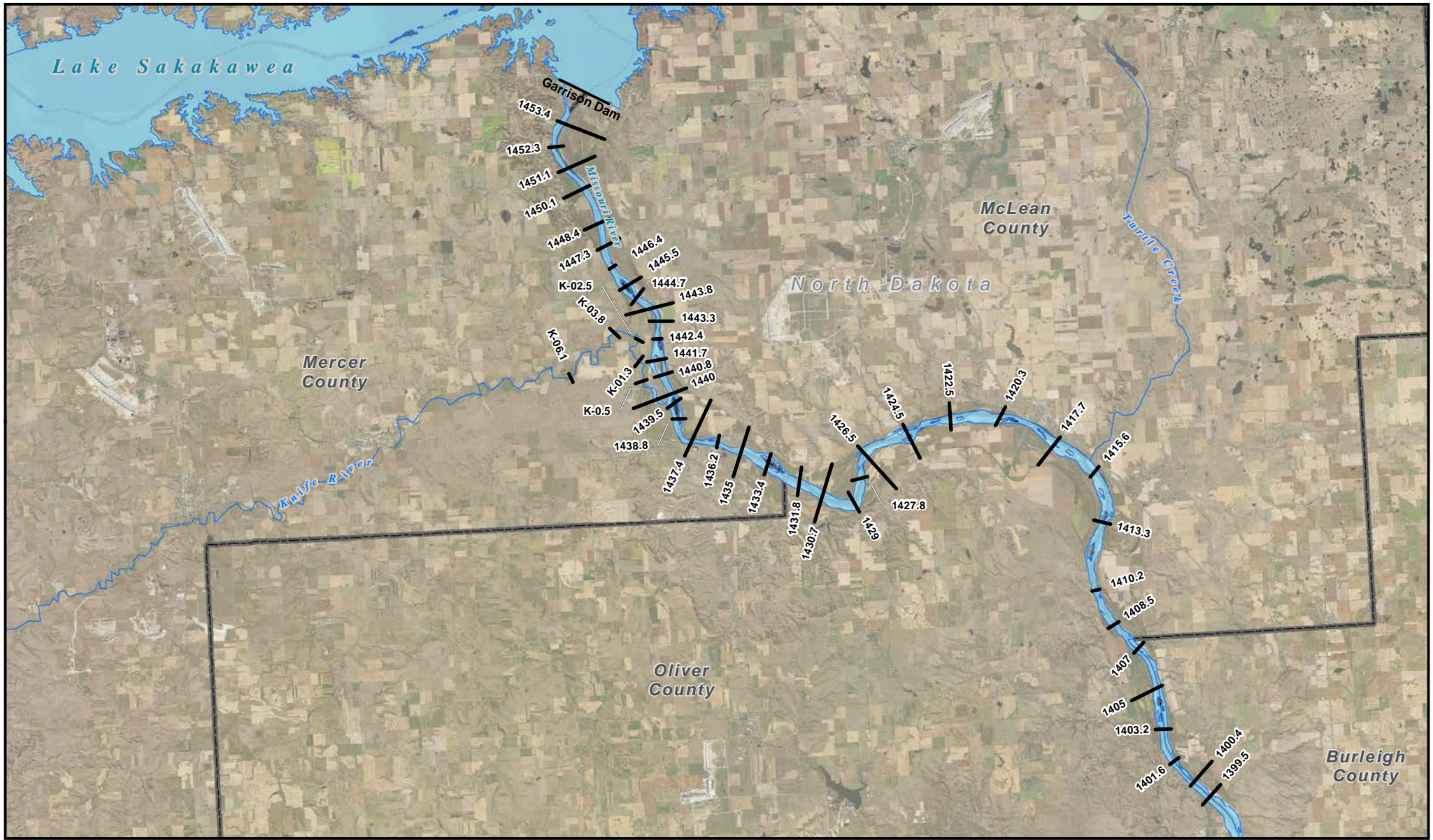
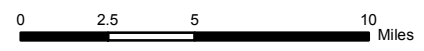


Plate III-19



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



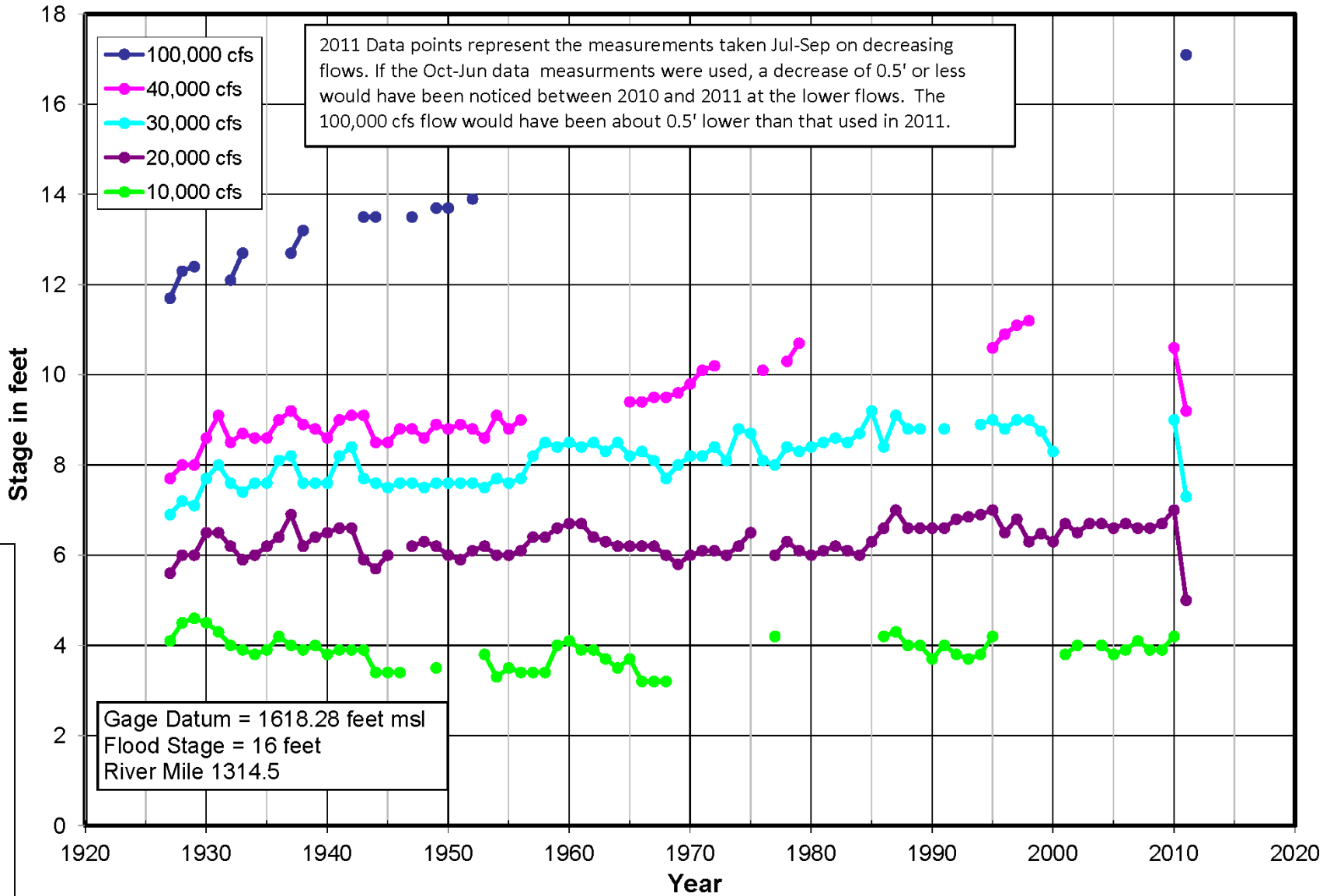
Imagery Source:  
U.S. Department of Agriculture,  
Farm Service Agency 2015



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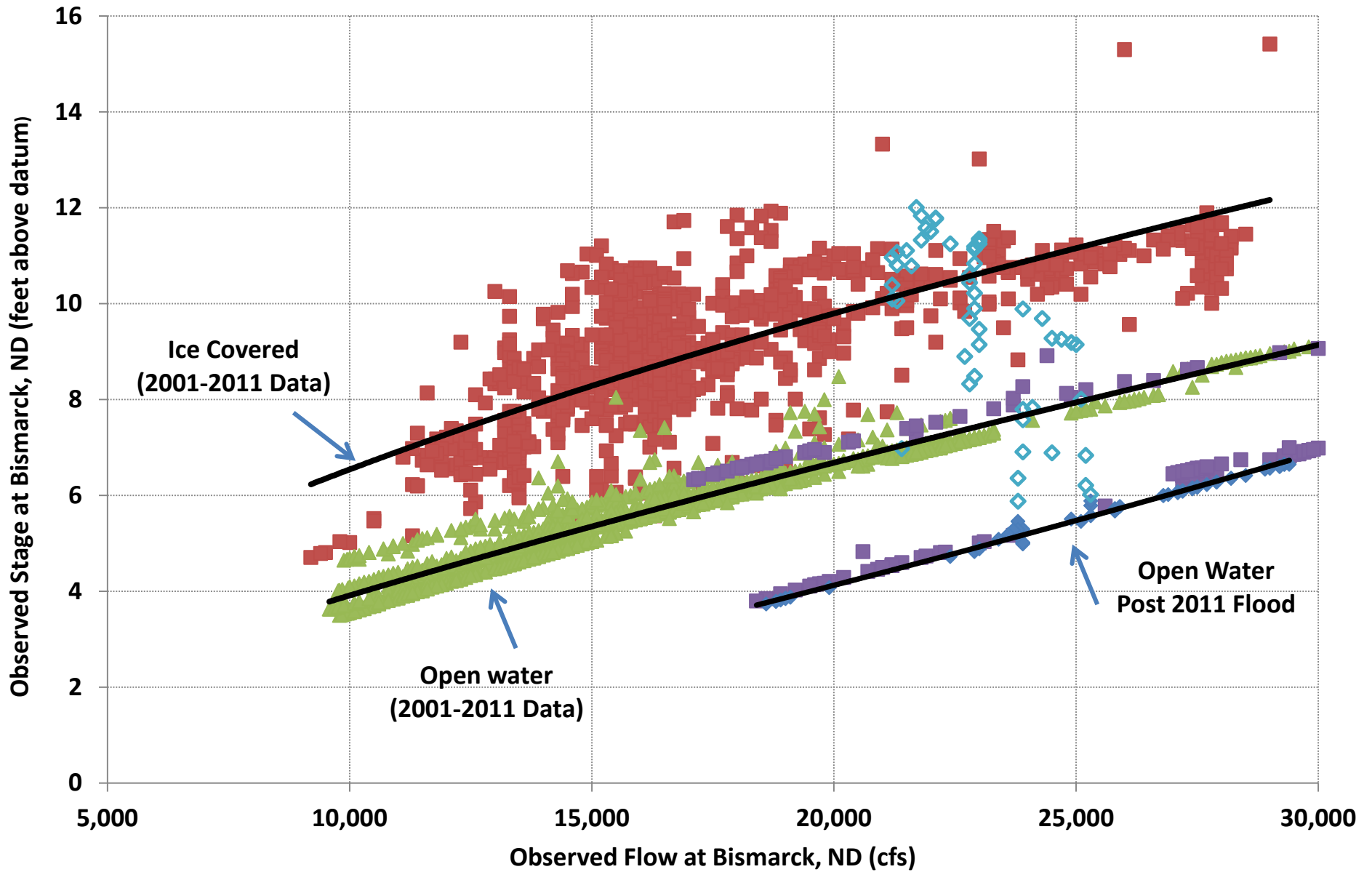
**Missouri River Basin  
GARRISON PROJECT  
SEDIMENT RANGE MAP**  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017

# Missouri River Stage Trends - Missouri River at Bismarck, ND



Missouri River Basin  
**Garrison Water Control Manual**  
 Bismarck Stage Trends  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

Source: Missouri River Water Management Division  
 Missouri River Stage Trends – August 2012



■ Ice thru to 2011    ▲ Open water prior to 2011    ■ 2011 open water    ◆ 2012 open water    ◆ 2012 Ice Cover

Graph from "Review of Ice Formation on the Missouri River at Bismarck, ND" report prepared by the Engineer Research and Development (ERDC) Cold Regions Research and Engineering Laboratory (CRREL).

Missouri River Basin  
**Garrison Water Control Manual**  
 Partial Bismarck Rating Curve –  
 Ice-Affected and Open Water  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

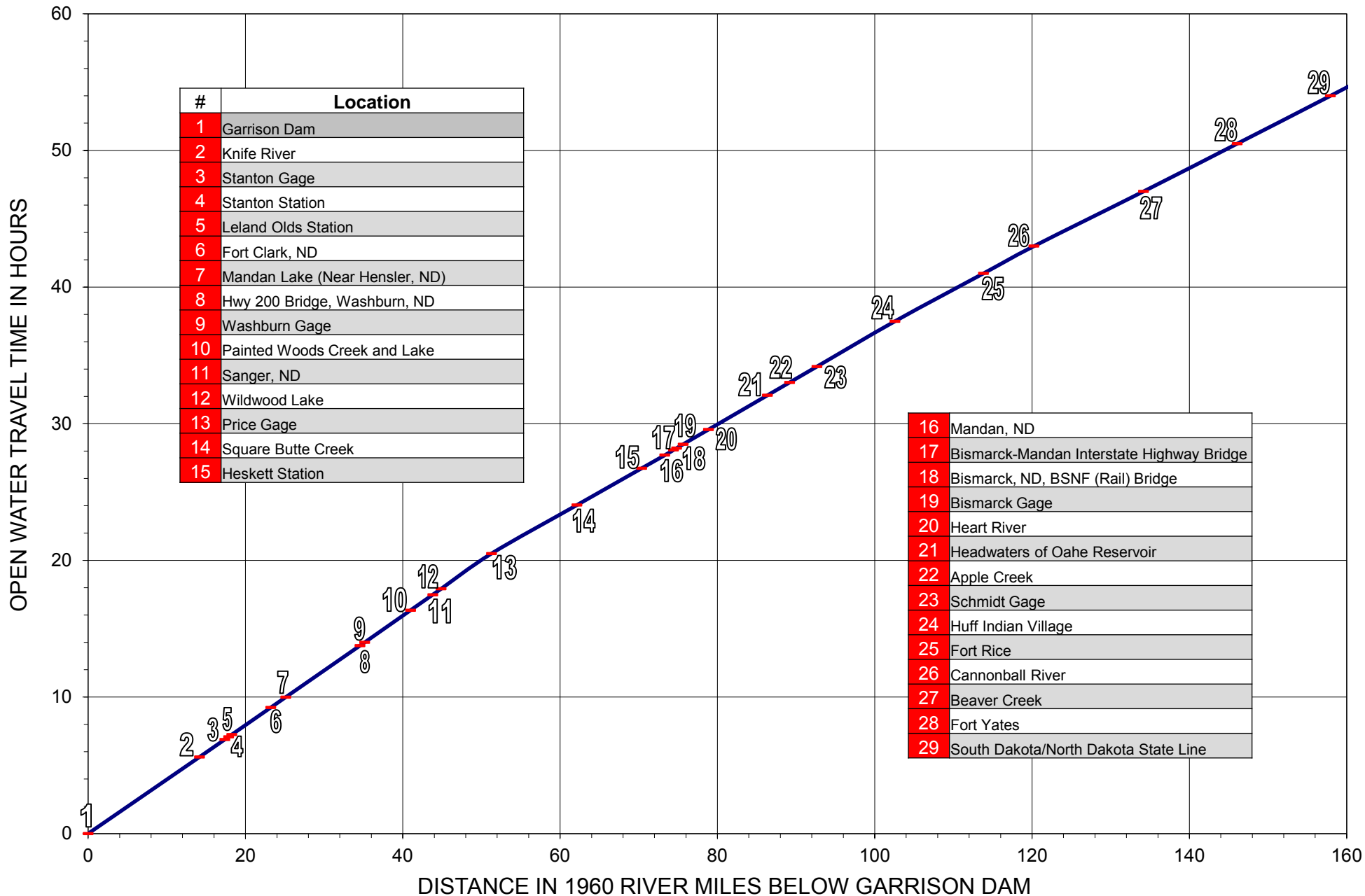


Plate III-22

Missouri River Basin  
**Garrison Water Control Manual**  
 Open Water Travel Time  
 Below Garrison Dam, Missouri River  
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017



Plate IV-1

Missouri River Basin  
**Garrison Water Control Manual**  
Reservoir, Embankment, Intakes,  
Powerhouse and Spillway  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017



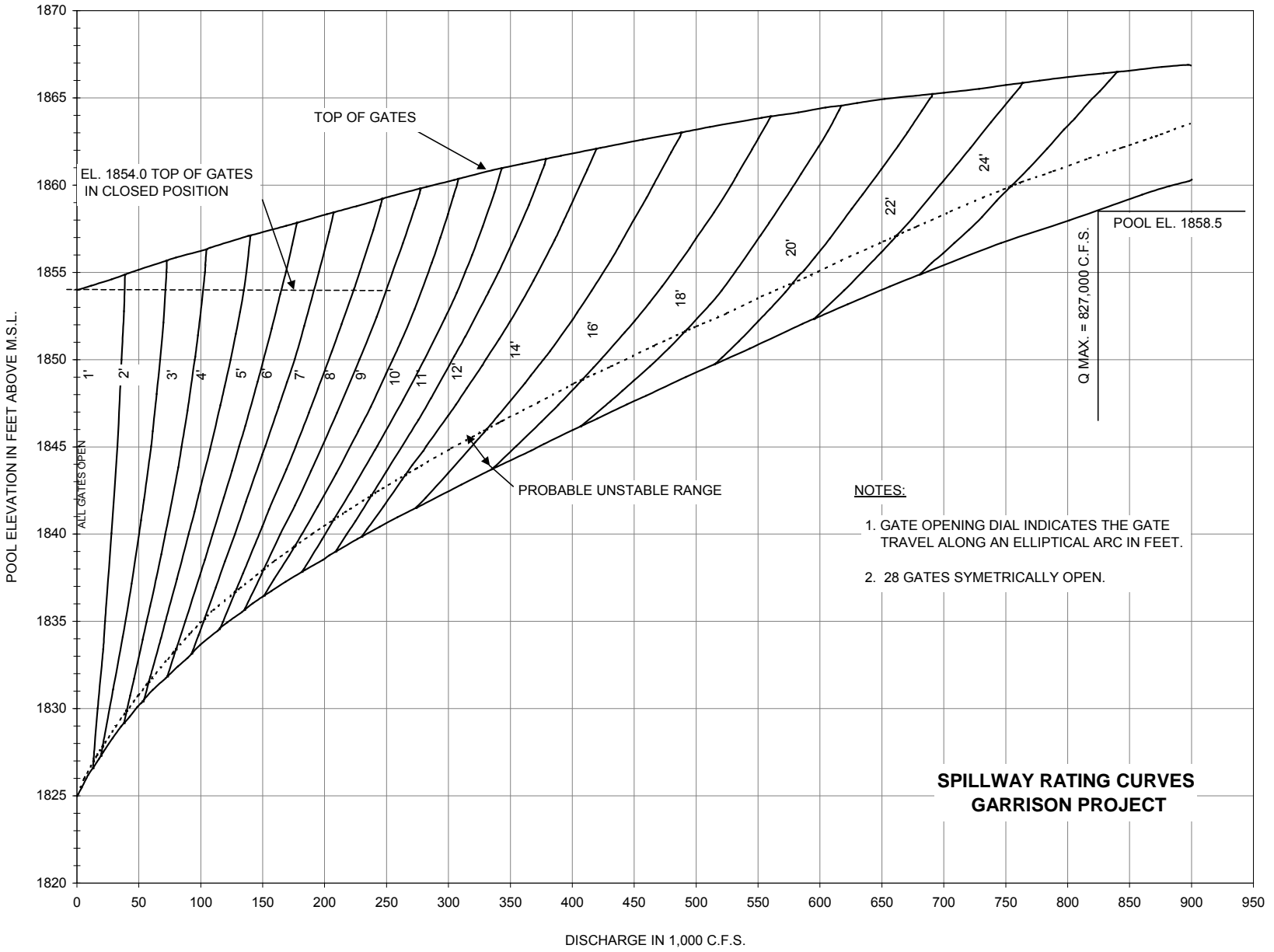


Missouri River Basin  
**Garrison Water Control Manual**  
**Spillway Gates**

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



Missouri River Basin  
**Garrison Water Control Manual**  
Spillway Gates and Discharge Chute  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017



**NOTES:**

- 1. GATE OPENING DIAL INDICATES THE GATE TRAVEL ALONG AN ELLIPTICAL ARC IN FEET.
- 2. 28 GATES SYMETRICALLY OPEN.

**SPILLWAY RATING CURVES  
GARRISON PROJECT**

**Missouri River Basin**  
**Garrison Water Control Manual**  
**Spillway Rating Curves**  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

Missouri River Basin  
**Garrison Water Control Manual**  
Flood Control Tunnels Rating Curve  
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
CORPS OF ENGINEERS, OMAHA, NEBRASKA  
September 2017

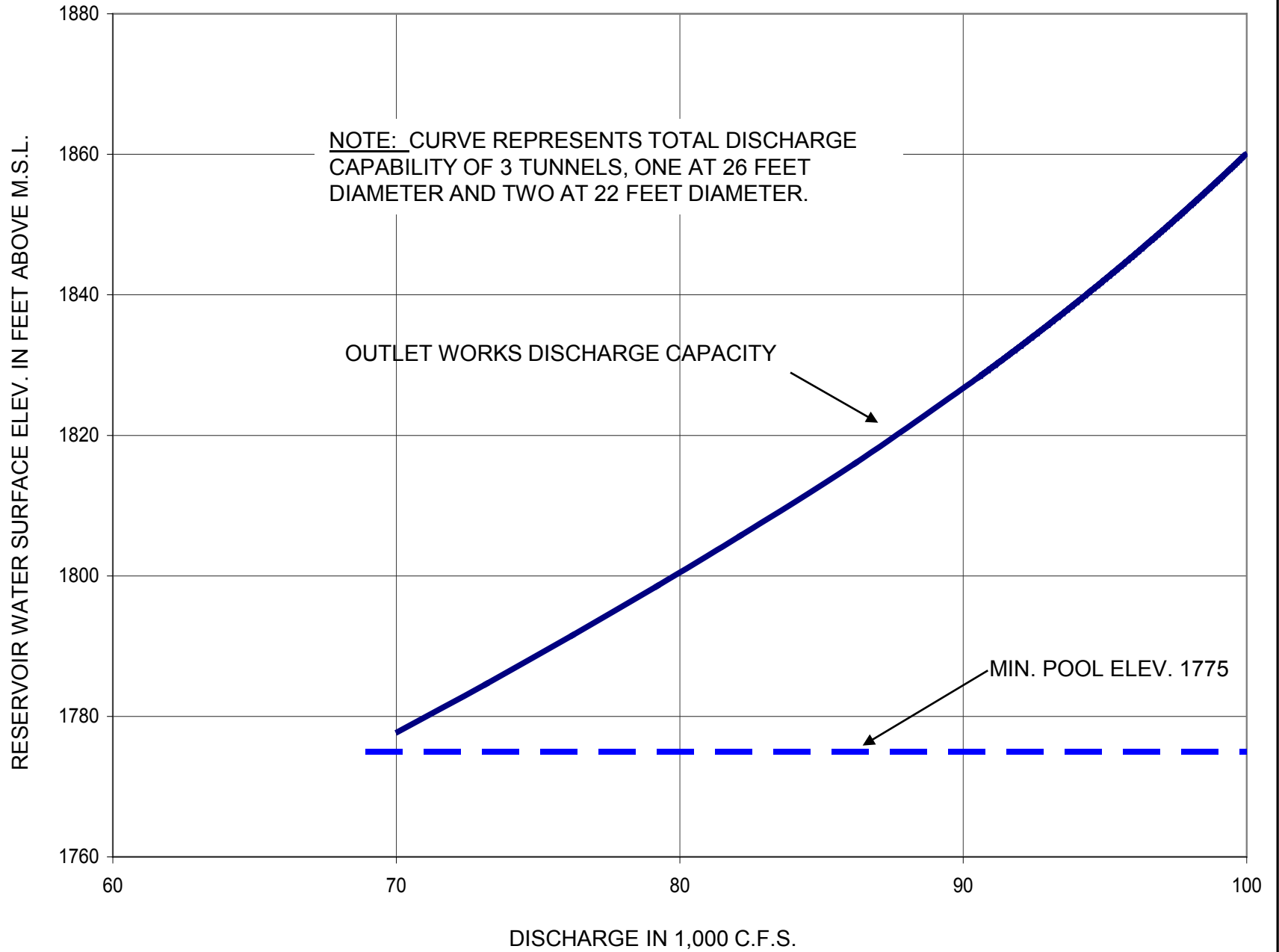
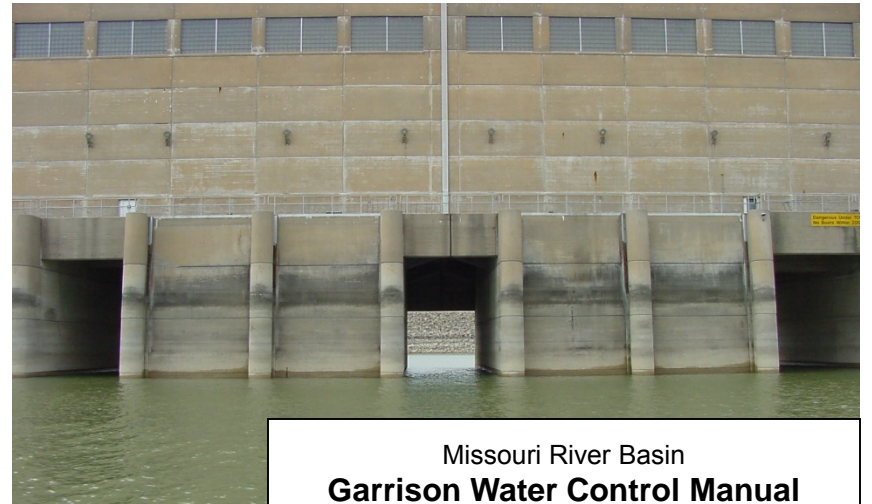




Plate IV-7

Missouri River Basin  
**Garrison Water Control Manual**  
Surge Tanks  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017





Missouri River Basin  
**Garrison Water Control Manual**  
Intake Structure

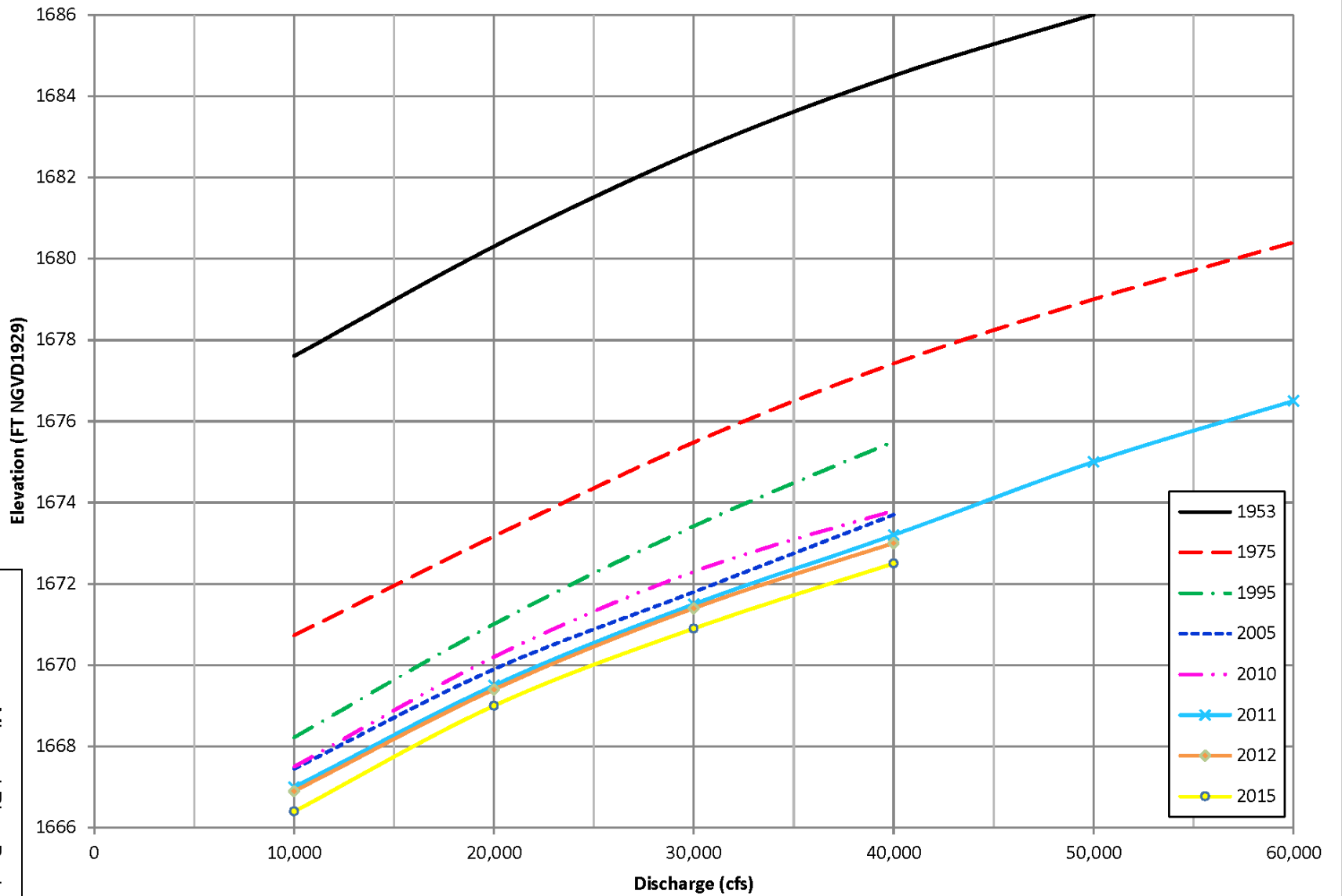
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017



Missouri River Basin  
**Garrison Water Control Manual**  
Generators

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

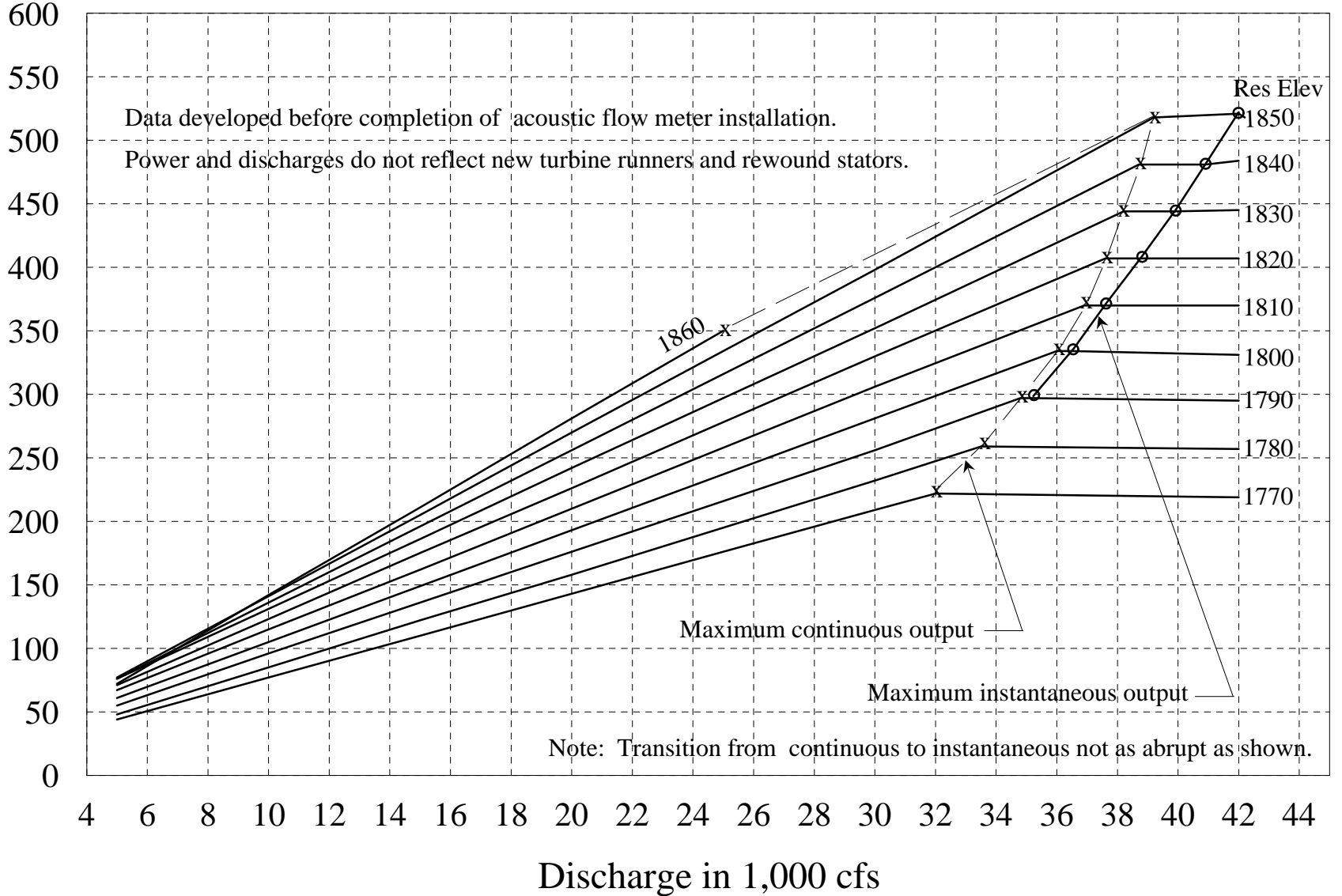
# Garrison Tailwater Rating Curves



Missouri River Basin  
**Garrison Water Control Manual**  
**Garrison Tailwater Rating Curves**  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

# Garrison Powerplant

Power in MW



Missouri River Basin

Garrison Water Control Manual

**Garrison Powerplant Characteristics**

U.S. Army Engineer Division, Northwestern

Corps of Engineers, Omaha, Nebraska

September 2017

Plate IV-12

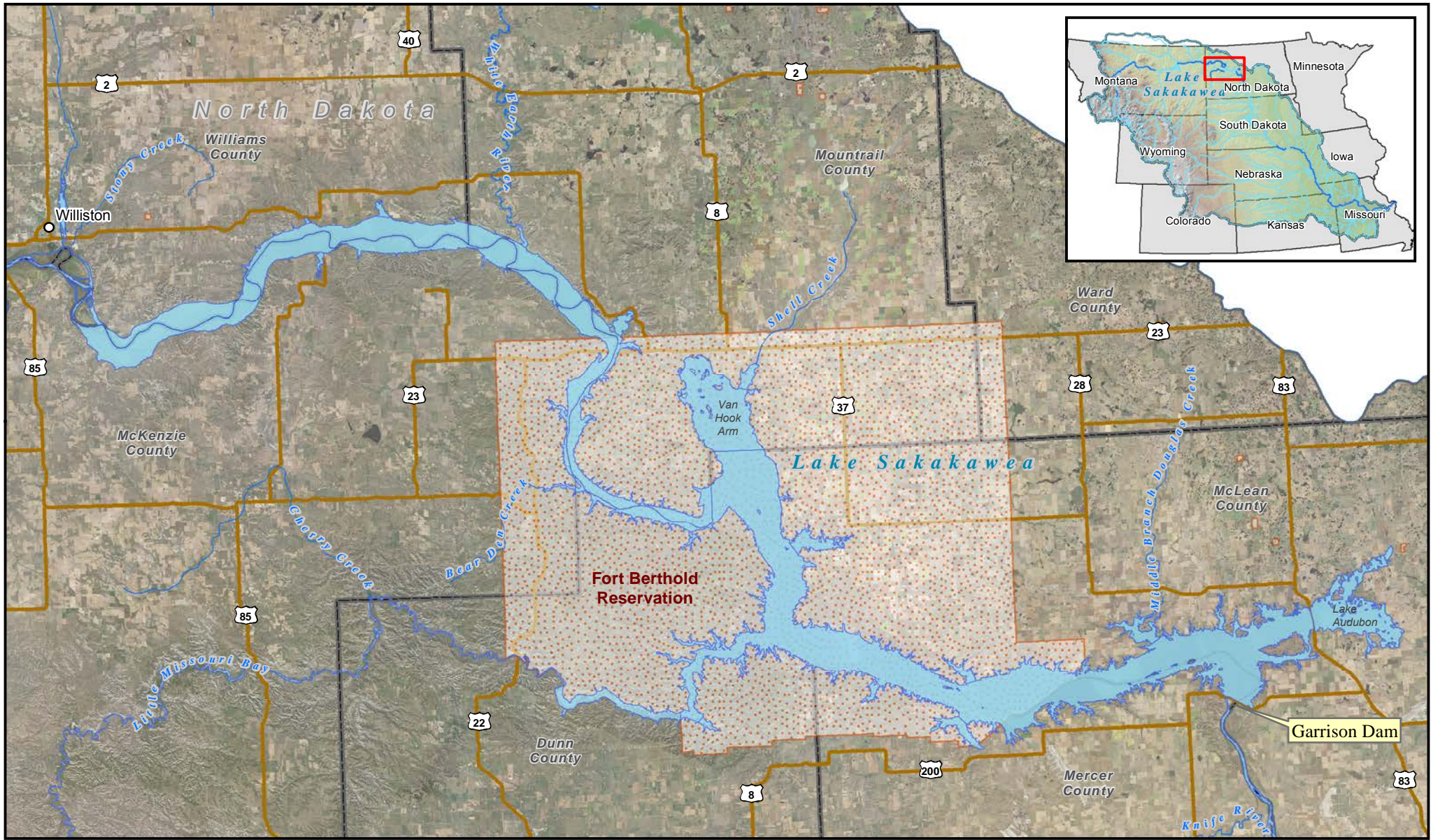


Plate IV-13



- Cities
- Rivers
- Roads
- ▣ Reservoirs/Lakes
- ▣ State Boundaries
- ▣ County Boundaries
- ▣ Reservations

0 5 10 20 30 Miles

Imagery Source:  
U.S. Department of Agriculture,  
Farm Service Agency 2015

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

**Garrison Area and Capacity Tables**

**Surface Area in Acres**

**(2010-2012 Survey Data)**

ELEV	0	1	2	3	4	5	6	7	8	9
1660.0	0	0	0	0	0	0	0	0	0	0
1670.0	7	6	6	22	52	97	156	231	320	424
1680.0	460	374	285	286	378	561	834	1198	1654	2199
1690.0	2632	2770	2853	3098	3504	4072	4802	5693	6745	7959
1700.0	9136	10046	10840	11702	12631	13628	14691	15823	17023	18289
1710.0	19492	20509	21482	22548	23707	24957	26300	27735	29263	30882
1720.0	32467	33880	35228	36632	38092	39608	41179	42807	44491	46231
1730.0	47931	49495	51023	52610	54257	55964	57731	59558	61443	63389
1740.0	65344	67235	69081	70921	72757	74587	76413	78233	80048	81858
1750.0	83684	85542	87400	89238	91054	92848	94621	96372	98101	99808
1760.0	101552	103378	105217	107006	108745	110434	112074	113663	115203	116693
1770.0	118070	119337	120653	122114	123719	125469	127364	129403	131587	133915
1780.0	136204	138246	140185	142191	144266	146409	148619	150897	153243	155658
1790.0	157953	159974	161958	164109	166427	168911	171561	174379	177362	180513
1800.0	183545	186177	188699	191397	194272	197322	200549	203949	207531	211285
1810.0	215125	218875	222480	225995	229410	232725	235955	239085	242115	245055
1820.0	247910	250750	253670	256700	259830	263065	266405	269850	273395	277050
1830.0	280485	283445	286360	289570	293080	296890	301000	305415	310135	315145
1840.0	320190	324895	329365	333835	338300	342750	347200	351645	356080	360510
1850.0	364935	369370	373810	378255	382695	387135	391580	396015	400455	404900
1860.0	409343									

**Garrison Area and Capacity Tables**

**Capacity in Acre-Feet**

**Implemented by MRBWM August 2013 (2010-2012 Survey Data)**

ELEV	0	1	2	3	4	5	6	7	8	9
1660.0	0	0	0	0	0	0	0	0	0	0
1670.0	5	15	18	28	62	133	256	446	718	1087
1680.0	1566	2008	2315	2578	2887	3334	4009	5002	6406	8310
1690.0	10805	13574	16345	19281	22542	26290	30687	35895	42074	49386
1700.0	57993	67659	78085	89340	101489	114602	128745	143985	160392	178031
1710.0	196970	217015	237988	259980	283085	307394	332999	359994	388470	418520
1720.0	450235	483455	517996	553912	591260	630096	670476	712455	756091	801438
1730.0	848553	897300	947544	999346	1052765	1107861	1164694	1223324	1283810	1346211
1740.0	1410589	1476900	1545060	1615062	1686903	1760577	1836078	1913403	1992545	2073500
1750.0	2156262	2240869	2327346	2415670	2505822	2597779	2691519	2787021	2884263	2983223
1760.0	3083880	3186327	3290637	3396761	3504649	3614251	3725518	3838399	3952844	4068805
1770.0	4186230	4304945	4424905	4546252	4669133	4793691	4920072	5048420	5178879	5311594
1780.0	5446709	5584003	5723202	5864373	6007584	6152905	6300402	6450143	6602196	6756630
1790.0	6913512	7072536	7233461	7396453	7561680	7729308	7899502	8072431	8248260	8427156
1800.0	8609286	8794246	8981641	9171645	9364436	9560189	9759081	9961287	10166980	10376350
1810.0	10589550	10806600	11027300	11251560	11479290	11710380	11944740	12182290	12422910	12666520
1820.0	12913020	13162340	13414520	13669680	13927920	14189340	14454050	14722150	14993750	15268940
1830.0	15547850	15829910	16114740	16402630	16693880	16988790	17287660	17590790	17898490	18211060
1840.0	18528780	18851440	19178570	19510170	19846240	20186770	20531740	20881170	21235030	21593330
1850.0	21956050	22323200	22694790	23070820	23451300	23836210	24225570	24619370	25017600	25420280
1860.0	25827400									

Missouri River Basin  
 Garrison Water Control Manual  
**Area and Capacity Tables**  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

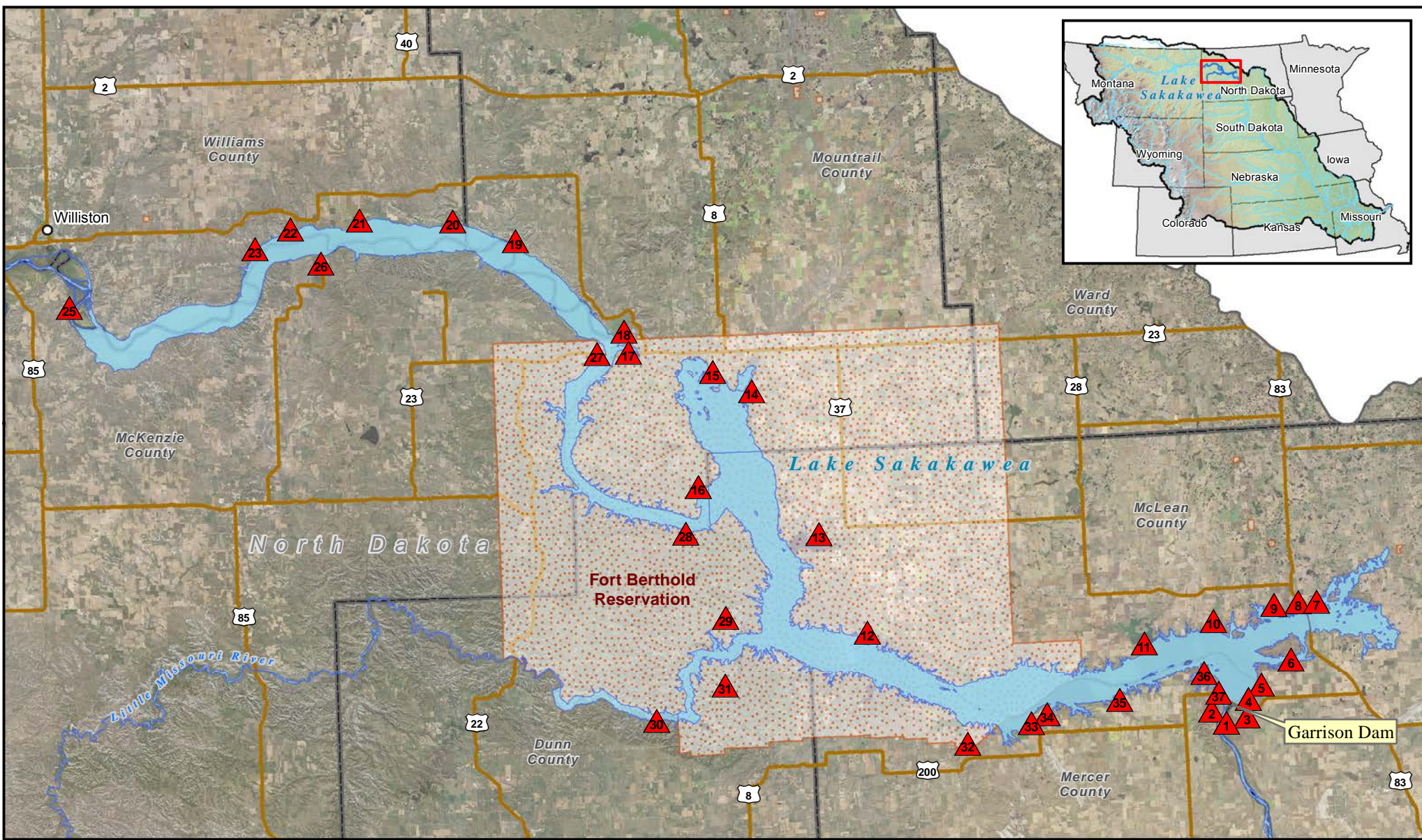


Plate IV-15



**US Army Corps of Engineers**  
Northwestern Division

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



Imagery Source:  
U.S. Department of Agriculture,  
Farm Service Agency 2015



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

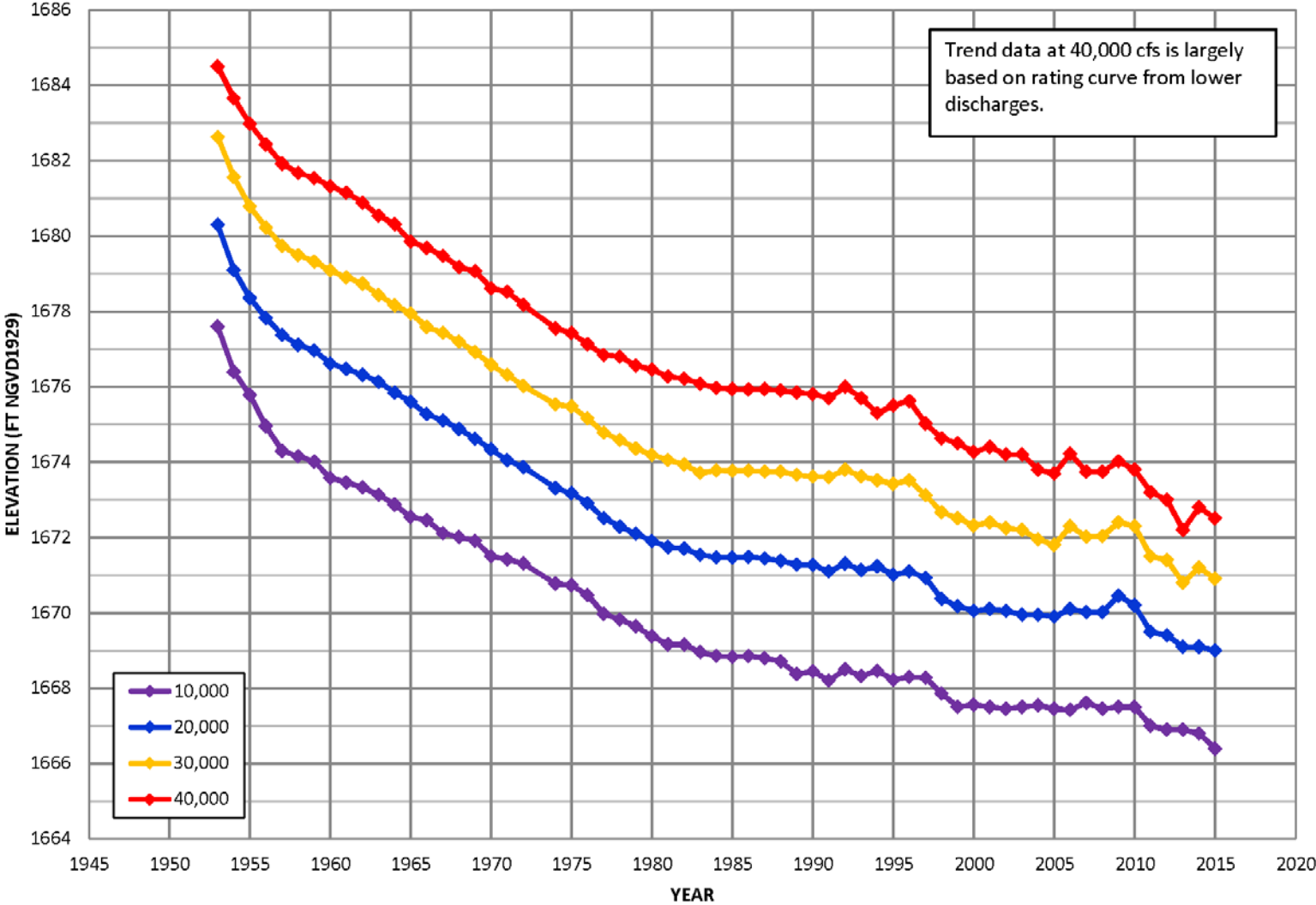


## Garrison Project Recreation Areas

- |                                      |                                    |                                     |
|--------------------------------------|------------------------------------|-------------------------------------|
| <b>1</b> Downstream Campground       | <b>14</b> Parshall Bay             | <b>26</b> Tobacco Gardens           |
| <b>2</b> Spillway Pond               | <b>15</b> Van Hook                 | <b>27</b> Four Bears                |
| <b>3</b> Spillway Overlook           | <b>16</b> Pouch Point              | <b>28</b> Skunk Creek               |
| <b>4</b> Riverdale Overlook          | <b>17</b> New Town Marina          | <b>29</b> McKenzie Bay              |
| <b>5</b> Government Bay              | <b>18</b> Sanish Bay               | <b>30</b> Little Missouri Bay       |
| <b>6</b> Wolf Creek                  | <b>19</b> White Earth Bay          | <b>31</b> Charging Eagle            |
| <b>7</b> East Totten Trail           | <b>20</b> Little Beaver Bay        | <b>32</b> Beaver Creek Bay          |
| <b>8</b> West Totten Trail           | <b>21</b> Little Egypt             | <b>33</b> Lake Shore Park           |
| <b>9</b> Sportsmen's Centennial Park | <b>22</b> White Tail Bay           | <b>34</b> Beulah Bay                |
| <b>10</b> Ft. Stevenson State Park   | <b>23</b> Lewis & Clark State Park | <b>35</b> Hazen Bay                 |
| <b>11</b> Douglas Creek              | <b>24</b> Lake Trenton             | <b>36</b> Lake Sakakawea State Park |
| <b>12</b> Indian Hills               | <b>25</b> American Legion Park     | <b>37</b> Tailrace                  |
| <b>13</b> Deepwater                  |                                    |                                     |



# Garrison Tailwater Trends



Missouri River Basin  
**Garrison Water Control Manual**  
**Garrison Tailwater Trends**  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

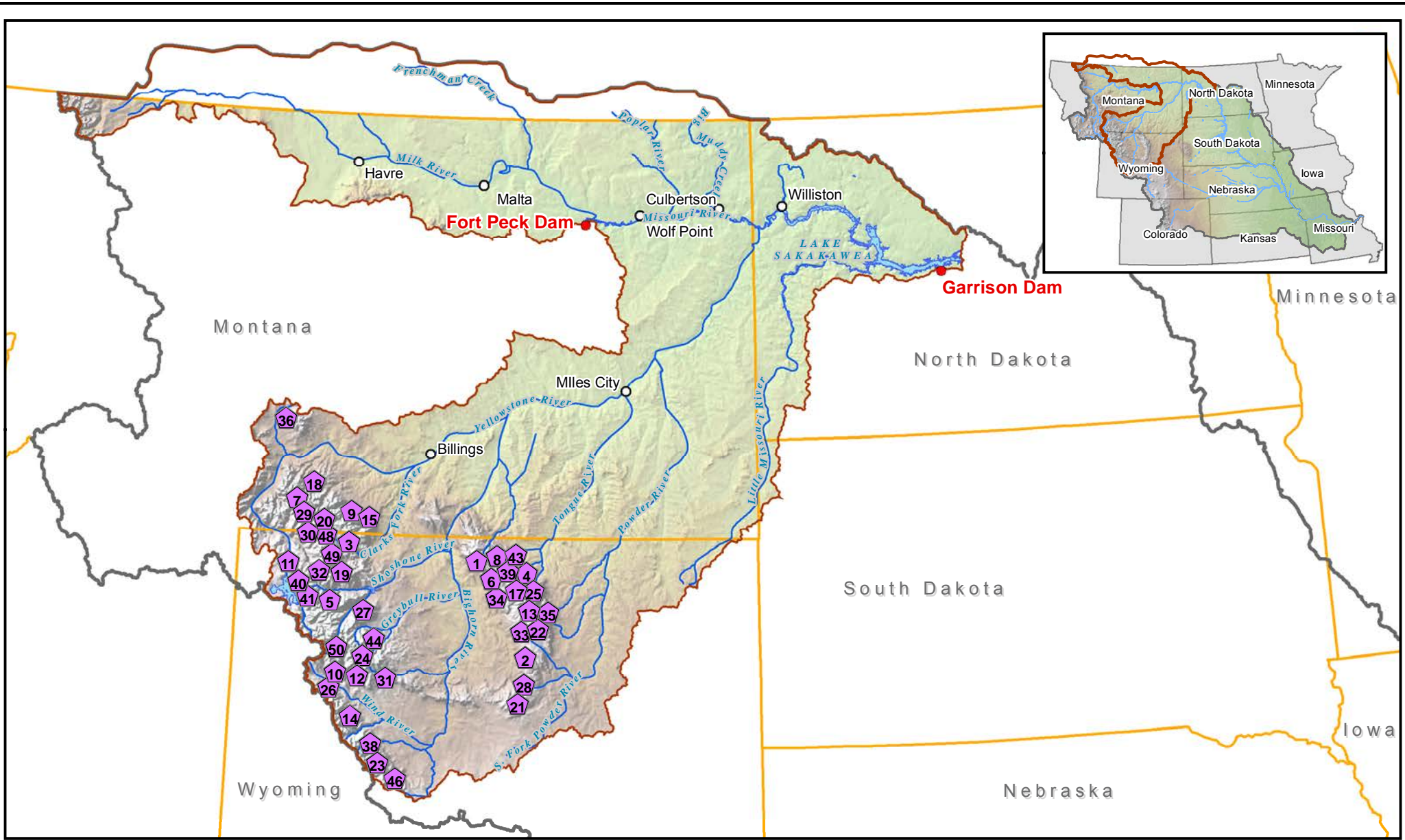


Plate V-1



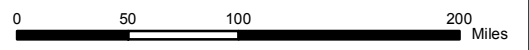
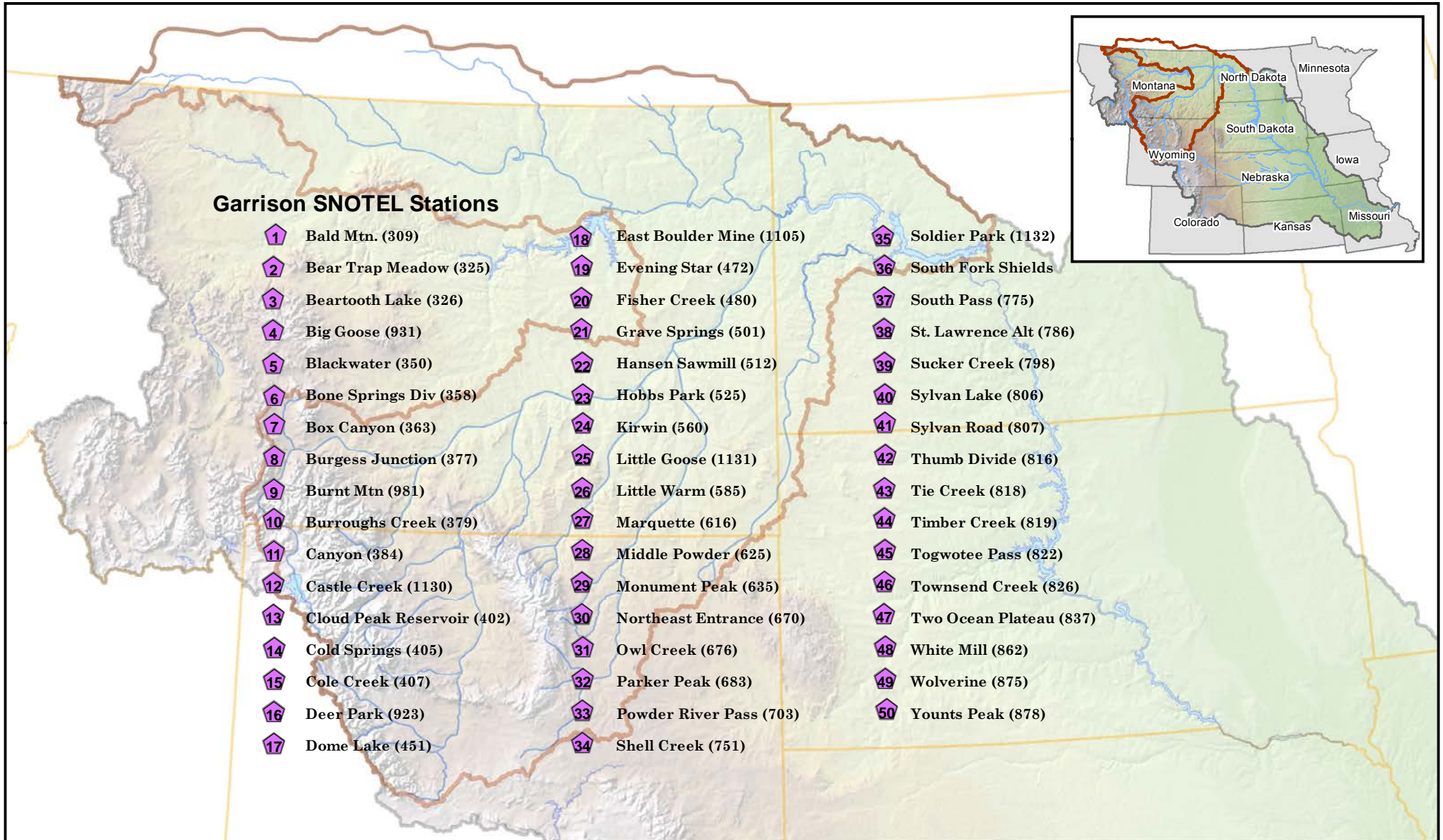
- Snow Telemetry Stations
- Mainstem Dam
- Cities
- Rivers
- Reservoirs/Lakes
- Garrison Drainage Area
- Omaha/Kansas City District Boundaries
- State Boundaries

0 50 100 200 Miles

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

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**Missouri River Basin**  
**GARRISON DRAINAGE AREA**  
**SNOTEL STATIONS**  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017



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



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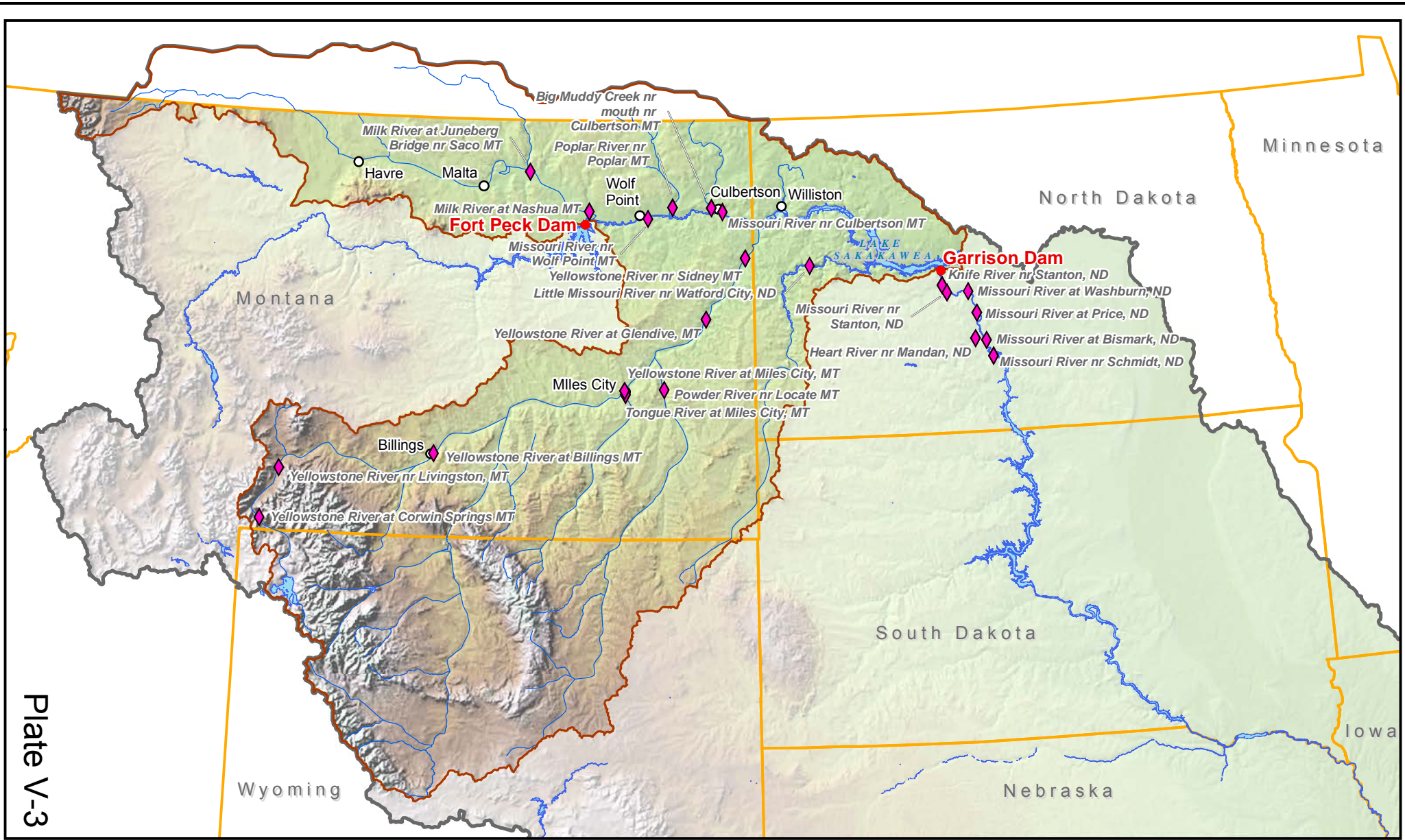
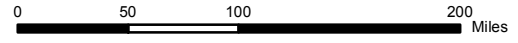


Plate V-3



**US Army Corps of Engineers**  
Northwestern Division

- ◆ Streamgaging Station
- Mainstem Dam
- Cities
- Rivers
- Reservoirs/Lakes
- Garrison Drainage Area
- Omaha/Kansas City District Boundaries
- State Boundaries



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



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

Stage	Flow in cfs									
	Milk River at Nashua, MT	Missouri River at Wolf Point, MT	Poplar River near Poplar, MT	Big Muddy Creek near Culbertson, MT	Missouri River at Culbertson, MT	Yellowstone River at Sidney, MT	Little Missouri River at Watford City, ND	Knife River at Hazen, ND	Missouri River at Bismarck, ND	Heart River at Mandan, ND
	Rating # 19.0 Fld Stg = 20.0'	Rating # 12.0 Fld Stg = 23.0'	Rating # 14.0 Fld Stg = 15.5'	Rating # 4.0 Fld Stg = n/a	Rating # 10.0 Fld Stg = 19.0'	Rating # 27 Fld Stg = 19.0'	Rating # 25.1 Fld Stg = 20.0'	Rating # 22.0 Fld Stg = 21.0'	Rating # 17.1 Fld Stg = 14.5'	Rating # 12.0 Fld Stg = 18.2'
0.0							171	20		
1.0			2		4,260		748	97		194
2.0	132		54		5,710		1,540	210		491
3.0	554		182		7,390		2,480	346		870
4.0	998		385	3	9,300	5,310	3,660	508		1,390
5.0	1,440		660	31	11,500	8,050	5,050	693		1,980
6.0	1,870		1,000	96	13,900	11,300	6,700	897	24,500	2,610
7.0	2,210		1,430	206	16,800	15,100	8,580	1,130	29,300	3,350
8.0	2,540		1,930	361	20,600	19,400	10,700	1,380	34,300	4,150
9.0	2,850		2,490	566	24,800	24,200	13,000	1,650	39,600	5,040
10.0	3,370		3,140	823	29,600	29,500	15,600	1,980	45,100	5,950
11.0	3,930		3,860	1,130	34,800	35,300	18,600	2,370	50,500	6,900
12.0	4,560		4,660	1,420	41,500	41,600	21,700	2,790	56,700	7,800
13.0	5,220		5,530		50,000	48,300	25,100	3,240	63,000	8,820
14.0	5,900		6,710		59,600	54,800	28,800	3,710	71,000	9,870
15.0	6,560		8,270		70,500	61,500	32,700	4,200	80,000	11,200
16.0	7,190		11,000		82,800	68,500	36,900	4,720	92,700	12,800
17.0	7,810		15,000		96,500	75,900	41,400	5,260	110,000	14,500
18.0	8,520	30,100			112,000	83,600	46,100	5,820	130,000	16,300
19.0	9,260	35,300			129,000	91,500	50,000	6,400	153,000	18,300
20.0	10,000	42,900			130,000	99,800		6,940	179,000	20,400
21.0	10,800	51,900				108,000		7,590	207,000	22,600
22.0	11,700	62,400				117,000		8,430	239,000	25,000
23.0	12,500	74,300				126,000		9,910	274,000	27,500
24.0	13,400	87,900				129,000		13,700	312,000	30,300
25.0	14,500	105,000						19,100	354,000	33,200
26.0	15,600	130,000						26,300	400,000	36,300
27.0	17,000							35,700	450,000	39,500
28.0	18,700							36,700		
29.0	21,900									
30.0	33,600									
31.0	35,100									

**Reservoir Elevation Corrections at Garrison  
to Allow for Wind Effects**  
Reservoir Elevation at 1850 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	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.6	-0.7	-0.9
10	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.4
20	-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
30	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.4	+0.4	+0.6	+0.7	+0.8	+0.9
40	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.1	+1.4	+1.5	+1.9
50	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.9	+1.1	+1.4	+1.6	+2.0	+2.4	+2.7
60	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.1	+1.4	+1.7	+2.1	+2.5	+3.0	+3.4
70	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+1.0	+1.4	+1.7	+2.1	+2.5	+3.0	+3.5	+4.0
80	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.2	+1.5	+1.9	+2.4	+2.9	+3.4	+3.9	+4.5
90	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.1	+2.6	+3.2	+3.7	+4.2	+4.8
100	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.3	+1.7	+2.2	+2.7	+3.3	+3.8	+4.4	+5.1
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.7	+2.2	+2.8	+3.3	+3.9	+4.5	+5.1
120	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.3	+1.7	+2.2	+2.7	+3.3	+3.8	+4.4	+5.1
130	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.1	+2.6	+3.2	+3.7	+4.2	+4.8
140	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.8	+1.2	+1.5	+1.9	+2.4	+2.9	+3.4	+3.9	+4.5
150	+0.0	+0.0	+0.0	+0.1	+0.3	+0.5	+0.7	+1.0	+1.4	+1.7	+2.1	+2.5	+3.0	+3.5	+4.0
160	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.1	+1.4	+1.7	+2.1	+2.5	+3.0	+3.4
170	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.9	+1.1	+1.4	+1.6	+2.0	+2.4	+2.7
180	+0.0	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.7	+0.9	+1.1	+1.4	+1.5	+1.9
190	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.2	+0.4	+0.4	+0.6	+0.7	+0.8	+0.9
200	-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
210	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.4
220	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.6	-0.7	-0.9
230	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-1.1	-1.4	-1.7
240	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.2	-1.5	-2.0	-2.4
250	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.1	-1.5	-2.0	-2.5	-3.1
260	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.4	-3.0	-3.6
270	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.7	-1.1	-1.5	-2.1	-2.7	-3.3	-4.0
280	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.8	-1.2	-1.7	-2.2	-2.8	-3.5	-4.3
290	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.6	-0.8	-1.2	-1.7	-2.3	-2.9	-3.6	-4.3
300	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.8	-1.2	-1.7	-2.2	-2.8	-3.5	-4.3
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.4	-0.5	-0.7	-1.1	-1.5	-2.1	-2.7	-3.3	-4.0
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-1.9	-2.4	-3.0	-3.6
330	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.1	-1.5	-2.0	-2.5	-3.1
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.8	-1.2	-1.5	-2.0	-2.4
350	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-1.1	-1.4	-1.7

Reservoir Elevation Wind Corrections in Feet

\* Pool elevation as measured at the dam.

Missouri River Basin  
**Garrison 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 Garrison  
to Allow for Wind Effects**  
Reservoir Elevation at 1840 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	-0.1	-0.2	-0.2	-0.3	-0.3	-0.5	-0.5	-0.8	-1.0
10	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3
20	-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
30	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.3	+0.5	+0.5	+0.6	+0.8	+0.9
40	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+0.9	+1.2	+1.4	+1.6	+1.9
50	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.6	+0.9	+1.1	+1.4	+1.7	+2.0	+2.4	+2.7
60	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.1	+1.4	+1.8	+2.2	+2.6	+3.0	+3.4
70	+0.0	+0.0	+0.1	+0.1	+0.3	+0.5	+0.8	+1.0	+1.3	+1.7	+2.2	+2.6	+3.0	+3.6	+4.0
80	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.2	+1.5	+1.9	+2.4	+2.9	+3.4	+4.0	+4.5
90	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.3	+1.6	+2.1	+2.6	+3.1	+3.7	+4.3	+4.9
100	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+1.0	+1.3	+1.7	+2.2	+2.8	+3.3	+3.8	+4.4	+5.1
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+1.0	+1.3	+1.7	+2.3	+2.8	+3.3	+3.9	+4.5	+5.2
120	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+1.0	+1.3	+1.7	+2.2	+2.8	+3.3	+3.8	+4.4	+5.1
130	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.3	+1.6	+2.1	+2.6	+3.1	+3.7	+4.3	+4.9
140	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.2	+1.5	+1.9	+2.4	+2.9	+3.4	+4.0	+4.5
150	+0.0	+0.0	+0.1	+0.1	+0.3	+0.5	+0.8	+1.0	+1.3	+1.7	+2.2	+2.6	+3.0	+3.6	+4.0
160	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.1	+1.4	+1.8	+2.2	+2.6	+3.0	+3.4
170	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.6	+0.9	+1.1	+1.4	+1.7	+2.0	+2.4	+2.7
180	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+0.9	+1.2	+1.4	+1.6	+1.9
190	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.3	+0.5	+0.5	+0.6	+0.8	+0.9
200	-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
210	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3
220	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.5	-0.5	-0.8	-1.0
230	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.5	-0.5	-0.8	-1.1	-1.4	-1.7
240	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.5	-0.6	-0.9	-1.2	-1.6	-2.0	-2.6
250	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.6	-2.1	-2.6	-3.2
260	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.5	-1.9	-2.5	-3.1	-3.8
270	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.8	-1.2	-1.6	-2.2	-2.8	-3.4	-4.1
280	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.5	-0.9	-1.3	-1.8	-2.3	-3.0	-3.7	-4.4
290	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.5	-0.9	-1.3	-1.8	-2.4	-3.0	-3.7	-4.5
300	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.5	-0.9	-1.3	-1.8	-2.3	-3.0	-3.7	-4.4
310	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.8	-1.2	-1.6	-2.2	-2.8	-3.4	-4.1
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.5	-1.9	-2.5	-3.1	-3.8
330	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.6	-2.1	-2.6	-3.2
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.5	-0.6	-0.9	-1.2	-1.6	-2.0	-2.6
350	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.5	-0.5	-0.8	-1.1	-1.4	-1.7

Reservoir Elevation Wind Corrections in Feet

\* Pool elevation as measured at the dam.

Missouri River Basin  
**Garrison 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 Garrison  
to Allow for Wind Effects**  
Reservoir Elevation at 1830 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	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.6	-0.8	-1.0
10	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4
20	-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
30	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.4	+0.6	+0.7	+0.8	+0.9
40	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+0.9	+1.2	+1.4	+1.6	+1.9
50	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.7	+2.0	+2.4	+2.8
60	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.4	+1.8	+2.2	+2.6	+3.0	+3.5
70	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.8	+1.0	+1.4	+1.8	+2.1	+2.6	+3.1	+3.6	+4.1
80	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.2	+1.5	+2.0	+2.5	+2.9	+3.5	+4.0	+4.6
90	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+0.9	+1.3	+1.7	+2.1	+2.7	+3.1	+3.7	+4.3	+4.9
100	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.3	+1.8	+2.3	+2.8	+3.3	+3.9	+4.5	+5.1
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+2.8	+3.4	+3.9	+4.6	+5.2
120	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.3	+1.8	+2.3	+2.8	+3.3	+3.9	+4.5	+5.1
130	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+0.9	+1.3	+1.7	+2.1	+2.7	+3.1	+3.7	+4.3	+4.9
140	+0.0	+0.0	+0.1	+0.2	+0.3	+0.6	+0.9	+1.2	+1.5	+2.0	+2.5	+2.9	+3.5	+4.0	+4.6
150	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.8	+1.0	+1.4	+1.8	+2.1	+2.6	+3.1	+3.6	+4.1
160	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.4	+1.8	+2.2	+2.6	+3.0	+3.5
170	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.4	+1.7	+2.0	+2.4	+2.8
180	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+0.9	+1.2	+1.4	+1.6	+1.9
190	+0.0	+0.0	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.4	+0.6	+0.7	+0.8	+0.9
200	-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
210	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4
220	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.4	-0.6	-0.8	-1.0
230	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.9	-1.2	-1.5	-1.8
240	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.7	-0.9	-1.3	-1.7	-2.1	-2.6
250	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.3	-1.7	-2.2	-2.8	-3.3
260	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.1	-1.5	-2.0	-2.6	-3.2	-3.9
270	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.8	-2.3	-2.9	-3.6	-4.3
280	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.9	-2.4	-3.1	-3.7	-4.5
290	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.9	-2.5	-3.1	-3.9	-4.6
300	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.9	-2.4	-3.1	-3.7	-4.5
310	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.9	-1.3	-1.8	-2.3	-2.9	-3.6	-4.3
320	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.1	-1.5	-2.0	-2.6	-3.2	-3.9
330	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.3	-1.7	-2.2	-2.8	-3.3
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.7	-0.9	-1.3	-1.7	-2.1	-2.6
350	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.9	-1.2	-1.5	-1.8

Reservoir Elevation Wind Corrections in Feet

\* Pool elevation as measured at the dam.

Missouri River Basin  
**Garrison 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 Garrison  
to Allow for Wind Effects**  
Reservoir Elevation at 1820 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	-0.1	-0.2	-0.3	-0.3	-0.4	-0.5	-0.7	-0.9	-1.1
10	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4
20	-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
30	+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	+1.0
40	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.0	+1.2	+1.4	+1.7	+1.9
50	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.0	+1.3	+1.6	+1.9	+2.2	+2.6
60	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.7	+0.9	+1.2	+1.5	+1.8	+2.2	+2.7	+3.1	+3.5
70	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.8	+1.1	+1.4	+1.8	+2.2	+2.7	+3.1	+3.6	+4.1
80	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.0	+2.5	+3.0	+3.5	+4.0	+4.6
90	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.3	+1.7	+2.2	+2.7	+3.2	+3.8	+4.3	+5.0
100	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+2.8	+3.4	+3.9	+4.5	+5.2
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+2.9	+3.4	+4.0	+4.6	+5.3
120	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.4	+1.8	+2.3	+2.8	+3.4	+3.9	+4.5	+5.2
130	+0.0	+0.0	+0.1	+0.2	+0.4	+0.7	+1.0	+1.3	+1.7	+2.2	+2.7	+3.2	+3.8	+4.3	+5.0
140	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.0	+2.5	+3.0	+3.5	+4.0	+4.6
150	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.8	+1.1	+1.4	+1.8	+2.2	+2.7	+3.1	+3.6	+4.1
160	+0.0	+0.0	+0.1	+0.1	+0.3	+0.4	+0.7	+0.9	+1.2	+1.5	+1.8	+2.2	+2.7	+3.1	+3.5
170	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.0	+1.3	+1.6	+1.9	+2.2	+2.6
180	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.5	+0.6	+0.8	+1.0	+1.2	+1.4	+1.7	+1.9
190	+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	+1.0
200	-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
210	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4
220	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.5	-0.7	-0.9	-1.1
230	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.8	-1.1	-1.4	-1.7
240	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-1.1	-1.4	-1.8	-2.3	-2.8
250	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.7	-1.0	-1.4	-1.8	-2.3	-2.9	-3.5
260	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.6	-2.2	-2.8	-3.4	-4.0
270	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.8	-2.4	-3.1	-3.7	-4.4
280	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-2.0	-2.6	-3.3	-4.0	-4.6
290	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.7	-1.1	-1.5	-2.0	-2.7	-3.3	-4.0	-4.7
300	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-1.0	-1.4	-2.0	-2.6	-3.3	-4.0	-4.6
310	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.6	-0.9	-1.4	-1.8	-2.4	-3.1	-3.7	-4.4
320	-0.0	-0.0	-0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.8	-1.2	-1.6	-2.2	-2.8	-3.4	-4.0
330	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.7	-1.0	-1.4	-1.8	-2.3	-2.9	-3.5
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-1.1	-1.4	-1.8	-2.3	-2.8
350	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.4	-0.6	-0.8	-1.1	-1.4	-1.7

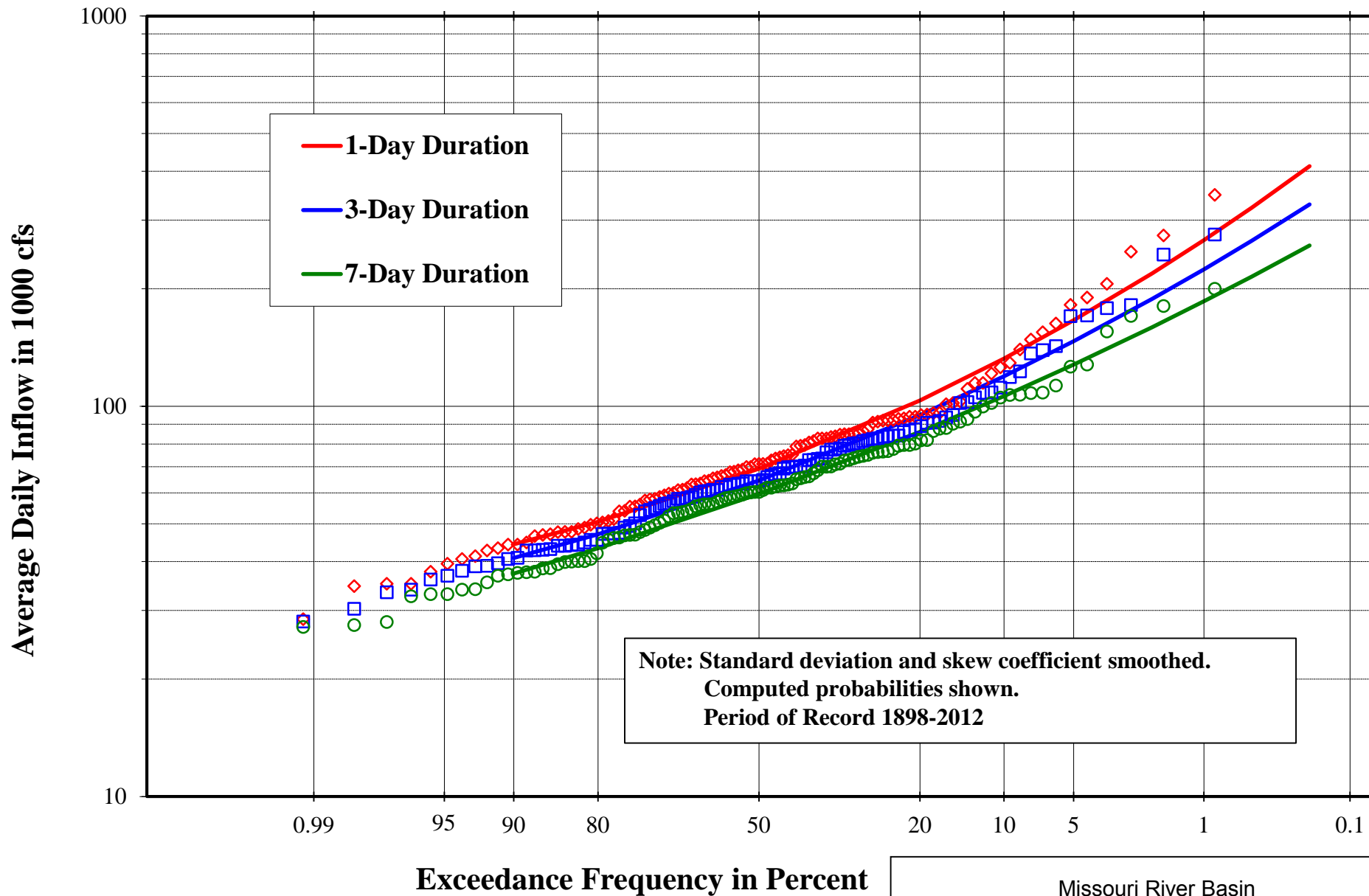
Reservoir Elevation Wind Corrections in Feet

\* Pool elevation as measured at the dam.

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

# Garrison - Regulated Inflow

## 1-, 3-, and 7-Day Volume Probability

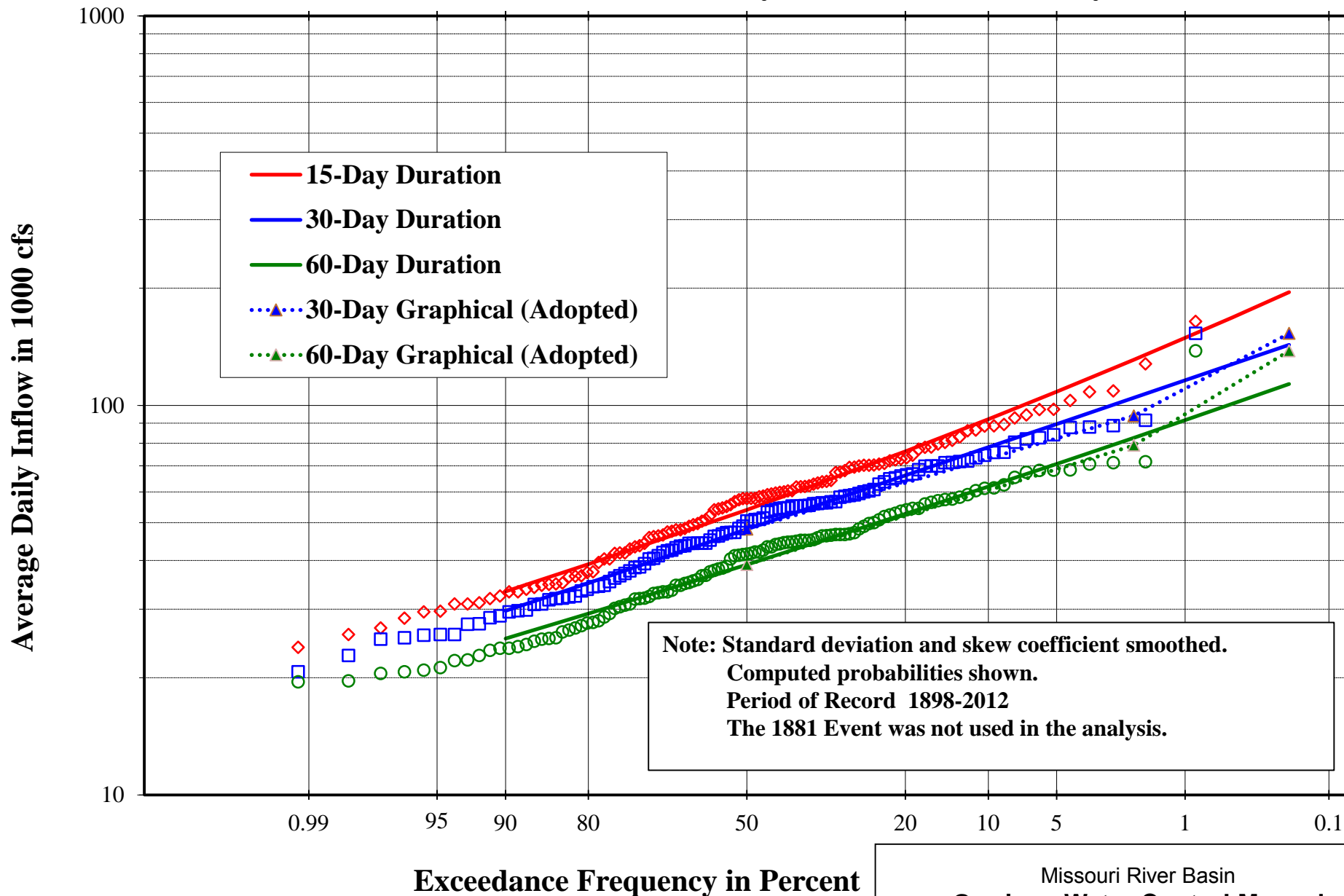


Note: Standard deviation and skew coefficient smoothed.  
Computed probabilities shown.  
Period of Record 1898-2012

Missouri River Basin  
**Garrison Water Control Manual**  
Garrison Regulated Inflow Probability  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017

# Garrison - Regulated Inflow

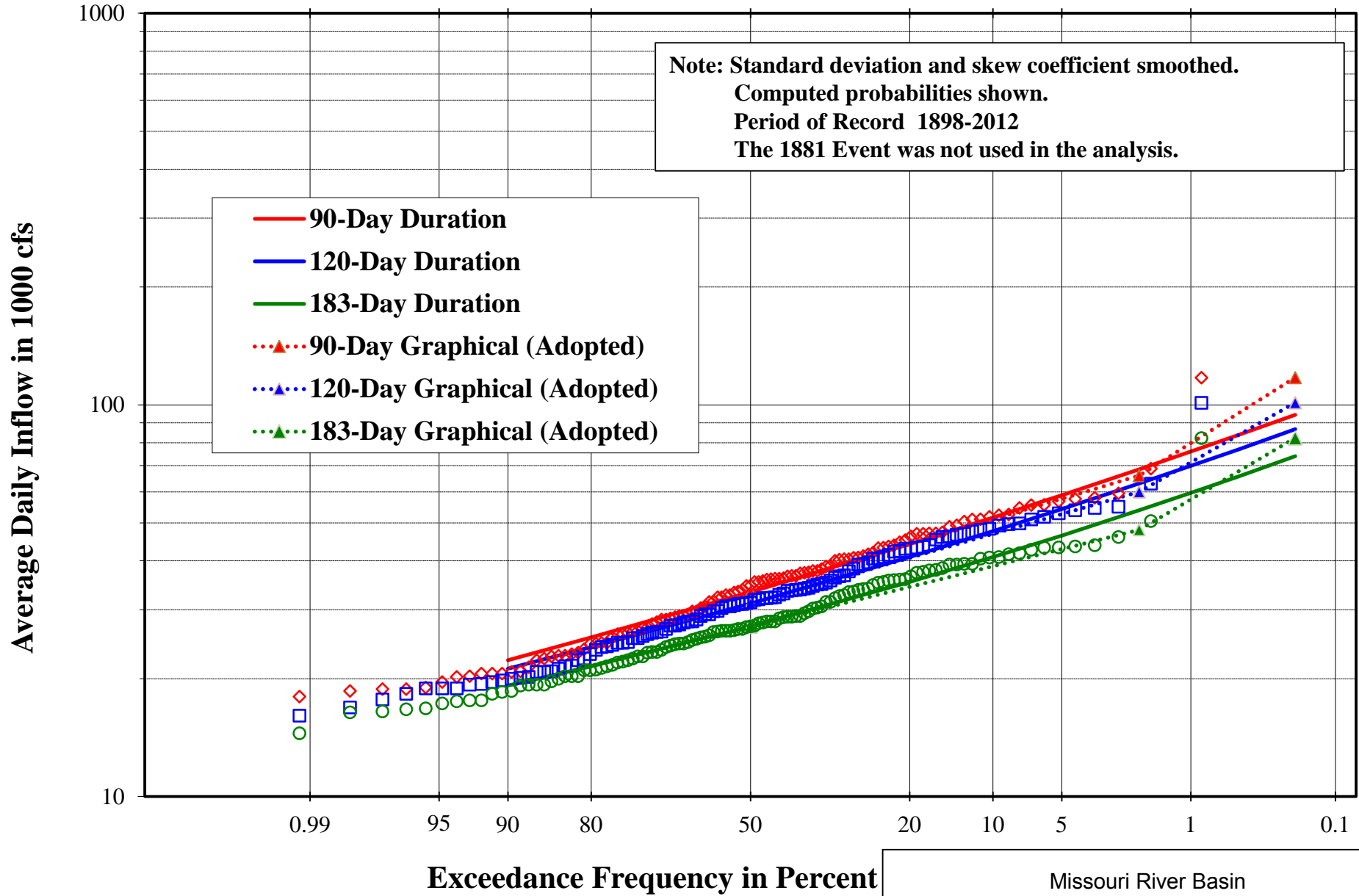
## 15-, 30-, and 60-Day Volume Probability



Missouri River Basin  
**Garrison Water Control Manual**  
 Garrison Regulated Inflow Probability  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

# Garrison - Regulated Inflow

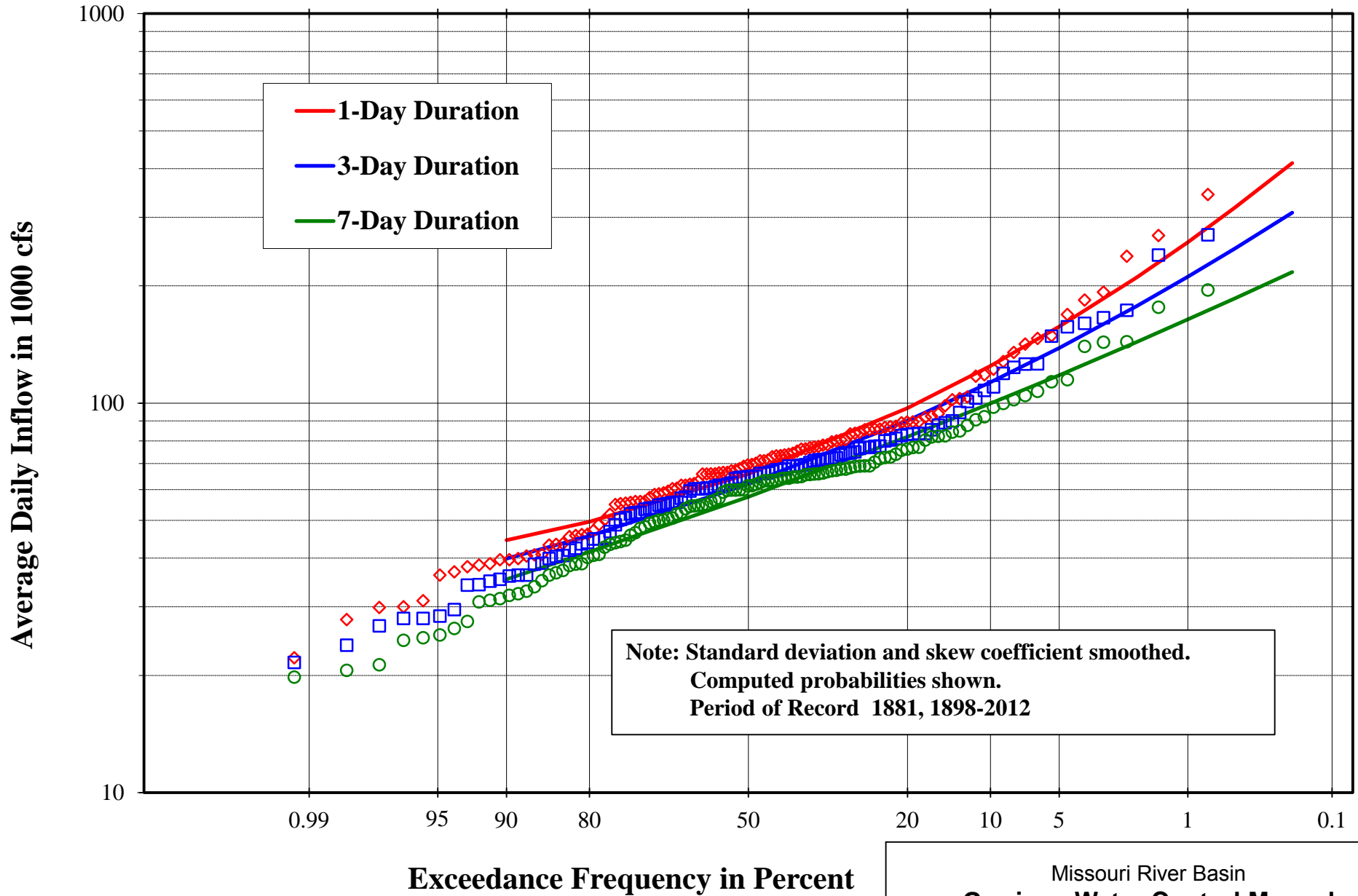
## 90-, 120- and 183-Day Volume Probability



Missouri River Basin  
**Garrison Water Control Manual**  
 Garrison Regulated Inflow Probability  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

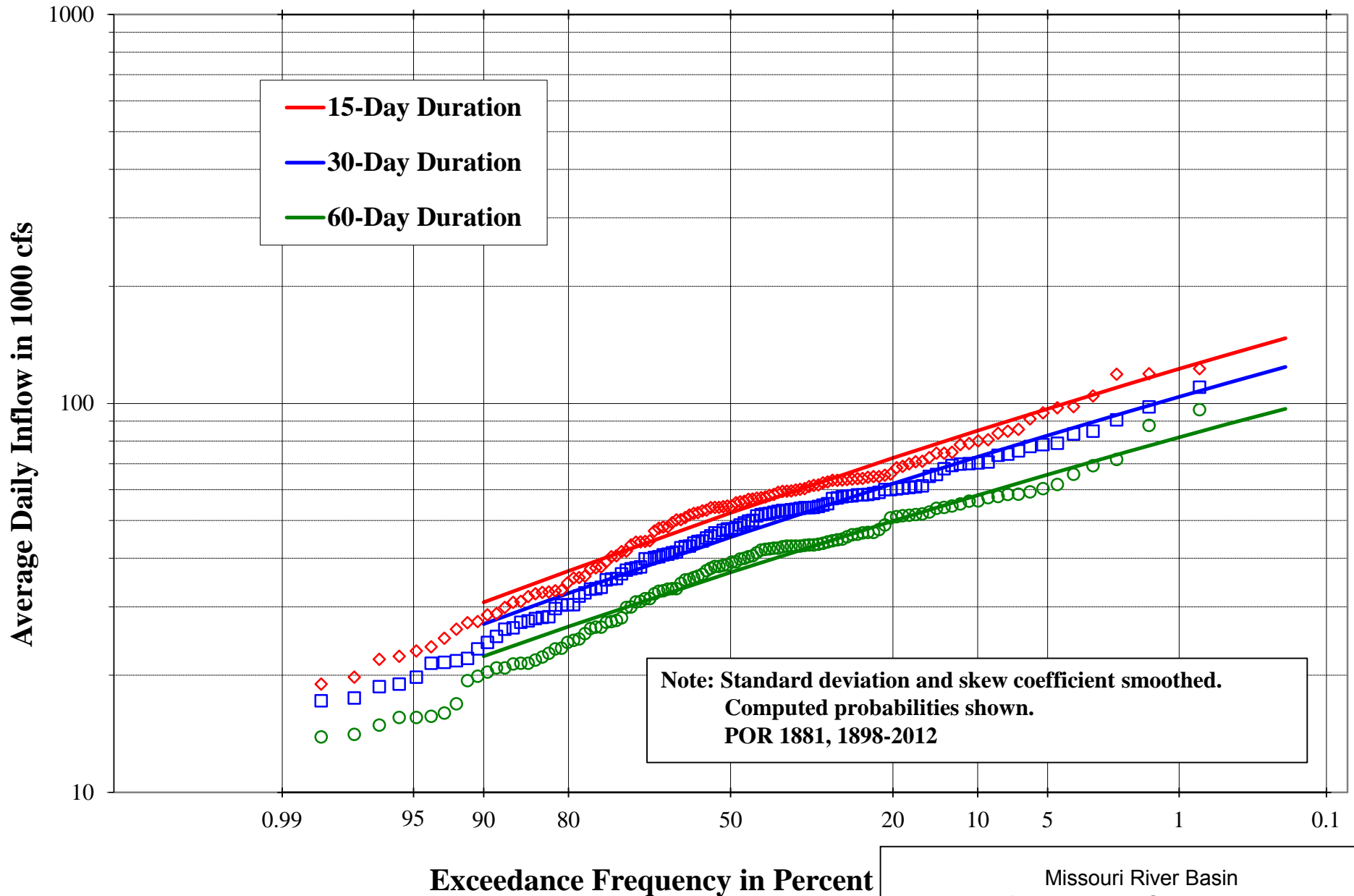
# Garrison - Incremental Inflow

## 1-, 3-, and 7-Day Volume Probability



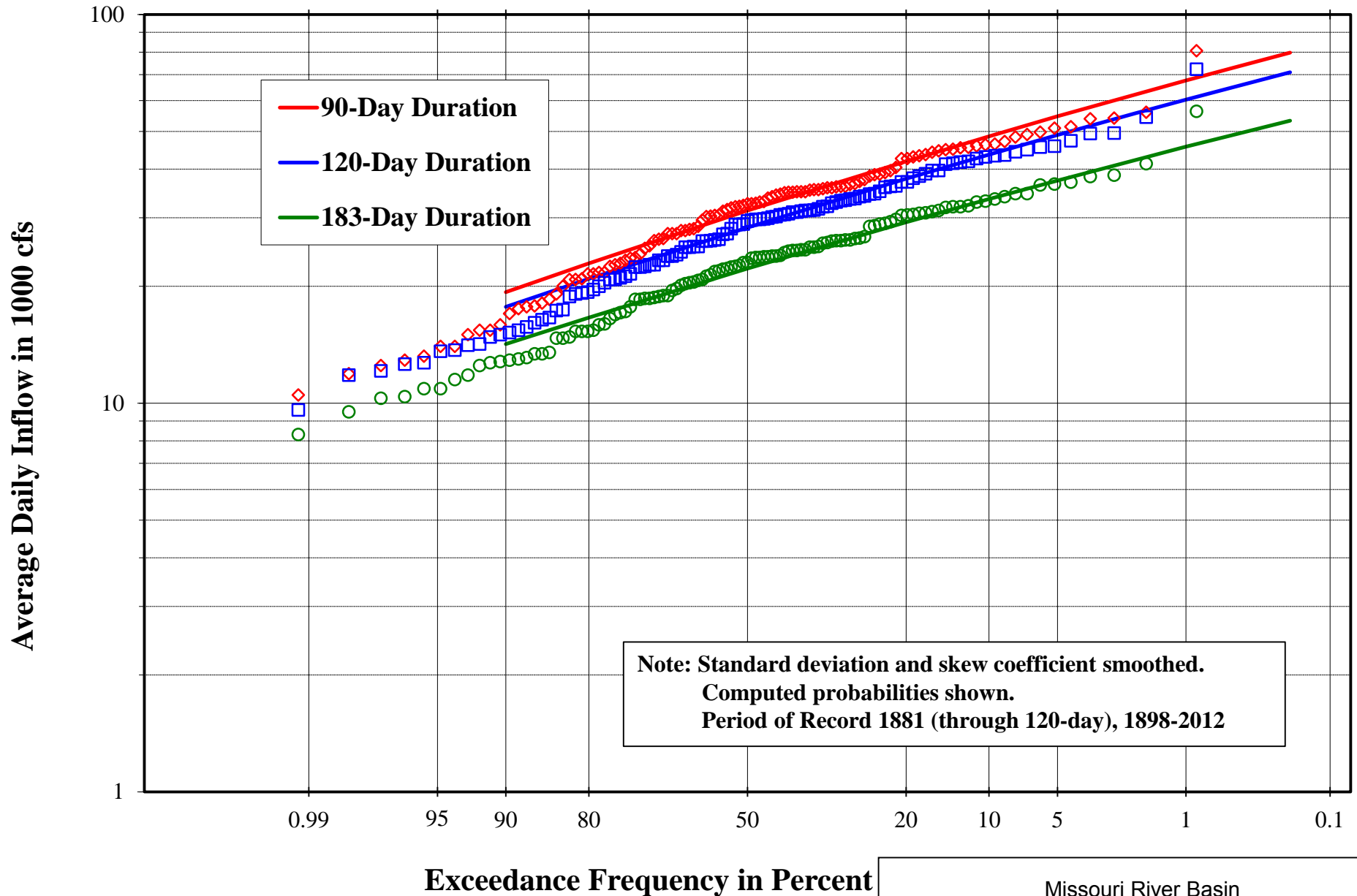
Missouri River Basin  
**Garrison Water Control Manual**  
Garrison Incremental Inflow Probability  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017

# Garrison - Incremental Inflow 15-, 30-, and 60-Day Volume Probability



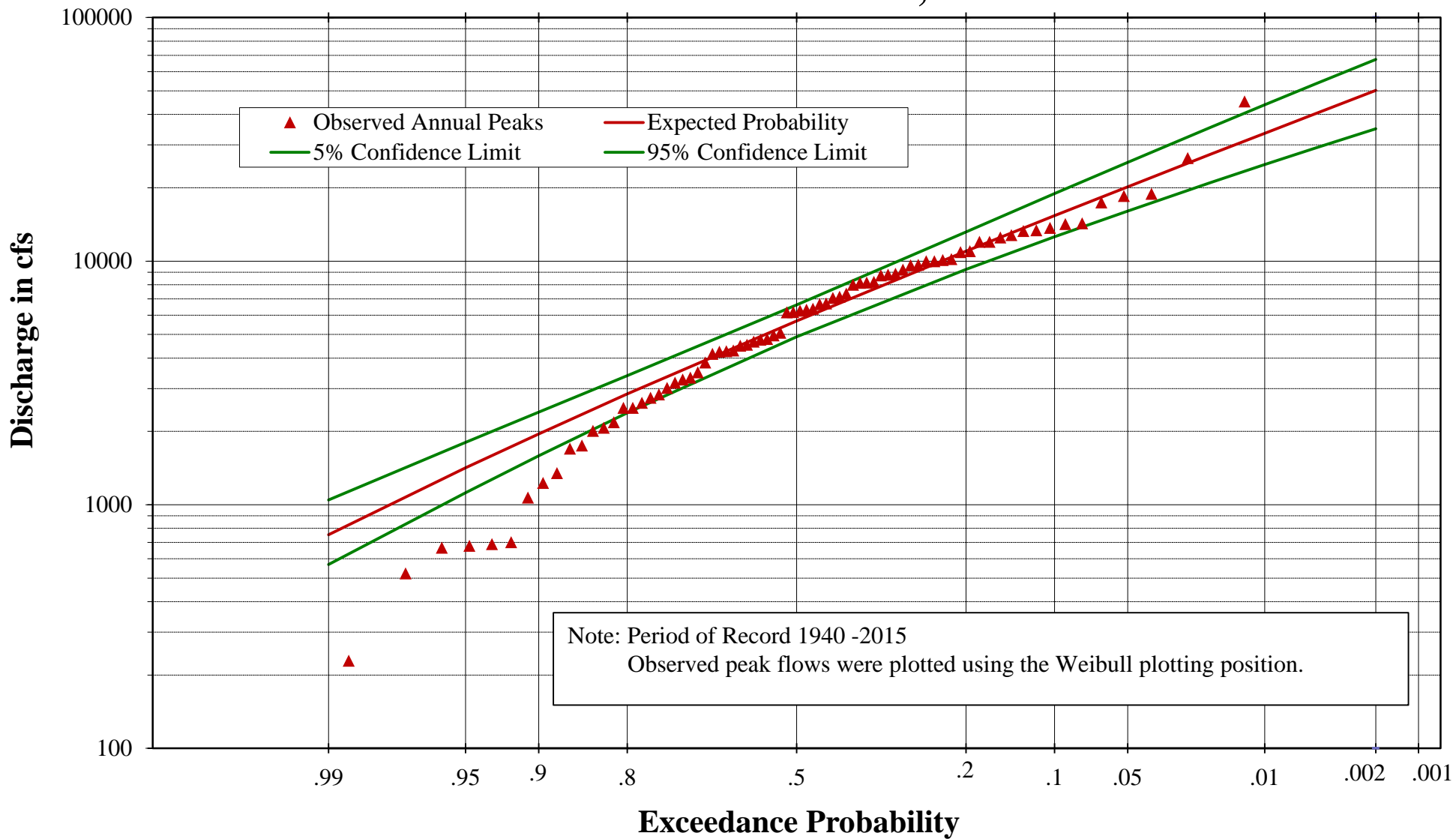
# Garrison - Incremental Inflow

## 90-, 120-, and 183-Day Volume Probability



Missouri River Basin  
**Garrison Water Control Manual**  
 Garrison Incremental Inflow Probability  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

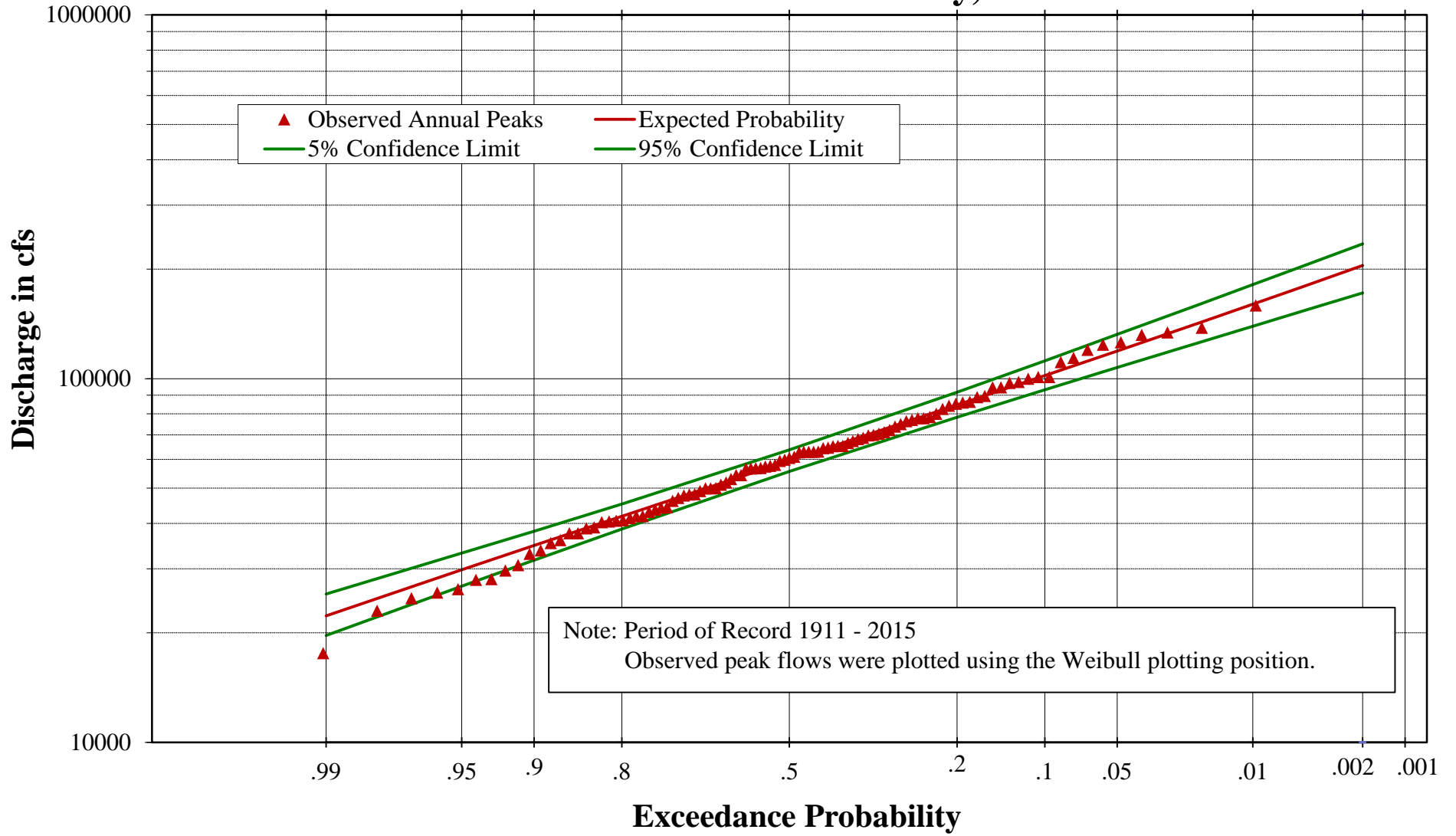
# Milk River at Nashua, MT



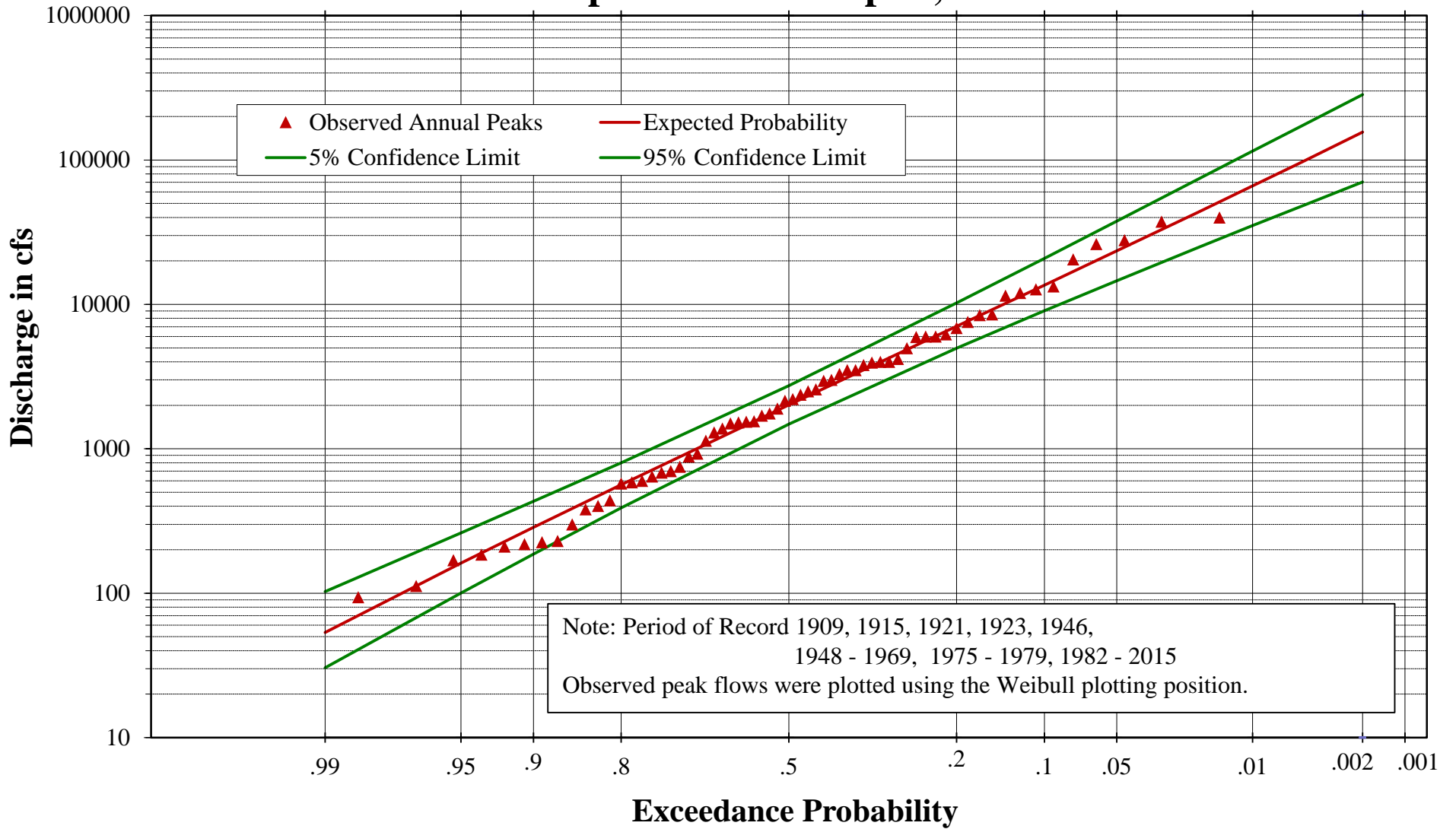
Note: Period of Record 1940 -2015  
Observed peak flows were plotted using the Weibull plotting position.

Missouri River Basin  
**Garrison Water Control Manual**  
Probability Curve – Milk River at Nashua, MT  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017

# Yellowstone River at Sidney, MT

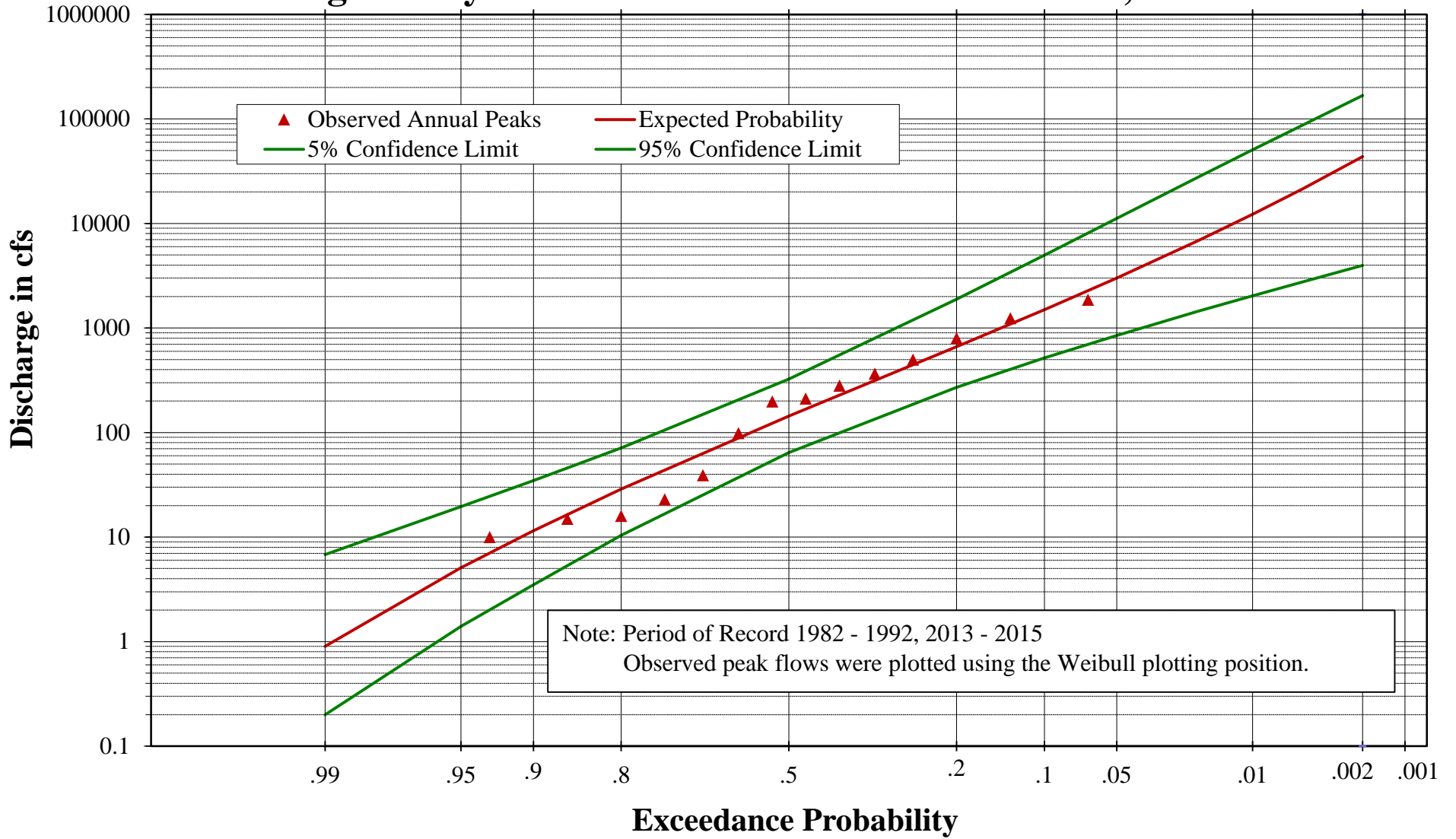


# Poplar River at Poplar, MT



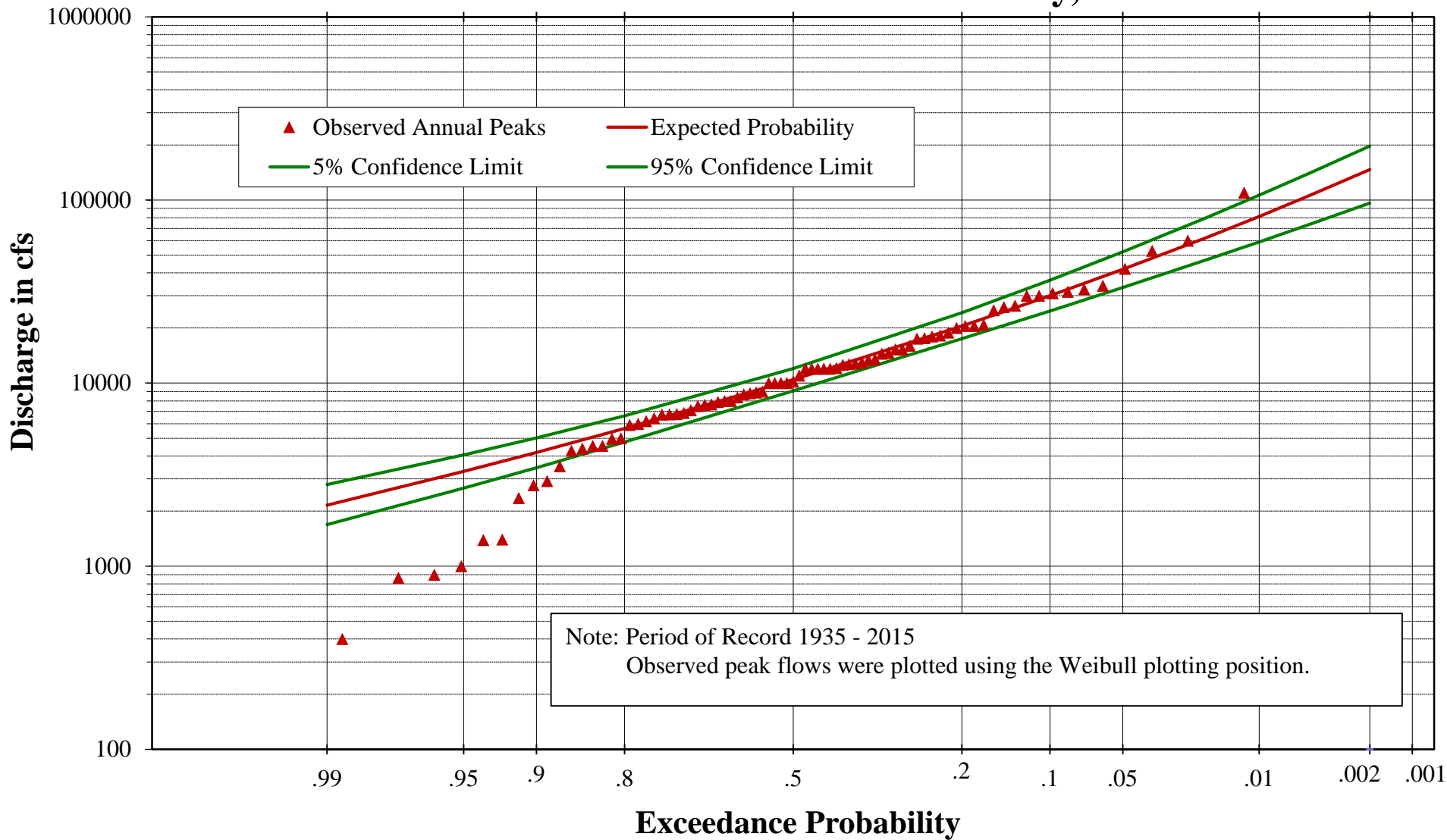
Missouri River Basin  
**Garrison Water Control Manual**  
 Probability Curve – Poplar River at Poplar, MT  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

# Big Muddy Creek at the mouth near Culbertson, MT



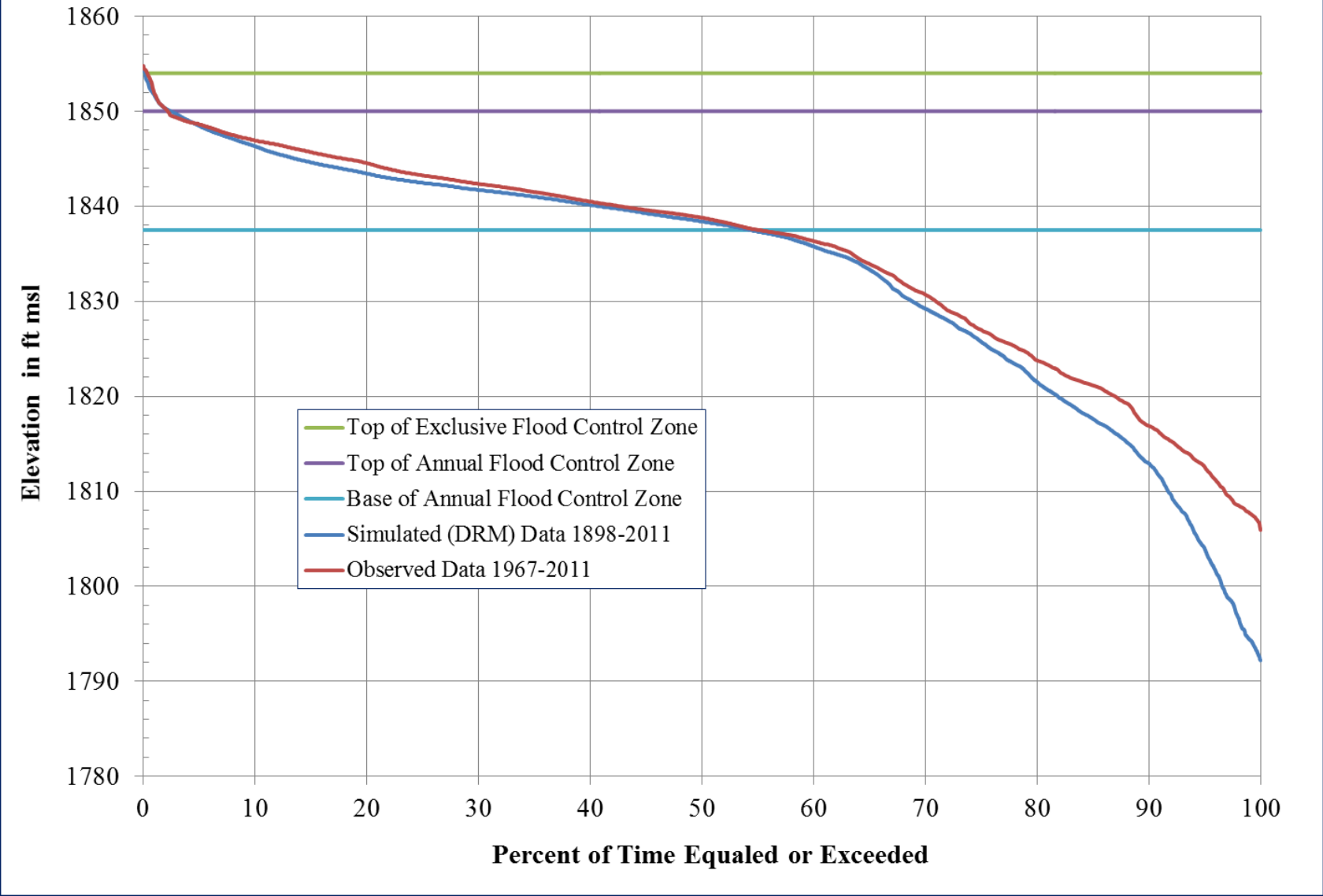
Missouri River Basin  
**Garrison Water Control Manual**  
 Probability Curve – Big Muddy Creek at the mouth near Culbertson, MT  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

# Little Missouri River at Watford City, ND



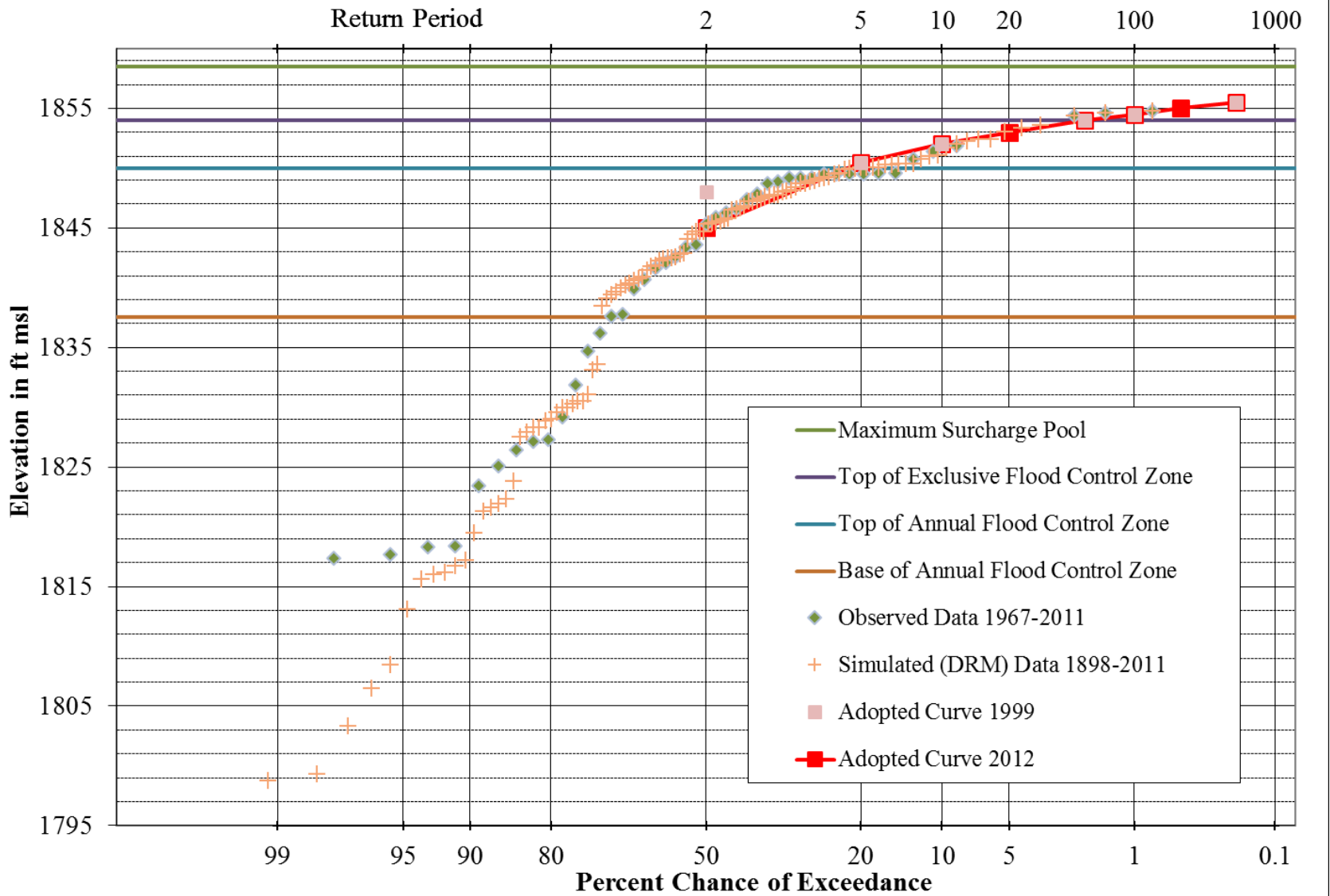
Missouri River Basin  
**Garrison Water Control Manual**  
 Probability Curve – Little Missouri River at Watford City, ND  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

# Garrison Annual Pool-Duration Relationship

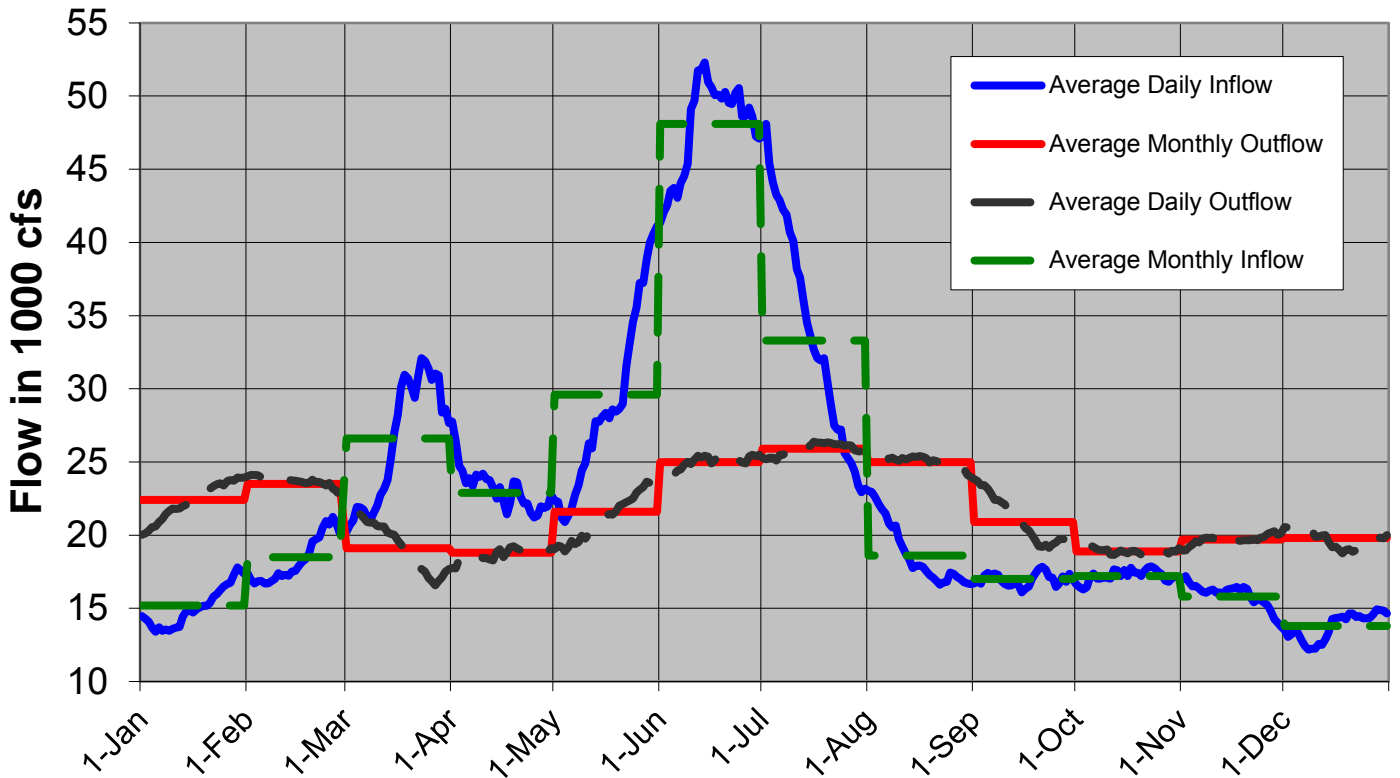
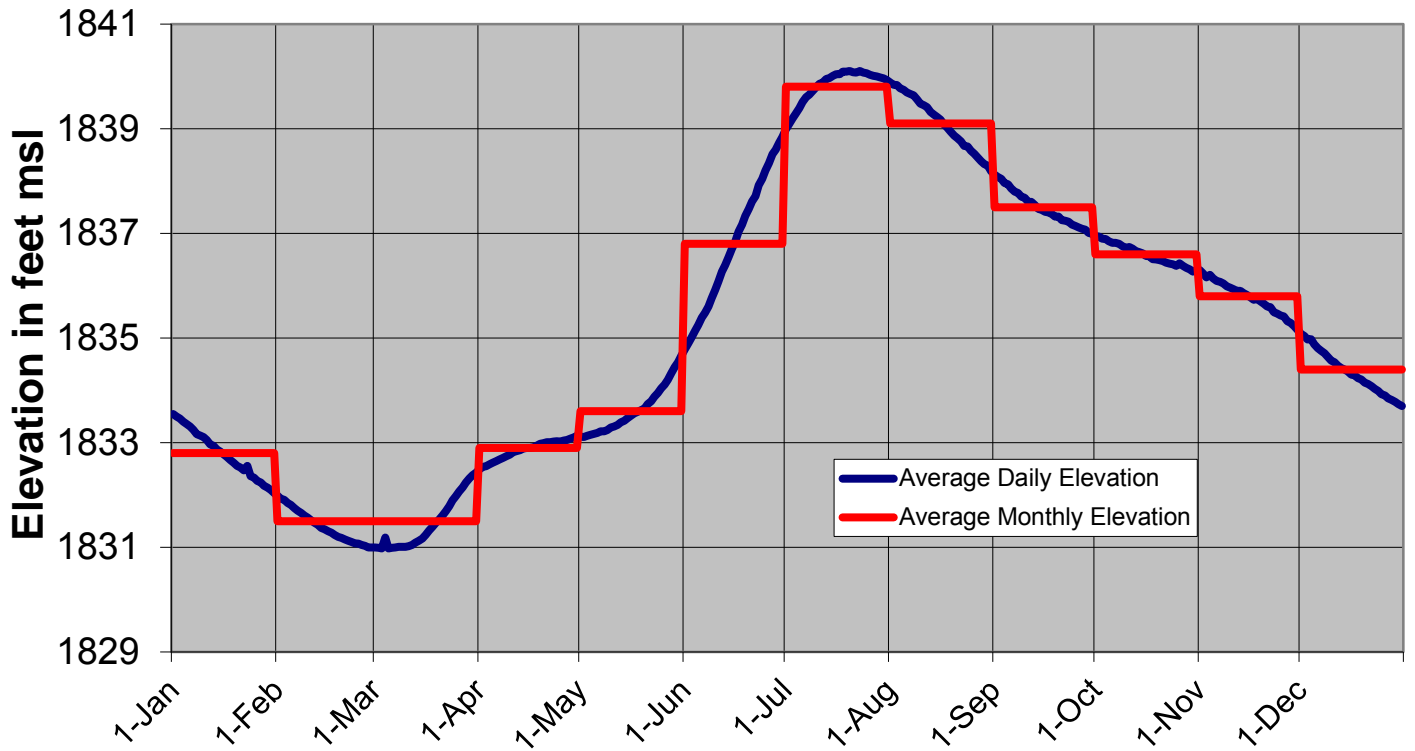


Missouri River Basin  
**Garrison Water Control Manual**  
**Garrison Pool-Duration Relationship**  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017

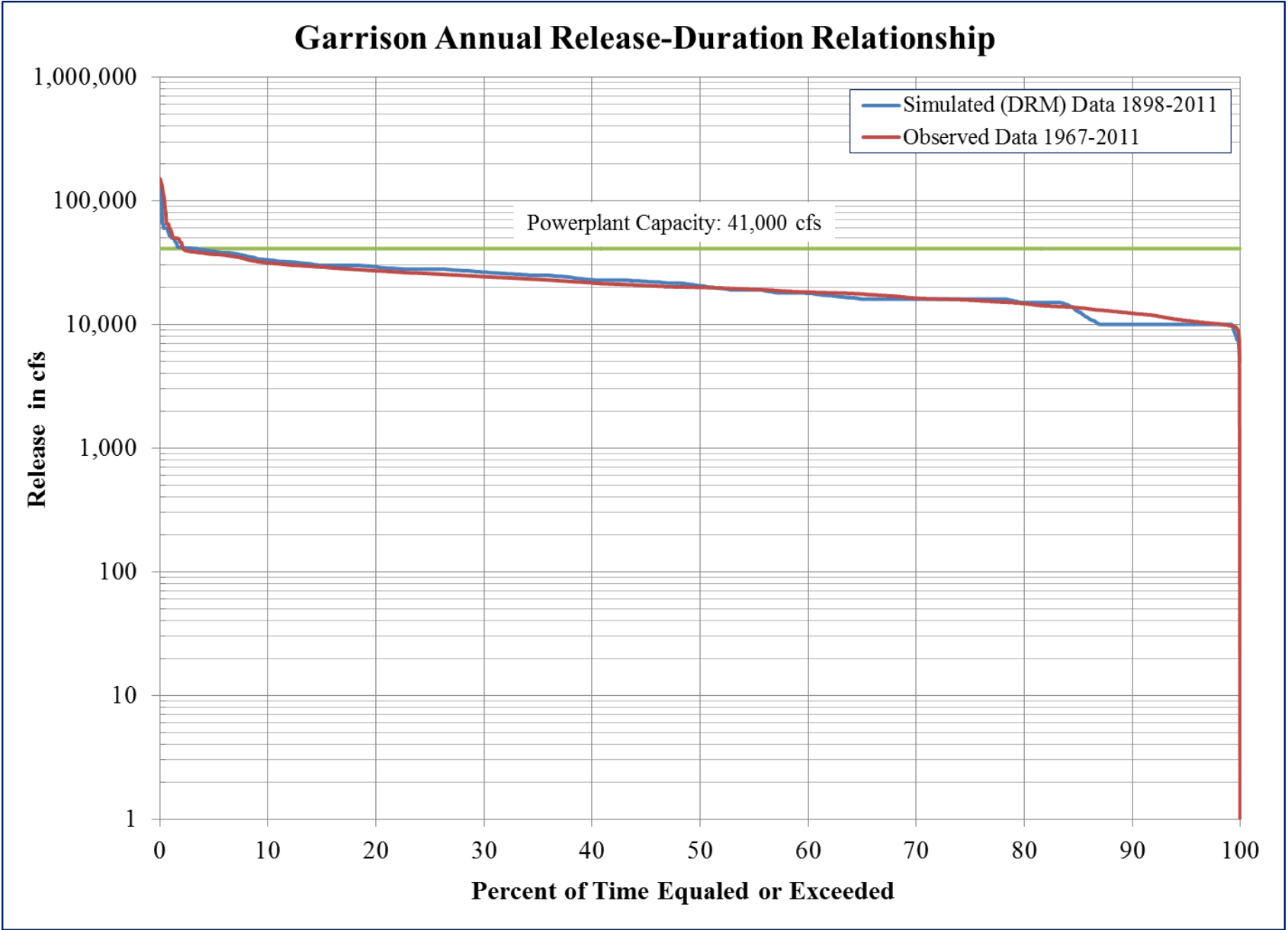
# Garrison Pool-Probability Relationship



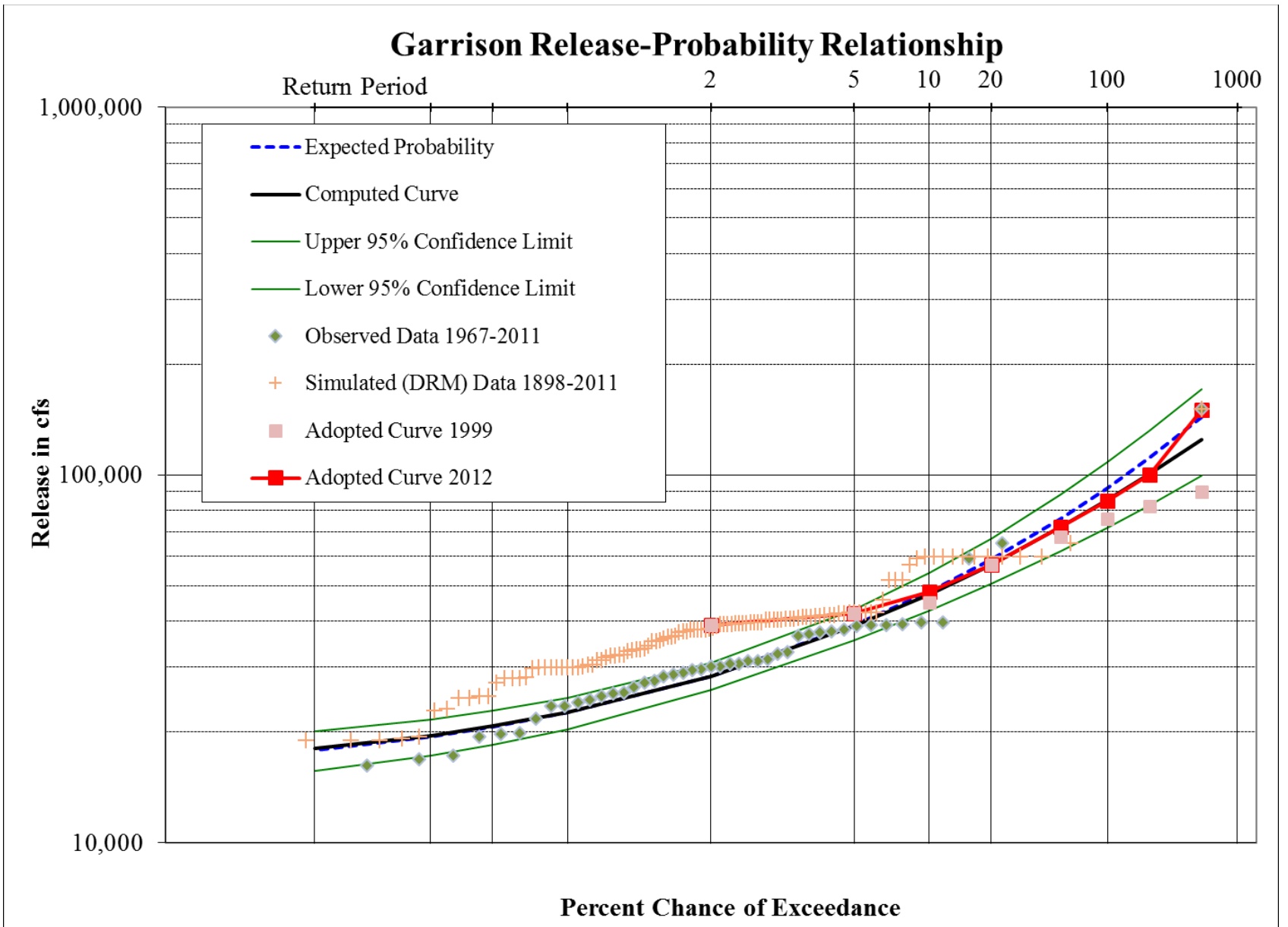
Missouri River Basin  
**Garrison Water Control Manual**  
**Garrison Pool-Probability Relationship**  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017



Missouri River Basin  
**Garrison 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  
**Garrison Water Control Manual**  
**Garrison Release-Duration Relationship**  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017



Missouri River Basin  
**Garrison Water Control Manual**  
**Garrison Release-Probability Relationship**  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

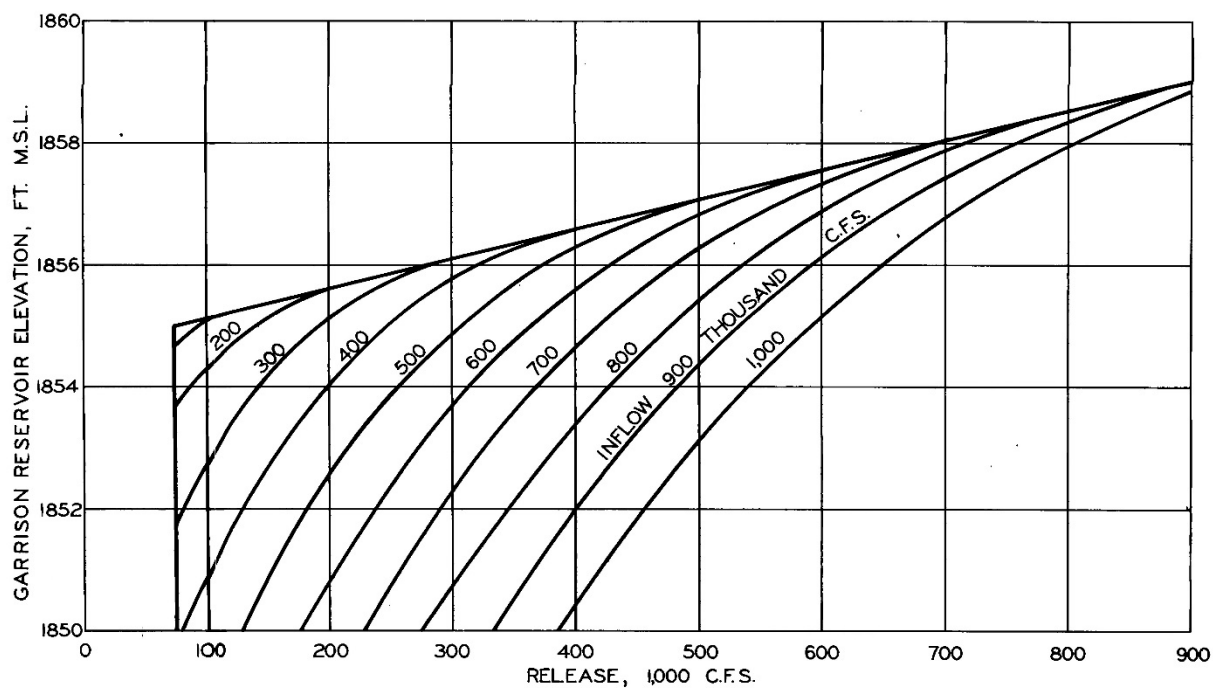
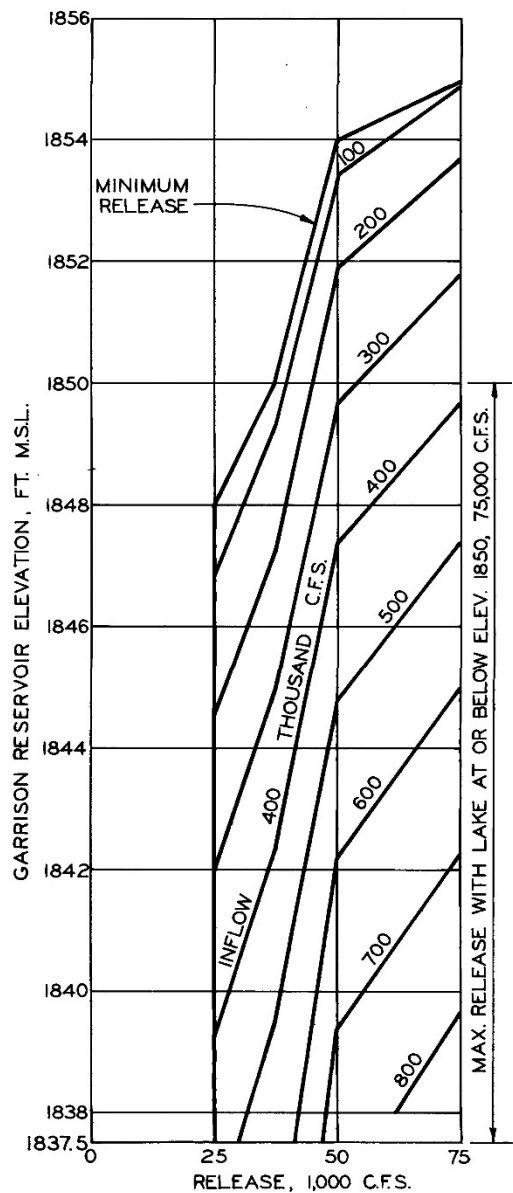


**NOTES:**

1. RELEASES ARE DETERMINED FROM POOL ELEVATION AND MEAN DAILY INFLOW.
2. CURVES ARE APPLICABLE FOR THE REGULATION OF MODERATE FLOODS SIMILAR TO THOSE OF PAST RECORD. FOR LARGER FLOODS, THE RULE CURVES INCLUDED IN THE EMERGENCY REGULATION PROCEDURES MAY BE USED AS REGULATION GUIDES.

Missouri River Basin  
**Garrison Water Control Manual**  
 Exclusive Flood Control Regulation  
 Curves

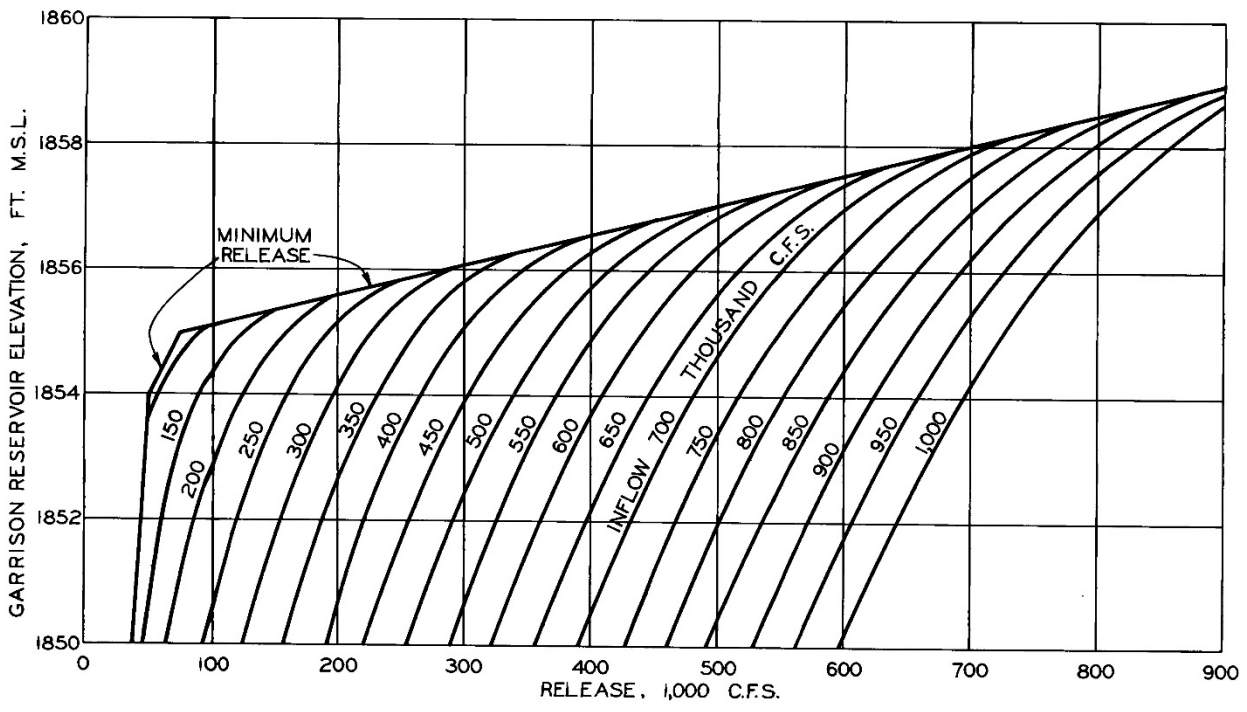
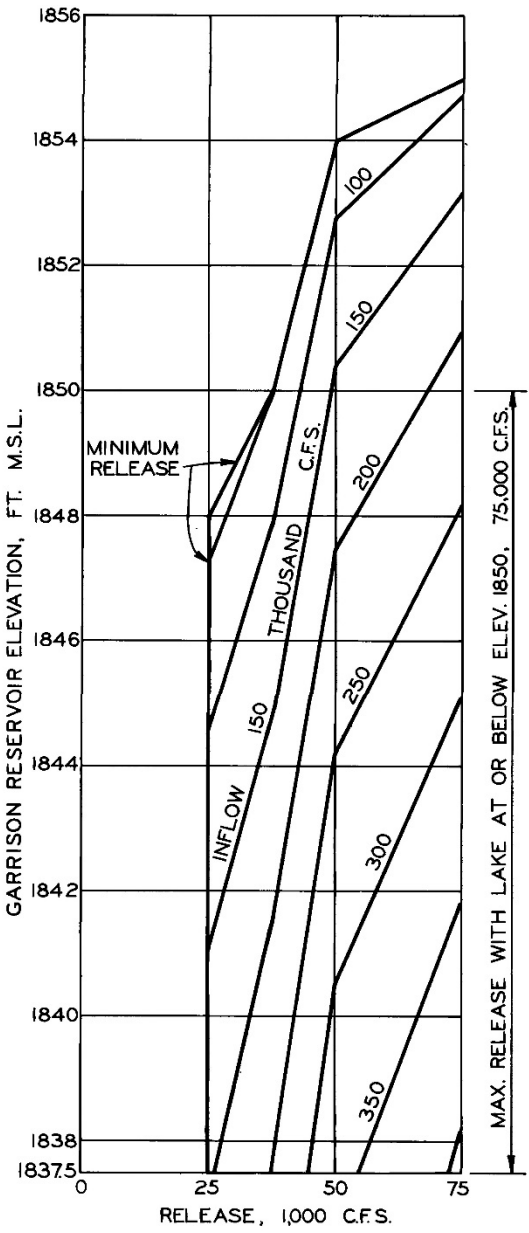
U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017



NOTES:

1. Curves are applicable for period 1 August to 30 April.
2. Numbered curves represent inflow in thousand C.F.S.
3. Emergency procedures will consist of:
  - a. Enter curves with current pool elevation.
  - b. Proceed to curve which equals inflow as determined for preceding 24 hours.
  - c. Maintain release as indicated by point of intersection.
  - d. No release shall exceed a rate greater than twice the average release rate for the preceding 24 hours.

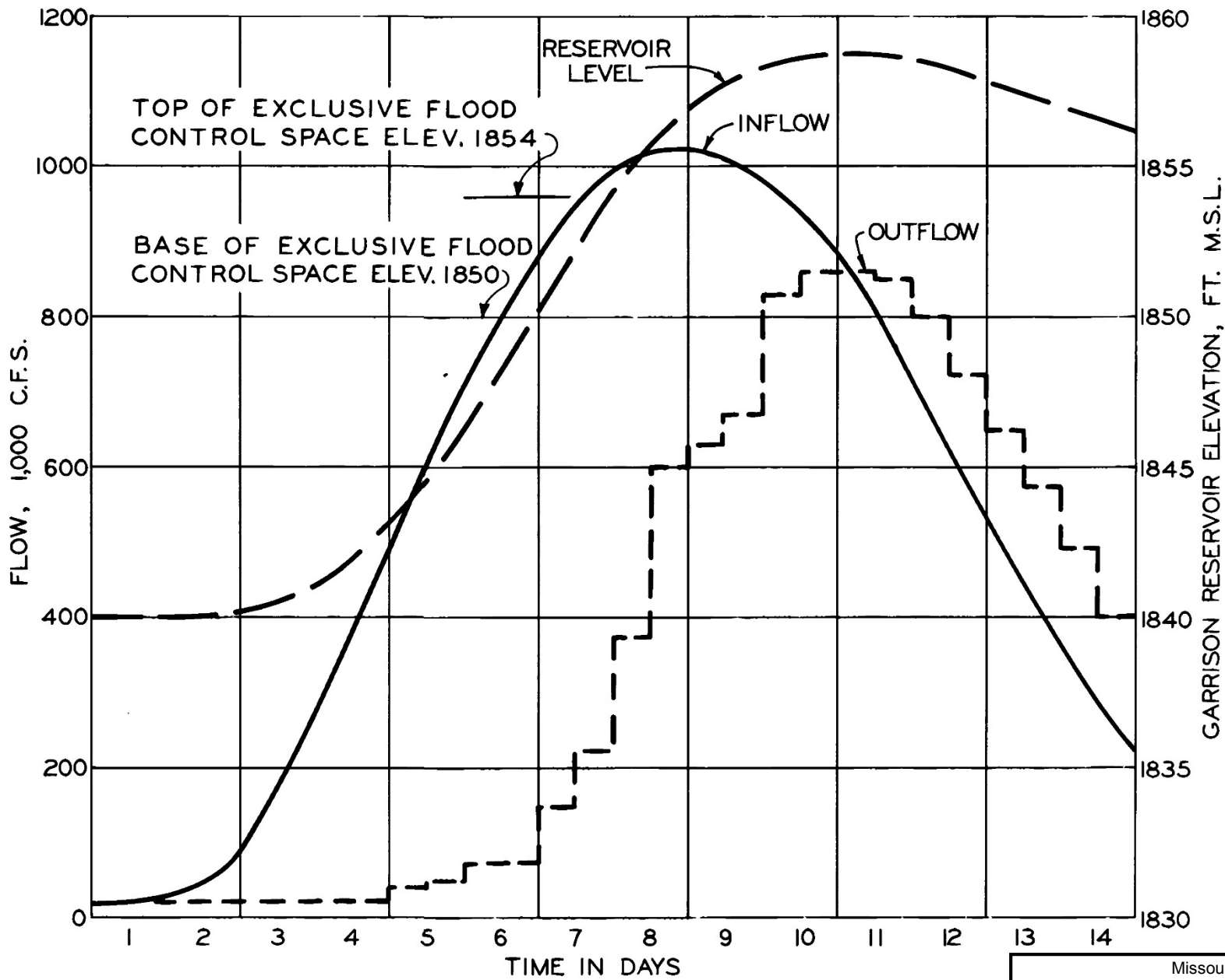
Missouri River Basin  
**Garrison Water Control Manual**  
 Emergency Regulation Curves  
 Rainfall and Plains Snowmelt  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017



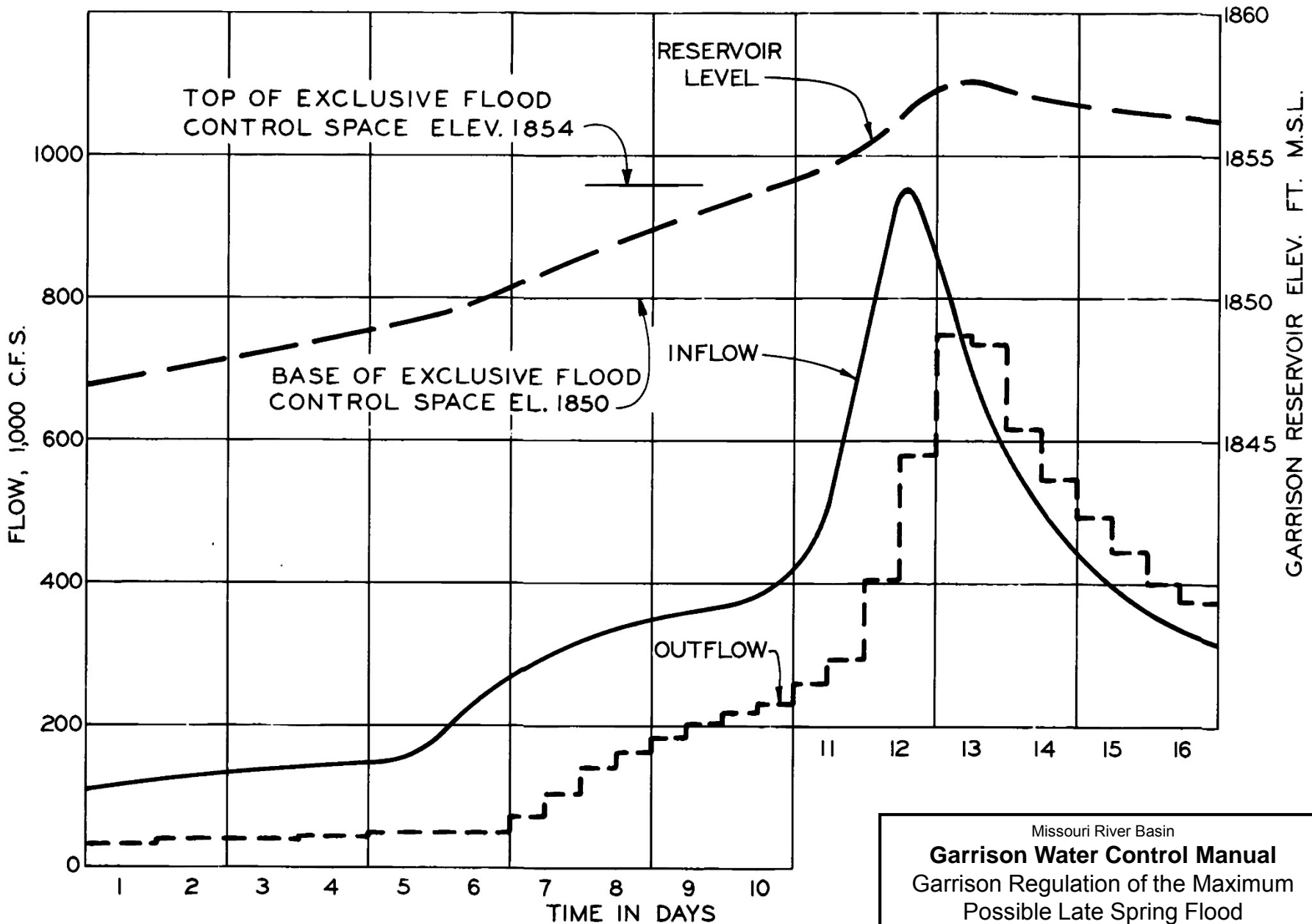
NOTES:

1. Curves are applicable for period 1 May to 31 July.
2. Numbered curves represent inflow in thousand C.F.S.
3. Emergency procedures will consist of:
  - a. Enter curves with current pool elevation.
  - b. Proceed to curve which equals inflow as determined for preceding 24 hours.
  - c. Maintain release as indicated by point of intersection.
  - d. No release shall exceed a rate greater than one and one-half times the average release rate for the preceding 24 hours

Missouri River Basin  
**Garrison Water Control Manual**  
 Emergency Regulation Curves  
 Mountain Snowmelt Period  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017



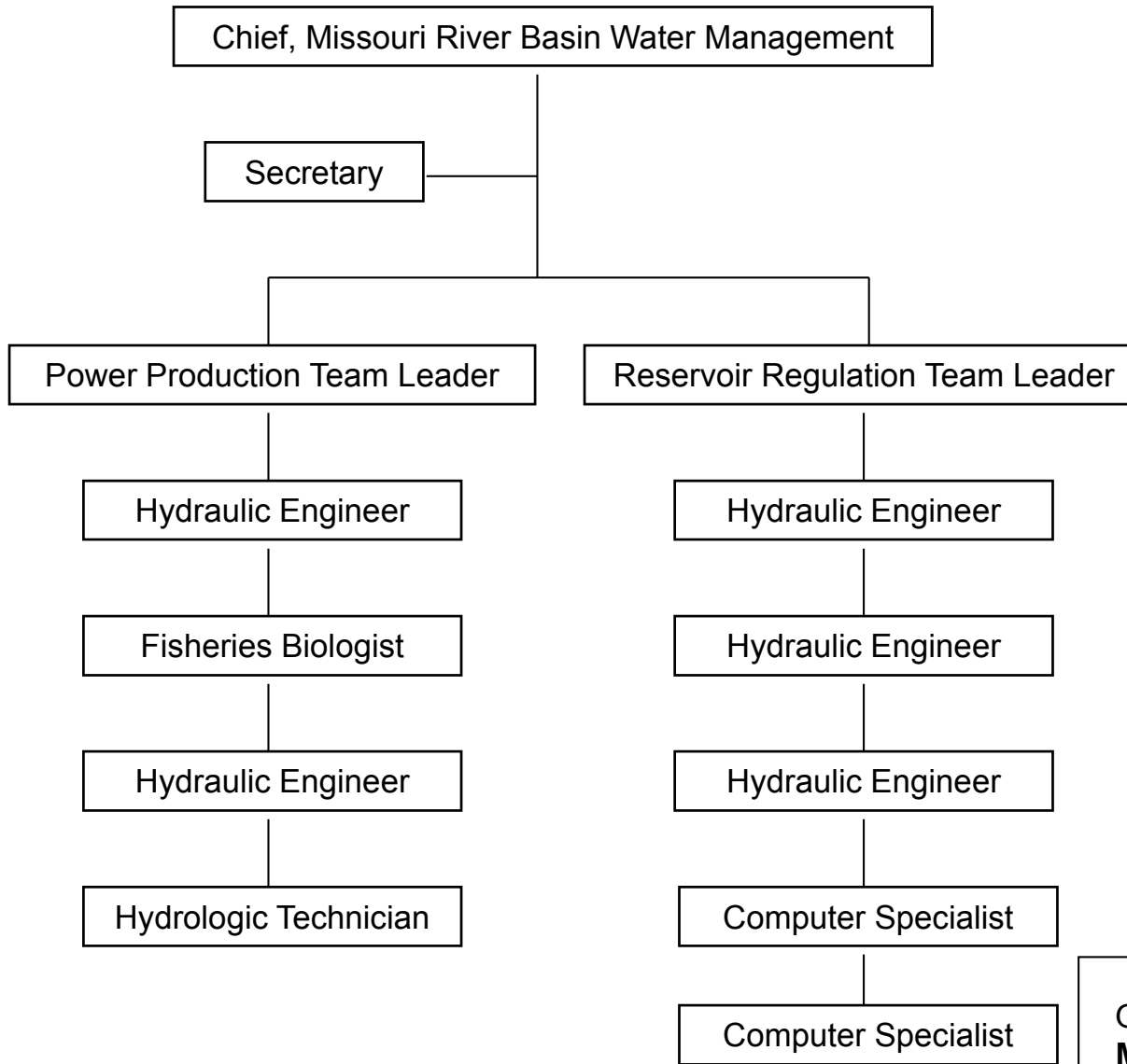
Missouri River Basin  
**Garrison Water Control Manual**  
Garrison Regulation of the Maximum  
Possible Early Spring Flood  
U.S. Army Engineer Division, Northwestern  
Corps of Engineers, Omaha, Nebraska  
September 2017



Missouri River Basin  
**Garrison Water Control Manual**  
 Garrison Regulation of the Maximum  
 Possible Late Spring Flood  
 U.S. Army Engineer Division, Northwestern  
 Corps of Engineers, Omaha, Nebraska  
 September 2017

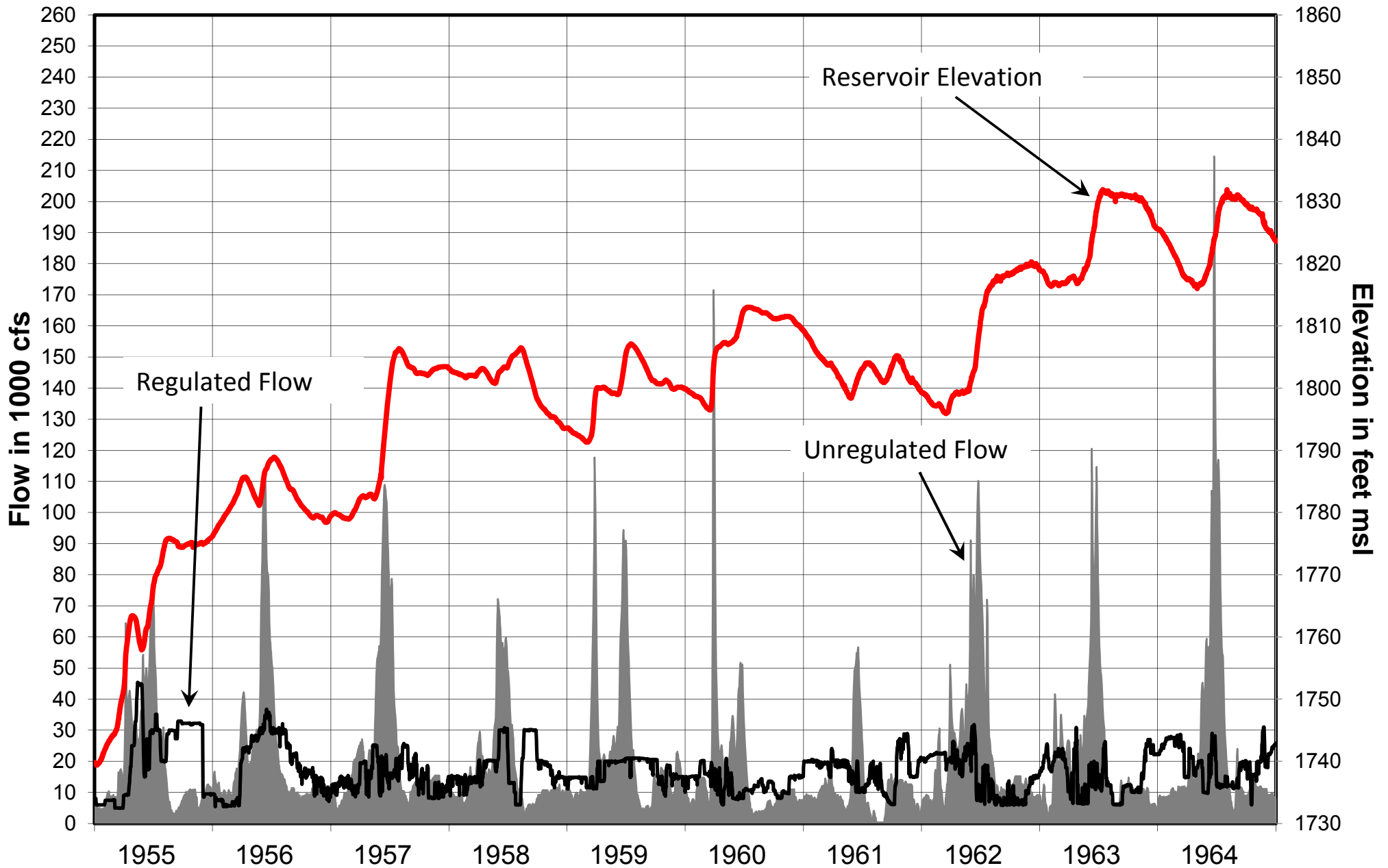
# NWD-Omaha

## Missouri River Basin Water Management Division



Budget Analyst is shared with Columbia River Basin Water Management

Missouri River Basin  
Garrison Water Control Manual  
**MRBWMD Organization Chart**  
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN  
CORPS OF ENGINEERS, OMAHA, NEBRASKA  
September 2017



Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1955 - 1964  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

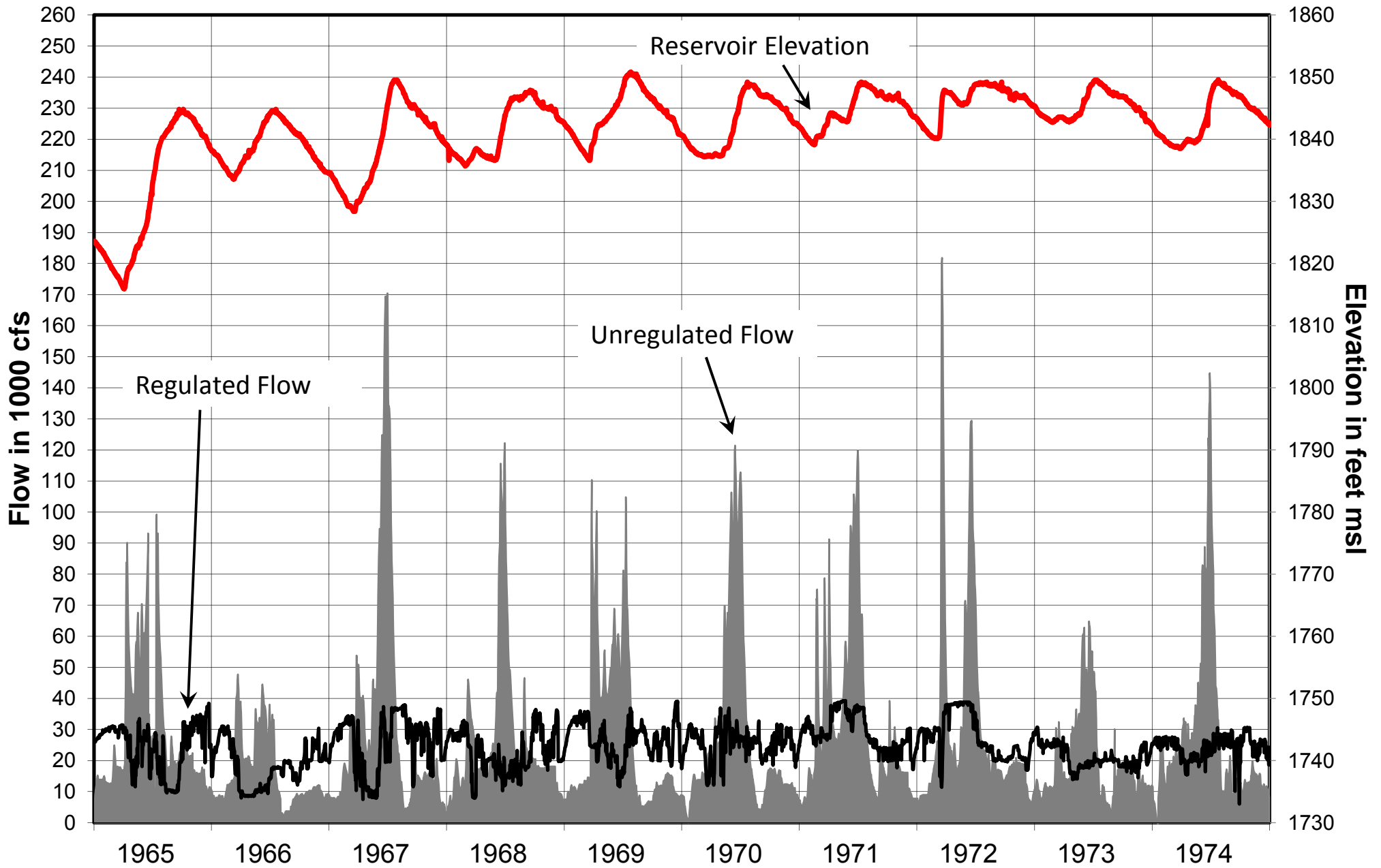


Plate A-2

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1965 - 1974  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

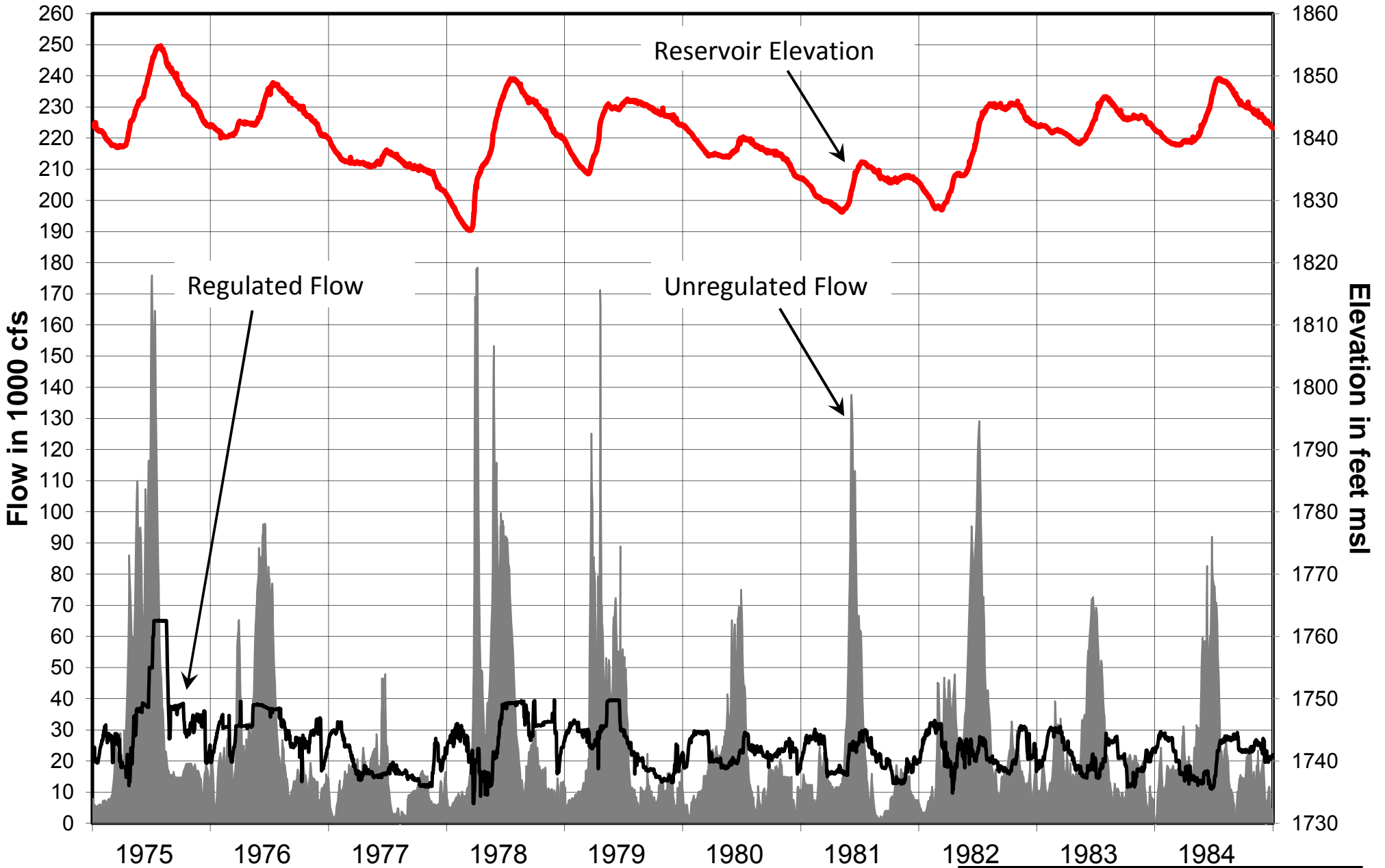


Plate A-3

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1975 - 1984  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

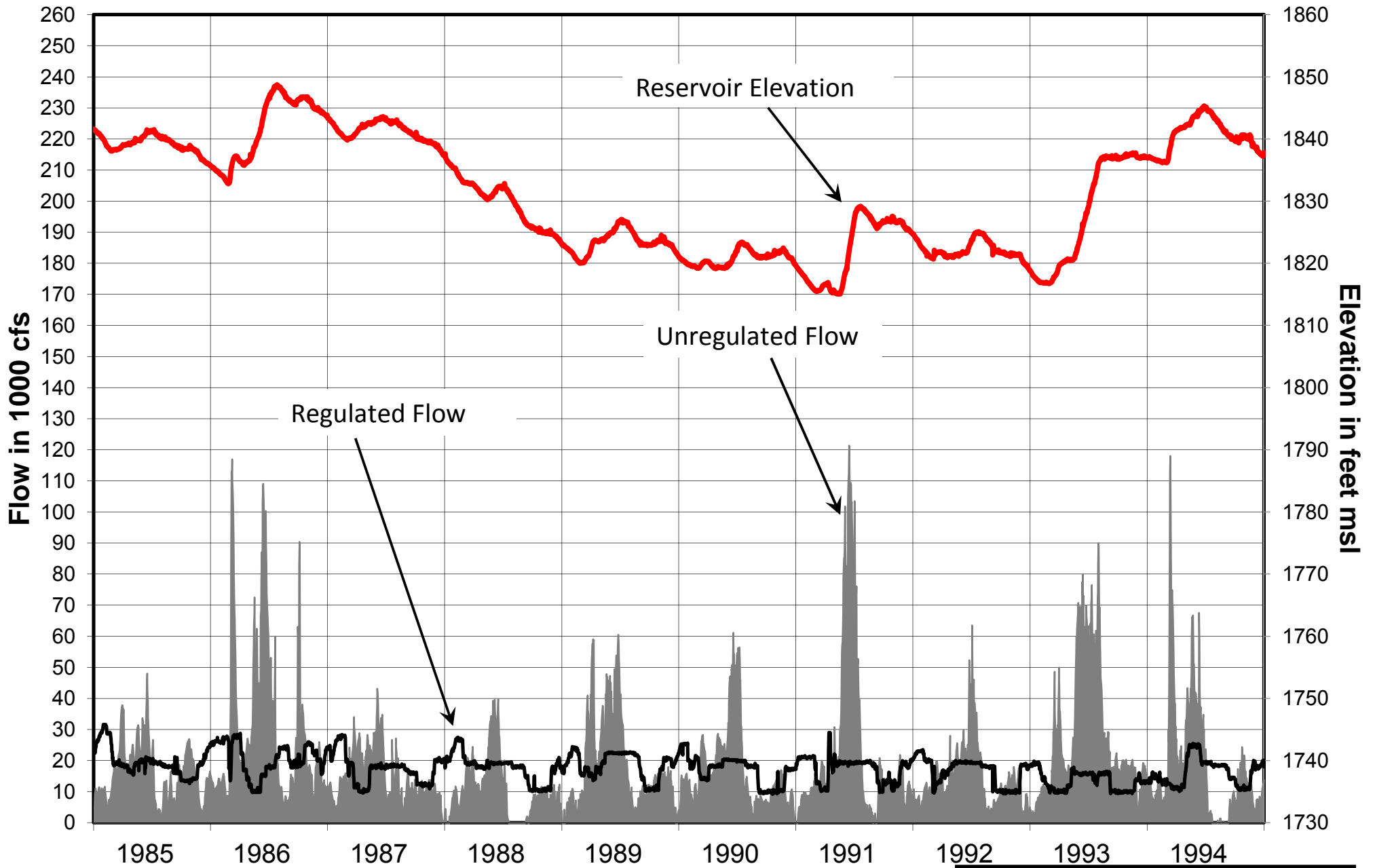
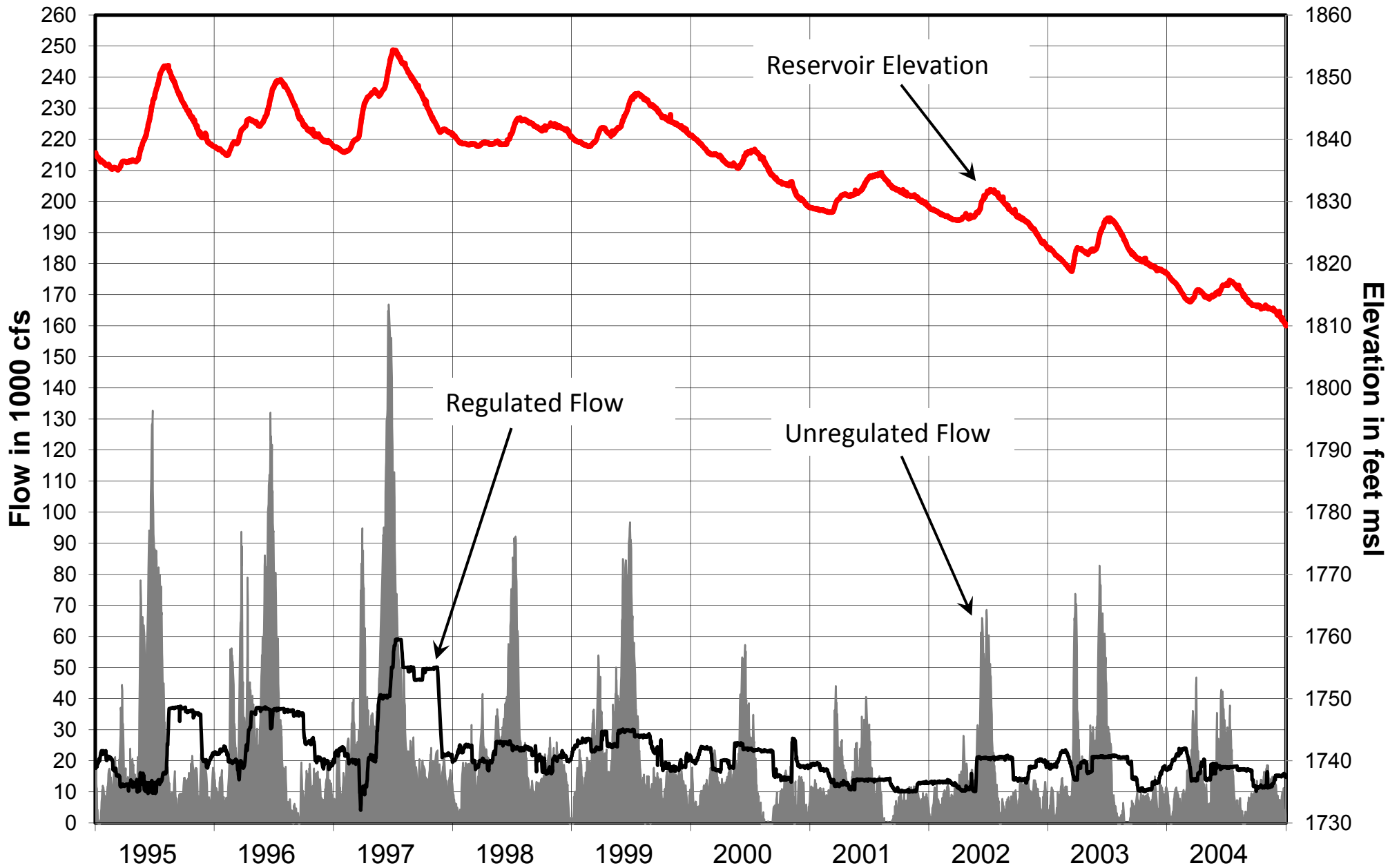


Plate A-4

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1985 - 1994  
 U.S.ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017



Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1995 - 2004  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

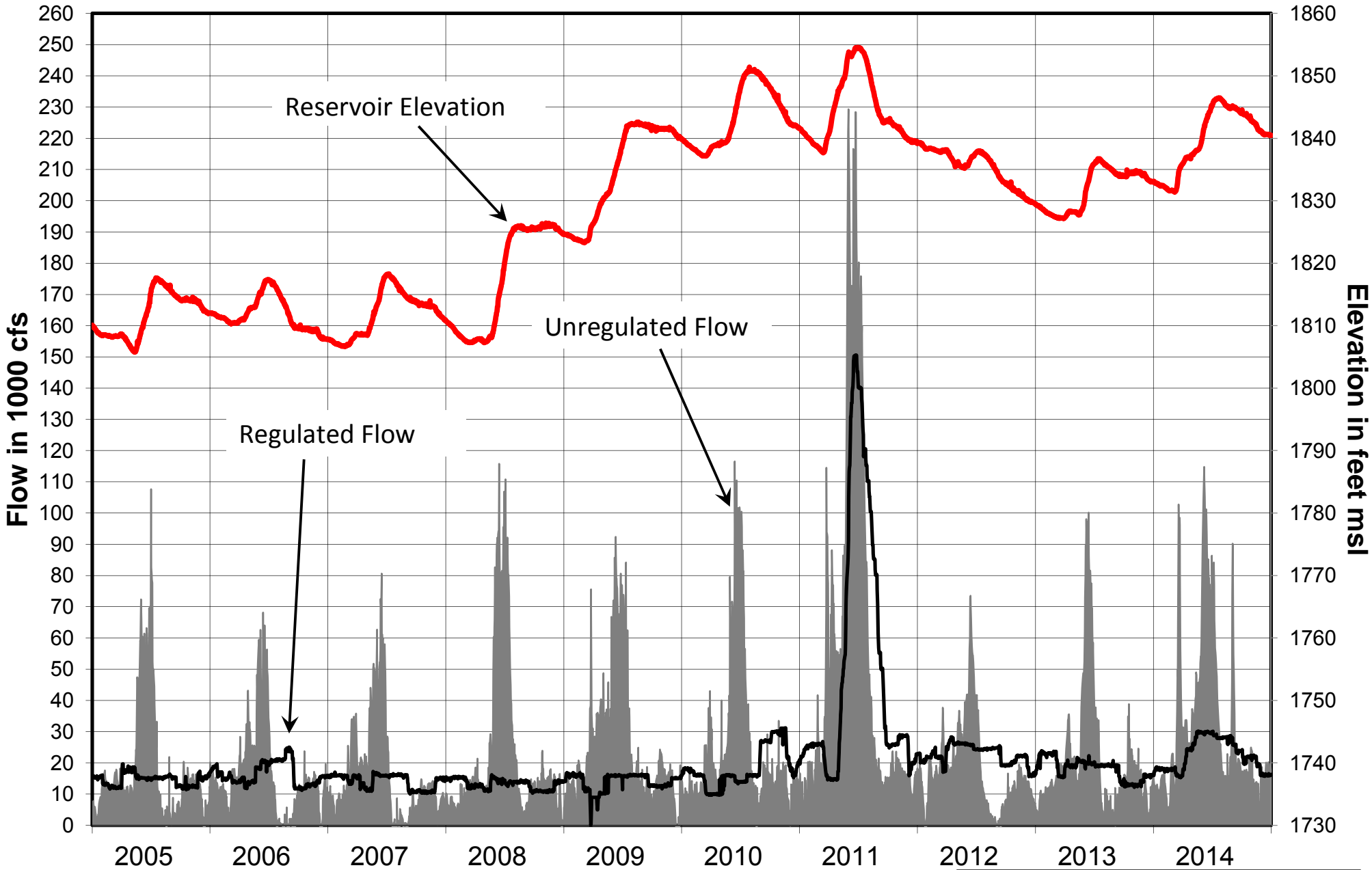


Plate A-6

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 2005 - 2014  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

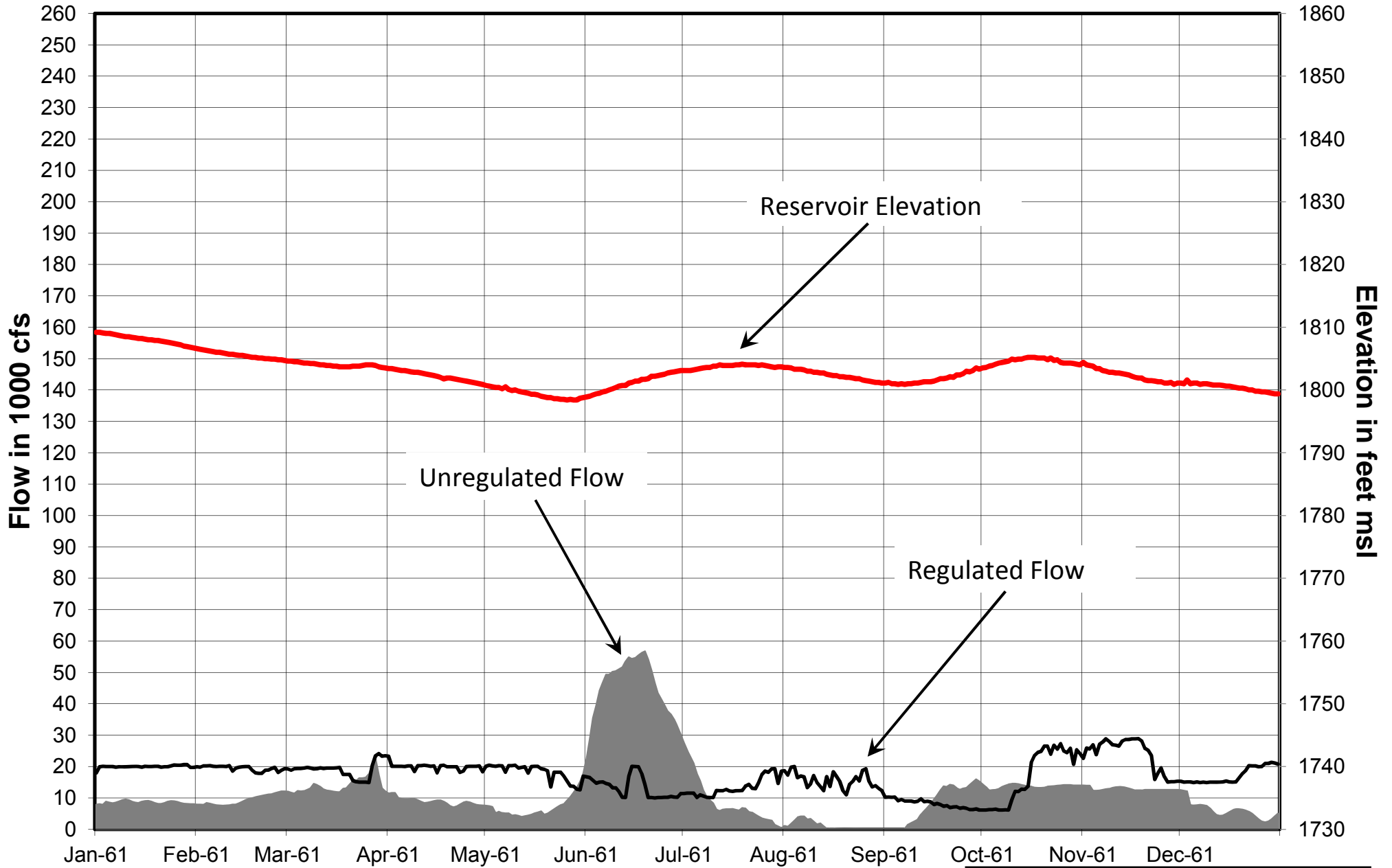


Plate A-7

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1961  
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

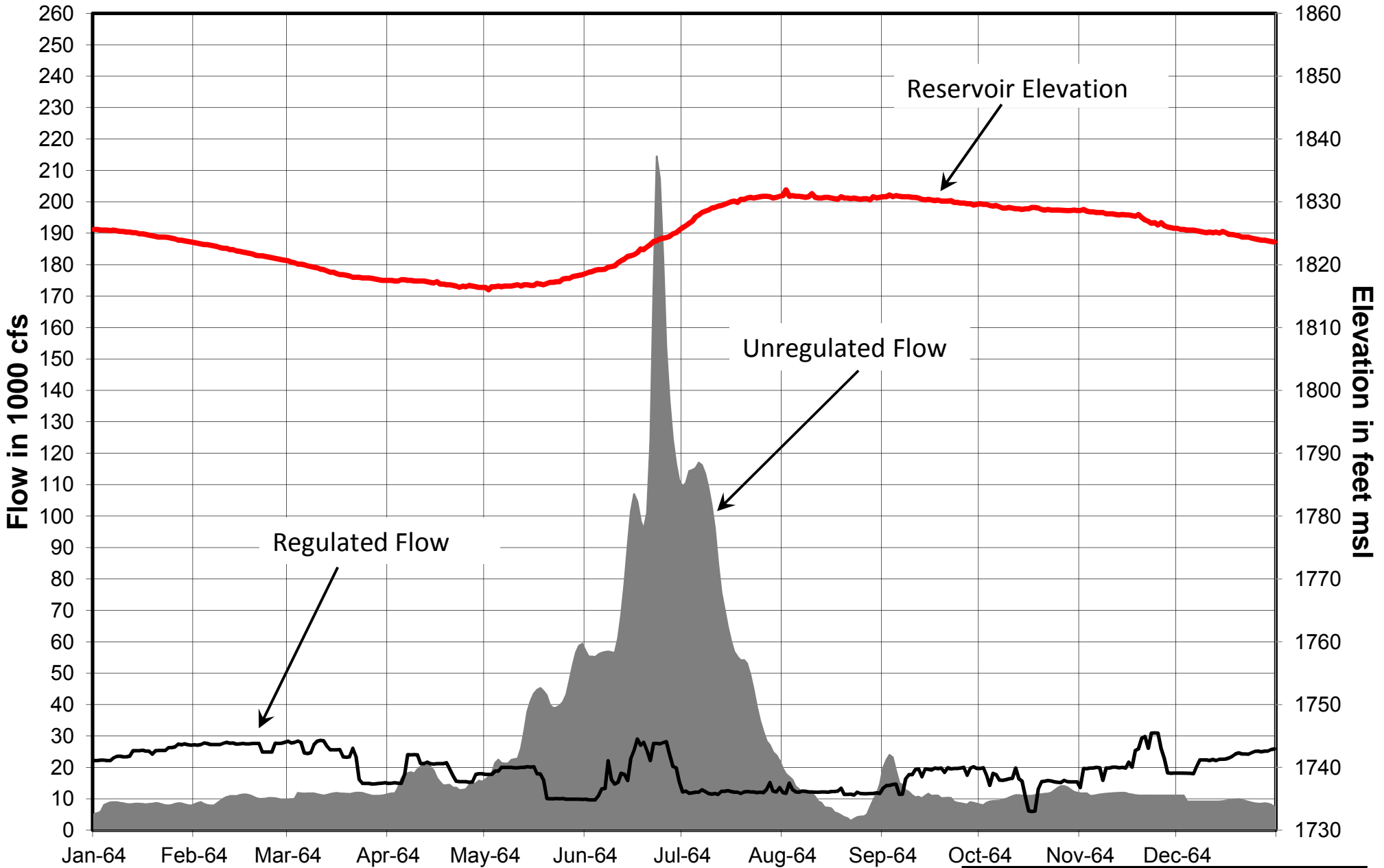
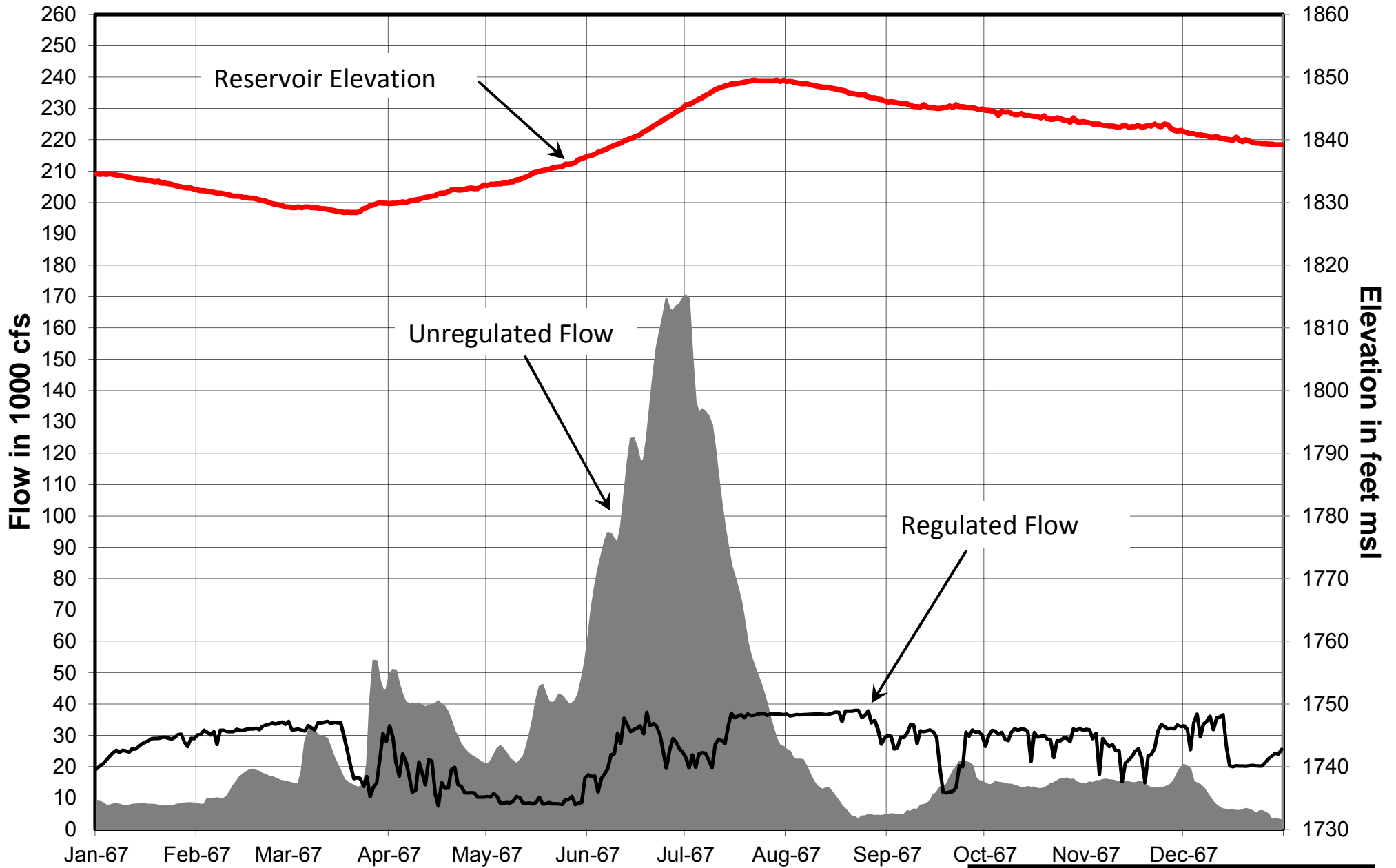


Plate A-8

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1964  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017



Flow in 1000 cfs

Elevation in feet msl

Plate A-9

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1967  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

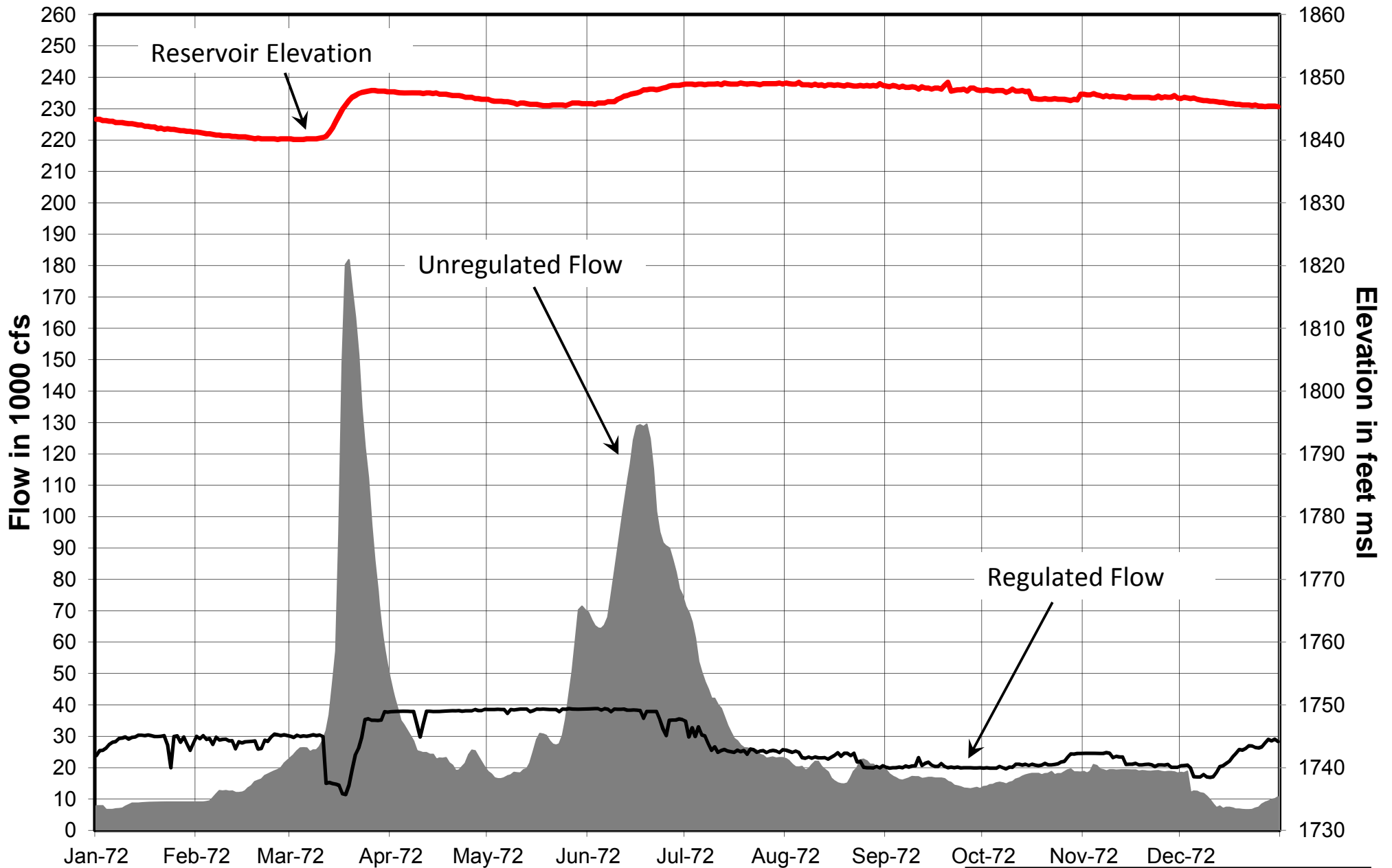
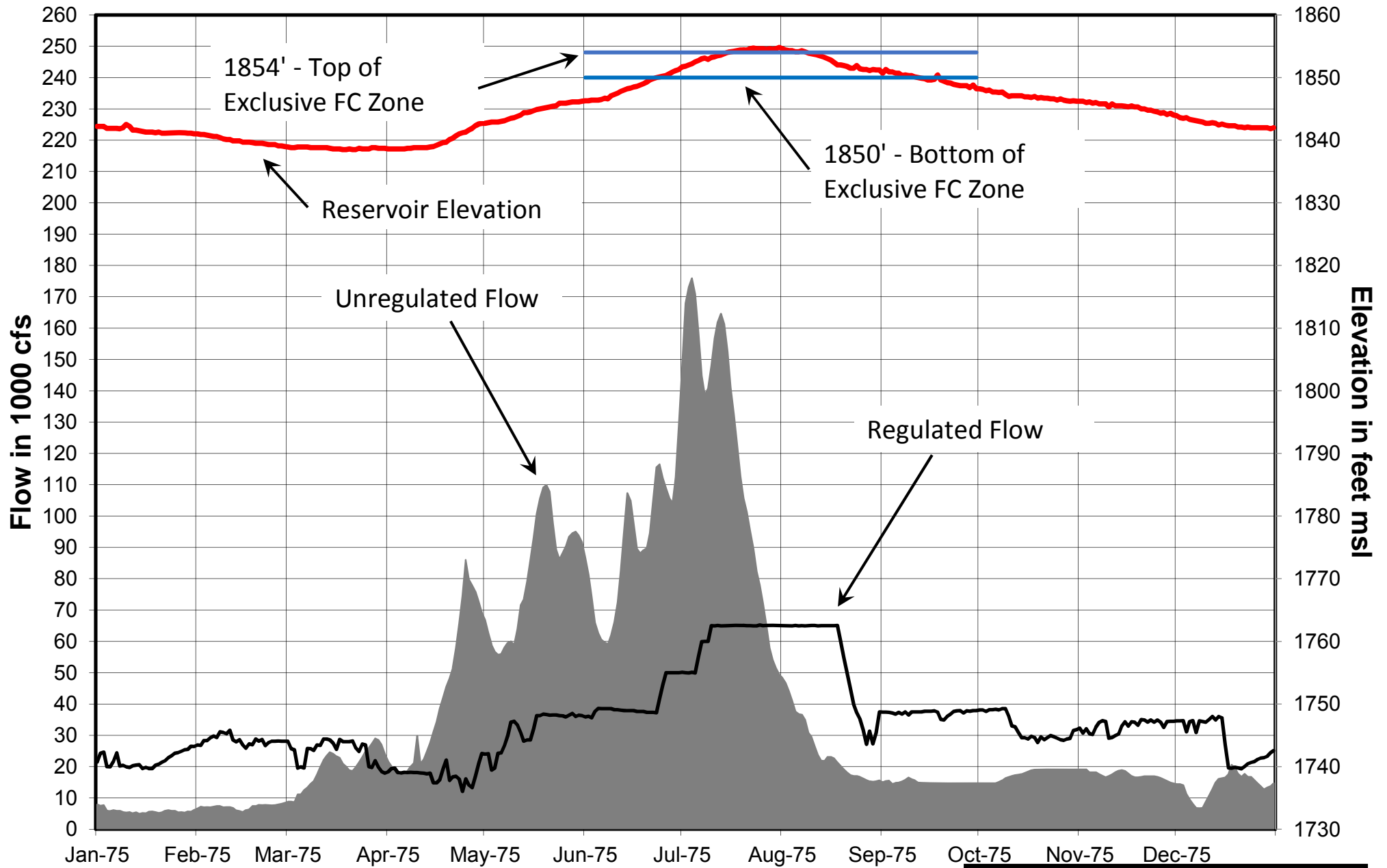


Plate A-10

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1972  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017



Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1975  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

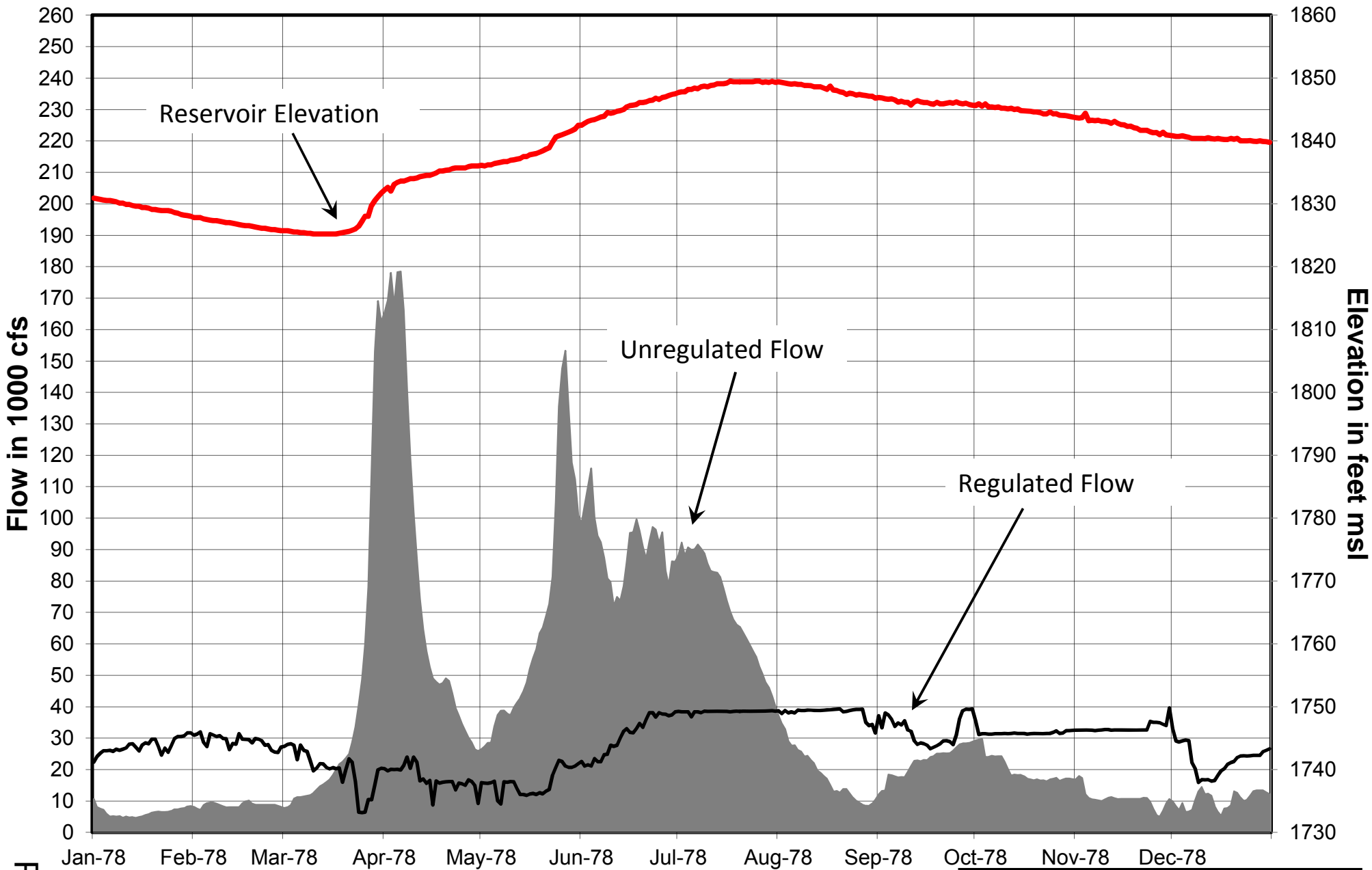


Plate A-12

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1978  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

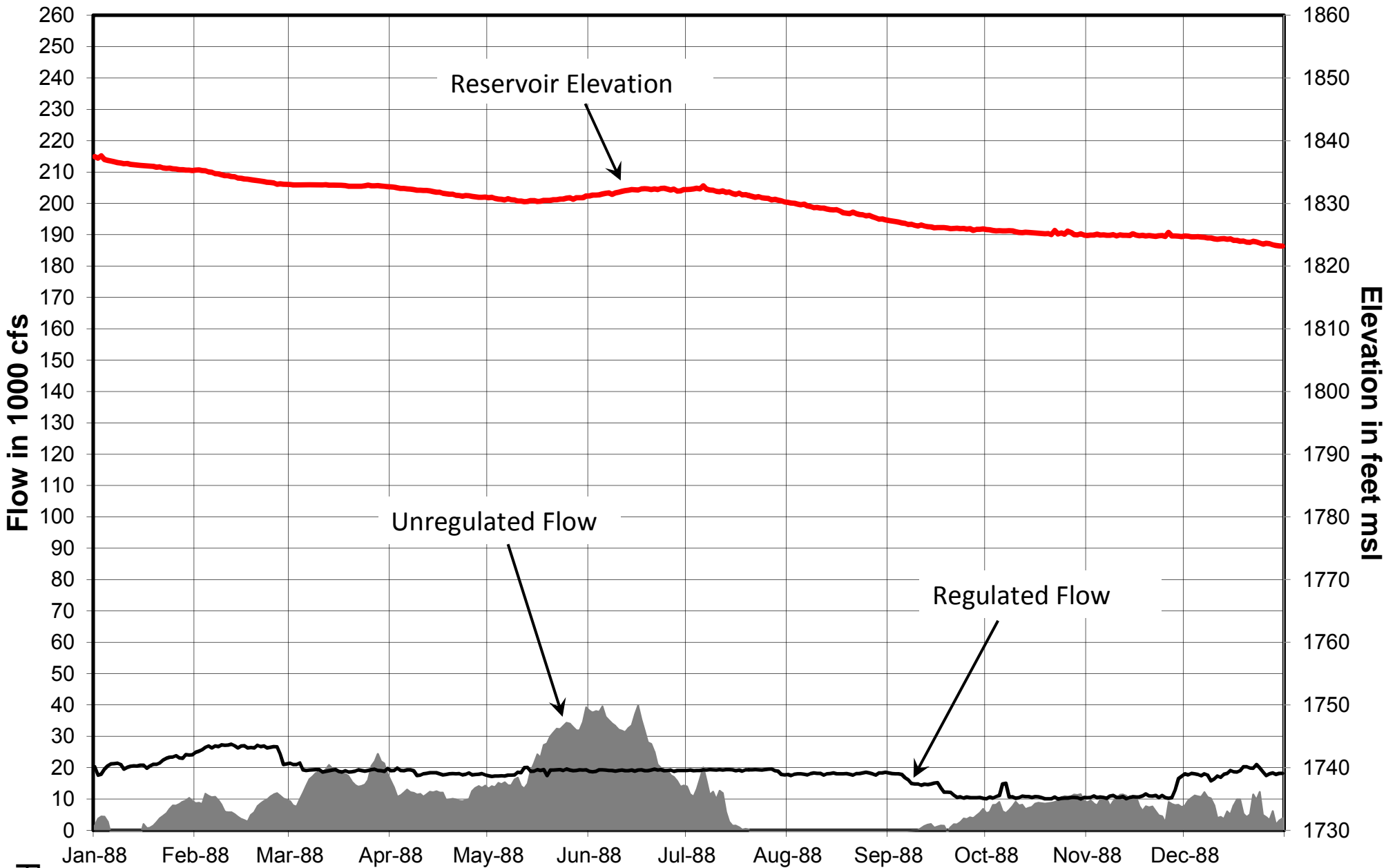


Plate A-13

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1988  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

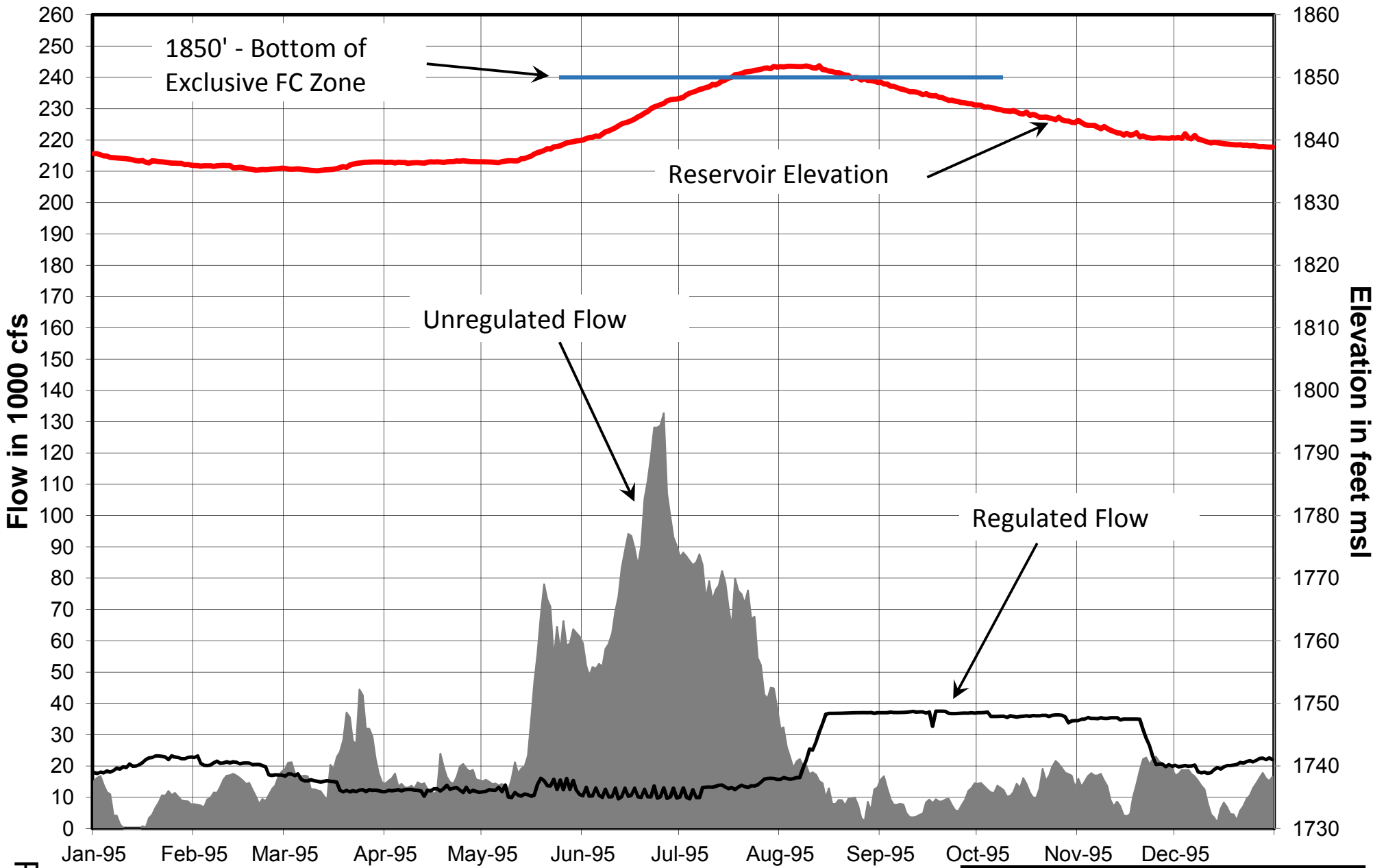


Plate A-14

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1995  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

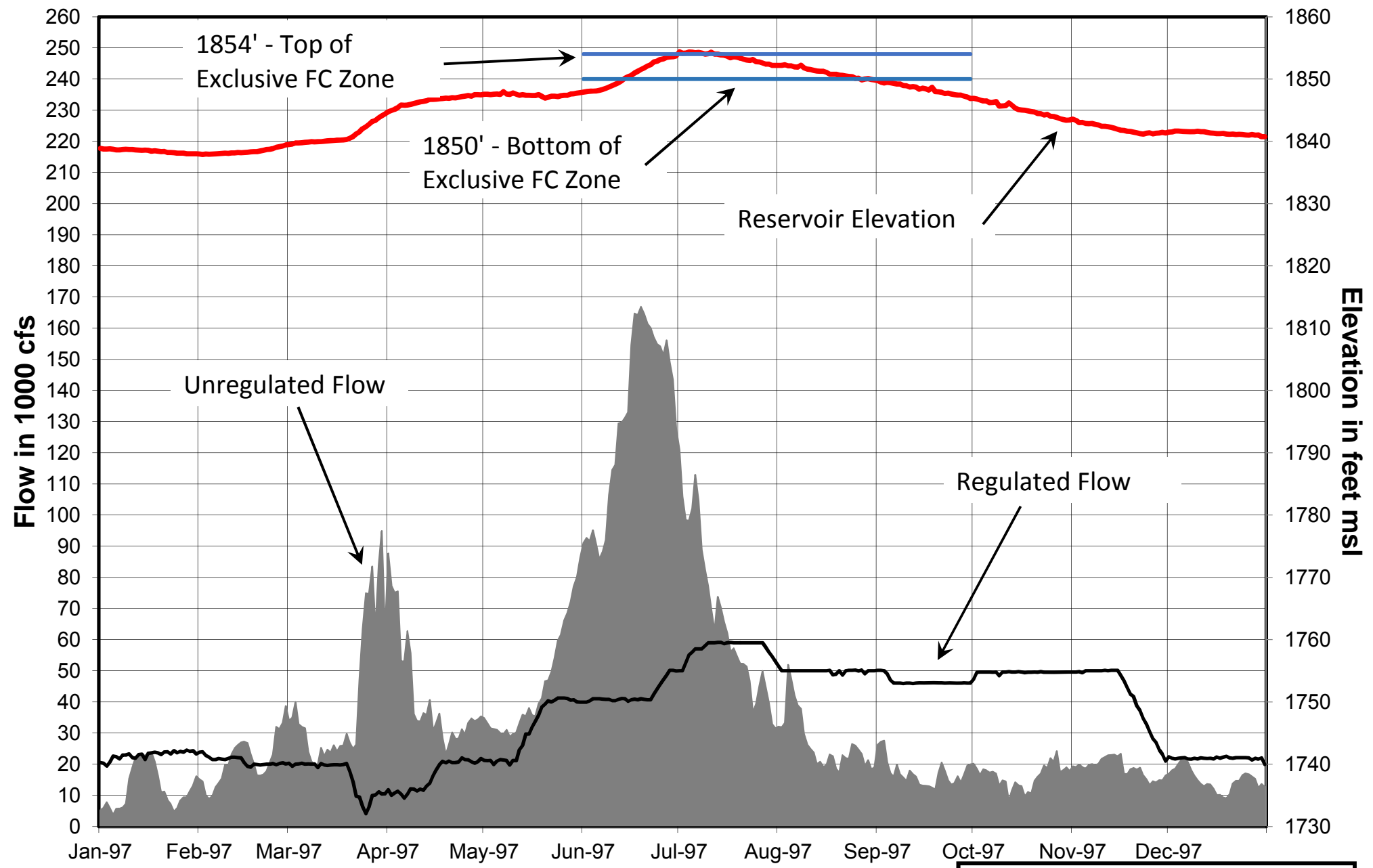


Plate A-15

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 1997  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

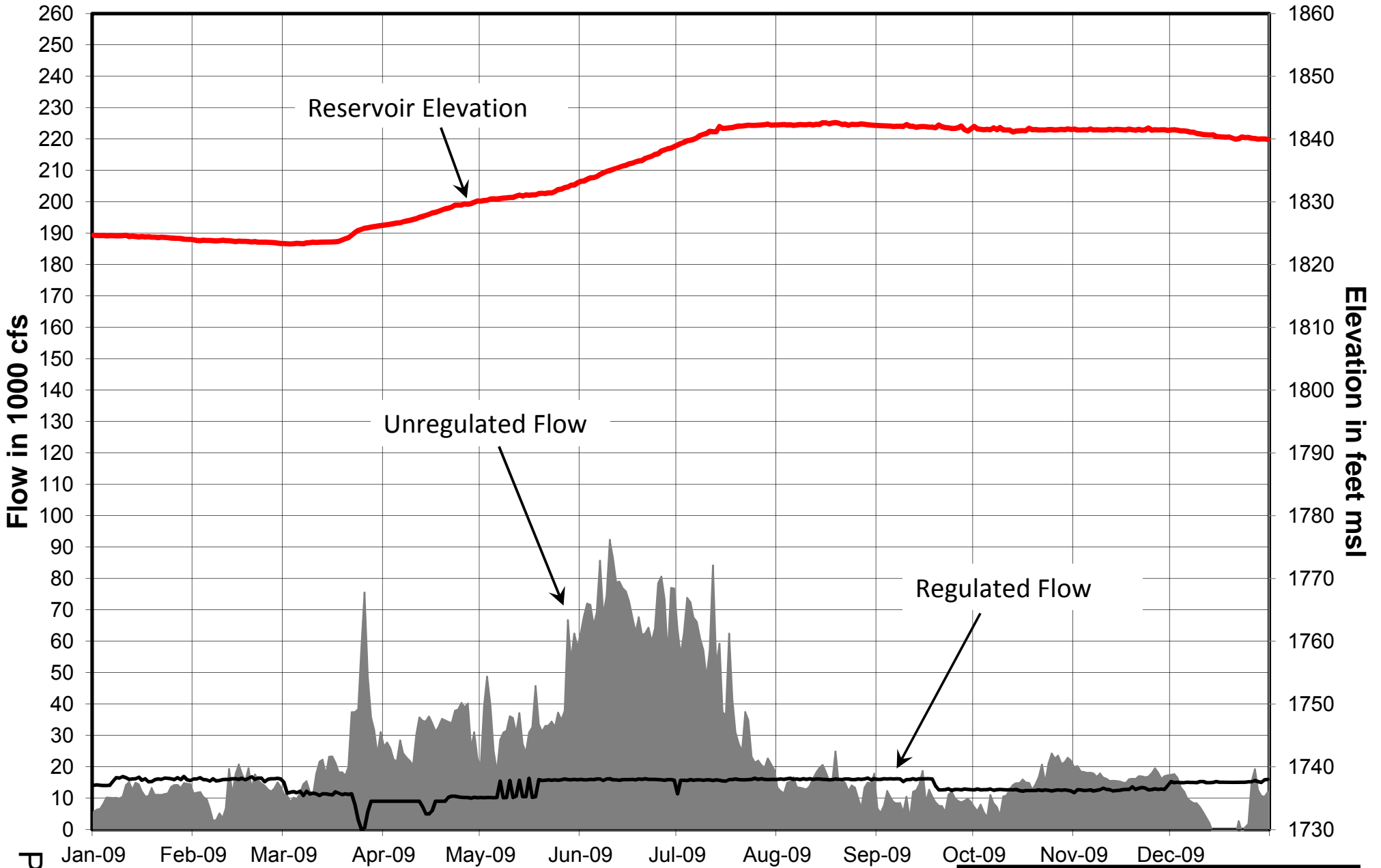
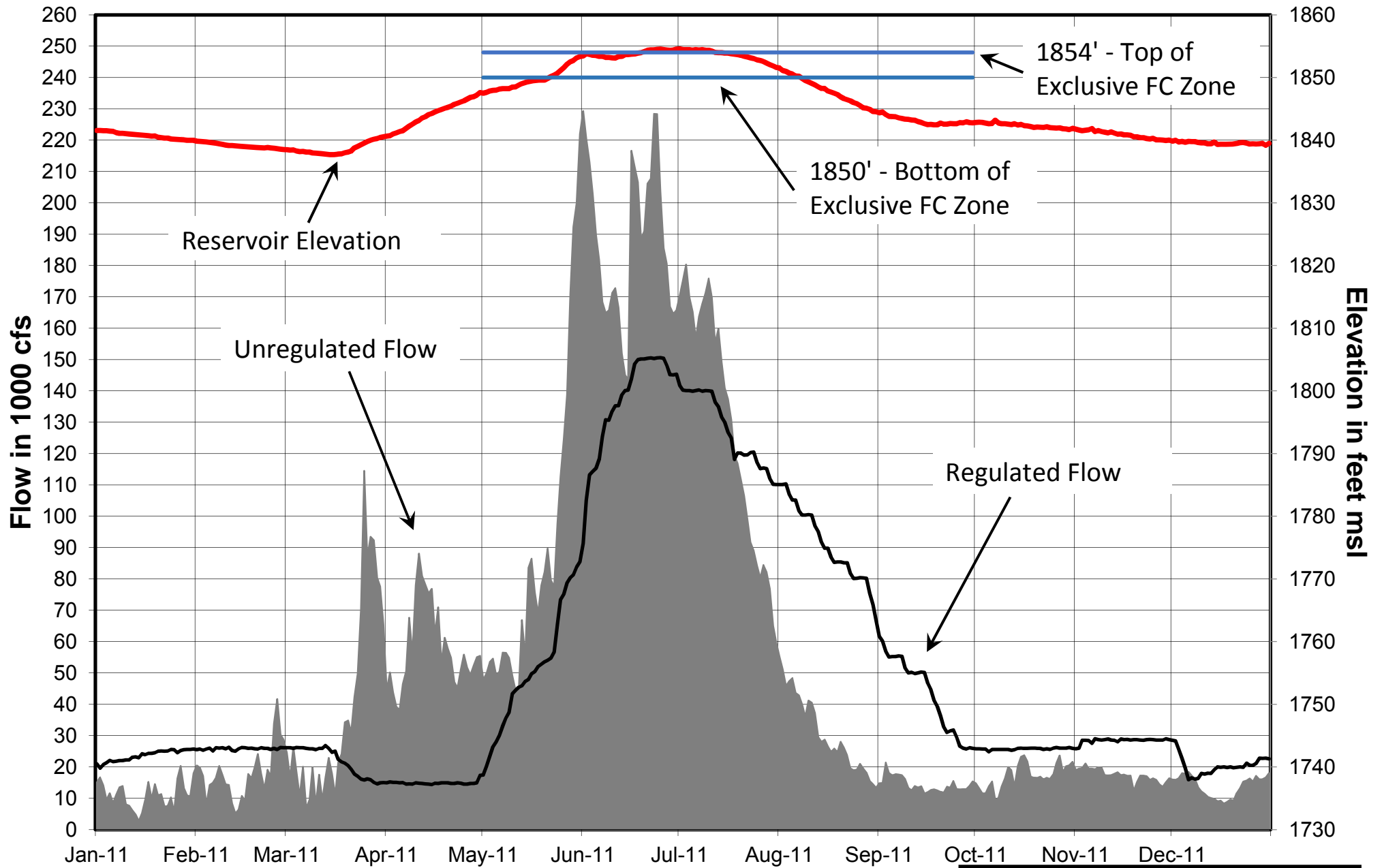


Plate A-16

Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 2009  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017



Missouri River Basin  
**Garrison Water Control Manual**  
 Reservoir Elevation, Regulated and  
 Unregulated Flows, 2011  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017

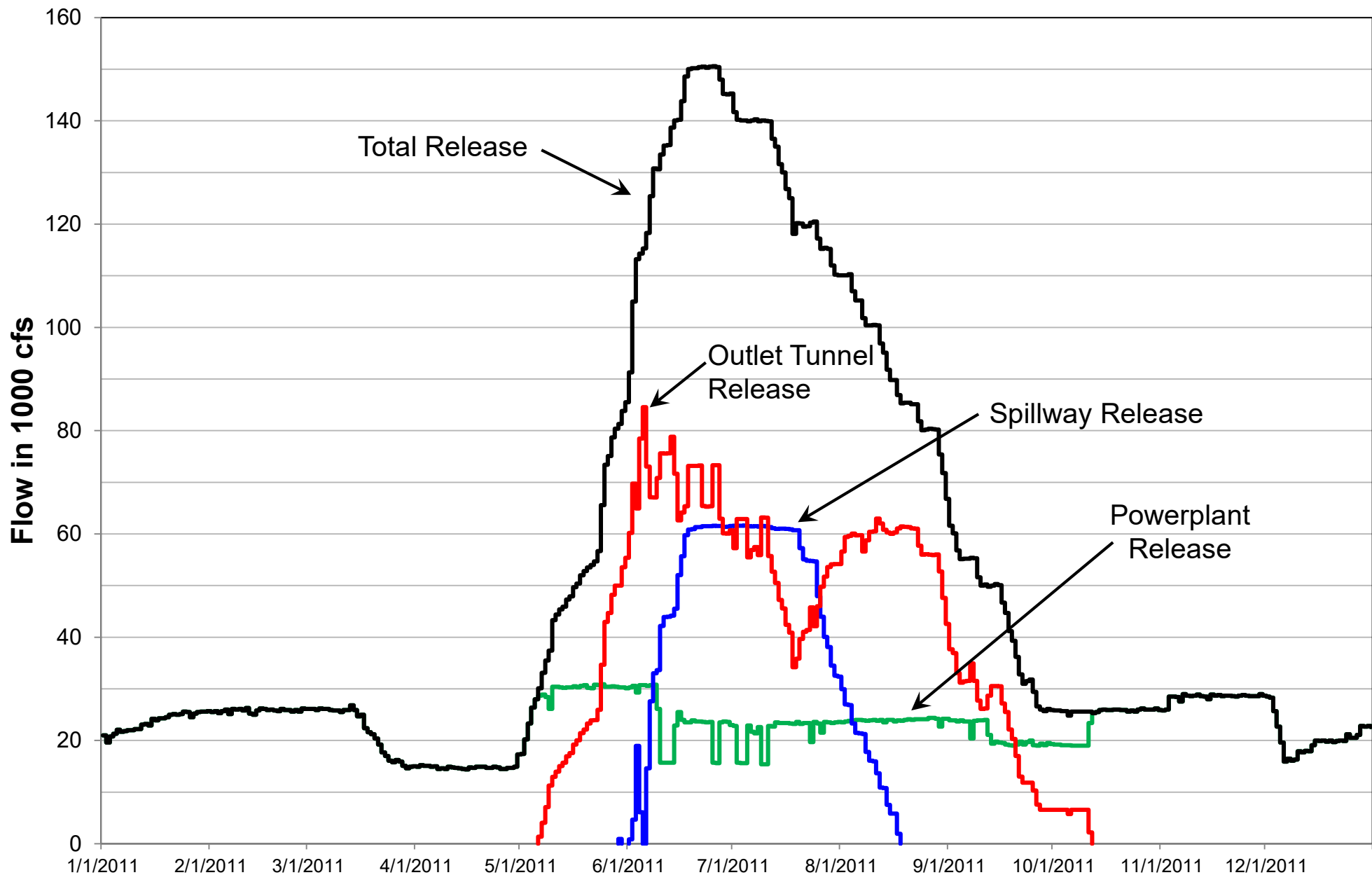
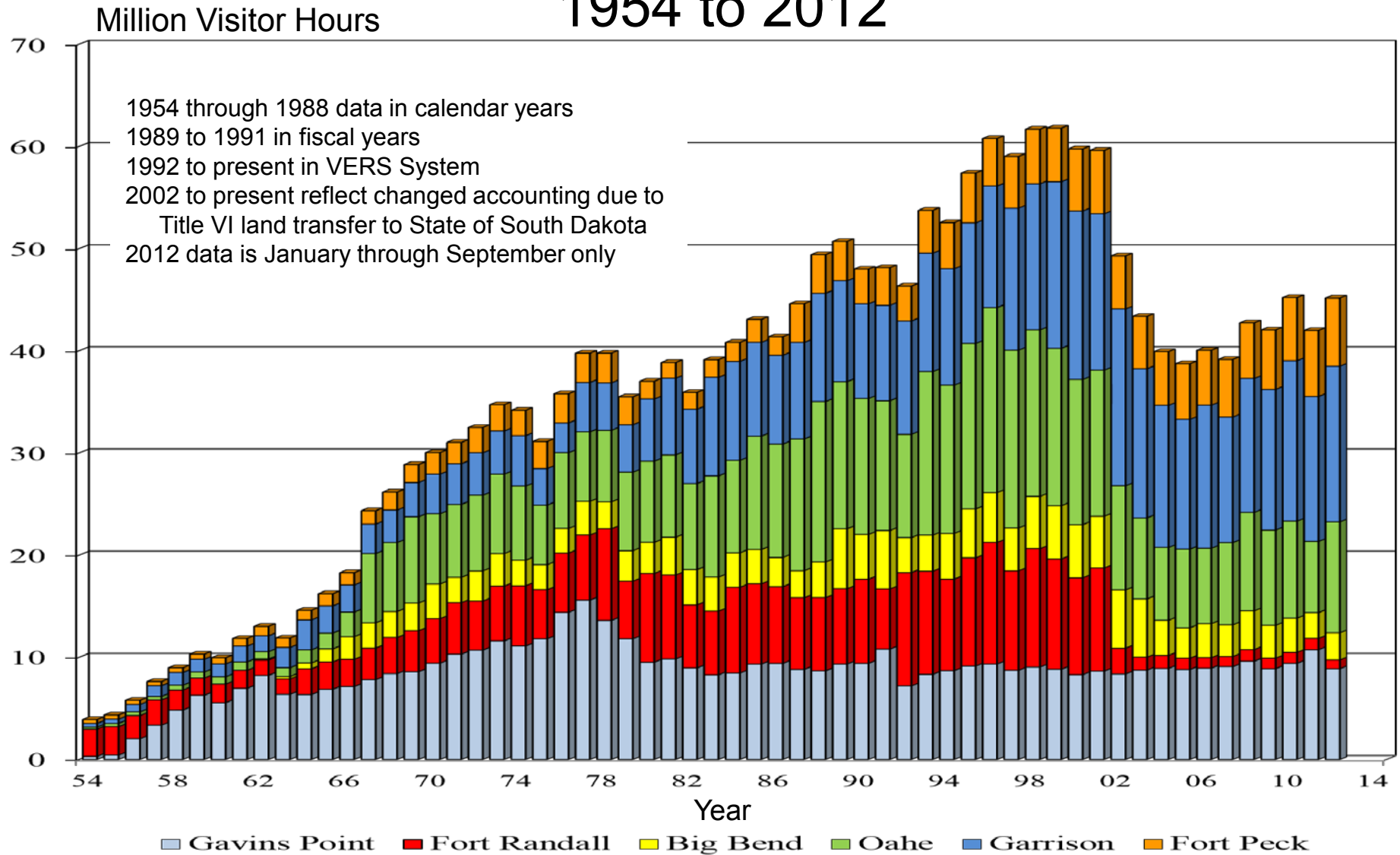


Plate A-18

Missouri River Basin  
**Garrison Water Control Manual**  
 2011 Powerplant, Spillway, Outlet  
 Tunnel and Total Releases  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 Revised – October 2020

# Mainstem Project Visits

## 1954 to 2012



Missouri River Basin  
 Garrison Water Control Manual  
**Mainstem Project Visitor Hours**  
 U.S. ARMY ENGINEER DIVISION, NORTHWESTERN  
 CORPS OF ENGINEERS, OMAHA, NEBRASKA  
 September 2017