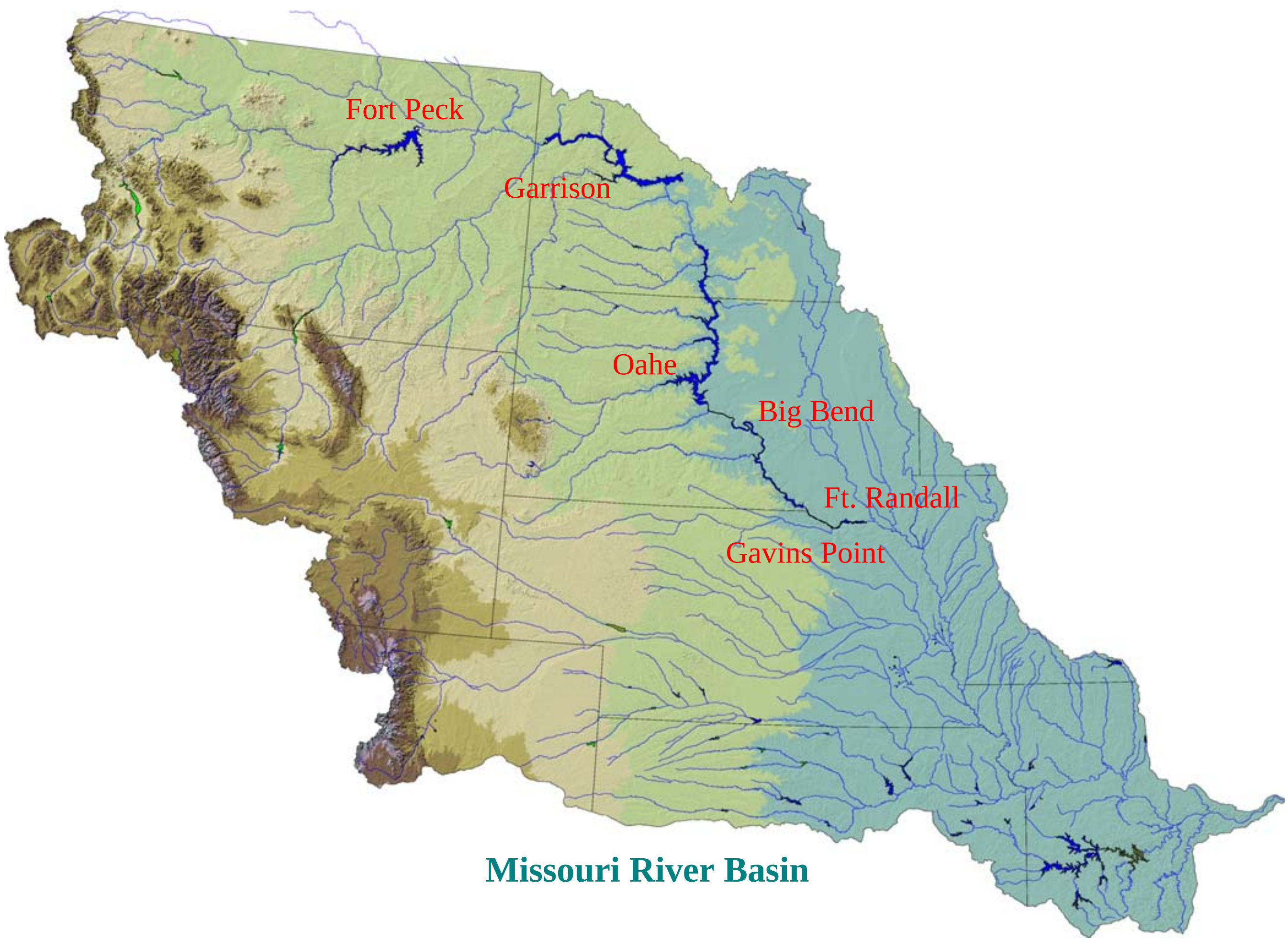
US Army Corps
of Engineers

Northwestern Division

Missouri River Mainstem Reservoir System

Water Control Manual

Big Bend Dam - Lake Sharpe



Missouri River Basin

Reservoir Control Center
U.S. Army Corps of Engineers
Northwestern Division - Missouri River Basin
Omaha, Nebraska

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Missouri River Basin
Mainstem Reservoir System
Water Control Manual

In 7 Volumes — Volume 5

BIG BEND DAM – LAKE SHARPE

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)

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Corps of Engineers
Omaha, Nebraska

May 2007

Missouri River Basin
Mainstem Reservoir System
Water Control Manual

In 7 Volumes Volume 5

BIG BEND DAM – LAKE SHARPE

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VI – Hydrologic Forecasts

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ABBREVIATIONS

AOP	-	annual operating plan
BIA	-	Bureau of Indian Affairs
cfs	-	cubic feet per second
COOP	-	Continuity of Operations Plan
Corps	-	Corps of Engineers
CWCP	-	current water control plans
DCP	-	Data Collection Platform
EIS	-	Environmental Impact Statement
EPA	-	Environmental Protection Agency
ESA	-	Endangered Species Act
F	-	Fahrenheit
Holdouts	-	Natural, or unregulated flows
Kcfs	-	1,000 cubic feet per second
kW	-	kilowatt
LRS	-	Long-Range System
Master Manual	-	Master Water Control Manual
MAPP	-	Mid-continent Area Power Pool
MBRFC	-	National Weather Service Missouri Basin River Forecast Center
MPE	-	Multi-sensor Precipitation Estimates
MRBA	-	Missouri River Basin Association
MRBWMD	-	Missouri River Basin Water Management Division
MRD	-	Missouri River Division
MOU	-	Memorandum of Understanding
msl	-	mean sea level
MW	-	megawatt
MWh	-	megawatt hour
NWD	-	Northwestern Division
NWS	-	National Weather Service
P.L.	-	Public Law
plover	-	piping plover
PPCS	-	Power Plant Control System
RCC	-	Reservoir Control Center
Service	-	U.S. Fish and Wildlife Service
Southwestern	-	Southwestern Power Administration
System	-	Missouri River Mainstem Reservoir System
T&E	-	threatened and endangered species
tern	-	interior least tern
USBR	-	Bureau of Reclamation
USGS	-	United States Geological Survey
Western	-	Western Area Power Administration
WSCC	-	Western Systems Coordinating Council

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I – Introduction

1-01. Authorization. This manual has been prepared as directed in the U.S. Army Corps of Engineers' Water Management Regulation, ER 1110-2-240, which prescribes the policies and procedures to be followed by the U.S. Army Corps of Engineers (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 for Big Bend, as discussed in that regulation. This manual is also prepared in accordance with pertinent sections of the Corps' Engineering Manual, EM 1110-2-3600, and entitled "Management of Water Control Systems." This Water Control Manual is prepared under the format and recommendations described in the Corps' Water Management Regulation, ER 1110-2-8156, dated August 31, 1995 and entitled "Preparation of Water Control Manuals." This Big Bend water control manual, like the Mainstem Master Manual and its selected plan, establish guidelines intended to be used by the Corps in regulating Big Bend. 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 water control plan. Revisions to this manual are processed in accordance with ER 1110-2-240. Deviations from this manual are processed in accordance with ER 1110-2-1400.

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 is for total System regulation (Master Manual):

Volume	Project
1	Master Manual
2	Fort Peck - Fort Peck Dam / Fort Peck Reservoir
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 Water Control Manual 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 manual also includes site-specific maps and regulation considerations. This individual project Water Control Manual, like the Master Manual, serves as a guide to the Reservoir Control Center (RCC) in meeting the operational objectives of the System when regulating the six System reservoirs. Since Big Bend is part of the System any discussions regarding the regulation of Big Bend dam 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 all constructed by the Corps for the purposes 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 operational objectives and the plans for their optimum fulfillment, with supporting basic data. The Big Bend Water Control Manual supplements the Master Manual by discussing the factors pertinent to the regulation of Big Bend reservoir. The regulation of major tributary reservoirs located within the Missouri River basin affecting the regulation of the Big Bend is detailed in separate water control manuals prepared for the individual tributary projects.

1-03.1. In an effort to reduce redundancy, frequent reference will be made in this manual 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 water control manual should, therefore, be considered as a supplement to the Master Manual that presents further information and expands or emphasizes details that are of particular importance to Big Bend.

1-03.2. In a further effort to reduce redundancy among the individual project manuals, frequent reference will be made to the Oahe Water Control Manual in connection to Big Bend inflows and releases. With the relatively small incremental drainage area contributing directly to Big Bend reservoir, the small amount of runoff usually originating from this area, and regulation procedures applicable to Big Bend, releases from Oahe dam define both the majority of the inflow and the quantity of release from Big Bend Dam most of the time.

1-04. Project Owner. Big Bend was constructed and is owned, operated, and maintained by the Corps of Engineers, Department of the Army.

1-05. Operating Agency. The Corps operates the System, part of which includes Big Bend. The Corps' Northwestern Division's (NWD) Missouri River Basin Water Management Division's (MRBWMD) Reservoir Control Center (RCC), located in Omaha, Nebraska, oversees the day-to-day regulation of the System. The Omaha District of the Northwestern Division has staff located at Big Bend, as well as the other System projects, to carry out the day-to-day operation (based on the water management regulation orders received from the RCC in Omaha) and maintenance of each project. All of the System dams serve hydropower as an authorized purpose and are automated into a system called the Power Plant 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. Project Power Production Orders, reflecting the daily and hourly hydropower limits imposed on project regulation, are generated by the RCC and sent to each mainstem project on a daily basis, or more frequently, as required. Also during critical periods, coordination between project personnel and RCC staff is conducted on an as-needed basis to assure that expected releases rates are achieved.

1-06. Regulating Agencies. As the Big Bend owner, the Corps has the direct responsibility of regulating the project, as well as the other five projects in the System, to meet the Congressionally authorized project purposes. This is accomplished in coordination with many others, including Federal, State, and Tribal agencies and a myriad of stakeholders. As these other entities provide input to the Corps regarding the System regulation through the Annual Operating Plan (AOP) processes, the Corps must determine if the proposal is within the Corps' authority and has met all applicable laws and regulations regarding System regulation prior to incorporating any of this input into the AOP or day-to-day regulation. As part of its regulation of the System, the RCC 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 (Service), which advises the Corps on the effects of System regulation related to endangered and threatened 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.

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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, 2d Session, 1934). While Big Bend, as it exists today, was not included in the document, the report did propose construction of reservoirs on both the main stem of the Missouri River and on tributary streams in the Missouri River basin together with levees along the lower Missouri River as a flood control measure. The beneficial influence of the reservoirs on Missouri and Mississippi River navigation was also recognized.

2-01.1. The first studies by a Federal agency for a dam in this reach of the Missouri River were made by the U.S. Bureau of Reclamation (Bureau) and were included in Senate Document 191, 78th Congress. The dam site proposed in this report was several miles upstream from the present location of Big Bend dam. Corps plans for Missouri River development, as contained in House Document 475 (78th Congress, 3d Session 1944), proposed several dam sites along the Missouri River, which included modifications as the Secretary of War and the Chief of Engineers might find advisable. A dam at the current Big Bend location was not included in this document. The difference between the Bureau's and Corps' plans was adjusted in an inter-departmental conference, and the coordinated plan, which included Big Bend near its present site, was presented to Congress in Senate Document 247, otherwise known as the "Pick-Sloan Plan" Legislative history of the individual System projects is described in greater detail in Chapter II of the Master Manual.

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

> "Sec. 9 (a) The general comprehensive plans set forth in House Document 475 and Senate Document 191, 78th Congress, 2d Session, as revised and coordinated by Senate Document 247, 78th Congress, 2d Session, are hereby approved and the initial stages recommended are hereby authorized and shall be prosecuted by the War Department and the Department of the Interior as speedily as may be consistent with budgetary requirements."

2-02. Project Development. Big Bend was planned and constructed by the Corps' Omaha District under supervision of the Missouri River Division and the Chief of Engineers. The initial design study of the project was completed in March 1954 (Omaha District Design Memorandum No. MO-27). Construction of the project began in 1959, with diversion of the Missouri River through the powerhouse during July 1963. Delivery of power began in October 1964, and most major construction was completed by December 1966. Formal dedication ceremonies were held on September 15, 1966. Regulation of the project has continued since that time.

2-03. Construction History. The initial construction contracts awarded for Big Bend were for the access road, a construction bridge across the Missouri River, and administrative facilities. Work was initiated in 1959. The first of the two earthwork contracts, which included the construction of the dam embankment, began in May 1960. The second stage earthwork contract was essentially complete by October 1963. The powerhouse substructure and intake were started on January 3, 1961 and were essentially complete by October 1963. The river was diverted through the powerhouse on July 24, 1963. Work on the spillway structure was essentially complete in December 1962. Work on the powerhouse superstructure and installation of equipment was started in October 1962. The first of the eight 58,500-kilowatt generating units (Unit No. 1) began power delivery in October 1964. The last generating unit (Unit No. 8) started production of power in July 1966. Contracts for the powerhouse superstructure, installation of generating equipment and appurtenances, roads and parking areas, crest road lighting, and relocations were essentially complete in December 1966. The Summary of Engineering Data, Plate II-1, presents a summary of the significant dates of the System dams' construction, diversion, closure, filling of the reservoir to the minimum operating pool, and initial generation of the first and last units.

2-04. Relocations. Extensive relocations resulting from construction of Big Bend were not required due to the sparsely settled condition of the surrounding area. It was necessary to modify approximately 6 miles of the Chicago and Northwestern Railway tracks adjacent to the reservoir areas while about 27 miles of Native American Reservation and county roads were affected. Fifteen miles of road were abandoned, and the remainder were relocated or improved to accommodate regulation of Big Bend to maximum operating pool levels. It was necessary to relocate several cemeteries, and the Big Bend dam embankment axis, as constructed, was chosen in a manner to provide minimum disturbance to a large cemetery located near the left abutment area. Recreational facilities, including a golf course on Farm Island immediately downstream from Pierre, were relocated to higher elevations outside the reservoir area to permit regulation of the reservoir at planned levels.

2-05. Real Estate Acquisition. Approximately 45,412 fee acres and 169 acres in easements were acquired by purchase and condemnation for Big Bend (dam and reservoir). In addition, Public Land Order transferred 13 acres from the public domain. In addition to the land acquired for Big Bend, approximately 15,000 acres of land in the Big Bend reservoir area had previously been acquired in connection with the construction of the Fort Randall project. Land acquisition was based on a guide taking line at elevation 1423, plus allowances for wave heights, set-up, wave run-up, erosion and bank caving, or 300 feet set back from the 1423 contour, whichever was the greater. Of the total easement acreage, flowage easements were acquired on four tracts of land having a total area of less than 10 acres.

2-06. Regulation History. Big Bend was the last of the Missouri River mainstem reservoir projects to be constructed. Closure of Big Bend dam and the first impoundment of water in the Big Bend reservoir began in July 1963. Run-of-river conditions, with no deliberate storage, were maintained until November 1963. After that time, the reservoir level was slowly raised to the interim fill limit of 1417 feet mean sea level (msl) by April 1964. Filling to the normal operating pool level of 1420 feet msl was delayed until December 1965. Big Bend has been and will continue to be regulated in conjunction with the other System reservoirs to 1) provide the best balance in meeting the contemporary needs of the basin, 2) serve the Congressionally authorized project purposes of the System, 3) meet the Corps' treaty and trust obligations to the Federally recognized tribes, and 4) comply with other Federal laws including the National Environmental Policy Act and Endangered Species Act. The Congressionally authorized project purposes include Flood Control, Navigation, Hydropower, Irrigation, Water Supply, Water Quality Control, Recreation, and Fish and Wildlife. Big Bend hydropower production began in October 1964 with the completion of Units Nos. 1 and 2 in October and November, respectively. Units Nos. 3, 4, and 5 went online in February, May, and October 1965, respectively, followed by Units Nos. 6, 7, and 8 in January, May, and July 1966, respectively. Historically, the reservoir level is regulated between elevations 1415 feet msl, the minimum operating pool level, and 1422 feet msl, the top of maximum normal operating pool level. Currently, the RCC strives to maintain the pool levels in the target range from 1420 and 1421 feet msl. Exclusive flood control storage space (above elevation 1422 feet msl) has been used once, in June of 1991, since regulation of the project began. Further information concerning historical regulation is contained in Appendix A of this manual. Detailed descriptions of each year's regulation of the project are detailed in the AOP and yearly summary reports published by the RCC.

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III – Basin Description and Characteristics

3-01. General Characteristics. The Missouri River basin drainage area upstream from Big Bend includes all of Montana east of the continental divide, northern Wyoming, southwestern North Dakota, northwestern South Dakota, a very small portion of northwestern Nebraska, and portions of the tributary Milk River drainage lying in southern Canada. The total area controlled by Big Bend dam is 249,330 square miles. This includes 57,500 square miles of drainage above Fort Peck Dam, 123,900 square miles of incremental drainage between Fort Peck and Garrison Dams, and 62,090 square miles of incremental area between Garrison and Oahe Dams. Those portions of the Missouri River basin lying upstream from Oahe Dam are described in the Fort Peck, Garrison, and Oahe Water Control Manuals. The portion of the Missouri River basin described in this manual consists only of the 5,840 square miles of incremental drainage area between Oahe Dam and Big Bend dam. Plate III-1 is a general location map of the Missouri River basin. The incremental drainage area defined by the Oahe and Big Bend dams and described in this manual is shown on Plate III-2.

3-02. Topography. The Missouri River drainage area between Oahe Dam and Big Bend dam forms a portion of the Great Plains province of the United States. The small portion of the incremental drainage area to the north and east of the Missouri River is within the Glaciated Missouri Plateau consisting of gently rolling topography in which stream dissection and drainage are not well established except in areas immediately adjacent to the Missouri River. Drainage in upland areas is largely into potholes, small intermittent lakes, and a few larger, permanent lakes. Most of the drainage in the Oahe-Big Bend incremental area lies within the Unglaciated Missouri Plateau, which is to the south and west of the Missouri River. Numerous small hilly areas, buttes, and hogbacks, having elevations higher than the general level of the plains, characterize this region. While the region, as a whole, is rolling and rather thoroughly dissected by streams, there are small, nearly level areas on the stream divides. There are a few relatively larger areas of gently rolling relief scattered throughout the region.

3-02.1. The Unglaciated Plateau region, comprising most of the incremental drainage area, has a general west to east slope of about 10 feet to the mile. Elevations range from about 3,000 feet msl in the western part of the incremental drainage area to near 1,350 feet msl on bottomlands adjacent to the Missouri River.

3-03. Land Use. Agriculture represents the primary use (96.4%) of the land in this portion of the Missouri River basin: grasslands (66.8%), pasture/hay (2.4%), row crops (13.3%), small grains (10.0%) and fallow areas (3.9%). The Missouri River and the Big Bend reservoir account for about 2% of the area. The remaining land use (less than 2%) consists of bare areas, wetlands, forested areas and residential and industrial areas. Forested areas are restricted to bottomlands adjacent to streams and woodlots or groves planted for protective or esthetic purposes. Due to the general lack of an assured water supply, irrigation is practiced on only a minor amount of land in the incremental drainage area. Refer to Plate III-3 for a graphical representation of land use in the Big Bend 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 Big Bend dam is the large area of the upper Missouri River basin controlled by the Fort Peck, Garrison, and Oahe Dams. The upstream mainstem dams control almost 98 percent of the total drainage area contributing to the Missouri River above Big Bend dam.

3-04.1. The prominent natural feature of the incremental area between Oahe and Big Bend dams, as shown on Plate III-2, is the Bad River, the only major tributary within this reach. The Bad River is a right bank tributary flowing in an easterly direction. The drainage pattern contributing from the area west of the Missouri River in this reach is generally well defined. Numerous potholes and depressions exist east of the Missouri River. Portions of this region do not contribute directly to streamflow unless substantial amounts of runoff occur that are sufficient to fill and overflow the low depressions that normally restrict runoff.

3-04.2. The Bad River tributary drainage area is about 100 miles long, has a maximum width of 46 miles, and enters the Missouri River near the headwaters of Big Bend reservoir 78 river miles upstream from Big Bend dam and 7 river miles below Oahe Dam. The Bad River drainage area of 3,120 square miles is all located in western South Dakota. Numerous small creeks discharging directly into the Missouri River drain the remainder of the Oahe-Big Bend incremental drainage area, which amounts to 2,720 square miles. The largest of these is Medicine Knoll Creek, a left bank tributary having a drainage area of about 800 square miles and entering the Missouri River about 60 miles upstream from Big Bend dam. Medicine Creek enters the Missouri River from the right bank about 33 miles upstream from Big Bend dam and has a drainage area of about 600 square miles.

3-05. Stream Slopes. The total fall of the Missouri River from Oahe Dam to Big Bend dam is about 75 feet, averaging about 0.8 foot per river mile. Tributary stream slopes are significantly steeper, generally averaging between 5 and 8 feet per mile. Slopes of the tributary streams progressively tend to reduce or flatten toward their mouths.

3-06. Climate. The incremental portion of the Missouri River basin discussed in this manual is located near the geographical center of the North American continent. The region lies near the center of the belt of westerly winds; however, the Rocky Mountains to the west form a barrier to a Pacific moisture source. Consequently, the climate of the region is generally classified as continental semi-arid. There is a marked seasonal variation in all weather phenomena.

3-06.1. **Annual Precipitation.** Although there is a slight increase in the amount of average annual precipitation from west to east within the Oahe-Big Bend incremental drainage area, at no point will it vary significantly from a range of 16 to 17 inches. The pattern of average annual precipitation throughout the Missouri River basin is presented in Plate III-4. Monthly precipitation patterns are presented in the Master Manual (MM Plates III-4 through III-15). Wide variations from the average amounts may be experienced in any year, with severe, extended drought periods as well as successive years of well above normal amounts of precipitation occasionally occurring.

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

3-06.3. **Snow.** Precipitation occurring as snow usually is at a very slow rate. During the entire winter season, about 24 to 36 inches of total snowfall can usually be expected through most of the incremental region. Snow does not usually progressively accumulate through the winter season, but is normally melted by intermittent thaws. However, there have been notable exceptions when plains area snow accumulations containing as much as 6 inches or more of water equivalent have blanketed large areas prior to a significant spring melt period. Snowfall is usually accompanied by high winds, resulting in significant drifting. Refer to Plate III-5 and Plate III-6 for a representation of mean annual snowfall and maximum annual snowfall, respectively, across the Missouri River basin.

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

3-06.5. **Evaporation.** Annual evaporation from the surface of Big Bend reservoir is normally slightly more than 3 feet. This evaporation loss equates to approximately 178,000 acre-feet of volume (refer to Plates III-9 through III-12). Studies made by the RCC conclude that the average net evaporation, which is evaporation adjusted for precipitation on the reservoir surface, runoff that would have occurred from land area now inundated by the reservoir and the channel surface area existing prior to development of Big Bend, amounts to almost 22 inches annually. Due to seasonal precipitation patterns, seasonal patterns of gross evaporation depths, and the lag in normal reservoir surface temperatures from corresponding air temperatures, most of the annual net evaporation from Big Bend reservoir can be expected to occur during the 6-month period from June through November.

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

3-07. Streamflow Records. Records of tributary streamflow within the incremental drainage area discussed in this manual have been accumulated on the Bad River, Medicine Knoll Creek, and Medicine Creek. Records near the mouth of the Bad River at the Fort Pierre gaging location are available since 1928. Missouri River streamflow records throughout the Missouri River basin are available since the early 1930's. As discussed in the Master Manual, planning of the System made it desirable to extend Missouri River streamflow records to the extent practicable. From the studies carried on at the time, based on stages and the discharge records available, records of monthly flows were developed for several locations along the main stem of the Missouri River. However, the Big Bend dam site was not one of these locations. Selected development locations in the vicinity were Pierre, South Dakota (Oahe dam site) and the Fort Randall dam site. Practice has been to consider the total incremental flow as developed from these two locations as being incremental inflow to the downstream Fort Randall dam site. Consequently, the only records of total incremental inflow between Oahe and Big Bend dams are those derived from simultaneous outflow records obtained since Big Bend became operational in 1964. As part of the revision of the Master Manual, a continuous record of daily data was developed for the entire Missouri River basin for the time period of 1898-present. A detailed explanation of the daily flow record and the modeling efforts is found in Chapter 6-04.1.6 of the Master Manual.

3-08. Runoff Characteristics. The primary source of runoff from the Oahe-Big Bend incremental drainage area is the melting of the snow accumulated during the winter months. However, on occasion rainfall during May and June has resulted in substantial runoff from the incremental area. Runoff is extremely variable from year to year. U.S. Geological Survey (USGS) flow records (1929-2003) indicate that runoff from the Bad River at the Fort Pierre gage averages about 125,000 acre-feet per year, equivalent to a runoff depth of 0.76 inch each year from the 3,107 square miles contributing to this location. Available streamflow records for Medicine Knoll Creek near Blunt, South Dakota (record of 1950-1989) and Medicine Creek near Kennebec, South Dakota (record of 1955-1989) indicate average annual runoff depths of 0.21 and 0.55 inch, respectively. Analysis of incremental runoff originating from the Oahe-Big Bend incremental area on the basis of simultaneous regulation of these two mainstem projects indicates an average annual incremental inflow of about 50,000 acre-feet. The average annual

Bad River flow at the Fort Pierre gage is 125,000 acre-feet. The reasons for this inconsistency are not apparent, but are believed largely due to minor inconsistencies in release determinations at the two projects. In any case, the runoff originating in the reach defined by the Oahe and Big Bend projects is miniscule when compared to the total runoff of the Missouri River originating from above these projects. The incremental runoff into Big Bend reservoir is on the order of one-half of one percent of the total Missouri River flow. Average annual runoff from the Missouri River basin above Oahe and Big Bend dams is about 21 million acre-feet at the 1949 level of water resource development. Refer to the Master Manual, Plate III-24, for a generalized estimate of annual runoff in the Missouri River basin.

3-08.1. **Seasonal Runoff Pattern.** Runoff from the Missouri River drainage basin between Oahe and Big Bend dams usually follows a characteristic seasonal pattern:

1) Winter is characterized by frozen streams, intermittent snowfall, and thaws in the drainage area where the season usually ends with a “spotty” snow cover of relatively low water content and a considerable amount of water in ice storage in the stream channels. Runoff during this period, which usually extends from late November into March, is very low.

2) Early spring is marked by a rapid melting of snow and ice on frozen ground, usually in March or April, as temperatures rise rapidly, accompanied usually by very little rainfall. This causes a characteristic early spring ice breakup and rise. Ice jams are frequently experienced on tributary streams during this period. The rapid release of water from melting snow and ice jams results in a flashy “March rise” in flow. Annual maximum peak stages and flows often occur at this time along tributary streams.

3) Late spring consists of the months of May and June. At this time extensive general rains may occasionally occur, sometimes accompanied by intense local rainstorms. Runoff is usually quite low unless these intense rains occur. However, intense rains sometimes will cause large and sharp crest flows on tributary streams. The maximum flow of record on the Bad River at Fort Pierre of 43,800 cubic feet per second (cfs), resulted from such a rainstorm in June 1967. Previous to the historic record period, historical evidence indicates a flow of about 55,000 cfs in April 1927. In July 1905 a stage occurred that was estimated to be 2 feet higher than in 1927.

4) Summer and autumn in this portion of the Missouri River basin are generally characterized by a lack of general rainfall and infrequent and widely scattered thundershowers that contribute little to runoff. Total runoff in the Oahe-Big Bend incremental drainage area is usually very low from July through the remainder of the calendar year.

3-08.2. Records of monthly runoff from the Oahe-Big Bend incremental reach are available for the period extending from 1964 to present. Average runoff amounts are very low for the months of July through January. Maximum average amounts occur in March and April; however, even in these months the average incremental flows are only in the 500-cfs range. Total Missouri River flows originating above the Big Bend dam during these months average about 36,000 cfs, and it is apparent that incremental flows originating between Oahe and Big Bend dams are only a small portion of the total basin runoff. However, on occasion substantial flows can originate in this reach. For example, in May 1942 a mean monthly flow of over 6,500 cfs was recorded at the Fort Pierre gaging station on the Bad River. At the same location in April 1952, a mean monthly flow of 7,300 cfs was recorded.

3-08.3. The larger amounts of total incremental runoff originating between Oahe and Big Bend dams since simultaneous regulation of these two projects began in 1963 is illustrated on Plate III-13. Of particular note is that, in 1966, 1978, and 1997, the incremental runoff volumes were more than 180,000 acre-feet, the amount of flood storage contained in Big Bend reservoir. However, it should be noted that during those three events the duration lasted from 17 to 31 days, which allowed adequate time for the redistribution of this runoff into other larger Mainstem reservoirs. Table III-1 shows the historical maximum incremental runoff into Big Bend reservoir.

Table III-1
Historical Maximum Incremental Runoff into Big Bend Reservoir

Event	Duration of Event (Days)	Maximum Daily Incremental Inflow (cfs)	Total Runoff Volume (acre-feet)
Mar 1966	18	13,200	190,000
Jun 1967	6	33,500	134,000
Mar 1978	17	29,800	355,000
May 1986	6	27,000	119,000
May 1996	8	24,300	164,000
Mar 1997	31	24,700	526,000
Jun 1997	5	34,800	147,000

3-08.4. Total unregulated Missouri River runoff originating above Big Bend dam usually follows a definite and characteristic annual pattern, with an increase in flows from January through June followed by decreasing flows during the remainder of the year. However, wide variations in monthly runoff amounts occur from year to year. Reference is made to the Oahe Water Control Manual for a further description of total Missouri River runoff patterns at the approximate Big Bend dam location.

3-09. Effect on Basin-wide Floods. The relatively minor amount of flood control storage capacity contained within Big Bend reservoir can be utilized for control of flood events originating in the Oahe-Big Bend incremental area. Big Bend flood storage is not sufficient for any significant degree of control over large basin-wide floods originating upstream. Flood control is considered a major function of the upper three larger System projects that control all but a very small portion of the total area. Only in very exceptional circumstances, if ever, would storage in the Big Bend reservoir be a factor in the control of floods originating from areas other than its immediate incremental drainage area.

3-10. Effects of Big Bend on Flood Inflows. With the amount of flood control space provided in the project, Big Bend release facilities, and the characteristics of the area immediately below Big Bend dam, studies conducted by the RCC indicate that regulation of Big Bend, in conjunction with other upstream System projects, would eliminate damages in the Big Bend tailwater to Fort Randall headwater reach during recurrence of any past floods of record. Further discussion of regulation effects on flood inflows is detailed in Appendix A of this manual.

3-11. Water Travel Time to Big Bend Reservoir. In the target pool range (between elevations 1420 and 1421 msl as described in paragraph 2-06) the Big Bend reservoir extends upstream into the Oahe tailwater area. Thus, Oahe outflows are fully reflected (observed at the elevation gage located at the Big Bend intake structure) as Big Bend inflows in a matter of approximately 12 hours. For most mainstem routing purposes, for which a minimum time interval of one-half day is utilized, the effect is considered to be instantaneous. The same is true for Bad River flows, as defined by the Fort Pierre gage. The travel time from the Bad River gaging station at Midland, South Dakota to the headwaters of the Big Bend reservoir is approximately 1 day – a distance of approximately 60 miles. Just as with the Oahe outflows, the Bad River flows are not reflected in the Big Bend elevation readings until those flows have traveled from the reservoir headwaters downstream to the intake structure (approximately 12 hours).

3-12. Water Quality. Most tributary streams originating in the Oahe-Big Bend drainage area traverse areas with rocks and soils containing many soluble salts. Water quality in the tributary streams is generally poor since salts that are leached from the land cause the water in the streams to be highly mineralized. Over much of this incremental drainage area, total dissolved solids in tributary streams range from 1,000 to 2,000 milligrams per liter although, in portions of the Bad River drainage, the dissolved solids approach 4,000 milligrams per liter. Table III-2 summarizes existing water quality conditions for the Bad River near Fort Pierre, South Dakota. The quality of Missouri River water within and below Big Bend reservoir is considered to be good due to dilution of the incremental inflows by upstream reservoir releases and the stabilizing effect provided by Big Bend reservoir and the other upstream System reservoirs (Fort Peck, Garrison and Oahe) as well as the other Corps and USBR tributary reservoirs. Table III-3 summarizes the water quality conditions that were monitored in the Big Bend dam tailrace in 2003. Water quality stations and sampling is detailed further in Chapter 5-02 of the Master Manual.

3-13. Sediment. It is estimated that the Bad River contributed about 2,200,000 tons per year of sediment to the Big Bend reservoir, from 1963 through 2003. This amount of sediment equates to about 2,525 acre-feet per year using a density of 40 pounds/cubic foot. Based on an analysis of sediment range line surveys taken in 1963 and 1997, the Corps estimates a Big Bend sediment depletion rate of about 5,350 acre-feet per year. This estimate correlates well with those of a study completed in 1999 (Missouri River - Oahe Dam to Big Bend Dam Aggradation Assessment, M.R.B. Sediment Memoranda #22) in which the Corps estimated that, between 1972 and 1997, 52 percent of the sediment came from the Bad River, 27 percent from reservoir bank erosion, and 21 percent from all other tributaries combined. Since the Oahe dam acts as a sediment trap for upstream Missouri River sediment, there is little sediment inflow into the Big Bend reservoir as a result of Missouri River bank erosion. See Plate III-14 for the location of sediment range lines in Big Bend reservoir, the Bad River, and the Oahe Dam tailrace.

3-14. Missouri River Channel Below Big Bend Dam. With the downstream Fort Randall reservoir (Lake Francis Case) at its normal operating level of elevation 1350 feet msl, the entire Missouri River channel immediately below Big Bend dam is occupied by this downstream reservoir. Since the normal operating levels of Fort Randall reservoir extend upward from elevation 1350 feet msl to as high as an elevation of 1375 feet msl, it is evident that there is no natural channel remaining that serves as a constraint upon Big Bend regulation. At such times that the Fort Randall reservoir is drawn below elevation 1350 feet msl toward its minimum operating level of elevation 1337 feet msl (1320 feet msl during extended drought), portions of the normally flooded original floodplain reappear. However, this is only temporary and does not result in any constraint on Big Bend regulation.

3-15. River Ice. Since Big Bend first began operation in 1963, the formation of ice on the Missouri River has not restricted regulation of the project. The only effect of such ice formation upon reservoir regulation would appear to be the increase in tailwater levels above what they would otherwise have been. To date, these increased tailwater levels have not resulted in any regulation constraints.

Table III-2
Bad River near Fort Pierre, SD – Water Quality Conditions

Parameter	Period of Data	Number of Obs.	Minimum	25th Percentile	Median	75th Percentile	Maximum
Alkalinity (mg/l)	1997-2003	23	104	176	203	258	370
Biochemical Oxygen Demand (mg/l)	1997-2003	20	n.d.*	n.d.	3	4	13
Calcium, Total (mg/l)	1997-2001	9	131	147	186	211	217
Dissolved Oxygen (mg/l)	1997-2003	21	8.6	10.9	11.5	13.1	16.0
Dissolved Solids, Total (mg/l)	1997-1998	7	1,106	2,046	2,905	3,231	3,978
Hardness (mg/l)	1997-2003	20	492	734	973	1,303	1,780
Ammonia, Total (mg/l)	1997-2003	23	n.d.	n.d.	n.d.	0.04	0.22
Kjeldahl Nitrogen, Total (mg/l)	1999-2003	15	n.d.	0.41	0.79	1.12	2.17
Nitrate-Nitrite as N (mg/l)	1997-2003	22	n.d.	0.03	0.85	4.8	18.1
pH (S.U.)	1997-2003	23	7.6	8.2	8.3	8.5	8.7
Phosphorus, Total (mg/l)	1997-2003	23	0.02	0.04	0.10	0.15	2.97
Sodium, Total (mg/l)	1997-2001	9	194	353	392	492	549
Specific Conductance (umhos/cm)	1997-2003	21	1,643	2,860	3,420	4,550	5,860
Suspended Solids, Total (mg/l)	1997-2003	23	6	24	47	131	13,400

*n.d. = Not Detected.

Table III-2 lists the summary of existing water quality conditions monitored in the Bad River near Fort Pierre, South Dakota by the South Dakota Department of Environmental and Natural Resources. The water quality data was obtained from the U.S. Environmental Protection Agency's (EPA) STORET water quality database: organization code 21SDAK01; station identification 460850.

Table III-3
Big Bend Tailrace - 2003 Water Quality Conditions

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	State WQS Criteria**	No. of WQS Exceedances	Percent WQS Exceedance
Water Temperature (°C)	0.1	5	21.2	20.7	14.8	26.1	≤ 26.7	0	0
Dissolved Oxygen (mg/l)	0.1	5	8.2	8.6	7.0	9.8	≥ 5.0	0	0
Dissolved Oxygen (% Sat.)	0.1	5	96.0	96.4	88.5	105.6	-----	-----	-----
Specific Conductance (umho/cm)	1	5	728	722	706	753	-----	-----	-----
pH (S.U.)	0.1	5	-----	8.3	7.6	8.4	≥6.5 & ≤9.0	0	0
Turbidity (NTUs)	0.1	4	15.0	11.2	2.9	34.8	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	4	337	341	295	270	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	177	171	169	192	-----	-----	-----
Ammonia, Total (mg/l)	0.01	5	0.26	0.33	n.d.	0.48	≤ 1.0(1)	0	0
Kjeldahl N, Total (mg/l)	0.1	6	-----	0.4	n.d.	0.7	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	5	-----	n.d	n.d	n.d	≤ 10	0	0
Hardness, Total (mg/l)	0.4	1	251	251	251	251	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	5	0.05	0.04	0.02	0.07	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	5	-----	n.d	n.d	n.d	-----	-----	-----
Suspended Solids, Total (mg/l)	4	5	-----	7	n.d.	16	≤ 90	0	0
Total Organic Carbon (mg/l)	0.05	5	3.2	3.1	3.0	3.3	-----	-----	-----
Chlorophyll *a* (ug/l)	1	4	2	2	1	3	-----	-----	-----
Arsenic, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	360(2) 190(3) 18(4)	0 0 0	0 0 0
Beryllium, Dissolved (ug/l)	4	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	9.6(2) 2.0(3)	0 b.d.	0 -----

n.d. = Not Detected.
b.d. = Bad Data.
* Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetect, mean in not reported. The arithmetic mean was not calculated for pH because pH values are logarithmic.
** (1) Total ammonia criterion pH and temperature dependent.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: several metal chronic criteria for aquatic life are hardness based.)
(4) Domestic drinking water supply.
*** The pesticide scan includes: acetochor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, ispropalin, metribuzin, molinate, oxadiazon, oxyflurorfen, pebulate, pendimenthalin, profluralin, prometon, propachlor, propozine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

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IV – Project Description and History

4-01. Location. Big Bend dam is located at Missouri river mile (RM) 987.4 (1960 mileage) in Buffalo and Lyman Counties, South Dakota, approximately 21 river miles upstream from Chamberlain, South Dakota. The project is fourth in downstream order of the six Missouri River System dams constructed by the Corps. The reservoir (Lake Sharpe) created by the dam extends 80 valley miles upstream with the headwaters located near Pierre, South Dakota.

4-02. Embankment. Big Bend dam is a rolled, earth-fill embankment, with the powerhouse at the right abutment and the spillway at the left abutment. The total embankment length, including the spillway, is 10,570 feet. Maximum dam height is 95 feet; top elevation is 1440 feet msl; maximum dam base width, including berms, is 1,200 feet; and the top-of-dam width is 50 feet. The embankment makes a gentle S-curve across the valley and is composed of approximately 17 million cubic yards of fill material. The embankment is built on dredged pervious fill, which has a top elevation near 1357 feet msl. A central impervious core along the entire length of the dam extends from the pervious fill to 5 feet below the top of the dam to control seepage through the embankment. An impervious blanket ties into the central impervious core and extends 425 to 540 feet through a major portion of the embankment. A pervious drain section is located on the downstream side of the impervious core. Refer to Plate VI-1 for aerial photo that shows the Big Bend embankment, powerhouse, spillway and reservoir. Plan and cross sections of the embankment are shown on Plate IV-2. Refer to Plate II-1 for other pertinent dam and reservoir information regarding Big Bend.

4-02.1. The embankment freeboard was based on a Big Bend reservoir level of 1433.6 feet msl, the maximum water surface level attained during routing of the spillway design flood. A set-up allowance of 0.7 feet and wave height plus ride-up allowance of 3.3 feet was developed in design studies. An additional safety factor of 2.4 feet resulted in a total freeboard allowance of 6.4 feet, establishing the Big Bend dam embankment crest at elevation 1440 feet msl.

4-03. Spillway. The Big Bend spillway is located on the left bank of the river at the end of the embankment section of the dam. The approach channel is about 2,700 feet long and curves through an angle of 90 degrees on the riverward side and 70 degrees on the land side. The bottom of the approach channel is excavated to elevation 1375 feet msl. Side slopes are 1 on 3. The minimum width of the approach channel is 376 feet at the gated weir. The maximum approach width, located at the junction with the reservoir, is approximately 1,400 feet. A concrete approach slab with semi-gravity sidewalls extends 100 feet upstream from the concrete weir. Riprap is provided on the curved side slopes of the approach channel sidewall on the riverward side and at the upstream end of the approach slab sidewall on the landward side. Refer to Plate VI-3 for a photo of the Big Bend spillway intake.

4-03.1. The spillway structure consists of an ogee weir with a crest elevation of 1385 feet msl. The spillway crest elevation is 10 feet above the bottom of the approach channel, surmounted by tainter gates, a highway bridge, equipment platforms, and service walkways. Eight tainter gates control the spillway. Each tainter gate is 40 feet wide and 38 feet high, and the gates are separated from each other by piers 8 feet wide. The net length of the spillway crest is 320 feet. The gates operate individually and may be opened or closed in 1-foot increments. At the time of the writing of this manual, the Big Bend spillway has never been used; however, the structure stands ready to be utilized if conditions warrant.

4-03.2. A 376-foot-wide concrete paved chute extends from the spillway weir to the stilling basin. From the downstream end of the weir, the chute slopes downstream on a 3 percent grade for a distance of 120 feet. Beyond this initial 120-foot distance, the slope steepens to a 25 percent grade for a distance of 175 feet to a transition with the stilling basin floor slab. The sidewalls of the chute are semi-gravity concrete walls and vary in height from 18 to 46 feet. The stilling basin, including the end sill, is 194 feet long. The floor of the stilling basin is at elevation 1320 feet msl. The stilling basin walls are sloped 4 on 1 from elevation 1362 feet msl to 1320 feet msl and vertical from elevation 1362 feet msl to 1345 feet msl. The bottom width of the stilling basin at elevation 1320 feet msl is 345 feet and the top width of the stilling basin is 376 feet. The end sill is stepped in 5-foot increments from elevation 1320 feet msl to 1330 feet msl. Two rows of concrete baffles with a top elevation of 1332 feet msl are located in the stilling basin. Refer to Plate VI-4 for a photo the spillway outlet and apron.

4-03.3. The spillway discharge channel is about 4,125 feet long. The channel immediately downstream from the stilling basin has been excavated to elevation 1330 feet msl and has a bottom width of 376 feet for a distance of about 3,000 feet. Immediately downstream of the stilling basin is a transition section that is about 750 feet long. This 750-foot transition section was excavated to elevation 1330 feet msl and converges to a bottom width of 200 feet at the downstream end. A second transition section about 375 feet long is excavated to a bottom elevation of 1350 feet msl with a bottom width of 50 feet at the downstream end for the pilot channel. The pilot channel has been excavated an additional 300 feet downstream. Side slopes of the discharge channel are 1 on 2.5 for slopes protected by riprap and 1 on 3 for unprotected excavated slopes. Riprap is provided for the side-slopes of the discharge channel from elevation 1330 feet msl to berms at elevation 1368 feet msl for about 3,000 feet downstream of the stilling basin on the riverward side and for about 500 feet downstream from the stilling basin on the landward side. A dike with a top elevation of 1380 feet msl extends along the right bank of the discharge channel to protect the embankment of the dam from high flows in the spillway channel. Plan, profile, and section of the spillway structure are shown on Plate IV-2. Refer to Plate VI-5 for a photo of the spillway channel. Spillway discharge rating curves are on Plate IV-6.

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

4-05. Powerplant and Switchyard. Power facilities at Big Bend are located in the right abutment of the dam. The flow of water from the reservoir is guided by an approach circular curving channel, which has a bottom elevation of 1345 feet msl with 1 on 2½ side slopes to berms on both sides to elevation 1355 feet msl. The side slopes above the berms are 1 on 3. The width of the channel at elevation 1345 feet msl is about 400 feet. At elevation 1355 feet msl, the channel width converges from a maximum of 800 feet approximately 600 feet upstream from the intake to 675 feet at the intake. About 120 feet upstream of the powerhouse intake, the bottom of the channel slopes downward on a 1 on 8 slope to elevation 1330 feet msl to provide sufficient entrance area at the intake. Concrete approach walls are provided for the approach channel at the intake. The left approach wall extends 285 feet upstream from the intake while the right wall extends 243 feet.

4-06. Intake Structure. The intake structure contains separate intakes for each of the eight turbines. Each unit intake is divided into three water passages by intermediate piers. Each of the water passages contains two sets of gate slots, one for the service gate and one for the bulkhead gate. Three tractor-type, vertical-lift, service gates are provided for each of the unit intakes. A total of three emergency bulkhead-type gates are provided for use in any of the upstream bulkhead gate slots. Refer to Plate IV-7 for a photo of the intake structure.

4-07. Powerhouse. The powerhouse consists of two elements, the main structure and the service bay. The powerhouse is constructed integrally with the intake structure. The main structure provides housing for the power units, service and storage rooms, and personnel facilities. The service bay is located along the downstream side and contains the control room, various service rooms, offices, and public facilities. The generator bay substructure is divided into eight separate monoliths, each 86 feet wide. The erection bay is located on the north end of the powerhouse and has a substructure of heavy reinforced concrete. The superstructure of the generator room and erection bay is constructed of massive reinforced concrete up to the elevation of the crane rails and light reinforced concrete walls above. Access roads to the powerhouse and tailrace are provided from the highway that crosses the dam.

4-07.1. Eight vertical-shaft, fixed-blade, propeller-type turbines, with concrete, semi-spiral cases and concrete, elbow-type draft tubes are installed in the powerhouse. Each turbine is rated at 90,300 horsepower (hp) at 67 feet net head, operating at a normal speed of 81.8 revolutions per minute (rpm). The cabinet-actuator, oil–hydraulic, conventional-type governors are capable of a full opening or full closing time of 5 seconds. The main generators installed in the powerplant include eight 3-phase, 60-cycle, 13.8–kV, wye-connected, vertical-shaft, hydraulic-turbine-driven, synchronous generators, with bus–connected, static-exciter voltage regulators. Generators 1, 2, and 3 were rewound in 1990 and 1991 and have a nameplate rating of 67.276 MW. Unit Nos. 5 through 8 have the original windings and have a nameplate rating of 58.5 MW. The generators have nameplate ratings of 70.8 MVA and 61.579 MVA, respectively, at 0.95 power factor. The generators have been designed for 115 percent of the nameplate rating. Main generator protection includes neutral grounding, surge protection equipment, differential relays, ground detectors, resistance temperature detectors, and overspeed protection for each unit. Each pair of the main generators is connected to one of the four 3-phase, 13.8-kV/230-kV main power transformers located on the draft tube deck. Refer to Plates IV-8 through IV-10 for photos of the draft tube deck, intake structure, and powerhouse generators, respectively.

4-07.2. The main power transformers and high voltage switching facilities consist of four 3-phase transformers, circuit switcher disconnects, busses, take-off structures, and appurtenances located on the draft tube deck of the powerhouse. Each pair of the main generators is connected to one of the four 3-phase main power transformers. Each of the main power transformers is rated 142 MVA, 13.8 kV to 230 kV and is paralleled through fault interrupting SF6 circuit switcher disconnects to a sectionalized 230-kV paralleling bus. The line take-offs are from the opposite ends of the paralleling bus at Unit Bay No. 1 and Unit Bay No. 8. Power generated at the Big Bend powerplant is transmitted to the Western switchyard at Fort Thompson.

4-07.3. The tailrace is 675 feet wide and 140 feet long rising from elevation 1290 feet msl at the draft tube exit on a 1 on 3½ slope to elevation 1330 feet msl. The tailrace is paved with reinforced concrete anchored to the foundation. The right tailrace wall is an anchored-slab type wall, which slopes upward on a 4 on l batter, a receding upward slope of the outer face of a structure, from the base at elevation 1290 feet msl. A retaining wall on the left side of the tailrace is constructed to elevation 1383 feet msl, retaining fill for parking and access to the powerhouse. The tailrace discharge channel is excavated to elevation 1330 feet msl to the chalk outcrop about 1,350 feet downstream from the downstream end of the tailrace paving. The bottom width of the tailrace channel widens to about 800 feet at the chalk outcrop. Side slopes are 1 on 2½. The tailrace channel extends for an additional 3,000 feet with a bottom width of 400 feet across an island formed near the chalk outcrop. A training dike, which is about 1,200 feet long with a top elevation of 1360 feet msl, extends along the left side of the tailrace channel between the embankment of the dam and the downstream island. Refer to Plate VI-11 for a photo of the tailrace channel.

4-07.4. A more detailed description of the power facilities and other structures developed at the dam site is contained in the Big Bend Operation and Maintenance Manual. Plans and sections of the powerhouse are shown on Plate IV-2. Powerplant tailwater rating curves and powerplant characteristic curves are shown on Plate IV-12 and Plate IV-13, respectively.

4-08. Reservoir. The reservoir formed by Big Bend dam (Lake Sharpe) extends through central South Dakota. At a normal operating pool level, the reservoir has a length of 80 miles, a shoreline of 200 miles, a surface area of 57,000 acres, and a maximum depth of 78 feet. The Big Bend reservoir is long and narrow and confined almost entirely to the Missouri River valley. Since no major tributaries enter the main body of the reservoir, there are no large tributary arms characteristic of the larger System projects. The Big Bend reservoir area is shown on Plate IV-14, and area and capacity tables for the reservoir are on Plates IV-15 and VI-16.

4-08.1. While allocation of storage in the larger System reservoirs was based on mainstem multiple-use requirements, as described in Section 4-02 of the Master Manual, storage space in Big Bend has been divided to give major contribution to the purpose of hydroelectric power generation. The relatively small amount of exclusive flood control storage space serves the purpose of providing only short-term storage for large and “flashy” runoff events that can occasionally occur from the Oahe to Big Bend drainage area. The small amount of flood control and multiple-use storage space between elevations 1420 feet msl and 1422 feet msl is primarily a zone within which power generation benefits can be maximized by storage fluctuations that best enable the System as a whole to follow daily and weekly variations in power demand. Types of storage space, with associated elevations and storage quantities for each type, are listed in Plate II-1. In addition to this allocated space, the peak reservoir level modeled during the spillway design flood crested at elevation 1433.6 feet msl, representing a surcharge of about 0.7 million acre-feet of storage above the top of the exclusive flood control storage zone.

4-09. Recreation Facilities. Fluctuating water levels can have a major effect on recreational use of the reservoirs in the System. However, Big Bend reservoir, like Gavins Point, is quite unique when compared to other reservoirs making up the Missouri River System, or to reservoirs in general, in that fluctuations are minor. Unless unusual conditions occur, Big Bend reservoir is maintained in the target operating range of elevation 1420 to 1421 feet msl. Numerous public use areas have been established around the Big Bend reservoir shoreline. Recreation at System reservoirs 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 lake access points to highly developed and extensively used campground areas. The six System projects have a total of 179 public recreation areas. There are 24 recreational facilities at Big Bend. In 2002, most of the Federal recreation areas in South Dakota were transferred in fee title to the State of South Dakota or to the Bureau of Indian Affairs (BIA), which holds the areas in trust for the Lower Brule Sioux Tribe and the Cheyenne River Sioux Tribe, under Title VI of Public Law (P.L.) 105-53, Water Resources Development Act of 1999 as amended by P.L. 106-541, Water Resources Development Act of 2000. The 65 recreation areas transferred in fee title, along with the nine recreation areas leased in perpetuity, will be managed for the restoration of terrestrial wildlife habitat loss that occurred as a result of the flooding of lands related to the construction of Oahe, Big Bend, Fort Randall, and Gavins Point. Plate IV-17 shows the location of recreation facilities on the Big Bend reservoir as well as the individual facility ownership and/or leasing status. Plate IV-18 indicates available recreation activities.

4-10. Leasing of Project Lands. Approximately 45,412 acres in fee, 13 acres of public domain, and 169 acres in easements were acquired for the Big Bend Dam - Lake Sharpe project. Land acquisition was based on a guide taking line at elevation 1423 (top of the exclusive flood control zone) plus allowances for wave heights, set-up, wave run-up, erosion, and bank caving or a 300-foot setback from the 1423-foot msl contour, whichever was the greater. Flowage easements were acquired on four tracts of land having a total area of less than 10 acres. All leases are subject to possible flooding of lands that may be needed for operational purposes and do not serve as an overriding constraint upon regulation of the project for authorized purposes.

4-11. Reservoir Aggradation and Backwater. Major sediment deposition occurs in the reservoir headwater area and tributary inlets as a result of soil erosion in the Oahe-Big Bend watershed. The Big Bend delta is moving primarily in the downstream direction, mainly due to the relatively high sediment-free releases from Oahe Dam. By 1997, the main river channel near upper Farm Island at Pierre had between 0 and 6 feet of deposition since closure of Big Bend dam in 1963. Over 14 feet of deposition had occurred in the Rousseau Area, and 20-plus feet had occurred near the DeGrey area. The Cedar Creek area, about 27 miles downstream from Farm Island, had just recently started to show increases in deposition. Deposits in this area were between 5 and 12 feet in the old Missouri River channel and 2 to 4 feet in the old floodplain. The first of two main problems associated with the Big Bend delta are winter ice jams, causing the releases through the Oahe powerhouse to be reduced to minimize residential flooding in Pierre and Fort Pierre when power production is needed most. The second main problem is aggradation in boating channels in Big Bend reservoir. Regarding this second problem, the first step in the process of delta formations in the tributary embayments is the establishment of a marshy area. As the sediment continues to accumulate, the embayment gradually fills in. If a boat ramp is located is such an embayment, recreation activities may be affected.

4-12. Tailwater Degradation. Since the Fort Randall reservoir extends into the Big Bend tailwater area most of the time, tailwater channel degradation will have only a minor, if any, influence on Big Bend regulation activities. Surveyed cross sections show little change from the 1950's to 1996 in this area.

4-13. History of Water Resources Development. Due to the lack of land transportation facilities, development of water resources in the portion of the Missouri River basin in the vicinity of Big Bend began soon after settlement by the white man in the early 1800's. Initial development was concerned with navigation as a means of transportation in the region. The economy of the region is primarily agricultural. This, combined with the semi-arid climate, could have been expected to foster irrigation development. The most widespread development in relatively recent history has been construction of dams controlling small drainage areas to provide a water supply for the extensive livestock grazing practiced throughout this region. Control of floods became a major concern in the 1940's, and in recent years municipal and industrial water supply, recreation, water quality enhancement, fish and wildlife, and 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 that publication, the Flood Control Act of 1944 is of primary importance through this portion of the basin. This act authorized the construction of Big Bend dam, as well as the four of the other System projects (Fort Peck Dam was already constructed by then and was authorized by this Act to become part of the System) and many tributary projects, and emphasized the multiple purpose aspects of water resource development.

4-13.2. One important means of water resource development in the Missouri River basin is the construction of dams controlling sizeable drainage areas and development of the associated reservoirs. However, in the Oahe-Big Bend drainage area, no sizeable reservoirs (other than Big Bend) have been developed. The lack of an assured irrigation water supply, infrequent substantial runoff amounts, and minimal flood damages due to sparse development in this drainage area have precluded tributary reservoir development.

4-14. Flood Control. Big Bend is the only major flood control project constructed in this relatively small area of the Missouri River basin. There are no local flood protection projects that affect, or are affected by, Big Bend regulation, except those downstream from the System, such as the Corps' Omaha and Kansas City District tributary projects. Additional information on flood control can be found in Section 12 of Chapter 7 and in Appendix A.

4-15. Irrigation. There are 115 water supply intakes located on Big Bend reservoir. These include 3 municipal intake facilities, 91 irrigation intakes, 19 domestic intakes, and 2 public intakes. The municipal water supply facilities serve a population of approximately 2,400 persons. Of the 115 water supply intakes, there are 55 and 22 water supply intakes serving the

Crow Creek and Lower Brule Reservations, respectively. Refer to Appendix E for additional information regarding irrigation.

4-16. Navigation. Although navigation on the Missouri River through South Dakota opened up this region for initial Caucasian settlement, there is now no commercial navigation through this reach of the river. Storage space has not been provided in the Big Bend reservoir to support Missouri River navigation. Releases from upstream System reservoirs intended to serve downstream navigation are passed through Big Bend.

4-17. Hydroelectric Power. The Big Bend powerplant, with an installed capacity of 468,000 kW, is the only hydroelectric power generating facility located in the incremental Missouri River drainage area discussed in this manual. All power generated by Federal facilities in the Missouri River basin is marketed by Western, and Big Bend 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 hydropower generation and Western's power marketing and transmission facilities are provided in Section 7 of Chapter 7 and Appendix F of the Master Manual.

4-18. Municipal and Industrial Water Supply. There are 115 water supply intakes located on Big Bend reservoir. These include 3 municipal intake facilities, 91 irrigation intakes, 19 domestic intakes, and 2 public intakes. The municipal water supply facilities serve a population of approximately 2,400 persons. Of the 115 water supply intakes, there are 55 and 22 water supply intakes serving the Crow Creek and Lower Brule Reservations, respectively. Additional information on intakes can be found in Appendix E of this manual. Information on water quality can be found in Section 5 of Chapter 7 and in Appendix C.

4-19. Land Treatment. In the 1970's, a program administered by the Department of Agriculture that included land treatment measures designed to reduce erosion and local floods and to increase the local surface water supply was in operation throughout the incremental drainage area discussed in this manual. Associated with this program are many stock ponds or farm ponds that were 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. During the last 10 years as part of the Wildlife Stewardship Program, the Corps, consisting primarily of Big Bend personnel, has been working with the Crow Creek Tribe in constructing small sediment retention structures to promote vegetative growth along the eroded reservoir bank line. During that same time period Big Bend personnel have also been coordinating with local farmers and ranchers in strategically placing biodegradable, environment-friendly hay bales near erosion points along the reservoir. The results of the hay bale placement have been mixed. The hay bales were a product of the hay and grazing leases to the locals for government-owned lands. Both the Wildlife Stewardship Program and the hay bale placement projects are on-going.

4-20. Fish, Wildlife, and Recreation. The effects of water resource development on fish and wildlife are a major concern throughout the drainage area in the planning and operational processes. Recreation opportunities have generally been increased as a result of water resource developments. To the degree practical, fish and wildlife interests are considered prior to regulation of projects and the potential effects on these functions may become an important constraint on regulation. Recreational use of the Big Bend reservoir continues to increase through the years and is a factor to be considered in regulation of the project. Refer to Appendices B and D for additional information on recreation and fish and wildlife, respectively.

4-21. Streambank Stabilization. Streambank erosion is a continuing process along the Missouri River and its tributaries in the region. Sediment inflow into the Big Bend reservoir results almost entirely from this erosion process along tributary streams contained within the incremental drainage area. The Missouri River channel from Oahe Dam to the headwaters of the Big Bend reservoir has been fairly well stabilized by means of bank protection and the construction of channel blocks. Current proposals include further bank protection measures, encompassing nearly all of the readily erodible banks within this relatively short reach of the Missouri River.

4-22. Streamflow Depletions. At the time of design and construction, depletion in the available water supply was expected to be a major effect of water resource developments in the incremental drainage between Oahe and Big Bend dams on the regulation of Big Bend. As resource development continues, a growth in depletions can be expected. While increasing depletions benefit the flood control, it is evident that they may have adverse effects on other authorized purposes that are dependent on the availability of a continuing water supply. However, it should be recognized that, with the exception of Big Bend, water resource development within this reach of the Missouri River has been very minor and consequent streamflow depletions also fall into this category. For most RCC study purposes, the Oahe to Big Bend reach has been combined with the Big Bend to Fort Randall reach of the Missouri River.

4-22.1. Prior to 1865, streamflow throughout the Missouri River basin was largely unused, except for transportation. Settlers and homesteaders in the late 1800's and soon after the turn of the century started substantial irrigation and mining ventures in several regions of the upper Missouri River basin. However, in the drainage area contributing to the Missouri River reach discussed in this manual, the available water supply was very small and unreliable. Consequently, irrigation development occurred in only widely scattered areas. During the years 1910 to 1949, average annual depletions in the Oahe to Big Bend drainage area increased by an estimated 7,500 acre-feet, primarily due to the minor amount of irrigation development. A further average annual increase of 8,300 acre-feet was estimated to have occurred between 1949 and 1970 from land treatment measures. The most significant factor in depletions since Big Bend was constructed has been reservoir evaporation. During the 1967-2004 period, Big Bend reservoir evaporation has accounted for an average annual depletion of 183,000 acre-feet.

4-22.2. A continuing small increase in depletions is expected from this incremental drainage area. The greatest impact to the depletions in the Big Bend reservoir will be due to the depletions upstream from Oahe Dam. The reservoir levels of the Big Bend reservoir will remain the same; however, the movement of water through Big Bend reservoir will diminish as upstream depletions grow.

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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. Big Bend Data. Hourly data files are automatically transmitted from the Big Bend PPCS to the RCC and to the Corps' Omaha District. The data include hourly releases, power generation, pool elevations, tailwater elevations, 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. Air temperature and wind data are obtained from a weather station located near the Big Bend powerplant. In the event the automatic data collection and transfer is not working, Big Bend personnel shall fax or email hourly and daily project powerplant data to the RCC. RCC staff will manually input the information into the database. The Big Bend monthly summary is faxed or emailed to the RCC and is used to verify daily data.

5-02.1. Throughout the year project personnel investigate requests and complaints that occur as a result of Big Bend regulation and report their findings and recommendations to the RCC. Since Big Bend releases are directly made into Fort Randall reservoir, there are usually no complaints relating to release rates other than infrequent requests for increased releases by fishermen who feel that this will enhance fishing in the tailwater. Project personnel are responsible for informing affected interests of any major change in the general level of Big Bend release rates or reservoir elevations that may be scheduled. Refer to Section 7-05.1 of this manual for special notification and coordination with Tribal leaders.

5-03. Precipitation and Temperatures. Refer to Section 1 of Chapter V of the Master Manual for detailed descriptions of data collection procedures throughout the Missouri River basin. Whenever significant amounts of precipitation occur, reports from many more locations than shown in the basic network presented in the Master Manual are received by the RCC. Plate V-1 presents locations of National Weather Service (NWS) Multi-sensor Precipitation Estimate (MPE) site locations in the Missouri River basin. The hourly MPE files are automatically retrieved from the NWS on a near real-time basis and stored on a RCC UNIX workstation. In addition precipitation and temperature are monitored at some of the Data Collection Platform (DCP) locations that are described in greater detail later in this chapter.

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

5-05. Stages and Discharges. River stage information reported to the RCC, as indicated by the basic network presented 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. Plate V-2 indicates key locations within the incremental Big Bend drainage area where stages, and in some cases, discharges are available.

5-06. Communication During Normal Regulation. Big Bend 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 RCC. Full details relating to organizational responsibilities, coordination, and communications pertinent to the System's regulation process are contained in Sections 5 through 7 of Chapter V of the Master Manual. Consequently, only a brief summarization is presented in this project manual and reference must be made to the Master Manual for a complete understanding of these factors.

5-06.1. Reservoir regulation / power production orders sent to project personnel control the regulation process. These are issued by the RCC and are based on detailed analysis of current and expected hydrologic conditions throughout the Missouri River basin to meet the Congressionally authorized project purposes of Big Bend and the System. The coordination with other Corps offices, outside agencies, and special interest groups is a responsibility of the RCC, as described in the Master Manual.

5-06.2. Since Big Bend releases have historically been made entirely through the powerplant, they are scheduled indirectly by means of power scheduling. Big Bend power production is normally controlled by Big Bend Operations staff in conjunction with Western.

5-06.3. Big Bend personnel are expected to continually furnish the RCC 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 are responsible for informing the public in the local area of current and probable near-future regulation activities. It is the responsibility of the RCC to keep project personnel informed of such activities. Any requests for information that are complex and/or long-term in nature or that involve policy are to be referred to the RCC.

5-06.4. The Corps' Omaha District is responsible for project maintenance, including maintenance of those facilities required to support the regulation process. District staff also collect data pertinent to Big Bend regulation and are responsible for analysis of runoff events, particularly over tributary drainage areas. The District is also responsible for flood fighting activities in the incremental drainage area. Information available to the Omaha District considered pertinent to regulation of Big Bend, or other System projects, is to be immediately furnished to the RCC.

5-07. Emergency Regulation. If emergency conditions develop at Big Bend, project personnel are expected to take appropriate action, 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, prompt action is required and project personnel are expected to take the actions deemed necessary. Prompt notification of the Omaha

District and the RCC of the circumstances and actions initiated is then accomplished. Subsequent modification or continuance of regulation of project facilities would then be based on evaluation of conditions and effects by all offices concerned and be directed by the RCC.

5-07.1. During critical reservoir regulation periods and to assure timely response, significant coordination is often conducted by telephone between Big Bend and the RCC. This direct contact assures that issues are completely coordinated and concerns by both offices are presented and considered before release decisions are made final by the RCC. The RCC's Reservoir Regulation and Power Production team leaders, as well as the MRBWMD chief, are generally available by cell phone as are several of the Project Operations Managers. The RCC weekend worker also carries a cell phone and has the responsibility of notifying the appropriate RCC staff so that proper coordination has occurred before significant changes are made to project releases.

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VI – Hydrologic Forecasts

6-01. General. Regulation of Big Bend 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. Annual Operating Plan studies are discussed in Appendix H of the Master Manual. Also discussed in Chapter VI of the Master Manual are analyses, forecasts, and studies that, while important for the regulation of Big Bend, have essentially the same degree of importance for all of the other mainstem projects. Analyses considered to be unique, or particularly important, to Big Bend regulation are presented in the following paragraphs.

6-02. Precipitation and Temperature Forecasts. As discussed in Section 1 of Chapter VI of the Master Manual, NWS forecasts that include various meteorological elements are utilized by the RCC, to the degree practicable, in the regulation process. NWS forecasts are supplemented by forecasts developed by the RCC and the Corps' Omaha District staffs. Particularly pertinent to regulation of Big Bend are forecasts prepared for the west central portions of South Dakota of those elements that would contribute to runoff from the Oahe to Big Bend incremental drainage area.

6-03. Precipitation-Runoff Relationships. Infiltration of rainfall over the Missouri River basin between Oahe and Big Bend dams ranges from 0.50 to 1.00 inch for the initial loss and from 0.10 to 0.25 inch per hour infiltration loss. These values are based on only a few observed rainfall events due to the rarity of historic heavy rainfall centers in the area. Snowmelt infiltration ranges from zero for frozen ground, or ice under snow, to approximately the values shown for rainfall. Runoff during any particular rainfall or snowmelt event would amount to the estimated depth of rainfall or snowmelt less the infiltration losses. In actual practice, estimating the rainfall or snowmelt runoff is very imprecise. This is due to the lack of a dense network of precipitation reporting stations, errors in estimating the snow cover available for melt, errors in estimating the snowmelt rate due primarily to large temperature variations, and marked departures from the average infiltration or loss rates given above. Recent technology that utilizes NWS gridded radar observed and forecasted precipitation and rainfall-runoff forecasting models allow the RCC to more accurately determine expected inflow into Big Bend.

6-04. Unit Hydrograph Analyses. A more traditional means of forecasting flows from a particular drainage area is by the use of unit hydrographs. However, unit hydrograph development and subsequent use of the developed hydrographs as a forecasting tool has been found to be impractical for the drainage area under consideration in this manual. Reasons for this include the lack of rainfall and subsequent runoff events for unit-hydrograph definition; the sparsity of rainfall reporting stations needed for both analysis and forecasting purposes; and the fact that by far the greatest amount of runoff that occurs from this drainage area does not result from particular rainfall events but results from progressive snowmelt, making runoff definition during a selected time period very imprecise. In addition, Big Bend reservoir has a relatively substantial amount of storage space above the normal operating level in relation to the amount of runoff that has been experienced from the Oahe-Big Bend incremental drainage area. The maximum amount of incremental runoff experienced in any one day since 1963 when Big Bend became operational was 42,000 acre-feet, coincident with the maximum discharge of record from the Bad River in June 1967. Storage space available above the normal operating pool elevation of 1420 feet msl is 177,000 acre-feet. The maximum experienced incremental inflow volume observed during a single flood event since the project became operational was in March 1966 when about 170,000 acre-feet occurred during a 2-week period. Consequently, the effort necessary for a valid, complete, and continuing analysis by means of unit-hydrograph procedures is not believed to be warranted, particularly in view of the ease by which Big Bend storage space can be evacuated through a combination of reducing Oahe releases and increasing Big Bend outflows. While unit-hydrograph procedures will continue to receive consideration as a means of possibly improving Big Bend regulation, the RCC is moving towards utilizing computer-based rainfall-runoff and reservoir routing models. When warranted, the Big Bend drainage area will be modeled and integrated into System regulation.

6-05. Plains Snow. In many years a major portion of the annual runoff from the plains contributing area above Big Bend dam is a result of melting the snow cover accumulated during the winter months. This melt usually occurs during late March or April and often results in the annual maximum peak flow from the Oahe-Big Bend drainage area. Basic data pertinent to plains area snowmelt volume analyses are precipitation during the late fall and winter months, winter season temperatures, water content of the accumulated snow cover prior to the melt period, and soil conditions. However, even with these data, forecasts of the plains snowmelt runoff volume are usually quite imprecise. Refer to Section 1 of Chapter V of the Master Manual for additional information on snow.

6-05.1. Plains area snow surveys, which historically have been conducted by the Omaha District, are made during any year that a substantial snow accumulation exists over the drainage area. These snow surveys in the past were requested by the RCC, however in recent years other approaches have also been used. The National Operational Hydrologic Remote Sensing Center (NOHRSC) has developed, and currently maintains, an operational Airborne Gamma Radiation Snow Survey Program to make airborne Snow Water Equivalent (SWE) and soil moisture measurements. Airborne SWE measurements are used by NWS Weather Forecast Offices (WFO) and NWS River Forecast Centers (RFC) when issuing river and flood forecasts, water supply forecasts, and spring flood outlooks. Another method involves obtaining quantitative estimates of runoff volume to compare 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 Oahe and Big Bend dams. 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, which could either increase or decrease the losses at the time of runoff. If analogous data are not available, it is necessary to estimate the runoff volume by noting runoff depths during previous years from other areas where snow cover conditions appear similar to the current year’s snow cover over the Oahe-Big Bend incremental drainage area. Three years in particular, 1952, 1969, and 1997, are directly comparable in that the floods were largely caused by melting of heavy snow cover on the northern plains. Refer to Table VI-1 for a plains snow comparison of the 3 years.

Table VI-1 – Plains Snow

Late Winter Snow Moisture in Major Flood Years* (Snow Water Equivalency in Inches)				
Stream	**Location**	**17-Mar-52**	**31-Mar-69**	**18-Mar-97**
Milk River	Nashua, MT	3.0	2.0	<1
Knife River	Hazen, ND	2.8	2.3	1.8
Heart River	Mandan, ND	3.5	3.0	1.8
Apple Creek	Bismarck, ND	3.0	3.0	3.0
Beaver Creek	Linton, ND	3.5	2.5	4.3
Cannonball River	Breien, ND	3.5	3.0	3.4
Grand River	Little Eagle, SD	3.6	2.3	2.6
Moreau River	Whitehorse, SD	4.0	2.3	1.7
Cheyenne River	Eagle Butte, SD	5.0	1.0	<1
Bad River	Fort Pierre, SD	3.0	1.5	<1
Elm River	Westport, SD	5.0	5.0	3.2
James River	Scotland, SD	3.6	4.0	3.9
Vermillion River	Wakonda, SD	0.5	4.5	3.4
Big Sioux River	Watertown, SD	3.8	4.2	4.2
Floyd River	Sioux City, IA	0.5	3.3	0
Little Sioux River	Turin, IA	0	3.2	<1

*From the 1997 Midwest Floods Post Flood and After Action Report, Volume 1

6-05.2. Improvement in the techniques of forecasting the runoff resulting from plains snowmelt is an ongoing process of the RCC. As technology continues to improve, more precise and objective methods are being developed. In addition, the NWS is investigating this matter and has initiated forecasts of plains snowmelt runoff volumes that are made just prior to the melt season. As experience is gained, it appears probable that more valid estimates will be available than in the past. These will be more valuable for regulation of the other System reservoirs than Big Bend.

6-06. Monthly Reach Inflow Forecasts. Soon after the first of each month throughout the year, a forecast of incremental inflows originating between most of the System dams is made. These forecasts are utilized to develop system regulation studies, as described in Section 4 of Chapter VI of the Master Manual. An exception is the Oahe to Big Bend reach. This relatively small incremental drainage area is considered in combination with the Big Bend to Fort Randall drainage area and forecasts for the Oahe to Fort Randall drainage area are made as described in the Fort Randall manual.

6-07. Short Range Forecasts of Daily Inflow. Daily inflows into Big Bend consist almost entirely of releases from the immediate upstream Oahe reservoir, except on those few occasions each year when the Bad River is contributing significant flows. As stated in paragraph 3-11 of this manual, at target operating pool levels (between elevations 1420 and 1421 msl as described in paragraph 2-06) the Big Bend reservoir extends upstream into the Oahe tailwater area. Thus, Oahe outflows are fully reflected (e.g. observed at the elevation gage located at the Big Bend intake structure) as Big Bend inflows in a matter of approximately 12 hours. For most System routing purposes, for which a minimum time interval of one-half day is utilized, the effect is considered to be instantaneous. Thus, daily inflow forecasts are usually identical with the anticipated Oahe release schedule. Modifications will be necessary when significant flows are originating in the Oahe-Big Bend reach. Incremental inflows originating between the Oahe and Big Bend dams are readily apparent on a daily basis. Forecasts of continuation of this inflow will be largely an extrapolation of past inflows in which current hydrologic conditions pertinent to short-term runoff are given due consideration. Typical inflow hydrographs from the total incremental area are discussed in Section 8 of Chapter III of this manual. These extrapolations will be modified on the basis of flows observed at the upstream Bad River gaging station at Midland, South Dakota.

6-08. Stage-Discharge Relationships. Stage-discharge relationships, sometimes referred to as rating curves, are maintained in the RCC for gaging stations on the Bad River. These are kept current on the basis of discharge measurements made by the USGS. Plates VI-1 and VI-2 show the present Bad River stage-discharge relationships at Midland and Fort Pierre, respectively. Midland flows can be routed to Big Bend reservoir by simple translation by assuming a travel time of 1 day. The Bad River flows at the Fort Pierre station reach the Missouri River in only a couple hours. Thus, flows observed at this location are considered to be a current component of the total Big Bend reservoir inflow.

6-09. Forecasts of Downstream Locations. Big Bend releases flow directly into the downstream Fort Randall reservoir. Consequently, there are no damage centers affected directly by Big Bend releases, and forecasts of the effects of Big Bend releases are not required other than those relating to Fort Randall inflows. These are discussed in the Fort Randall water control manual.

6-10. Evaporation. Due to the large surface area, evaporation is an important component of the overall water budget of Big Bend 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 upon the available water supply. One means of estimating daily evaporation depths is application of the commonly used 0.7 pan-to-reservoir factor. This is not considered reliable for Big Bend reservoir due to the difference between the reservoir surface temperature and pan temperature. MRD-RCC Technical Report JE-73, Reservoir Evaporation Estimates, addresses this problem in detail and recommends the use of a variable pan-to-reservoir factor. This factor for Big Bend reservoir varies from as little as 0.35 (May) during periods when reservoir surface temperatures are less than air temperatures to as high as 1.52 (November), when reservoir surface temperatures materially exceed air temperatures. Plates III-9 through III-12 indicate pertinent evaporation information for the six System reservoirs. During those portions of the year when evaporation pan data are not available, normal evaporation depths for each season of the year appear to offer the most practical means of developing evaporation estimates for day-to-day regulation activities. Reference is made to the cited technical report for further details pertinent to the development of evaporation estimates for this project. This report also recommends procedures for the adjustment of observed Big Bend pan evaporation to representative pan evaporation and adjustment of initial estimates at the time of detailed analyses of the effects of the project upon streamflow. Recently, the RCC has coordinated with the Omaha District and CRREL in the development of a physically-based evaporation computer model to compute real-time evaporation for each of the System reservoirs. As of 2007 the automated evaporation technique was being tested at one System reservoir (Oahe) and at one Omaha District tributary reservoir (Cherry Creek). The physical parameters utilized in the model consist of hourly weather data such as wind speed, wind direction, ambient air temperature, humidity, barometric pressure and cloud cover that are all available via an NWS automated data collection system.

6-10.1. In addition to evaporation, development of the effects of Big Bend reservoir on streamflow must consider precipitation upon 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, which prior to the reservoir would have contributed to direct runoff from the area now inundated. Precise calculations of these factors are impractical and unnecessary. 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.

6-11. Wind Effects on Water Surface Elevations. The general orientation of Big Bend reservoir is to the northwest from Big Bend dam. However, the large bend in the Missouri River, from which the project derives its name, materially reduces the fetch through which the wind action can influence the water surface at the dam. Nevertheless, winds with a northwesterly component result in set-up at the dam while a wind component from the opposite direction results in set-down. See Plate VI-3 for a wind correction table for the pool level recorder at the dam. An anemometer is located adjacent to the dam; however, it should be recognized that only approximations of the wind effect on the reported pool level can be obtained with data from this instrument. The time required for set-up to be fully established, variations in wind velocity and direction over the reservoir surface, and the unrepresentativeness of the observations at the dam will all 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.

6-12. Daily Inflow Estimates. Estimates of inflow to Big Bend reservoir are made each day for regulation purposes. The steps involved consist of

a) plotting hourly pool elevations as reported by the Corps' Power Plant Control System (PPCS);
b) utilizing reported wind measurements to estimate the set-up or set-down effects on the reservoir;
c) calculating the reservoir storage change equivalent to the estimated 24-hour reservoir elevation change; and

d) combining all this information with reported releases and estimated evaporation to compute the equivalent reservoir inflow.

An additional estimate of reservoir inflows consists of comparing the Oahe releases during the preceding 24-hour period, adjusted by about 12 hours to correspond to the short travel time through Big Bend reservoir. When significant runoff is originating in the Oahe-Big Bend incremental area, this additional inflow is estimated by noting probable Bad River flows combined with estimates of ungaged flow and precipitation on the reservoir surface. Differences in inflow estimates as determined by c) and d) 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 evident during those days. See Plates VI-4 through VI-9 for regulated and incremental inflow volume probability relationships for various durations.

6-13. Unregulated Flows. Construction of Big Bend dam, together with the other System and tributary projects in the Missouri River basin, has materially altered flows downstream from the dam. Flood peaks have been reduced and low flows augmented by reservoir regulation. However, since Big Bend is essentially a run-of-river project, little modification results from Big Bend regulation alone. While the unregulated flows at the Big Bend dam site are determined (as described in RCC Technical Study S-73), the development is primarily required as a part of the analysis of the System as a whole. Records of flows at the 1949 level of basin development, which is prior to construction of Big Bend dam and most other water resource development in the Missouri River basin, are not maintained for the Big Bend site. This is because of the minor difference in flows at Big Bend as compared to Oahe. Refer to Plates VI-10 and VI-11 for tributary computed probability curves at the Bad River at Fort Pierre and Medicine Knoll Creek near Blunt, respectively. Discharge frequency relationships were developed for tributary streams flowing into Big Bend reservoir between Oahe Dam and Big Bend dam and are shown in Table VI-2.

Table VI-2
Tributary Discharge Frequency Relationships

Tributary	Drainage Area (square miles)	Peak Discharge (in cfs) for Given Return Period (in years)			
		10	50	100	500
Bad River at Fort Pierre	3,107	21,400	44,300	57,000	94,300
Antelope Creek	106	1,900	4,500	5,400	9,100
Cedar Creek	155	2,300	5,500	6,600	11,000
Medicine Creek	668	5,400	12,800	15,000	24,700
Medicine Knoll Creek near Blunt	317	1,400	7,600	13,500	40,900
Medicine Knoll Creek at mouth	847	2,800	10,000	15,200	33,100
Chapelle Creek	260	3,100	7,400	8,800	14,600

6-14. Evaluation of Regulation Effects. In the evaluation of the effects of regulation upon downstream flows and consequent flood damage reduction estimates, Big Bend 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 given in Chapter VII of the Master Manual.

6-15. Long-Term Studies. Simulated regulation of Big Bend as a component of the System has been accomplished through numerous long-term reservoir regulation studies of the period of hydrologic record since 1898. This technique is utilized by the RCC for the development of regulation criteria, subsequent analyses of those criteria, and criteria modification, with respect to service provided to Congressionally-authorized project functions. 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 Chapters 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 criteria for regulation under a number of potential future levels of water-resource development in the Missouri River basin, many long-term examples of Big Bend regulation are available. Criteria utilized in the long-term studies assume a constant Big Bend reservoir level of elevation 1420 feet msl and also assume that Big Bend releases are identical to those from the upstream Oahe reservoir.

6-16. Frequency Estimates. Frequency of occurrence estimates of reservoir elevations and releases at each of the System reservoirs were developed as described in MRD-RCC Technical Report B-76 (updated to RCC Technical Report F-99). The 100-year Big Bend reservoir level is estimated to be at elevation 1422.4 feet msl while historic data would indicate that the maximum level likely to be experienced in any given year is about 1 foot lower. Instantaneous releases at the powerplant capacity, 110,000 cfs, can be expected in every year, and this level would probably not be exceeded during a 100-year event. See Plates VI-12 through VI-14 for pool duration, pool probability, and release probability curves, respectively.

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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 System projects, this subject has been explored thoroughly in the Master Manual and will not be repeated in this Big Bend water control manual. Rather, the following paragraphs will be concerned with amplifying the regulation objectives and requirements given in the Master Manual as they are pertinent to regulation of Big Bend for the Congressionally authorized project purposes of flood control, navigation, hydropower, water supply, water quality, irrigation, recreation, and fish and wildlife, which includes Threatened and Endangered (T&E) species. Carryover multiple use storage space is not provided in Big Bend reservoir to specifically serve all Missouri River authorized purposes. Regulation of Big Bend for flood control is discussed later in this chapter.

7-02. Basis for Service. As an introduction to regulation of Big Bend, the need to conform to certain storage provisions and basic regulation criteria should be recognized. The bottom, inactive storage zone of Big Bend reservoir, or that zone lying below elevation 1420 feet msl, is to remain filled with water except for drawdowns of a temporary nature. This insures maintenance of a minimum power head; a minimum level for irrigation diversion and water supply facilities; and a minimum pool for future sediment storage, recreation, fish, and wildlife purposes. The top storage zone in the reservoir, extending above elevation 1422 feet msl, is provided only for the handling of large floods and to insure safety of the project structures. The upper storage zone is reserved exclusively for this purpose. Storage space intermediate to these zones, extending from 1420 to 1422 feet msl, provides for the multiple purposes mentioned in the previous section and for the control of moderate floods. Together with the upper zone, a degree of control of major floods, including those approaching the maximum possible, can occur.

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

a) Regulation of Big Bend as an individual project must be subordinate to regulation of the entire System as a whole.

b) Flood control will be provided for by maintaining the reservoir level near elevation 1420 feet msl, particularly during the March-July flood season when substantial runoff amounts may occur from the Oahe-Big Bend incremental drainage area.

c) The Corps will balance the other authorized purposes of irrigation, navigation, hydropower, water supply, water quality, recreation, and fish and wildlife to obtain the optimum development and to best serve the needs of the people, as stated in Chapter VII of the Master Manual.

d) Releases will be through the Big Bend powerplant to the maximum degree practicable, subject to storage limitations and powerplant release capabilities imposed by project design.

e) Releases from upstream reservoirs to support Missouri River navigation will be passed downstream through the Big Bend powerplant.

7-04. Irrigation. No Federally financed irrigation projects are either in existence or are currently being proposed that are directly associated with Big Bend. However, upstream irrigation has a depleting effect upon inflows. During its authorization and design it was anticipated that power revenues derived from the project would help finance Federal irrigation projects in the Missouri River basin. Minor, private irrigation withdrawals from the reservoir are occurring, and these can be expected to increase in the future. Maintenance of Big Bend reservoir near elevation 1420 feet msl at all times provides almost ideal reservoir level conditions for setting and operation of the irrigation intakes. The Big Bend release level should not normally affect irrigation withdrawals from below Big Bend dam since the Fort Randall reservoir extends upstream to the Big Bend tailwater area during the irrigation season.

7-05. Water Supply and Quality Control. Extension of the upstream limits of the Fort Randall reservoir into the Big Bend tailwater area precludes the necessity of making Big Bend releases for any water supply demands that may develop downstream from the dam. Maintenance of the Big Bend reservoir level near elevation 1420 feet msl provides near ideal conditions for any water supply intakes utilizing the reservoir as a source. The only pollutant contribution of consequence in the area is at the upstream end of reservoir, where the cities of Pierre and Fort Pierre, South Dakota, are located. Minor fluctuations in Big Bend reservoir levels have a tendency to move the pollutants from their source.

7-05.1. As per a settlement agreement [United States District Court, District of South Dakota, August 8, 2003, Lower Brule Sioux Tribe et al. v. Rumsfeld], the Corps will consult with the Lower Brule Tribe and the Crow Creek Sioux Tribe during any review and revision of the Master Manual. This agreement also provides that the Corps will coordinate the regulation of Big Bend and the water level of The Big Bend reservoir with the two Tribes to include the following:

> "9a.) The Corps will normally strive to maintain an operating level at Lake Sharpe as measured at the gauge on the Big Bend Dam and adjusted for wind effects between elevation 1419 m.s.l. and 1421.5 m.s.l. For the purposes of this settlement agreement and for no other purpose, the parties agree that this operating level shall be referred to as a "normal" operating level. When Lake Sharpe is at a normal operating level, the Tribes, acting through such persons for the Lower Brule Sioux Tribe and for the Crow Creek Sioux Tribe as the Tribes shall designate in writing to the Corps and the Corps, acting through the Chief, Missouri River Basin Water Management Division, shall use their best efforts to provide notice on an as-needed basis concerning the operations of Big Bend and their impact on Lake Sharpe.

9b.) Whenever the elevation of Lake Sharpe as measured at the gauge on the Big Bend Dam, and adjusted for wind effects, is expected to, or does, drop below elevation 1419 m.s.l. or exceed elevation 1421.5 m.s.l., the Corps, acting through the Office of the Chief, Missouri River Basin Water Management Division, shall use its best efforts to provide notice on an as-needed basis of the operations affecting pool elevation to such persons for the Lower Brule Sioux Tribe and for the Crow Creek Sioux Tribe as the Tribes shall designate in writing to the Corps.

9c.) When the Corps anticipates that conditions may result in a water level below 1418 m.s.l. or above 1422 m.s.l., and adjusted for wind effects, or in the event the water level falls below 1418 m.s.l. or rises above 1422 m.s.l., and adjusted for wind effects, the Commander, Northwest Division of the Corps, or such person as the Commander shall designate in writing to the Tribes, shall immediately contact the Chairpersons of the Tribes or other persons as the Tribes may designate in writing to the Corps to notify them of the situation, the reasons for the situation, and to discuss proposed action to eliminate the situation. The Commander or the Commander's designee shall use his or her best efforts to continue appropriate ongoing communication with the Tribes until the situation is ended and Lake Sharpe is back to a normal operation level."

7-06. Navigation. Storage space to sustain navigation on the lower Missouri River is not provided in Big Bend. Upstream reservoir storage released for this purpose is passed downstream through the Big Bend powerplant. Although Big Bend does not have storage space specifically identified for navigation support the reservoir was drawn down in 2002 to maintain navigation support during a series a lawsuits that restricted releases from other System reservoirs.

7-07. Power Production. Hydroelectric power generated by at Big Bend 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. The release capability of the full Big Bend powerplant is in excess of 100,000 cfs; therefore, the necessity of making releases in excess of the powerplant capacity is extremely remote. A supplementary release may be occasionally required for test and maintenance purposes. However, such outflows will represent only a very minute fraction of total releases. During the large runoff year of 1975, when flood season runoff above Big Bend dam was the greatest in the available record period extending back to 1898, mean daily releases were at all times less than 70,000 cfs, well below the powerplant capacity.

7-07.1. While hourly loadings of the Big Bend powerplant are scheduled by the Western system power dispatcher in Watertown, South Dakota, these loadings must be within limits prescribed by the RCC. These limits are developed on the basis of releases required to serve authorized purposes other than power. Due to the changing power loads during the day, instantaneous releases will often fluctuate widely. The release may be as low as zero at times when demand is light and as high as full powerplant capacity, exceeding 100,000 cfs, during the heavy load hours. A weekly cycle in Big Bend power releases and reservoir levels is normally advantageous. Big Bend releases are reduced on Saturday and Sunday, when power loads are lower, and the reservoir level is allowed to rise to near elevation 1421 feet msl. This provides water for additional power generation during the ensuing week, when power demand are higher, by increasing Big Bend power releases and drawing the reservoir down to near 1420 feet msl. A typical hourly and weekly release pattern is shown on Plate VII-1. Further discussion on power scheduling is presented in Section 12 of Chapter VII of the Master Manual.

7-07.2. A seasonal variation in the general level of power releases from Big Bend usually occurs, reflecting service being provided to other authorized purposes by the remaining reservoirs in the System. During the open-water season, relatively large releases are required from Gavins Point, the lower-most reservoir of the System, to support navigation. These 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-Gavins Point portion of the basin during the navigation season. Although Big Bend storage space does not specifically serve navigation, the lack of such space makes it necessary to essentially release inflow to serve downstream flow support for navigation and other purposes. The inflow to Big Bend consists primarily of the Oahe releases. Additionally, during years of above-normal water supply, the major portion of required storage evacuation of upstream reservoirs through Big Bend must be made during the open-water season. These large releases generate substantial amounts of power.

7-07.3. During the winter months when navigation is not possible and in October and November when the navigation season may be shortened in extended droughts, releases from the System are usually restricted to less than one-half their navigation-season level. In many years, the release is influenced in the winter months by the capacity of the ice-covered Missouri River channel below Gavins Point Dam. With the limited System storage capacity downstream from Oahe, reductions in System releases from Gavins Point will usually require a reduction in the average releases from Oahe, and in turn, Big Bend and Fort Randall.

7-08. Fish and Wildlife. Regulation of the Big Bend reservoir for fishery purposes largely involves pool level manipulations that will provide a suitable environment for the spawning and initial growth of game and forage fish. Stationary or rising reservoir elevations through the late March to early July period are desirable for this purpose. Since Big Bend reservoir is regulated to maintain reservoir levels very close to elevation 1420 feet msl at all times, propagation of most fish species is enhanced. The opportunity for a substantial increase of reservoir levels into the vegetation zone around the Big Bend reservoir is not available as it may be on other System projects, nor is it possible to provide any continuing significant increase in levels throughout the spawning season. However, during April and May, pool fluctuation is generally limited to less than half a foot in order to assist with fish spawning. Refer to Appendix D of this manual for further discussion of Fish and Wildlife.

7-09. Threatened and Endangered Species. The Service has identified three protected species – the endangered least tern, the threatened piping plover and the endangered pallid sturgeon – that are affected by the regulation of the System. As of 2006 none of these species have been found living in the immediate vicinity of Big Bend. However, the birds have been found nesting on both Oahe and Fort Randall reservoirs.

7-10. Recreation. Water-based recreation at Big Bend is dependent on the constructed access facilities. Boat ramps constructed around the perimeter of the project have top elevations extending from 1423 feet msl to 1430 feet msl and bottom elevations ranging from 1412 feet msl to 1415 feet msl. The continuing regulation of the Big Bend reservoir level very close to elevation 1420 feet msl, as is practiced, provides ideal access to the reservoir at all times. Access to the tailwater area is largely dependent on the downstream Fort Randall reservoir elevation. Through most of the year, this downstream project is at a level where no access problems exist.

7-11. Release Scheduling. As discussed in the Master Manual, scheduling of releases from Big Bend and the other System projects, is normally based on continuing studies by the RCC in which all authorized purpose requirements, including flood control, are considered. These studies are made at maximum time intervals of 1 month and incorporate current reservoir storage conditions with the most recent estimates of future runoff, as expressed in terms of forecasted inflow to the individual System projects. Service to all authorized purposes receives consideration, including current projections of power demands and navigation requirements. The frequency of these studies, perhaps resulting in modifications of the current and projected Big Bend release levels, 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 annual operation plan (AOP).

7-11.1. Regulation orders, furnished by the RCC to operating personnel at the Big Bend project, are the basis for scheduling mean daily releases from Big Bend. Since exact daily power demands cannot be anticipated, regulation orders usually allow a specified variation from this scheduled mean daily release rate. Allowable variations in Big Bend release rates from those specified in the order are frequently quite high because Big Bend and the upstream Oahe powerplant are often designated as the “swing” plants. Releases from these projects vary to meet the fluctuations in actual system energy load. Due to the limited fluctuations allowed in the level of the Big Bend reservoir, releases scheduled from Oahe and Big Bend and their “swings”, or variations in actual releases from scheduled releases, are normally very similar. Hourly patterning of the Big Bend mean daily release rate within limits prescribed by the RCC is accomplished by Western’s scheduling of daily power production.

7-12. Objectives of Flood Control Regulation. The primary objective during flood regulation of Big Bend is to control flood runoff originating between Oahe and Big Bend dams. Since there are no damage centers immediately below Big Bend dam and releases are made directly into Fort Randall reservoir, this objective essentially becomes control of inflows in such a manner that releases during the flood period can be limited insofar as possible to the powerplant capacity and the maximum beneficial uses attained from these releases.

7-13. Storage Space Available for Flood Control Regulation. Storage space allocated for flood control in Big Bend reservoir totals 177,000 acre-feet. Of this, 60,000 acre-feet are allocated to the exclusive flood control storage space, which is to be used only during unusually large flood inflows. The remain 117,000 acre-feet is annual flood control and multiple use space, which is to be deliberately used temporarily during periods of low flood potential in the Oahe-Big Bend incremental area to improve power production from the System as a whole or for other multiple-purpose uses such as fish propagation. During periods of high flood potential in the incremental area, this space will be kept available to temporarily store increased runoff as it occurs. Surcharge storage space has also been provided in Big Bend reservoir to insure the safety of Big Bend during extreme flood events. However, use of the entire flood control storage space will have only a minor effect upon regulation of the downstream System projects.

7-14. Flow Regulation Devices. Releases from Big Bend may be made through the powerplant and the spillway. Normally discharge through the powerplant will be used to the fullest extent possible to achieve the maximum economic return from the project. The discharge capacity of the Big Bend powerplant approximates 110,000 cfs. This discharge rate greatly exceeds the discharge rate that will be maintained from downstream reservoirs or that can be expected to occur for any significant period of time from the Oahe-Big Bend incremental drainage area except under extreme conditions. Consequently, the possibility of spillway discharges is very remote. The spillway has a discharge capacity of 270,000 cfs at elevation 1423 feet msl, the top of the exclusive flood control storage zone.

7-15. General Plan of Flood Regulation. The plan for regulating flood storage in Big Bend is quite simple, namely the maintenance of reservoir levels near elevation 1420 feet msl. This will be accomplished either by appropriate manipulation of Big Bend releases or through manipulation of inflows by adjusting releases from Oahe reservoir or a combination of the two processes. Selection of the more appropriate method will be dependent upon the advisability of transferring storage from Big Bend into Fort Randall.

7-16. Coordinated System Flood Control Regulation. The System, of which Big Bend is an integral component, is regulated to reduce flooding to the maximum degree practical along the Missouri River below the System and in the river reaches between the System dams. In most projections of System flood control regulation and subsequent releases scheduling, Big Bend inflows and releases are assumed to be identical with Oahe outflows. Scheduling of outflows from Oahe and Big Bend to accomplish System flood control is based on studies performed by the RCC. The long-range studies extend from the current date through the succeeding months up to the subsequent March 1, when the start of the following flood season occurs. Such studies are made at a maximum interval of 1 month, as new estimates of future runoff are developed and, if conditions change materially from those anticipated in previous monthly studies, additional within-month studies are made. The published AOP, discussed in Chapter VIII of the Master Manual, is based on one of these studies, with deviations from the published plan based on the results of subsequent monthly, and sometime more frequent, studies. Details of flood control regulation procedures applicable to the System are given in Section 4 of Chapter VII of the Master Manual.

7-17. Exclusive Flood Control Regulation Techniques. Only under the most extreme conditions, will the storage of water in the exclusive flood control zone of Big Bend be necessary for any extended period of time. Ordinarily any encroachment into this zone will be evacuated as soon as practicable. Long-term utilization of the exclusive flood space in Big Bend will probably represent a surcharge operation of other System projects. Unless flood inflows approach the spillway design capacity, the Big Bend reservoir level should be maintained near to or below elevation 1423 feet msl, the top of exclusive flood control storage space by adjusting Big Bend and Oahe releases. Refer to Section 7-05.1 of this manual for the agreement for coordination with the Crow Creek and Lower Brule Sioux Tribes should there be storage of water in the Big Bend exclusive flood control zone.

7-18. Surcharge Regulation Techniques. During exceptionally large flood inflows, all available flood control storage space may be utilized, and Big Bend reservoir may rise into the surcharge zone above elevation 1423 feet msl. The primary reason for providing surcharge space is to insure the safety of Big Bend dam. Since real estate surrounding the reservoir has, in general, not been acquired above elevation 1423 feet msl, significant surcharge encroachment will occur only if unprecedented flood inflows occur. When unprecedented flood inflows occur and reservoir levels exceed elevation 1423 feet msl, the normal daily model will be used to determine Big Bend releases. Should there be a loss of communication between the RCC and Big Bend, the regulation procedures given with the emergency instructions presented as Exhibit A in this manual may be used as a guide for release scheduling. These procedures permit releases up to the full capacity of the Big Bend spillway to prevent reservoir levels from materially exceeding an elevation 1423 feet msl.

7-19. Responsibility for Application of Flood Control Regulation Techniques. As described in Section 6 of Chapter V of the Master Manual, the RCC is responsible for and directs all regulation, including flood control regulation, of Big Bend and the other System reservoirs. Instructions to assure continuation of Big Bend regulation during periods of communication failure between the project and the RCC are given in succeeding paragraphs and in Exhibit A of this manual.

7-20. Emergency Regulation. Reliable and rapid communication is usually available between the RCC and operating personnel of Big Bend. In the event that communications are interrupted for any extended period of time, project personnel will be required to continue regulation, as discussed in Chapter V of this manual. Exhibit A of this manual outlines the emergency procedures to be followed. In general, these procedures are written such that regulation will continue to serve all authorized purposes through the period of communications failure at the same approximate level prevailing prior to the communications outage if Big Bend inflows continue in the range of those previously anticipated. The emergency procedures also allow for appropriate regulation to occur during periods of increased inflows, up to those approaching those considered to produce maximum possible floods.

7-20.1. Emergency regulation procedures presented in Exhibit A recognize the relatively small amount of storage space contained in the Big Bend reservoir surcharge zone and the lack of any damage centers immediately below the project. Consequently, there is no effort to induce surcharge storage during extremely large flood inflows. Rather, all effort at such times should be to limit the amount of encroachment into storage space above elevation 1423 feet msl.

7-21. Spillway Design Flood. One example of using the emergency regulation procedures presented in Exhibit A for regulation of the Big Bend reservoir is shown on Plate VII-2. The flood examined is the maximum probable summer flood, which was developed for spillway design purposes, having a peak inflow of 725,000 cfs and a maximum 6-day volume of 2,825000 acre-feet.. An initial level of the Big Bend reservoir at elevation 1420 feet msl was considered to be reasonable. The respective crest reservoir level and associated release rate are elevation

1433.5 feet msl and 388,000 cfs. This routing assumed that the Big Bend powerplant would be inoperative when releases exceeded 100,000 cfs. Continuation of powerplant releases in addition to spillway releases during the maximum probable spring flood routing would have resulted in a lower maximum pool level and greater maximum releases, but with a lower maximum release over the spillway. The crest values given on Plate VII-2 are essentially the same as those developed in Big Bend spillway design studies, which indicate the crest elevation and release at 1433.6 feet msl and 390,000 cfs, respectively. The minor variation in these results from the original design studies (1433.9 feet msl and 392,000 cfs) is due to capacity curve changes since the completion of the original design studies and minor modifications in the release schedule.

7-22. One-Quarter Spillway Design Flood. In order to more completely illustrate application of the emergency procedures, an inflow hydrograph approximating one-fourth of the maximum probable summer flood hydrograph was routed through Big Bend reservoir utilizing these emergency procedures. Results are illustrated on Plate VII-3. The crest inflow of about 185,000 cfs was reduced to a maximum outflow of 140,000 cfs while the reservoir was maintained at elevation 1423.8 feet msl or below throughout the flood period.

Missouri River Basin
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VIII – Water Management Organization

8-01. Responsibilities and Organization. This chapter describes the personnel and coordination necessary to regulate Big Bend. Big Bend is regulated as part of the System, which is comprised of six projects on the Missouri River mainstem. The Corps has the long- and short-term direct responsibility for regulating Big Bend as a hydraulically and electrically integrated project. This has been the case since July 1963, when Big Bend was closed to begin storing water.

8-01.1. Corps of Engineers. The Northwestern Division's (NWD) Missouri River Basin Water Management Division (MRBWMD) of the Programs Directorate, located in Omaha, Nebraska, is comprised of a 17-person staff of engineers, biologists, information management specialists, program analysts, hydrologic technicians, and support staff. The MRBWMD is comprised of three teams: Reservoir Regulation, Power Production, and Master Manual Review and Update. The Reservoir Control Center (RCC) is a subset of MRBWMD that includes the Reservoir Regulation and Power Production Teams and consists of 11 individuals involved in real-time regulation of the System. The Corps' Guidance Memorandum entitled, "Reservoir Control Center", dated March 1972, serves as the document that details the role and responsibilities of the RCC in managing and regulating the System. The RCC was founded in 1954 and was the first RCC established in the Corps. The organization chart for the MRBWMD in the NWD is provided on Plate VIII-1.

8-01.1.1. The Corps started construction of Big Bend in 1959. Big Bend 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 of the Corps has delegated the regulation of this System to the NWD Commander, who provides oversight of the MRBWMD's day-to-day regulation of the System. The RCC, under the supervision of the Deputy Director, Programs Directorate – Missouri River/Chief, MRBWMD (a dual-hatted position), has the direct responsibility of regulating the System and issues daily release and hydropower production orders to accomplish this mission. The operation and maintenance 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 actual gate changes stated on the System project orders developed and sent by the RCC. The System is the largest reservoir system in the United States, based on the storage capacity. The Corps has the responsibility to coordinate the regulation of this System, both within and outside of the Missouri River basin. The RCC 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 manual. Refer to Exhibit A of this manual for instructions to the Big Bend Operations Manager (OM) in case of loss of communication for an extended period of time during a significant or catastrophic event. The RCC staff maintains communication with each other and 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 RCC, for at least part of the each day of the year. Detailed calling lists are provided to the System projects and Omaha District Emergency Operations staff in case there is a need to contact RCC staff during normal off-duty hours.

8-01.1.2. The two teams within the RCC have the responsibility for regulating the System. The Reservoir Regulation Team in the RCC has the responsibility of running the daily Missouri River streamflow forecast to determine releases (often called the System release) from the lower-most System dam (Gavins Point Dam). This team also forecasts all runoff volumes for both long- and short-range model simulations. Because runoff forecasting is a critical component in the decision process to determine the most effective flood control release rate, the Reservoir Regulation Team has the responsibility of making all individual System project release determinations during significant System flood control operations. The Reservoir Regulation Team also directs and approves the deviation requests from the Omaha and Kansas City Districts for Corps tributary reservoirs and USBR tributary projects that have Corps-regulated flood control zones. The Power Production Team has the responsibility of intra-System regulation and threatened and endangered species (T&E) coordination relating to System regulation. Intra-System 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. The Missouri River Programs Team was formed to oversee the studies and documentation required for the review of the Master Manual that led to the 2004 and 2006 updates of the Master Manual. This team also provides program management for, and oversight of, the non-flow Missouri River and tributaries related actions necessary to comply with the Endangered Species Act (ESA). This team has the responsibility to ensure that the overall adaptive management process for both the flow and non-flow ESA-related actions are established and proceed in an effective and efficient manner.

8-01.1.4. **Adaptive Management.** The Corps has conducted System water management within an adaptive management framework for many years. The Master Manual documents the Corps' vision for the future adaptive management process. This process will allow for the review of System water management by Federal and state agencies, basin Tribes, and the public and allow for their input into the implementation of, and changes to, the Current Water Control Plan (CWCP). Additional details regarding adaptive management are presented in Appendix I of the Master Manual.

8-02. System Coordination. The RCC strives to keep stakeholders 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 RCC, 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 dependant on a group of well-informed stakeholders and partners providing continual dialog on the effects of actual and proposed System regulation. The following paragraphs detail how this coordination is accomplished.

8-02.1. **Local Press and Corps Bulletins.** The RCC provides monthly and other special press releases concerning the regulation of the System. The NWD Public Affairs Office is responsible for issuing the official RCC press releases.

8-02.2. **RCC Website.** The RCC maintains a public website at the following address: www.nwd-mr.usace.army.mil/rcc. This site contains information concerning System regulation. It includes forecasted reservoir levels and dam releases as well as historic data in both tabular and graphic formats. The website contains user-friendly, clickable maps to observe graphical streamflow and System project data. The NWS has the responsibility for issuing streamflow forecasts. While the RCC also performs streamflow forecasting at select locations, these results are not available for public dissemination. The NWS forecasts are available as a link from the RCC website. The website contains special news releases regarding closure of the river for navigation during to extremely large flood events, deviations from approved water control plans, water control plan information meetings, T&E nesting operations, and other significant items that occur on an unscheduled basis. In addition, the Corps produces numerous reports on a daily basis that provide continual updates of the System's status and regulation changes. These reports are available to the public by either World Wide Web access or email.

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 forecasts the regulation of the System for various runoff scenarios for the remainder of the current year, plus the following calendar year. Copies of the Draft AOP are mailed to all interested stakeholders each fall. Public meetings are held at three to six sites within the basin, normally in October, to accept comments from the public and provide a forum for discussion of the Draft AOP. Written comments on the Draft AOP are also considered for a period of generally 30 days after initial coordination. After considering the comments from the public meetings and any written comments provided during the coordination period, appropriate changes are made to the Draft AOP to produce a Final AOP, which is normally made available around the first of the calendar year. In the spring, the Corps again conducts public meetings to provide information on the current hydrologic conditions in the basin and the expected effects of System regulation for the remainder of the year given the most-likely forecast and other possible runoff scenarios. Once again, comments are obtained for fine-tuning the System regulation for the spring and summer. The RCC follows the Final AOP as closely as possible for the remainder of the year, and the process begins again in August for the next AOP. It should be stated that not all circumstances are covered in the AOP. Even with this public process, flexibility to deviate from the Final AOP is prudent. This flexibility allows the Corps to regulate the System for maximum benefit in an area of the continent where extreme climate changes can and frequently do occur.

8.02.5 **Tribal Consultation on AOP.** In March 2004 the Corps signed the "Programmatic Agreement for the Operation and Management of the Missouri River Main Stem System for Compliance with the National Historic Preservation Act, as amended" (PA). Stipulation 18 of the PA states that the Corps will consult with affected Tribes and Tribal and State Historic Preservation Officers, the Advisory Council on Historic Preservation and other consulting parties on draft AOPs and other decision documents to determine whether operational changes are likely to cause changes to the nature, location or severity of adverse effects to historic properties or to the types of historical properties affected and whether amendments to the Corps' Cultural Resource Management Plans and Five-Year Plan are warranted in order to better address such effects to historic properties.

8-02.5. **National Weather Service Coordination.** The NWS is the official Federal agency responsible for issuing streamflow forecasts to the public. The Corps uses these forecasts in its regulation of the System. The NWS office interface for the RCC is the NWS Missouri River Basin Forecast (MBRFC), located in Prairie Hill, Missouri. 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 RCC 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 exchange is through web-displayed products or by direct telephone contact, when required. The Corps receives MBRFC forecasts and MPE rainfall radar imagery, as described in Chapter V, Paragraph 5-01.2.1 of the Master Manual and Section 3 of Chapter 5 of this manual for integration into the RCC real-time forecasting models. During years of significant plains snowmelt, additional coordination between the Corps and MBRFC is necessary to assure a 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.

8-02.6. **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 RCC in a real-time mode. This prompt delivery of data allows the RCC to meet its mission of managing the Nation's water resources. This effort is conducted through a cooperative stream-gaging program (CO-OP). This CO-OP program covers the 1) maintenance of Data Collection Platform (DCP) stations, 2) measurement of streamflow at select locations, and 3) sediment and water quality sampling at select locations. The RCC 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. The USGS also conducts specific data collection efforts to support the Corps. For example, it acquired the specific data needed for impacts modeling of groundwater and fish and wildlife effects of alternative water control plans leading to the selection of the CWCP presented in the Master Manual.

8-02.7. **Western Area Power Administration Coordination.** 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 forecasts are also used to reflect unanticipated adjustments in project releases, such as flood control regulation and lawsuits that can dramatically alter energy generation schedules. Scheduled and forced outages of the generating units are closely coordinated with Western. Coordination and letters of support from Western are required during the planning and execution of major rehabilitation of the System powerplants.

8-02.8. **U. S. Fish and Wildlife Service Coordination.** The Service is the primary Federal agency in charge of administering the Endangered Species Act of 1973 as it relates to protected species in the Missouri River basin. The RCC and Service coordinate extensively on regulation of the System during the nesting season for the endangered interior least tern and threatened piping plover and on other issues relating to the implementation of the Service's "Biological Opinion the Operation of the Missouri River Main Stem Reservoir System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, and Operation of the Kansas River System", dated November 30, 2000 and its December 16, 2003 Amendment to that Biological Opinion. 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 RCC and the Federal agencies that have missions that are affected by the System. In 2003, the RCC participated in a Memorandum of Understanding (MOU) with the Southwestern Power Administration (Southwestern) with regard to hydropower generation on the Corps' tributary projects in the Kansas City District. The RCC also had an agreement with the USBR from Boise, Idaho, as recently as 1999, for mutual satellite data collection and backup. This MOU was not renewed because each agency had developed Continuity of Operation Plans (COOP) using other sources for data system redundancy. The RCC has an existing agreement with the Great Plains Region of the USBR for the use of System Replacement 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 RCC has not exercised the option of using this storage since the drought of the 1980's; however, the water control plans for the System and the individual USBR projects describe this storage and how it would be used to enhance overall basin benefits.

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. Currently the Missouri River Basin Association (MRBA) and the Missouri River Basin Interagency Roundtable are the only two active groups.

8-04.1.1. **Missouri River Basin Association.** In 1993, the Missouri Basin States Association changed its name to the Missouri River Basin Association (MRBA), reflecting the inclusion of the basin Tribes in its membership. The MRBA also expanded its role as providing a single location for resolving water resource issues occurring in the basin. Basin coordination and cooperation on water resource issues were the primary goal of the MRBA.

8-04.1.2. **Missouri River Basin Interagency Roundtable.** This group was organized 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, the Service, USBR, Bureau of Indian Affairs, EPA, Western, U.S. Forest Service, and the Natural Resources Conservation Service.

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

8-06. Reports. The RCC 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 RCC website – www.nwd-mr.usace.army.mil/rcc. This website is used for public dissemination of water resource information related to regulation of the System. In addition to the reports shown in Table VIII-1, the RCC prepares technical reports on an as-required basis to provide information and additional guidance in regulation of the System.

Table VIII-1
Reservoir Control Center Reports

Frequency	Type of Report	Reporting Requirement[1]
Hourly	15-day plots of hourly DCP data of basin streams and reservoirs.	
Daily	Daily bulletin	
	Weekly bulletin	
	Monthly bulletin	
	Yearly bulletin	
	Reservoir Summary Bulletins	
	Flood report	
	Power Production Orders	
	Missouri River Streamflow Forecast – 14 days	
	Ice Report (Seasonal Dec-Apr)	
	Mainstem Release and Energy Schedule	
Weekly	Reach Runoff Report	
	LRS 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 Press Release	
	Monthly Project and System Energy Summary	
Yearly	Draft Annual Operating Plan	
	Final Annual Operating Plan	
	Annual Summary of Actual Operations	
	Division Annual Report	ER Requirement, includes District Reservoirs
	Flood Damages Report	ER Requirement – RCC provide holdouts and districts provide estimated damages prevented
	Stage Trends Report	
	Annual Sediment Report	Technical Report
	Annual Water Quality Report	ER Requirement
	Cooperative Stream Gage Program	ER Requirement

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

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Appendix A – Historic Flood and Flood Control Regulation Examples

A-01. Floods. Regulation provided by Oahe reservoir and other upstream System projects, augmented by upstream tributary reservoir storage, has virtually eliminated flooding along the portion of the Missouri River in the vicinity of Big Bend. Many instances of above bank-full flows were experienced through this reach prior to construction of the System projects and would be continuing if the projects were not in operation. All floods recorded in this portion of the Missouri River prior to System reservoir operation occurred in the March-July flood season. The Master Manual contains relatively detailed descriptions of several Missouri River floods, including data that are pertinent to the incremental reach described in this manual. Since there are little additional data beyond that given in the Master Manual for several of these floods, they will not be discussed in this manual.

A-02. Runoff. Within the incremental Oahe-Big Bend drainage area, streamflow records are available on the Bad River. As indicated previously, the average annual runoff from this tributary is only slightly greater than 100,000 acre-feet; however, on occasion this volume may be greatly exceeded during a single runoff event. Crest flows and 10-day volumes of major Bad River flood events experienced during the past 60 years are given in Table A-1.

Table A-1
Bad River Flood Flows at Fort Pierre, South Dakota

Month/Year	Flood Type	Crest Flow in cfs	Frequency of Flow[1]	Maximum 10-Day Flood Volume in Acre-Feet
Jul 1905	Rainfall	70,000(est.)	140 years	Not known
Apr 1927	Plains snowmelt	55,000	75 years	Not known
May 1942	Rainfall	34,200	25 years	207,800
Apr 1950	Plains snowmelt	16,700	7 years	161,300
Apr 1952	Plains snowmelt	28,100	17 years	377,300
May 1962	Rainfall	10,500	3 years	28,700
Mar 1966	Plains snowmelt	10,700	3 years	119,600
Jun 1967	Rainfall	43,800	45 years	133,000
Jul 1969	Plains snowmelt	37,700	33 years	21,000
Apr 1975	Rainfall	3,770	2 years	36,800
Mar 1978	Plains snowmelt	19,200	8 years	193,300
Jun 1984	Plains snowmelt	13,500	5 years	65,600
May 1986	Plains snowmelt	13,600	5 years	61,100
Mar 1987	Plains snowmelt	16,600	6 years	93,600
Jul 1993	Rainfall	6,160	2 years	14,000
May 1997	Plains snowmelt	14,700	6 years	77,500

[1]See Plate VI-10. Based on the 75 years of observed data at the location, the 1905 crest occurs approximately once every 140 years; the 1978 crest occurs approximately once every 8 years.

A-03. Incremental Runoff. Of interest is the incremental flow originating between Oahe and Big Bend exclusive of, but coincident with, Bad River floods. Simultaneous discharge and storage change records of both Oahe and Big Bend since 1963 enable calculations of total incremental inflow. The runoff from the ungaged incremental area may be determined by subtracting the total incremental inflow from the gaged Bad River flow. Table A-2 presents these data relative to observed flood events.

Table A-2
Incremental Flood Flows – Oahe to Big Bend

Month, Year	Monthly Flood Volume in Acre-Feet					
	Big Bend In[1]	Oahe Out[1]	Total Flood	Bad River[2]	Ungaged	% Ungaged
Mar 1966	1,209,000	1,016,000	193,000	150,000	43,000	22
Jun 1967	1,609,000	1,392,000	217,000	153,000	64,000	29
Mar 1969	1,176,000	1,105,000	71,000	24,000	47,000	66
Apr 1970	1,389,000	1,284,000	105,000	59,000	46,000	44
Apr 1971	2,065,000	1,971,000	94,000	66,000	28,000	30
May 1972	1,834,000	1,725,000	109,000	60,000	49,000	45
Apr 1975	1,529,000	1,463,000	66,000	55,500	10,500	16
Mar 1978	1,016,000	638,000	378,000	179,000	199,000	53
Jun 1984	846,900	726,100	120,800	95,000	25,800	21
May 1986	1,386,000	1,224,000	162,000	84,000	78,000	48
Mar 1987	1,347,000	1,176,000	171,000	107,000	64,000	37
Jul 1993	309,000	256,000	53,000	22,000	31,000	58
May 1997	2,775,000	2,688,000	87,000	101,000	-14,000	0

[1]Data obtained from monthly summary reports
[2]Data obtained from USGS daily flow data: 06441500-Bad River at Fort Pierre, SD

A-04. Historical Regulation – Big Bend Reservoir Elevations. Closure of Big Bend dam was made in July 1963, beginning the accumulation of storage in the reservoir. The first power unit did not become operable until October 1964, and, until that time, significant storage was not accumulated. From October 1964 through 1965 relocation work in the reservoir area required that fill be limited and it was not until December 1965 that regulation near the normal operating pool level of elevation 1420 feet msl began. Since that time, the reservoir has been regulated at a very uniform level near elevation 1420 feet msl. With one exception, mean monthly reservoir levels have been within 0.6 foot of this elevation. The exception occurred in 1971 when a mean monthly level at elevation 1421.4 feet msl was recorded as a result of deliberate storage in the reservoir to enhance fish spawning activities.

A-04.1. Maximum and minimum storages during each month and year of the record period, as evidenced by reservoir levels, have also been very close to elevation 1420 feet msl. The average annual variation between maximum and minimum levels has been about 2 feet. The only year that a significant variation in reservoir levels has occurred since 1965 was in 1996, when the Big Bend reservoir was temporarily lowered to elevation 1414.9 feet msl in October. This lowering was to investigate the effects higher Oahe releases in combination with a lowered Big Bend pool level would have in the redistribution of Bad River sediment in the Big Bend headwaters area. Monthly maximum, minimum, and mean elevations, as well as daily reservoir levels are on record in the RCC.

A-05. Big Bend Releases. Since there has been very little variation experienced in Big Bend reservoir levels, it follows that at all times mean releases from the project are a close approximation of inflows over a period of a day or two. The large power peaking capability available at Big Bend has occasionally resulted in some variations between inflow and release, particularly during and following weekends. This has also resulted in extreme fluctuations in hourly releases. Frequently a daily pattern will experience hourly releases ranging from zero during the low power demand periods in the early morning to near the powerplant release capability of over 100,000 cfs during the maximum load hours. An illustration of experienced variations in releases is shown on Plate VII-1. As future power loads within the region increase, the daily variations can be expected to become more extreme. Releases in excess of the Big Bend powerplant capacity have never been necessary.

A-05.1. The small incremental drainage area between Oahe and Big Bend dams, together with the generally small runoff depths contributed from this area, results in Big Bend inflows almost identical to Oahe releases. Since Big Bend storage effects are minimal, there is very little difference between Oahe and Big Bend releases. The Oahe mean daily and mean monthly releases presented on plates in the Oahe manual reflect closely the releases from Big Bend; therefore, a similar plate is not included in this manual. Reference should be made to the Oahe manual for this information.

A-06. Regulation Effects. The historical effects of regulation provided by the Oahe reservoir, combined with regulation of upstream reservoir projects, are illustrated in the Oahe manual. The mean monthly, unregulated flows shown are the computed estimates of flows at the dam site if none of the upstream projects, including Oahe, had been in operation. Mean daily maximum and minimum flows for each year of the period for regulated (observed) and unregulated conditions are also presented. From these data it is evident that upstream reservoir regulation has resulted in substantial reductions to all annual crest flows that would have been experienced at the Oahe dam site. The Oahe manual also presents detailed daily hydrographs of regulation effects during particular years of the experienced record period. The lack of any significant re-regulation of Oahe releases by Big Bend reservoir, as well as the general lack of substantial incremental inflows, makes development of similar data for Big Bend superfluous. Reference is made to the Oahe manual for such data that are essentially applicable to Big Bend reservoir.

A-07. Summary of Historical Regulation. Historical regulation of Big Bend covers only a relatively short period of time; however, annual upstream runoff during this period has ranged from near minimum to the maximum recorded since 1898. Therefore, regulation during these years is believed to be quite representative of conditions that are likely to prevail through the life of the project. Based on this experience, supplemented by analyses of the entire period of hydrologic record, the regulation criteria developed for Big Bend, and for the System as a whole (as presented in the Master Manual) as it affects Big Bend 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. In general, unless the most extreme conditions occur, Big Bend releases will be maintained within the capacity of the Big Bend powerplant. Greater releases are very likely to contribute to downstream floods and these releases would be necessary only if a Big Bend level higher than elevation 1423 feet msl appeared probable. With the large amount of storage space provided in other System reservoirs, chances are very remote that such a high reservoir level will occur. Reservoir levels significantly below elevation 1420 feet msl have not been experienced, nor would they be anticipated in the future, except of an occasional temporary nature in connection with some special operation not covered by routine regulation procedures.

A-07.1. Great variations in Big Bend releases have occurred, from hour-to-hour and day-to-day. Big Bend daily releases nearly always parallel those made from Oahe and appropriate plates in the Oahe manual illustrate the daily variations and the weekly cycle in release rates occasioned by low power demands during weekends. During any one day, Big Bend releases have frequently ranged from zero to near the full powerplant capacity, and, to efficiently produce power, these patterns are not only expected to continue but are expected to be intensified as the power peaking demands from the load area served increase.

Appendix B – Recreation

B-01. General. The six reservoirs of the System and the Missouri River reaches between and downstream of these reservoirs provide significant 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 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, boating-related activities, 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 viable recreation industry below the System on the lower Missouri River; approximately 23 percent of the total recreation benefits attributed to the Missouri River occur below the System.

B-02. System Recreation Visitation. Visitation data is maintained by the Corps in the Natural Resource Management System database. Plate B-1 shows the annual visitation graphically for the System and the six System projects. 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. In 2002 the Corps transferred project lands back to the State of SD and the Tribes. As a result, visitation data was no longer collected at numerous sites, which were once Corps recreation facilities. Reduced data collection sites, in combination with the drought, are the reason for the sharp decline shown on Plate B-1 in visitation from 2001-2004. Other factors, such as the overall United States economy, also affect the visitation. 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. Big Bend Recreation Visitation. Refer to Table B-1 for a history of Big Bend recreation visitation. The reservoir levels of the lower three reservoirs (Big Bend, Fort Randall and Gavins Point) do not vary as much as the larger, upper three reservoirs. The lower reservoirs do not contain the flood 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.

Table B-1
Big Bend Recreation Visitation

Year	Visitation in hours	Year	Visitation in hours
1962	115,400	1985	3,354,446
1963	240,130	1986	2,850,351
1964	570,910	1987	2,634,700
1965	1,279,460	1988	3,489,800
1966	2,229,250	1989	5,853,500
1967	2,472,340	1990	4,379,700
1968	2,537,090	1991	5,709,600
1969	2,713,950	1992	3,423,500
1970	3,400,300	1993	3,537,100
1971	2,477,520	1994	4,474,500
1972	2,944,830	1995	4,779,200
1973	3,184,220	1996	4,886,700
1974	2,508,600	1997	4,196,400
1975	2,442,740	1998	5,107,500
1976	2,405,496	1999	5,215,300
1977	3,294,850	2000	5,261,800
1978	2,634,382	2001	5,057,400
1979	2,973,690	2002	5,706,800
1980	3,035,110	2003	5,701,600
1981	3,686,310	2004	3,433,500
1982	3,452,470	2005	2,980,900
1983	3,330,740	2006	3,325,000
1984	3,370,108		

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 that affects human health and plant and animal life; temperature, which affect 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. Overall current water quality conditions in the Big Bend reservoir are considered generally "good". From a historical perspective, water quality degradation has occurred in the Missouri River basin. 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 majority of the water quality degradation that is 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 reservoir 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 below). In turn, coldwater fish species in the reservoirs may be adversely affected.

C-03. Indirect Water Quality Impacts of System Regulation. Most water quality impairments 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 is not the source of the pollutants that enter the Missouri River; however, it is responsible for managing 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 generally lead to lower hypolimnetic volumes in the three larger System reservoirs. This volume reduction may cause an increase in the overall temperature of the water in the reservoir and may reduce the total amount of oxygen available 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 (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 heavy metal concentrations have been detected both in the water column and within the sediments of the System. The major metals of concern in the System are arsenic and mercury. Arsenic and mercury concentrations greater than State water quality criteria have been detected in several of the System reservoirs. 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. Arsenic is a water quality parameter that commonly exceeds water quality standards criteria in the System reservoirs. 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 elevated concentrations in the System reservoirs are copper, lead, iron, and manganese.

C-03.4. Agricultural practices, both past and present, include the application of pesticides throughout much of the Missouri River basin. Pesticides detected include chlordane, atrazine, alachlor, diazinon, dacthal, benzene hexachloride, metolachlor, dieldrin, DDT, simazine, metribuzin, and propachlor. Because of the widespread occurrence of pesticides, bioaccumulation of some pesticides in the tissue of aquatic organisms is a potential threat to all consumers of these organisms.

C-03.5. 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. **Big Bend Reservoir**. Pursuant to the Federal Clean Water Act (CWA), the State of South Dakota has designated the following water quality-dependent beneficial uses for Big Bend reservoir: recreation (i.e., immersion and limited-contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. Big Bend dam is the demarcation point between coldwater and warmwater use designation on the Missouri River system in South Dakota. Therefore, the designated use of warmwater permanent fish life propagation applies to the Big Bend dam tailwaters instead of the coldwater permanent fish life propagation use that applies to Big Bend reservoir. The State of South Dakota has delisted Big Bend reservoir from the State's Section 303(d) list of impaired waters. The lake was previously listed as impaired due to accumulated sediment from the Bad River watershed. A total maximum daily load (TMDL) was developed and is being implemented to address this concern, resulting in the delisting of Big Bend reservoir. An extensive delta has formed in the reservoir due to sediment deposition from the Bad River.

C-04.1. Table C-1 summarizes the water quality conditions that were monitored in Big Bend reservoir by the Corps' Omaha District during 2003. A review of these results indicated that water temperature and dissolved oxygen might be water quality concerns. Based on the criteria for the protection of coldwater permanent fish life propagation, water temperature criteria were exceeded 77 percent of the time and dissolved oxygen criteria up to 29 percent of the time. It is noted that, if the reservoir were classified for the protection of warmwater permanent fish propagation instead of coldwater, there would have been no exceedances of water quality criteria for either temperature or dissolved oxygen. It does not appear that ambient water temperatures in Big Bend reservoir are low enough to support coldwater permanent fish life propagation as defined by South Dakota's water quality standards criteria. Consideration should be given to reclassify Big Bend reservoir for a warmwater permanent fish life propagation use, based on a use attainability assessment of "natural conditions" regarding ambient water temperature.

C-04.2. Water quality conditions in Big Bend reservoir were assessed based on data collected by the Corps' Omaha District at a near-dam, long-term, fixed station water quality monitoring site during the period 1999 to 2003. Temperature and dissolved oxygen depth profiles were constructed from water quality data collected during the period May through September. These data indicated that significant temperature and dissolved oxygen gradients did not exist in Big Bend reservoir during this period. The size of the reservoir, configuration of the outlet structure, and the release of water through Big Bend dam for peaking power generation (i.e., up to 110,000 cfs) seemingly do not allow significant thermal stratification to occur in Big Bend reservoir. Trophic State Index (TSI) values calculated for this reservoir during this period indicate that the reservoir is in a mesotrophic state.

Table C-1
Big Bend Reservoir Water Quality Summary

Parameter	Monitoring Results: Detection Limit	No. of Obs.	Mean*	Median	Min.	Max.	Water Quality Standards Attainment: State WQS Criteria**	No. of WQS Exceedences	Percent WQS Exceedence
Water Temperature (°C)	0.1	112	19.7	19.5	13.1	26.4	≤ 18.3	86	77
Dissolved Oxygen (mg/l)	0.1	112	8.1	8.6	5.5	10.3	≥ 6.0 ≥ 7.0	9 32	8 29
Dissolved Oxygen (% Sat.)	0.1	112	91.4	94.9	65.9	107.7	-----	-----	-----
Specific Conductance (umho/cm)	1	112	726	722	103	747	-----	-----	-----
pH (S.U.)	0.1	112	-----	8.3	8.0	8.4	≥6.6 & ≤8.6	0	0
Turbidity (NTUs)	0.1	88	3.0	2.4	n.d.	7.6	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	91	345	357	298	374	-----	-----	-----
Secchi Depth (in.)	1	4	121	112	63	196	-----	-----	-----
Alkalinity, Total (mg/l)	7	10	179	176	166	198	-----	-----	-----
Ammonia, Total (mg/l)	0.01	10	0.17	0.09	n.d.	0.48	≤ 0.5(1)	0	0
Kjeldahl N, Total (mg/l)	0.1	11	-----	0.2	n.d.	0.6	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	10	-----	n.d.	n.d.	n.d.	≤ 10	0	0
Hardness, Total (mg/l)	0.4	2	324	324	246	401	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	10	0.09	0.02	n.d.	0.47	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.01	10	-----	n.d.	n.d.	0.01	-----	-----	-----
Suspended Solids, Total (mg/l)	4	10	-----	n.d.	n.d.	5	≤ 53	0	0
Total Organic Carbon (mg/l)	0.05	10	3.3	3.1	3.0	3.8	-----	-----	-----
Chlorophyll *a* (ug/l)	1	3	2	2	1	2	-----	-----	-----
Arsenic, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	360(2) 190(3) 18(4)	0 0 0	0 0 0
Beryllium, Dissolved (ug/l)	4	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Cadmium, Dissolved (ug/l)	3	1	-----	n.d.	n.d.	n.d.	9.6(2) 2.0(3)	0 b.d.	0 -----
Chromium, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	1,137(2) 367(3)	0 0	0 0
Copper, Dissolved (ug/l)	20	1	-----	n.d.	n.d.	n.d.	39.1(2) 24.2(3) 1,300(4)	0 0 0	0 0 0
Lead, Dissolved (ug/l)	5	1	-----	n.d.	n.d.	n.d.	166.6(2) 6.5(3)	0 0	0 0
Thallium, Dissolved, (ug/l)	10	1	-----	n.d.	n.d.	n.d.	1.7(4)	b.d.	-----
Nickel, Dissolved (ug/l)	40	1	-----	n.d.	n.d.	n.d.	2,989(2) 332(3) 610(4)	0 0 0	0 0 0
Silver, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	15.8(2)	0	0
Antimony, Dissolved (ug/l)	20	1	-----	n.d.	n.d.	n.d.	14(4)	b.d.	-----
Selenium, Dissolved (ug/l)	10	1	-----	n.d.	n.d.	n.d.	20(2) 5(3)	0 b.d.	0 -----
Selenium, Total (ug/l)	10	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Dissolved (ug/l)	0.2	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Mercury, Total (ug/l)	0.2	1	-----	n.d.	n.d.	n.d.	2.1(2) 0.012(3) 0.14(4)	0 b.d. b.d	0 ----- -----
Atrazine, Total (ug/l)	0.05	5	-----	0.06	n.d.	0.08	-----	-----	-----
Metolachlor (ug/l)	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Alachlor (ug/l)	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Pesticide Scan (ug/l)***	0.05	1	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.
b.d. = WQS criterion below detection limit.
* Non-detected values set to 0 to calculate mean. If 20 percent or more of observations were non-detected, mean is not reported. The arithmetic mean was not calculated for pH because pH values are logarithmic.
** (1) Total ammonia criterion pH and temperature dependent.
(2) Acute criterion for aquatic life. (Note: Several metals acute criteria for aquatic life are hardness based.)
(3) Chronic criterion for aquatic life. (Note: Several metal chronic criteria for aquatic life are hardness based.)
(4) Domestic drinking water supply.
*** The pesticide scan includes: acetochlor, benfluralin, butylate, chlorpyrifos, cyanazine, cycloate, EPTC, hexazinone, isopropalin, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, profluralin, prometon, propachlor, propazine, simazine, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Note: The data listed in Table C-1 were obtained by the Corps' Omaha District during 2003 at a near-dam location.

Appendix D – Fish and Wildlife

D-01. General. The Service 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. Pallid sturgeon have been documented downstream of Oahe Dam in the vicinity of the Big Bend reservoir. While the birds have been found nesting on both Oahe and Fort Randall reservoirs, they have not been found in Lake Sharpe. 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 upon 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 project contruction. Regulation of the System 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 affect on the environment is constantly changing as it adapts 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 plant and animal 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 Appendix I in the Master Manual will provide 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 threatened and endangered 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 practical for improving migratory waterfowl habitat and hunter access along the 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.

D-02. **Fish and Wildlife.** Fish and wildlife enhancement has been discussed in the Master Manual. Chapter IV, Paragraph 4-06.6 presents information on the activities of two existing

Federal National Fish Hatcheries and the Fort Peck National Fish Hatchery that is currently being constructed. At all times of the year, but particularly during the fish spawning period and the endangered species nesting season, the RCC recognizes and integrates fish and wildlife purpose considerations into System regulation decisions. The Corps coordinates closely with the Service and the State organizations to assure that the consideration is given to the effects on fish and wildlife. 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. The goal of the updated water control plan is to continue to provide environmental stewardship in managing the natural resources in the Missouri River basin while recovering the Missouri River ecosystem.

D-02.1. Since the Big Bend reservoir is kept at a fairly stable elevation regardless of whether basin conditions are normal, drought or flooding, access to the reservoir is also consistent. The Big Bend reservoir offers a very attractive walleye fishery. While the size of walleye may be larger in other System reservoirs, the walleye catch-rate in the Big Bend reservoir is considered better than average. In addition to walleye, the small mouth bass population has expanded considerably in the last few years.

Appendix E – Water Supply and Irrigation

E-01. Introduction. System regulation has assured a relatively uniform supply of water for downstream municipalities and industrial uses. The Corps provides more than adequate flow in the river to meet the requirements of all who choose to utilize the Missouri River for their water supply. At times, releases from individual System projects have been adjusted to assure 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 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 has resulted in a dependency from 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 reservoir levels and releases during extended drought. Generally, these access problems have been accommodated. The Missouri River below the System has the greater dependency on the Missouri River for its municipal water supply and thermal powerplant intakes. Per the 2004 Corps' Final Environmental Impact Statement (EIS), of the approximately 3 million persons are served for water supply from the System, 94 percent are located below Gavins Point Dam. Approximately 2,400 persons, of which 600 consist of a Tribal Reservation population, are served by water supply from the Big Bend reservoir (Lake Sharpe). There are no thermal powerplants in the Big Bend reservoir area. More detailed discussion on water supply and irrigation can be found in Appendix E of the Master Manual.

E-02. Big Bend Reservoir. There are 115 water supply intakes located on Big Bend reservoir. These include 3 municipal intake facilities, 91 irrigation intakes, 19 domestic intakes, and 2 public intakes. The municipal water supply facilities serve a population of approximately 2,400 persons. Of the 115 water supply intakes, there are 22 water supply intakes serving the Lower Brule Reservation. These include a single municipal intake facility, 20 irrigation intakes, and 1 domestic intake. The municipal water supply facility serves a population of approximately 300 persons. Additionally, there are 55 water supply intakes serving the Crow Creek Reservation. These include a municipal intake facility, 51 irrigation intakes, and 3 domestic intakes. The municipal water supply facility serves a population of approximately 300 persons. There have been problems associated with intakes in Big Bend reservoir resulting from turbidity of the water and its suitability for domestic use. Usually these problems clear up as soon as weather conditions improve since this is normally related to wind effects on the reservoir or local tributary flow.

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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 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 cash revenues to the Treasury of the United States. 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 been generated from the regulation of the System. At the six System dams, 36 hydropower units provide a combined capacity of 2,435 megawatts (MW), as shown in Table F-1. These units have provided an average of 10.2 million megawatt hours (MWh) per year, or about 9 percent of the energy used in the Mid-continent Area Power Pool (MAPP) region. The MAPP region includes all of Nebraska and North Dakota; most of South Dakota and Minnesota; and portions of Montana, Iowa, and Wisconsin, as well as Manitoba and Saskatchewan in Canada. Western, of the U.S. Department of Energy, markets power generated at the System dams within the MAPP and Western Systems Coordinating Council (WSCC) regions.

F-02. Hydropower Capacity. The aggregate installed capacity of all powerplants in the Missouri River basin exceeds 20 thousand 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, which make up the other 40 percent, consist of about 40 percent Federal hydroelectric capacity and 60 percent thermal capacity owned by non-Federal public bodies. Hydropower installations in the basin total about 3,300 MW, of which about 82 percent is Federal, 14 percent is investor-owned, and 4 percent is publicly owned. The Federal power system in the upper Missouri River basin includes the six Corps System powerplants as well as the Canyon Ferry and Yellowtail powerplants constructed by the USBR. Until October 1, 1977, power from all Missouri River basin Federal powerplants was marketed by the USBR. At that time, the power marketing responsibility shifted to Western. The Federal hydroelectric powerplants are connected with the extensive Federal transmission system within the USBR's Eastern Division, Pick-Sloan Missouri Basin Program, power-marketing area, which includes Montana east of the Continental Divide, North and South Dakota, eastern Nebraska, western Minnesota, and western Iowa. The transmission network is interconnected with numerous Rural Electric Association-financed cooperatives, municipal power systems, and investor-owned utilities. The Eastern Division transmission network is interconnected with the Southwestern Power Administration at Maryville, Missouri, and with the Western Division through a 100 MW D.C. tie at Stegall, Nebraska, 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 paragraphs 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 Hydropower Data

Dam	Generator Capacity (MW)	Energy (million MWh)	Average Annual Energy Plant Factor (%)	Units	Average Gross Head (feet)	Average Flow (kcfs)	Normal Powerhouse* Capacity (kcfs)	Average Annual Flow Plant Factor (%)	Type
Fort Peck	185	1.2	74	5	200	10.1	16.0	63	Semi-Peaking
Garrison	518	2.5	55	5	173	22.8	38.0	60	Semi-Peaking
Oahe	786	2.9	42	7	181	25.4	55	46	Peaking
Big Bend	494	1.1	25	8	68	25.4	103.0	25	Peaking
Fort Randall	320	1.8	64	8	118	26.7	44.5	60	Semi-Peaking
Gavins Point	132	0.7	61	3	48	29.0	35.0	83	Baseload
Total	**2,435**	**10.2**		**36**	**788**				

* Normal powerhouse capacity is based on average reservoir elevation. Also, kcfs equals thousand cfs.
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, 1967-1997 actual data.

F-04. Big Bend Dam. Eight units operate at Big Bend, with a generating capacity of 494 MW. At this rating, the powerhouse release capacity is 109,000 cfs. The average release is 25,400 cfs and the average annual plant factor is 25 percent, the lowest of the six System powerplants. The powerplant produces 1.1 million MWh per year. Power generating units came on line from 1964 through 1966. Big Bend has primarily a peaking powerplant that normally only fluctuates through a very narrow 2-foot range in reservoir elevation.

F-05. Big Bend dam Releases. Releases experienced from this project have been very similar to that described for Oahe, with a maximum average daily outflow of 74,300 cfs occurring during 1997. Releases have been entirely through the powerplant since these facilities became fully operational. An average daily release of zero is frequently made from the project, usually on a Sunday to facilitate refilling the project for the next week's releases.

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 releases at Gavins Point in the winter is low, the winter Oahe and Big Bend powerplant releases must be stored in Fort

Randall Reservoir (Lake Francis Case). To allow for this, Fort Randall reservoir is drawn down during the fall of each year, as discussed in the following paragraphs.

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 upon daily peaking (with the exception of Gavins Point) up to the capacities of the individual powerplants, provided the limiting average daily discharge is not exceeded. However, at Oahe peak release may be restricted during periods of ice formation downstream to prevent flooding in the Pierre and Fort Pierre areas. Gavins Point is normally flat loaded with very little hourly release variation. Should daily peaking at this project be required for a limited time, a limit on hourly variations in discharge is normally imposed to the extent that cumulative releases will not depart more than 10 percent of the total daily release from a flat schedule. Once an ice cover forms on the downstream Missouri River, the Gavins Point release is normally scheduled at a flat release rate to minimize the potential risk to ice-jam flooding downstream. The peaking capability of this project during the winter months is normally limited to the capability of just two units as the other unit is undergoing maintenance. The minimum allowable hourly generation, and corresponding release, is dependent upon the hydraulic characteristics of the river below each of the projects and the effect upon 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 discussed in more detail in the appropriate individual System project manuals.

F-06.2. In addition to hourly patterning, it is possible, due to the flexibility inherent in such a large system of reservoirs, 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 higher upstream releases for extended periods without correspondingly high inflows. High summer releases from Gavins Point, Fort Randall, Big Bend, and Oahe Dams mean 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 one-fourth to one-half of summer levels and the chain reaction proceeds upstream, curtailing releases from Fort Randall, Big Bend, and Oahe. At this time, Fort Peck and Garrison releases are usually maintained at the maximum levels permitted by the downstream ice cover to partially compensate for the reduction in generation downstream.

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CENWD-PDM (11-2-240a) 20 April 2007

MEMORANDUM FOR Oahe and Big Bend Operations Managers

SUBJECT: Reservoir Regulation Order, Emergency Regulation Procedure for Big Bend Reservoir

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

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

3. The RCC normally transmits the reservoir regulation orders via e-mail to Big Bend on a daily basis. Regulation instructions for the weekend and holidays are contained in the previous normal working day's orders. Big Bend utilizes the Power Plant Control System (PPCS) to transmit observed hourly and daily project data, via the Local Area Network (LAN) to the RCC. If e-mail or network communication between the RCC and Big Bend 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 Big Bend and the RCC.

b. Following a communications failure, 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 provide the daily energy schedule specified in the RCC-provided regulation order and will be patterned similar to recent experience. 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 Big Bend reservoir level remains below elevation 1422 feet msl, the top of the flood control pool.

c. If the Big Bend reservoir level is between elevation 1422 and 1423 feet msl, or above elevation 1423 feet msl and falling, procedures outlined in paragraph 4.b. will be applicable during the first day of communication failure after which conditions will be reviewed to determine if the release level should be changed. If the reservoir level is above 1423 feet msl and rising, release changes, if required, will begin as soon as the communications failure becomes apparent. Procedures are as follows:

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

(2) A continuing surveillance of reservoir elevations will be maintained. Normally those elevations will follow a relatively smooth curve. Therefore, any sudden fluctuations in the reservoir level recorder trace from a smooth curve (likely due to wind effects on the reservoir gage) should be disregarded and the estimated true reservoir level should be based on extrapolation of the smoothed reservoir level curve.

(3) With an estimated true reservoir level between elevation 1422 and 1423 feet msl, after the first day of communications failure, release the greater of:

(a) The full discharge capability of all available power units.

(b) 100,000 cfs.

(4) With an estimated true reservoir elevation between elevation 1423 and 1423.5 feet msl, release as necessary to maintain the reservoir within this range, subject to a minimum release as outlined in (3) above.

(5) With an estimated true reservoir level above elevation 1423.5 feet msl, release at the full capacity of the Big Bend spillway with gates fully open.

(6) With a Big Bend reservoir level between 1422 and 1423 feet msl, any release adjustments made necessary by these instructions should be made at intervals of 6 hours or less. With a pool level above elevation 1423 feet msl the release adjustments should be made at 2-hour intervals.

5. The aforementioned procedures are not intended to relieve the Big Bend Operations Manager of taking such additional measures believed necessary to assure the safety of the project.

Lawrence J. Cieslik

LAWRENCE J. CIESLIK, P.E.
Chief, Missouri River Basin Water
Management Division

	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
	<u>Dam and Embankment</u>			
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
	<u>Spillway Data</u>			
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
	<u>Reservoir Data (6)</u>			
26	Max. operating pool elev. & area	2250 msl 246,000 acres	1854 msl 380,000 acres	1620 msl 374,000 acres
27	Max. normal op. pool elev. & area	2246 msl 240,000 acres	1850 msl 364,000 acres	1617 msl 360,000 acres
28	Base flood control elev & area	2234 msl 212,000 acres	1837.5 msl 307,000 acres	1607.5 msl 312,000 acres
29	Min. operating pool elev. & area	2160 msl 90,000 acres	1775 msl 128,000 acres	1540 msl 117,000 acres
	<u>Storage allocation & capacity</u>			
30	Exclusive flood control	2250-2246 975,000 a.f.	1854-1850 1,489,000 a.f.	1620-1617 1,102,000 a.f.
31	Flood control & multiple use	2246-2234 2,717,000 a.f.	1850-1837.5 4,222,000 a.f.	1617-1607.5 3,201,000 a.f.
32	Carryover multiple use	2234-2160 10,785,000 a.f.	1837.5-1775 13,130,000 a.f.	1607.5-1540 13,461,000 a.f.
33	Permanent	2160-2030 4,211,000 a.f.	1775-1673 4,980,000 a.f.	1540-1415 5,373,000 a.f.
34	Gross	2250-2030 18,688,000 a.f.	1854-1673 23,821,000 a.f.	1620-1415 23,137,000 a.f.
35	Reservoir filling initiated	November 1937	December 1953	August 1958
36	Initially reached min. operating pool	27 May 1942	7 August 1955	3 April 1962
37	Estimated annual sediment inflow	18,100 a.f. 1030 yrs.	25,900 a.f. 920 yrs.	19,800 a.f. 1170 yrs.
	<u>Outlet Works Data</u>			
38	Location	Right bank	Right Bank	Right Bank
39	Number and size of conduits	2 - 24' 8" diameter (nos. 3 & 4)	1 - 26' dia. and 2 - 22' dia.	6 - 19.75' dia. upstream, 18.25' dia. downstream
40	Length of conduits in feet (8)	No. 3 - 6,615, No. 4 - 7,240	1529	3496 to 3659
41	No., size, and type of service gates	1 - 28' dia. cylindrical gate 6 ports, 7.6' x 8.5' high (net opening) in each control shaft	1 - 18' x 24.5' Tainter gate per conduit for fine regulation	1 - 13' x 22' per conduit, vertical lift, 4 cable suspension and 2 hydraulic suspension (fine regulation)
42	Entrance invert elevation (msl)	2095	1672	1425
43	Avg. discharge capacity per conduit & total	Elev. 2250 22,500 cfs - 45,000 cfs	Elev. 1854 30,400 cfs - 98,000 cfs	Elev. 1620 18,500 cfs - 111,000 cfs
44	Present tailwater elevation (ft msl)	2032-2036 5,000 - 35,000 cfs	1670-1680 15,000- 60,000 cfs	1423-1428 20,000-55,000 cfs
	<u>Power Facilities and Data</u>			
45	Avg. gross head available in feet (14)	194	161	174
46	Number and size of conduits	No. 1-24'8" dia., No. 2-22'4" dia.	5 - 29' dia., 25' penstocks	7 - 24' dia., imbedded penstocks
47	Length of conduits in feet (8)	No. 1 - 5,653, No. 2 - 6,355	1829	From 3,280 to 4,005
48	Surge tanks	PH#1: 3-40' dia., PH#2: 2-65' dia.	65' dia. - 2 per penstock	70' dia., 2 per penstock
49	No., type and speed of turbines	5 Francis, PH#1-2: 128.5 rpm, 1-164 rpm , PH#2-2: 128.6 rpm	5 Francis, 90 rpm	7 Francis, 100 rpm
50	Discharge cap. at rated head in cfs	PH#1, units 1&3 170', 2-140' 8,800 cfs, PH#2-4&5 170'-7,200 cfs	150' 41,000 cfs	185' 54,000 cfs
51	Generator nameplate rating in kW	1&3: 43,500; 2: 18,250; 4&5: 40,000	3 - 121,600, 2 - 109,250	112,290
52	Plant capacity in kW	185,250	583,300	786,030
53	Dependable capacity in kW (9)	181,000	388,000	534,000
54	Avg. annual energy, million kWh (12)	1,087	2,318	2,717
55	Initial generation, first and last unit	July 1943 - June 1961	January 1956 - October 1960	April 1962 - June 1963
56	Estimated cost September 1999 completed project (13)	$158,428,000	$305,274,000	$346,521,000

Plate II-1

Summary of Engineering Data -- Missouri River Mainstem System

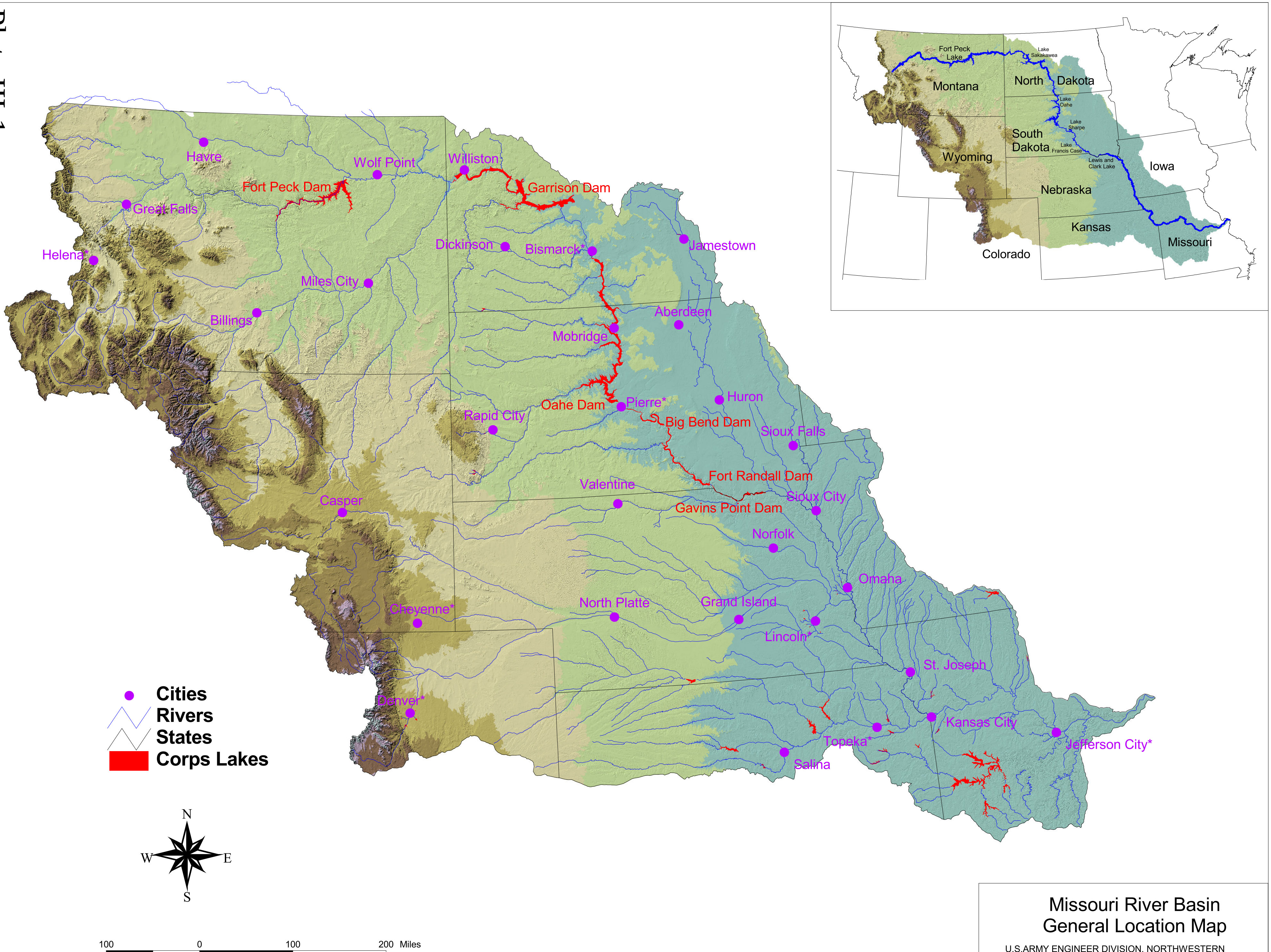
Big Bend Dam - Lake Sharpe	Fort Randall Dam - Lake Francis Case	Gavins Point Dam - Lewis & Clark Lake	Total	Item No.
21 miles upstream Chamberlain, SD	Near Lake Andes, SD	Near Yankton, SD		1
Mile 987.4	Mile 880.0	Mile 811.1		2
249,330 (1) 5,840	263,480 (1) 14,150	279,480 (1) 16,000		3
80, ending near Pierre, SD	107, ending at Big Bend Dam	25, ending near Niobrara, NE	755 miles	4
200 (elevation 1420)	540 (elevation 1350)	90 (elevation 1204.5)	5,940 miles	5
28,900	30,000 1,100	32,000 2,000		6
440,000 (April 1952)	447,000 (April 1952)	480,000 (April 1952)		7
1959	1946	1952		8
1964	1953	1955		9
1440	1395	1234		10
10,570 (including spillway)	10,700 (including spillway)	8,700 (including spillway)	71,596	11
78	140	45	863 feet	12
95	165	74		13
1200, 700	4300, 1250	850, 450		14
Pierre shale & Niobrara chalk	Niobrara chalk	Niobrara chalk & Carlile shale		15
Rolled earth, shale, chalk fill	Rolled earth fill & chalk berms	Rolled earth & chalk fill		16
17,000,000	28,000,000 & 22,000,000	7,000,000	358,128,000 cu. yds	17
540,000	961,000	308,000	5,554,000 cu. yds.	18
24 July 1963	20 July 1952	31 July 1955		19
Left bank - adjacent	Left bank - adjacent	Right bank - adjacent		20
1385	1346	1180		21
376 gated	1000 gated	664 gated		22
8 - 40' x 38' Tainter	21 - 40' x 29' Tainter	14 - 40' x 30' Tainter		23
390,000 at elev 1433.6	620,000 at elev 1379.3	584,000 at elev 1221.4		24
270,000	508,000	345,000		25
1423 msl 61,000 acres	1375 msl 102,000 acres	1210 msl 31,000 acres	1,194,000 acres	26
1422 msl 60,000 acres	1365 msl 95,000 acres	1208 msl 28,000 acres	1,147,000 acres	27
1420 msl 57,000 acres	1350 msl 77,000 acres	1204.5 msl 24,000 acres	989,000 acres	28
1415 msl 51,000 acres	1320 msl 38,000 acres	1204.5 msl 24,000 acres	450,000 acres	29
1423-1422 60,000 a.f.	1375-1365 985,000 a.f.	1210-1208 59,000 a.f.	4,670,000 a.f.	30
1422-1420 117,000 a.f.	1365-1350 1,309,000 a.f.	1208-1204.5 90,000 a.f.	11,656,000 a.f.	31
	1350-1320 1,607,000 a.f.		38,983,000 a.f.	32
1420-1345 1,621,000 a.f.	1320-1240 1,517,000 a.f.	1204.5-1160 321,000 a.f.	18,023,000 a.f.	33
1423-1345 1,798,000 a.f.	1375-1240 5,418,000 a.f.	1210-1160 470,000 a.f.	73,332,000 a.f.	34
November 1963	January 1953	August 1955		35
25 March 1964	24 November 1953	22 December 1955		36
4,300 a.f. 430 yrs.	18,300 a.f. 250 yrs.	2,600 a.f. 180 yrs.	92,500 a.f.	37
	Left Bank			38
None (7)	4 - 22' diameter	None (7)		39
	1013			40
	2 - 11' x 23' per conduit, vertical lift, cable suspension			41
1385 (11)	1229	1180 (11)		42
	Elev 1375 32,000 cfs - 128,000 cfs			43
1351-1355(10) 25,000-100,000 cfs	1228-1239 5,000-60,000 cfs	1155-1163 15,000-60,000 cfs		44
70	117	48	764 feet	45
None: direct intake	8 - 28' dia., 22' penstocks	None: direct intake		46
	1,074		55,083	47
None	59' dia, 2 per alternate penstock	None		48
8 Fixed blade, 81.8 rpm	8 Francis, 85.7 rpm	3 Kaplan, 75 rpm	36 units	49
67' 103,000 cfs	112' 44,500 cfs	48' 36,000 cfs		50
3 - 67,276, 5 - 58,500	40,000	44,100		51
494,320	320,000	132,300	2,501,200 kw	52
497,000	293,000	74,000	1,967,000 kw	53
1,001	1,778	740	9,642 million kWh	54
October 1964 - July 1966	March 1954 - January 1956	September 1956 - January 1957	July 1943 - July 1966	55
$107,498,000	$199,066,000	$49,617,000	$1,166,404,000	56

Remarks

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

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

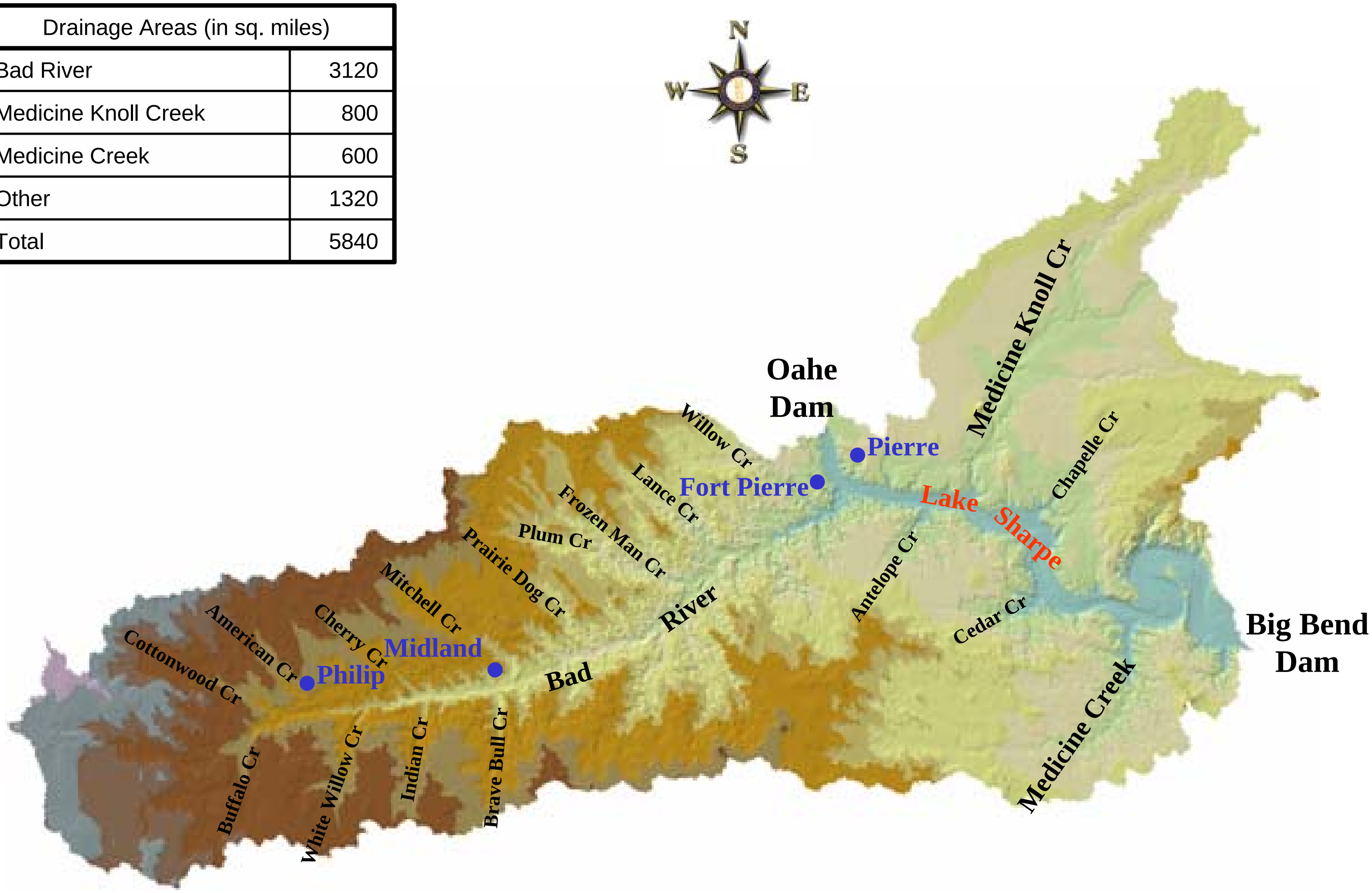
Plate III-1



Missouri River Basin
General Location Map

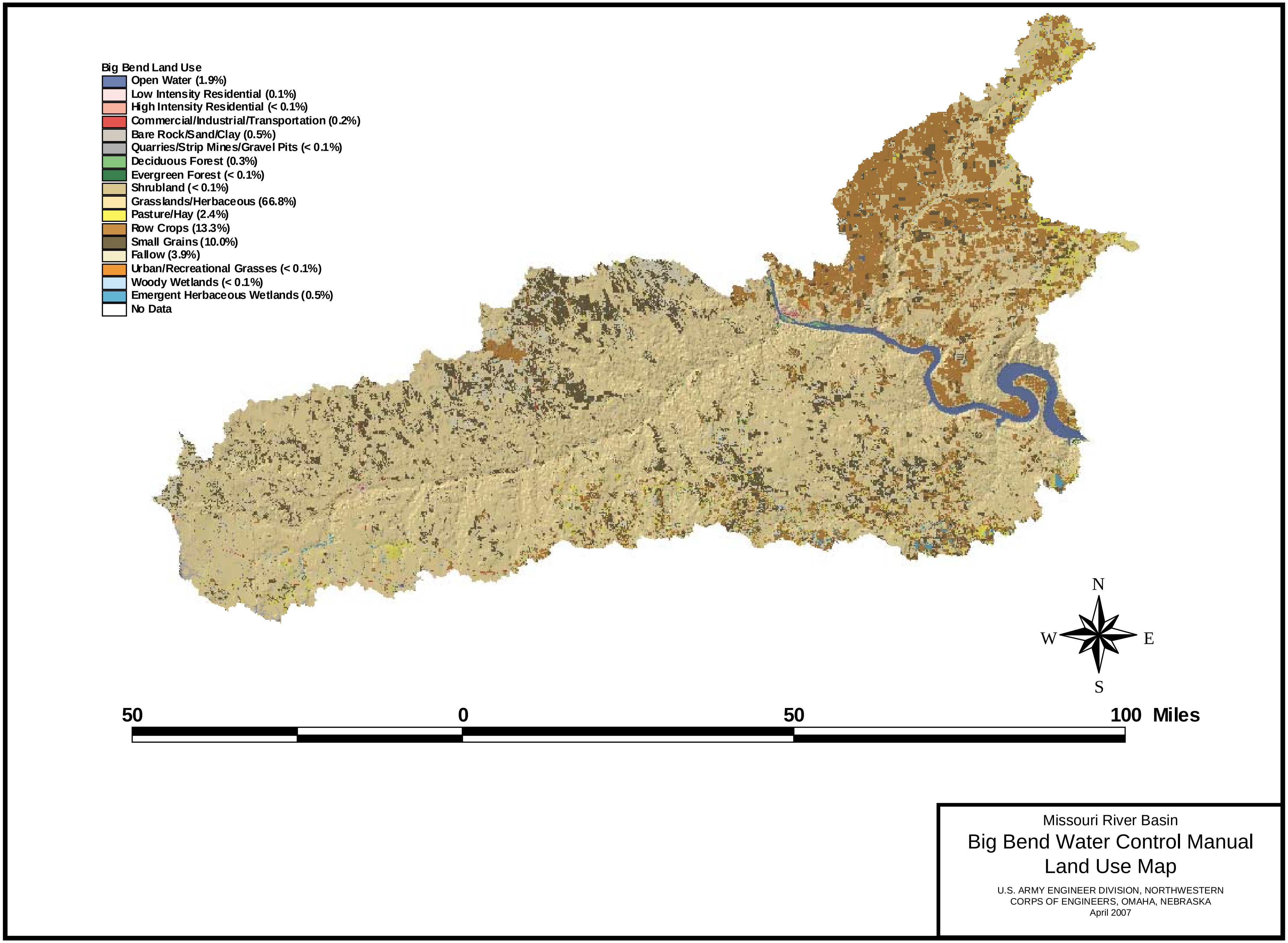
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

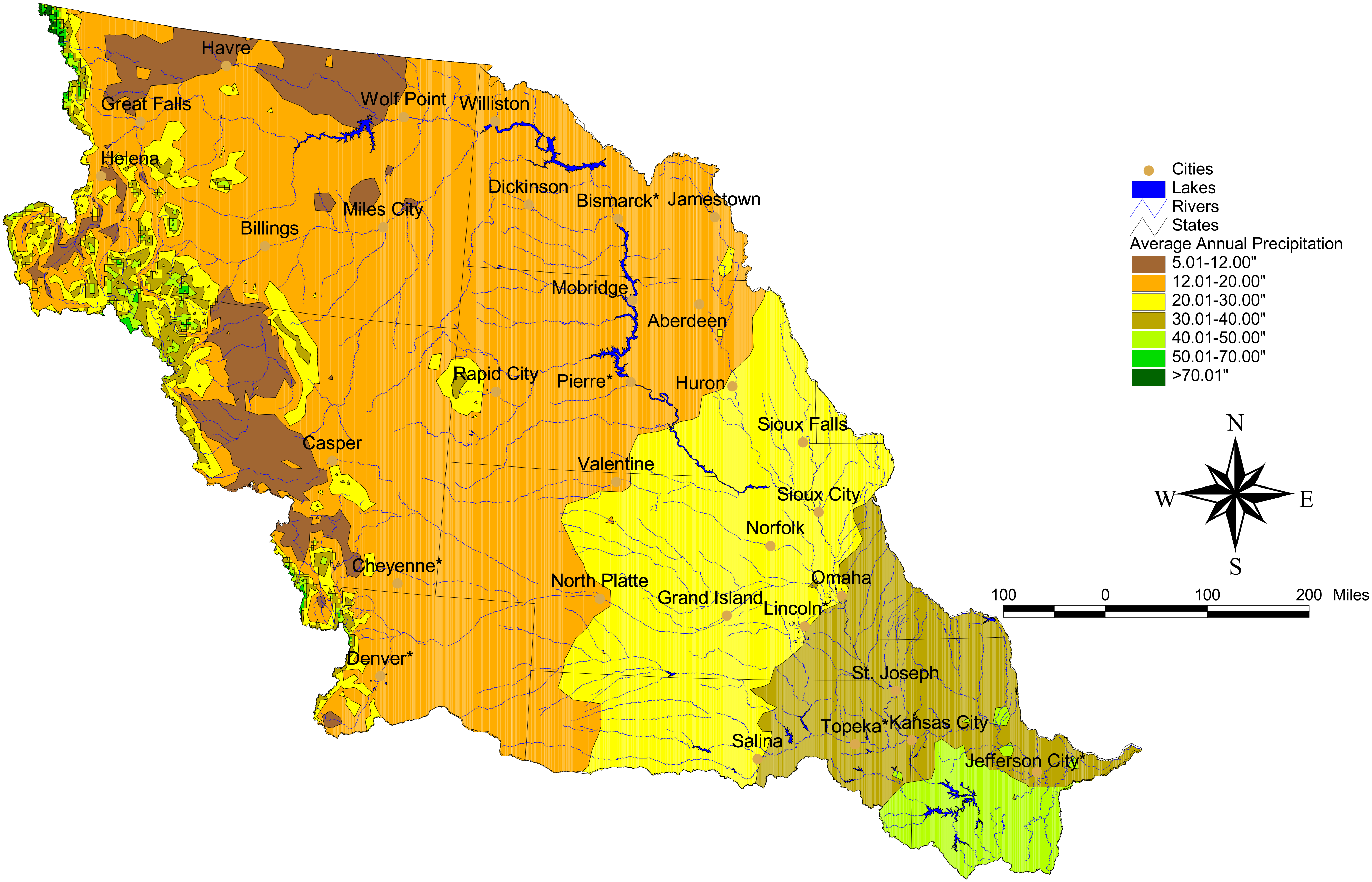
Drainage Areas (in sq. miles)	
Bad River	3120
Medicine Knoll Creek	800
Medicine Creek	600
Other	1320
Total	5840



Missouri River Basin
Big Bend Water Control Manual
Incremental Drainage Area

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007


Big Bend Land Use
Open Water (1.9%)
Low Intensity Residential (0.1%)
High Intensity Residential (< 0.1%)
Commercial/Industrial/Transportation (0.2%)
Bare Rock/Sand/Clay (0.5%)
Quarries/Strip Mines/Gravel Pits (< 0.1%)
Deciduous Forest (0.3%)
Evergreen Forest (< 0.1%)
Shrubland (< 0.1%)
Grasslands/Herbaceous (66.8%)
Pasture/Hay (2.4%)
Row Crops (13.3%)
Small Grains (10.0%)
Fallow (3.9%)
Urban/Recreational Grasses (< 0.1%)
Woody Wetlands (< 0.1%)
Emergent Herbaceous Wetlands (0.5%)
No Data
N
W
E
S
50
0
50
100 Miles
Missouri River Basin
Big Bend Water Control Manual
Land Use Map
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

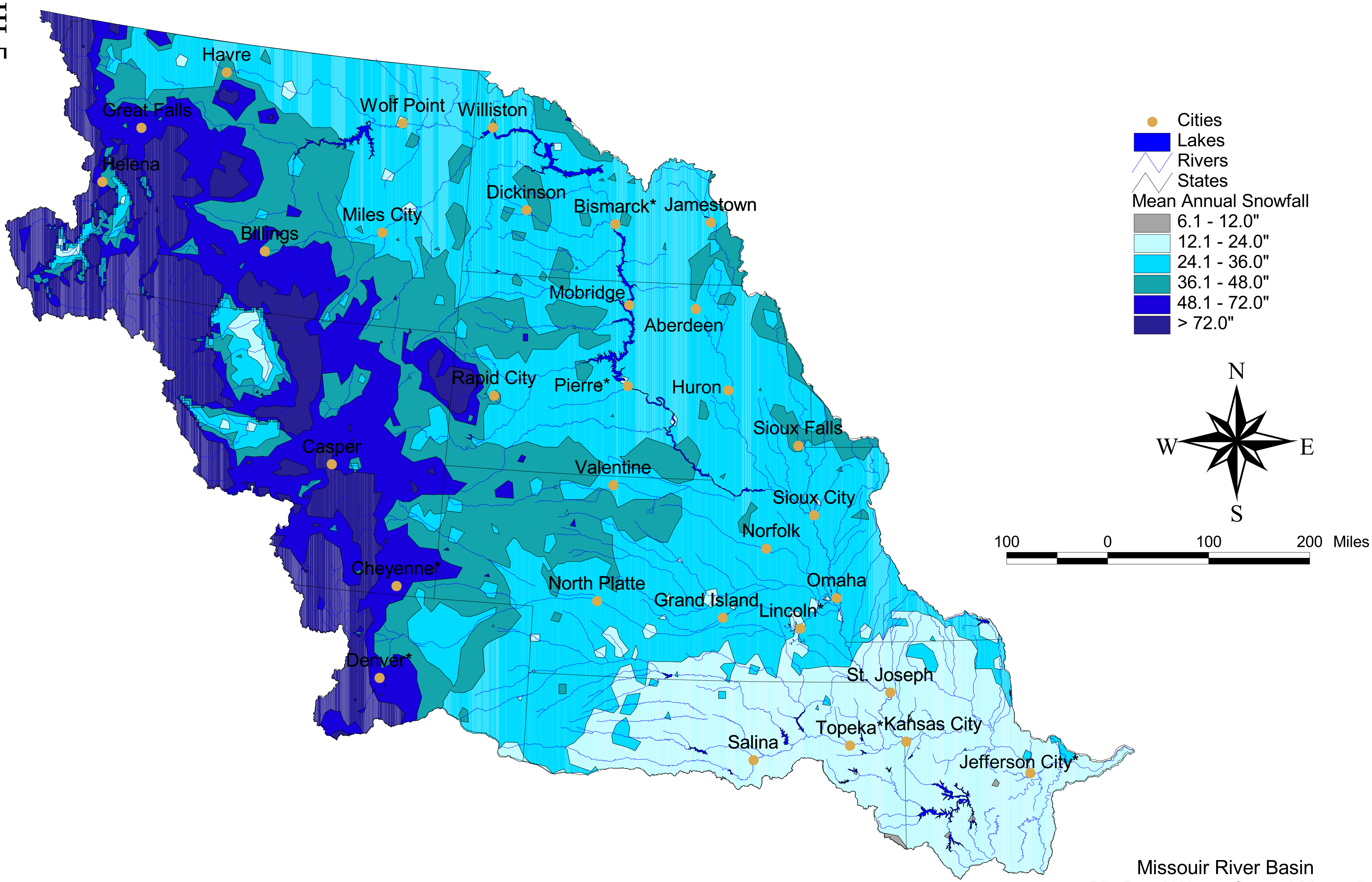


GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE.

Missouir River Basin
Big Bend Water Control Manual
Average Annual Precipitation

U.S ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA
April 2007

Plate III-4

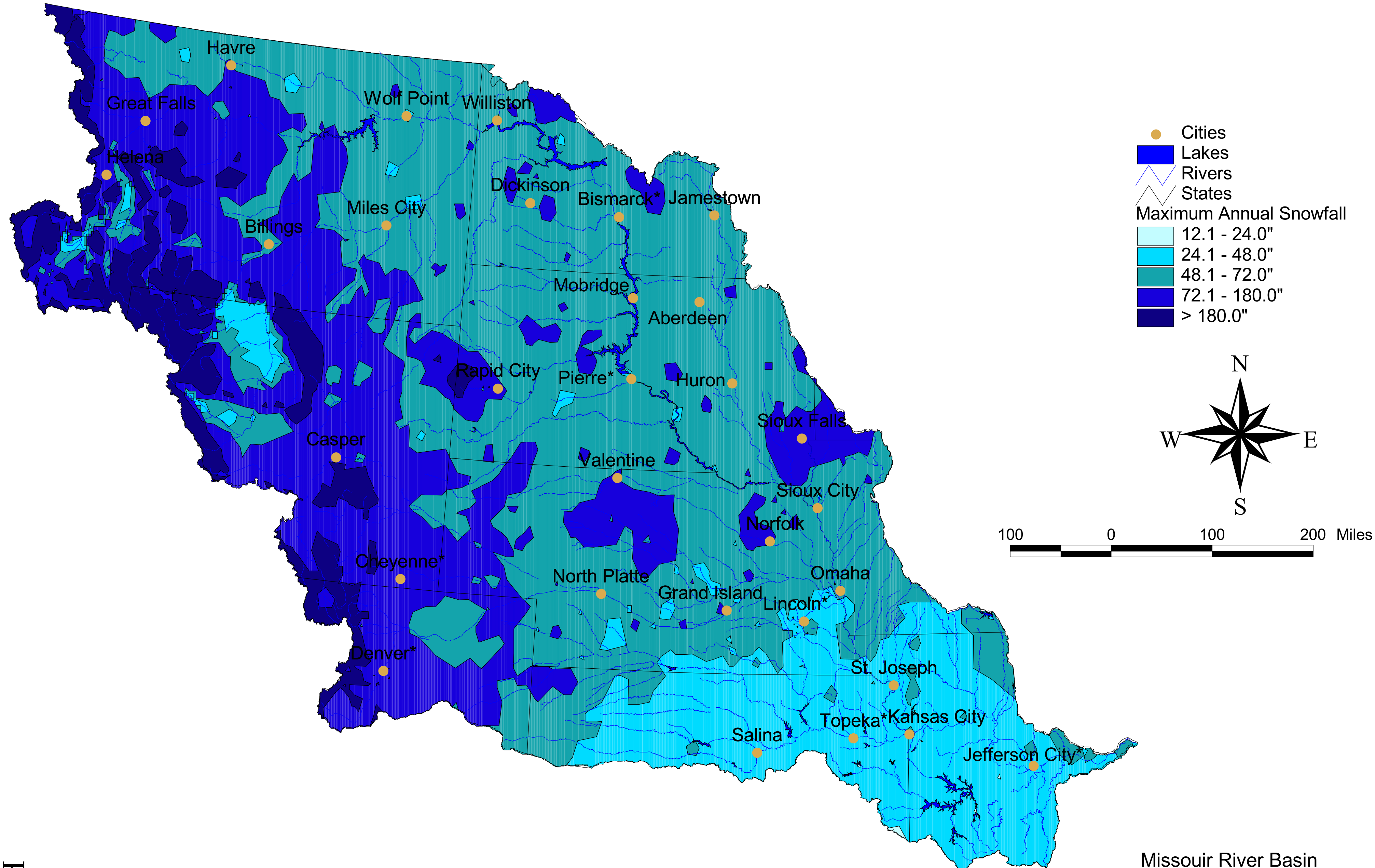


Missouir River Basin
Big Bend Water Control Manual
Mean Annual Snowfall

U.S ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA
April 2007

GIS DATA OBTAINED FROM THE NATIONAL
WEATHER SERVICE.

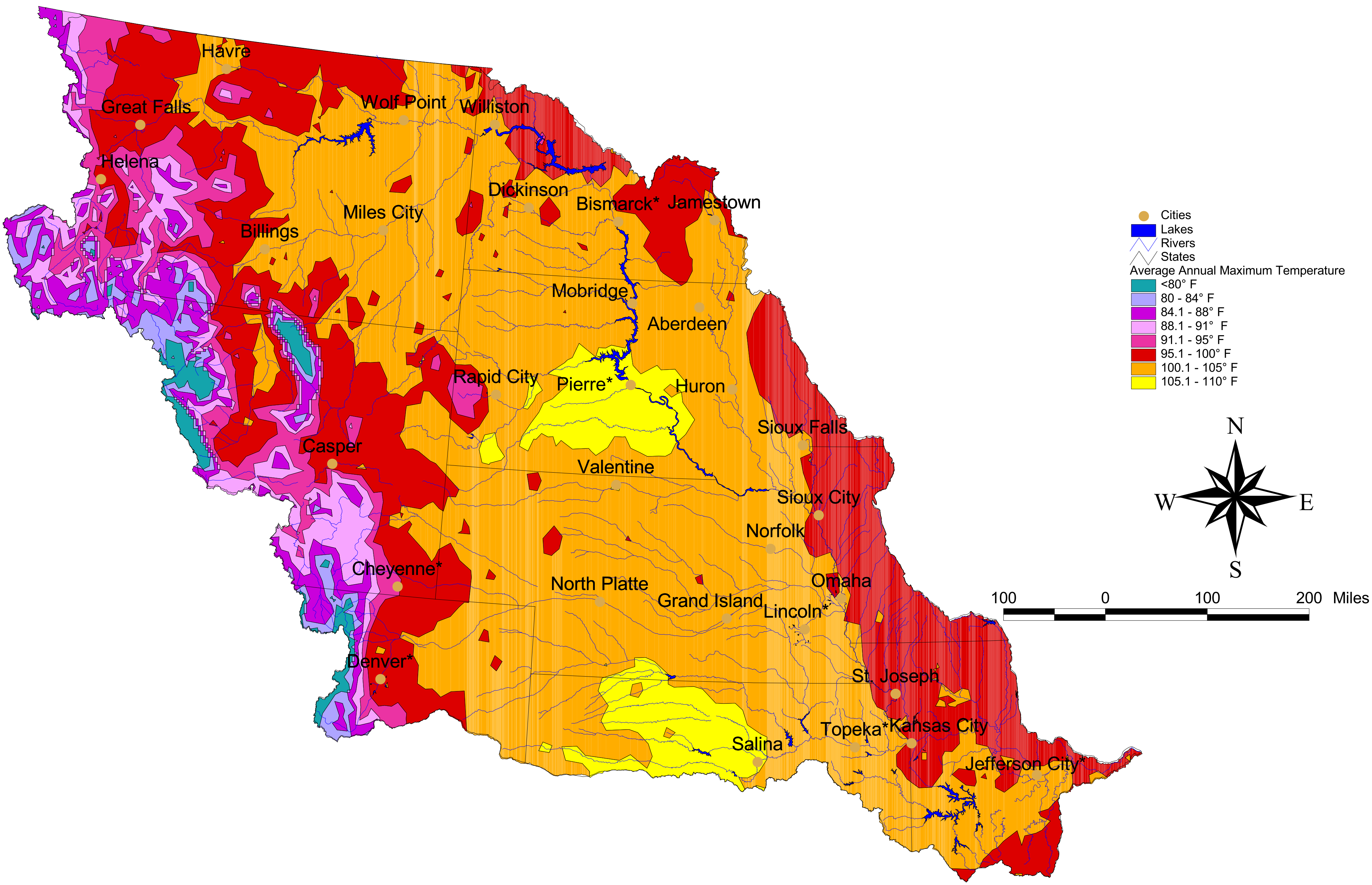
Plate III-5



Missouir River Basin
Big Bend Water Control Manual
Maximum Annual Snowfall

U.S ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA
April 2007

GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE.

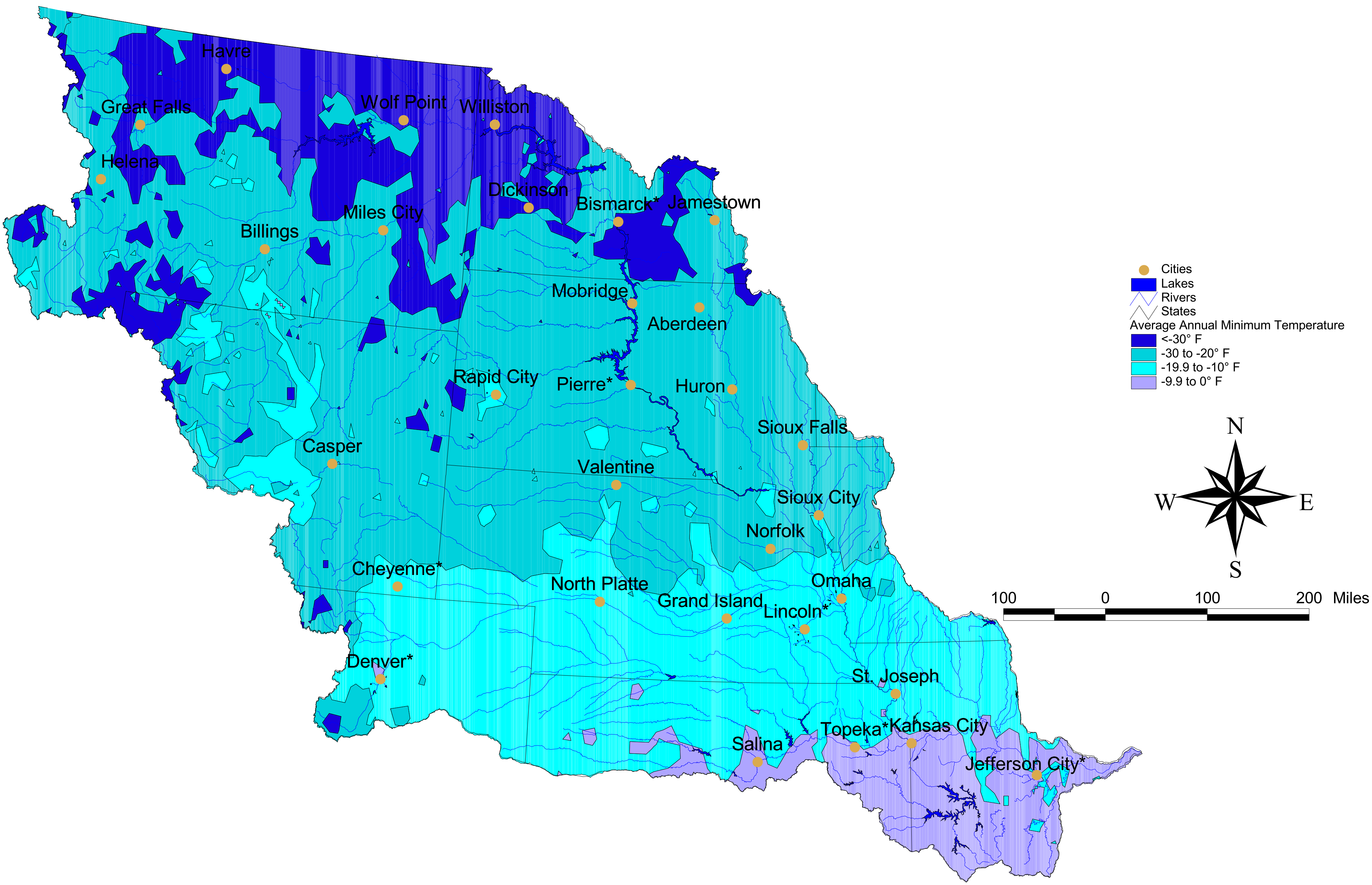


GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE.

Missouir River Basin
Big Bend Water Control Manual
Average Annual Maximum Temperature

U.S ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA
April 2007

Plate III-7



GIS DATA OBTAINED FROM THE NATIONAL
WEATHER SERVICE.

Missouir River Basin
Big Bend Water Control Manual
Average Annual Minimum Temperature

U.S ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA
April 2007

Plate III-8

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
Big Bend Water Control Manual
Normal Monthly Pan Evaporation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

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
Big Bend Water Control Manual
Pan to Lake Evaporation Coefficients

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

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} (BB WCM Plate III-10) to the normal monthly pan evaporation as shown on {Figure 9} (BB WCM Plate III-9).

Missouri River Basin

Big Bend Water Control Manual
Normal Monthly Lake Evaporation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

Missouri River Mainstem Reservoir System

Normal Monthly Lake Evaporation
in 1000 Acre-Feet

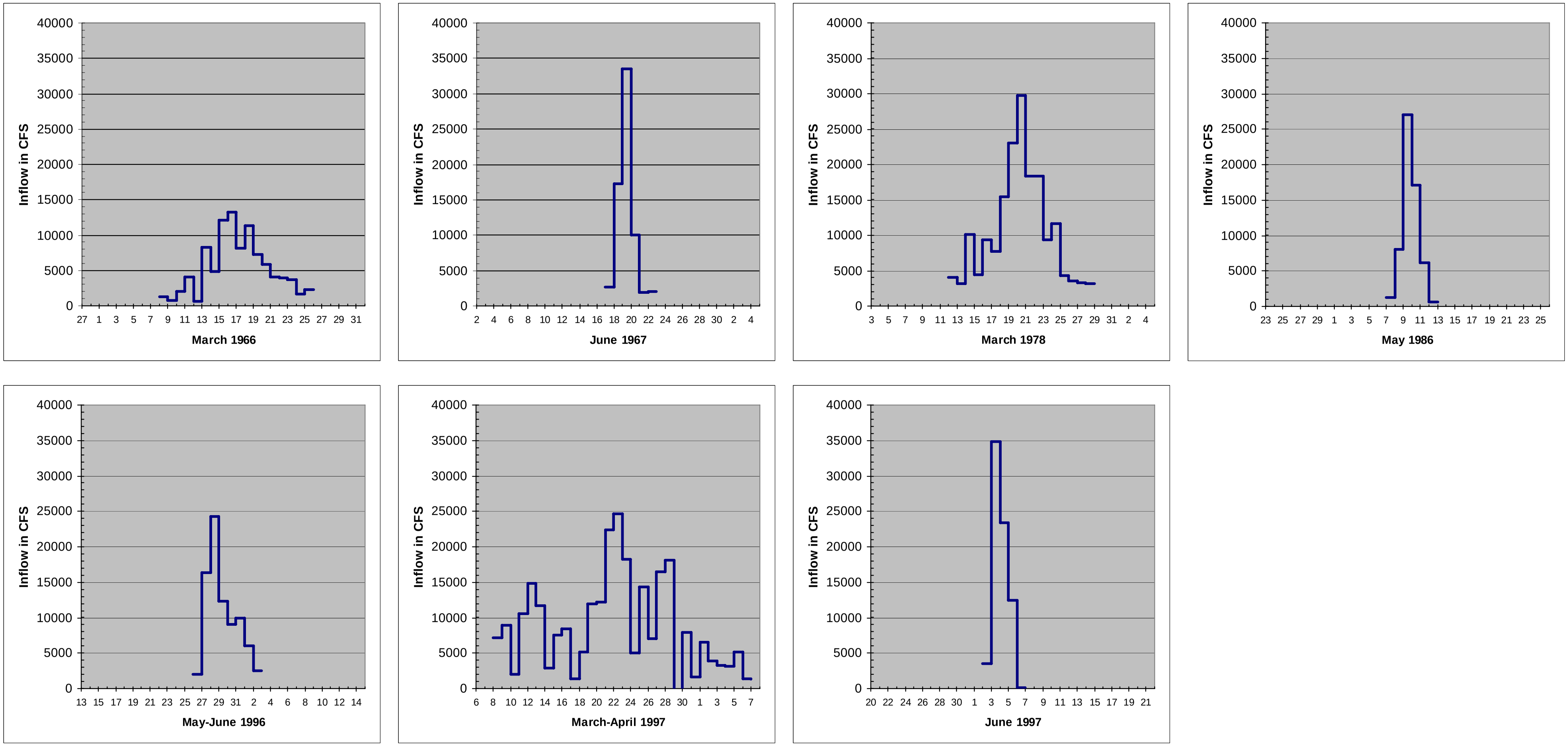
Month	Missouri River Mainstem Project						System
	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point	
January	14	9	19	2	5	1	50
February	9	11	17	3	5	1	46
March	18	26	29	5	10	3	91
April	7	10	16	10	5	5	53
May	27	33	33	13	14	8	128
June	46	39	40	16	19	10	170
July	73	61	62	27	25	12	260
August	117	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
Big Bend Water Control Manual
Normal Monthly Lake Evaporation in 1000 AF

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007



Event	Duration of Event (days)	Maximum Daily Incremental Inflow (cfs)	Total Runoff Volume (acre-feet)	Equivalent Event Frequency/Duration*
March 1966	18	13,200	190,000	10-yr / 15-day
June 1967	6	33,500	134,000	20-yr / 7-day
March 1978	17	29,800	355,000	55-yr / 15-day
May 1986	6	27,000	119,000	15-yr / 7-day
May-June 1996	8	24,300	164,000	20-yr / 7-day
March-April 1997	31	24,700	526,000	90-yr / 30-day
June 1997	5	34,800	147,000	15-yr/3-day; 45-yr/7-day

*Hydrologic Statistics on Inflows, RCC Technical Report F-05.

Missouri River Basin
Big Bend Water Control Manual
Incremental Inflow Hydrographs – Oahe to Big Bend Dams
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

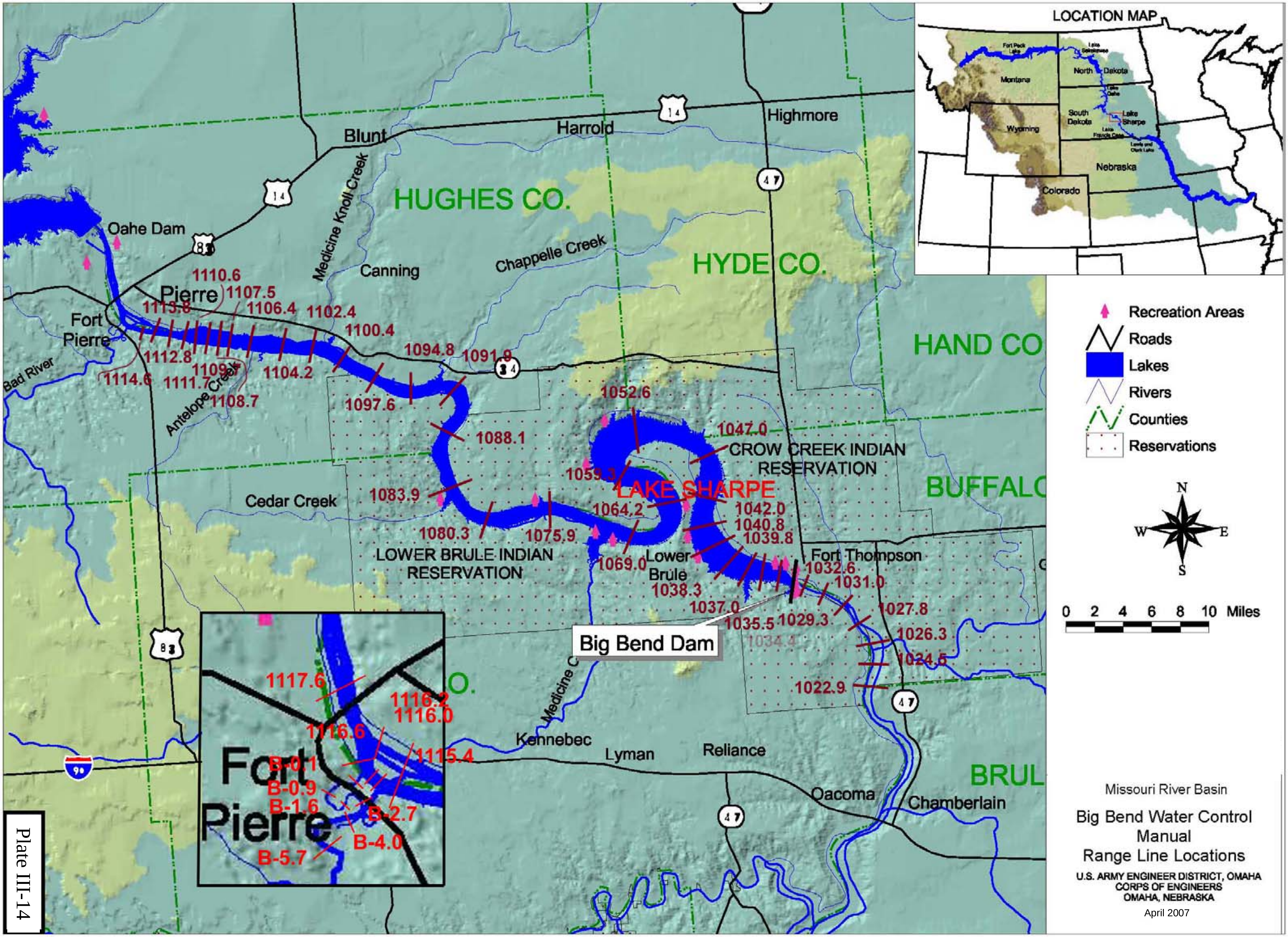
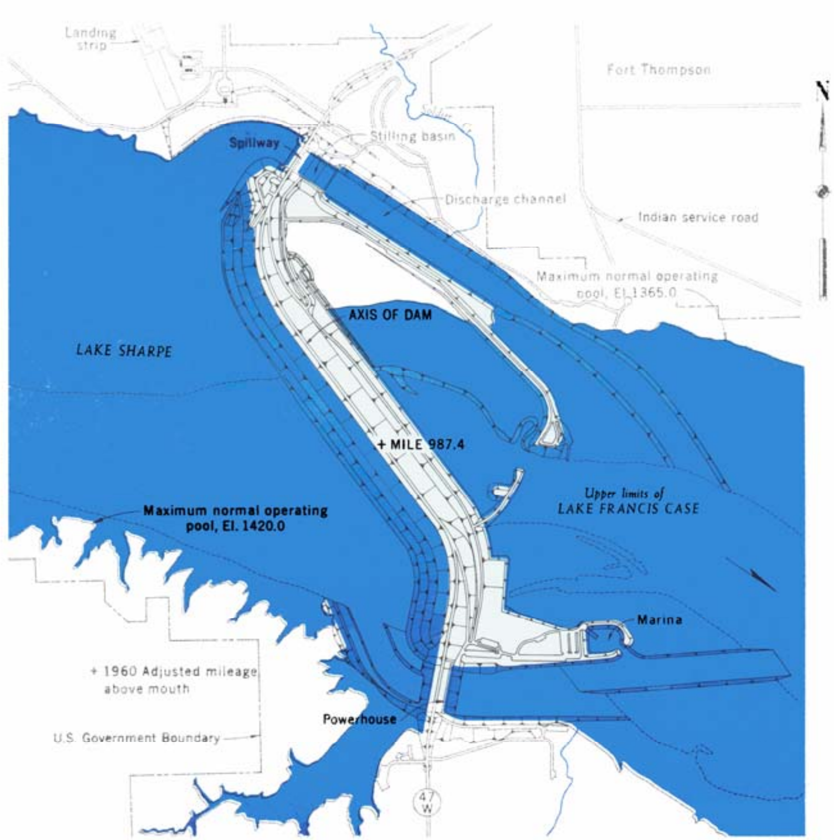

LOCATION MAP
Montana
North Dakota
South Dakota
Wyoming
Nebraska
Colorado
Recreation Areas
Roads
Lakes
Rivers
Counties
Reservations
N
S
E
W
0 2 4 6 8 10 Miles
HUGHES CO.
HYDE CO.
HAND CO
BUFFALO
BRUL
LAKE SHARPE
CROW CREEK INDIAN RESERVATION
LOWER BRULE INDIAN RESERVATION
Oahe Dam
Pierre
Fort Pierre
Blunt
Harrold
Highmore
Canning
Medicine Knoll Creek
Chappelle Creek
Cedar Creek
Antelope Creek
Bad River
Medicine C
Kennebec
Lyman
Reliance
Oacoma
Chamberlain
Lower Brule
Fort Thompson
Big Bend Dam
1113.8
1110.6
1107.5
1106.4
1102.4
1100.4
1094.8
1091.9
1112.8
1109.1
1104.2
1114.6
1111.7
1108.7
1097.6
1088.1
1083.9
1080.3
1075.9
1069.0
1064.2
1059.3
1052.6
1047.0
1042.0
1040.8
1039.8
1038.3
1037.0
1035.5
1034.4
1032.6
1031.0
1029.3
1027.8
1026.3
1024.5
1022.9
1117.6
1116.2
1116.0
1116.6
1115.4
B-0.1
B-0.9
B-1.6
B-2.7
B-4.0
B-5.7
Fort Pierre
Missouri River Basin
Big Bend Water Control Manual
Range Line Locations
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
April 2007

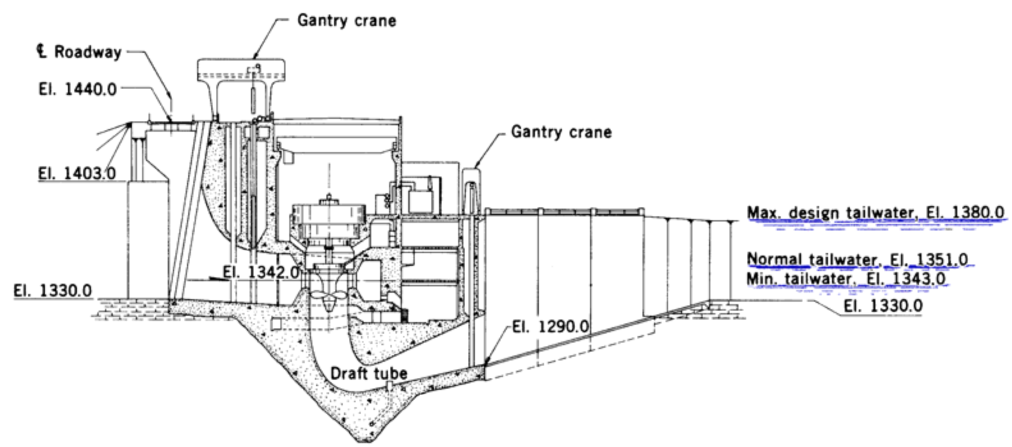
Plate III-14

Missouri River Basin
Big Bend Water Control Manual
Powerhouse, Spillway, Reservoir
and Embankment
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

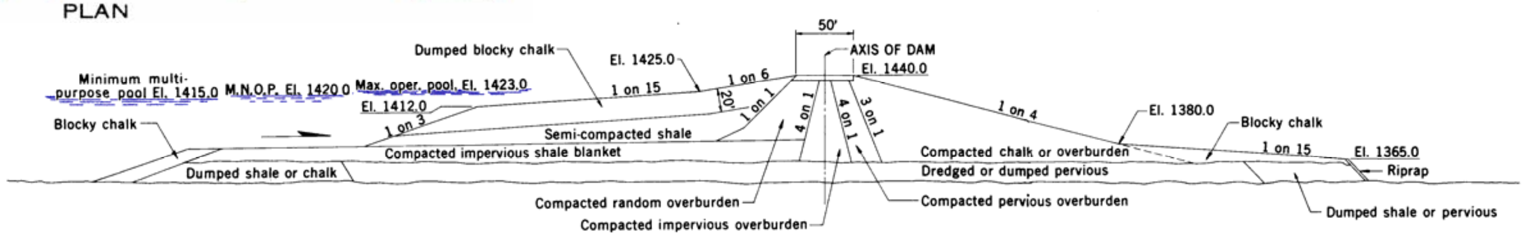
Plate IV-1



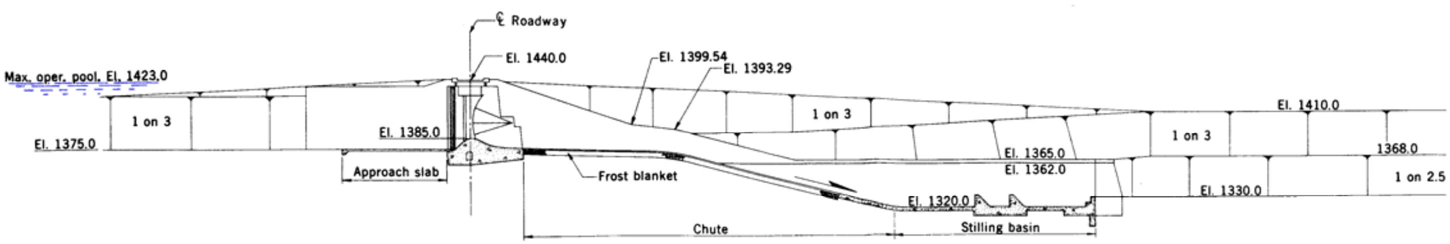
PLAN



POWERHOUSE SECTION



EMBANKMENT SECTION



SPILLWAY PROFILE

Missouri River Basin
Big Bend Water Control Manual
Plan and Sections

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007


Missouri River Basin
Big Bend Water Control Manual
Spillway Intake
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

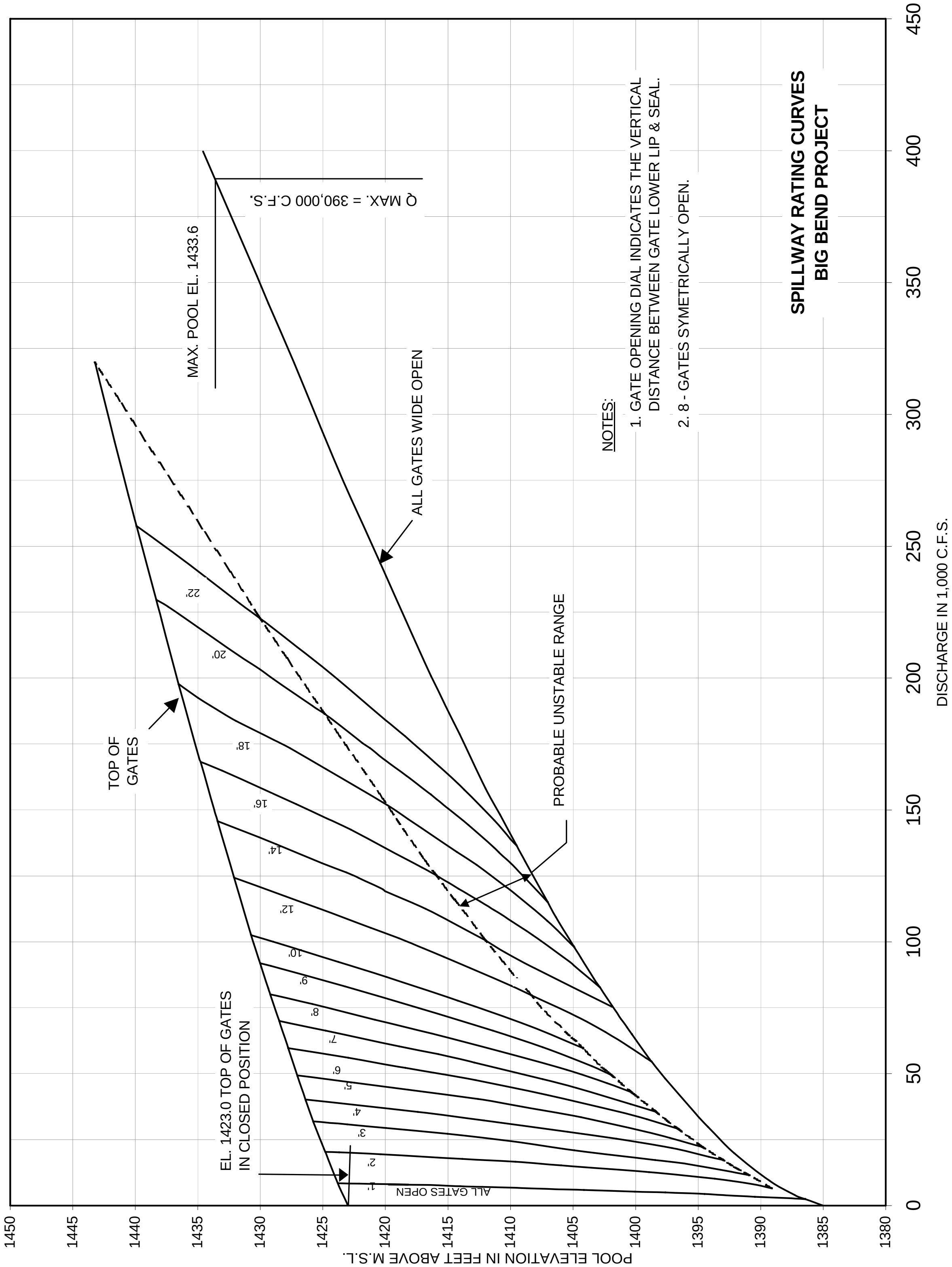
Plate IV-3

Missouri River Basin
Big Bend Water Control Manual
Spillway Outlet - Apron
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Plate IV-4

Missouri River Basin
Big Bend Water Control Manual
Spillway Channel
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Plate IV-5



Missouri River Basin

Big Bend Water Control Manual

Spillway Rating Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

Plate IV-6

Missouri River Basin
Big Bend Water Control Manual
Intake Structure
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Missouri River Basin
Big Bend Water Control Manual
Draft Tube Deck
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

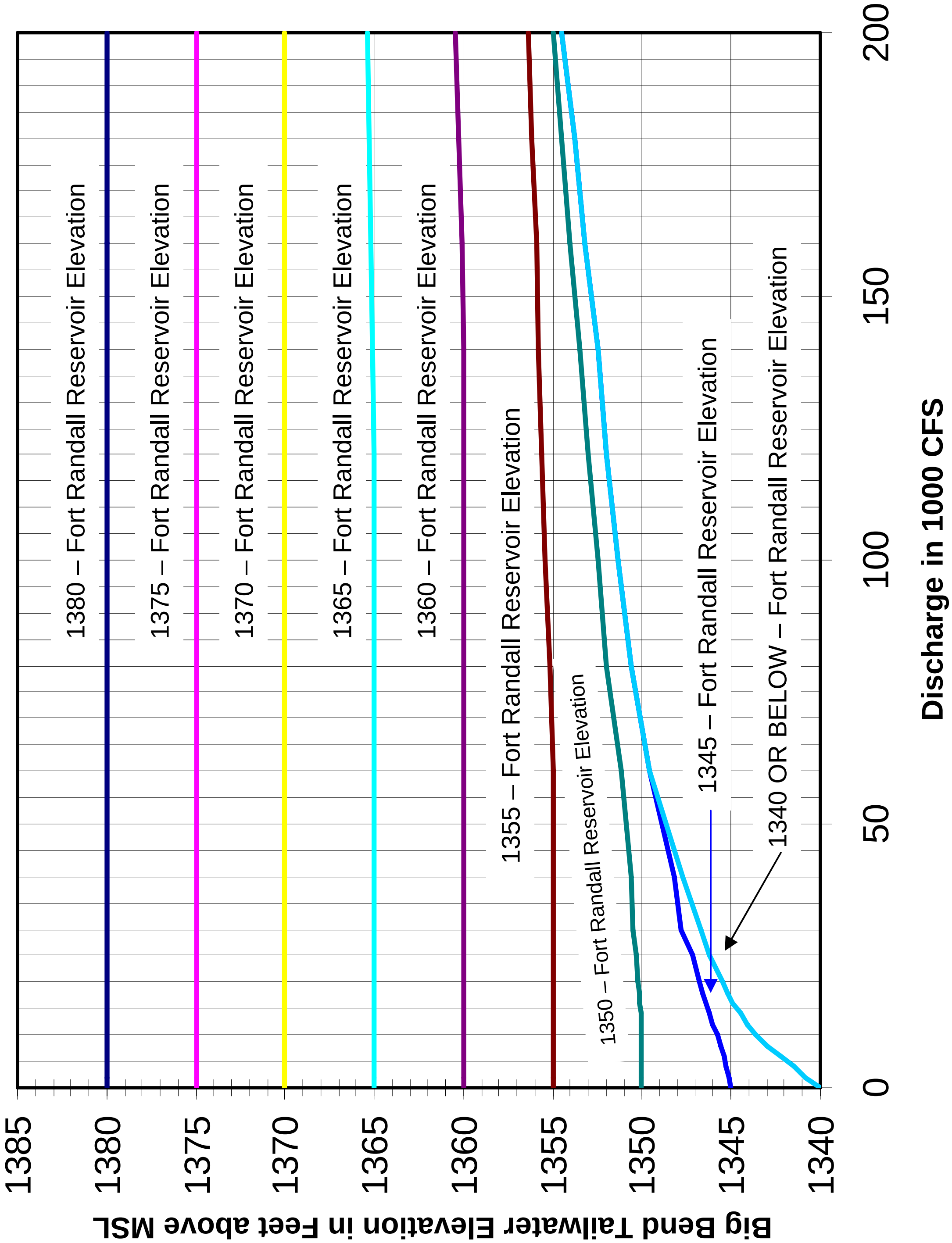
Missouri River Basin
Big Bend Water Control Manual
Intake Structure - Draft Tube
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Plate IV-9

Missouri River Basin
Big Bend Water Control Manual
Powerhouse Generators

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Missouri River Basin
Big Bend Water Control Manual
Tailrace Channel
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007



Missouri River Basin

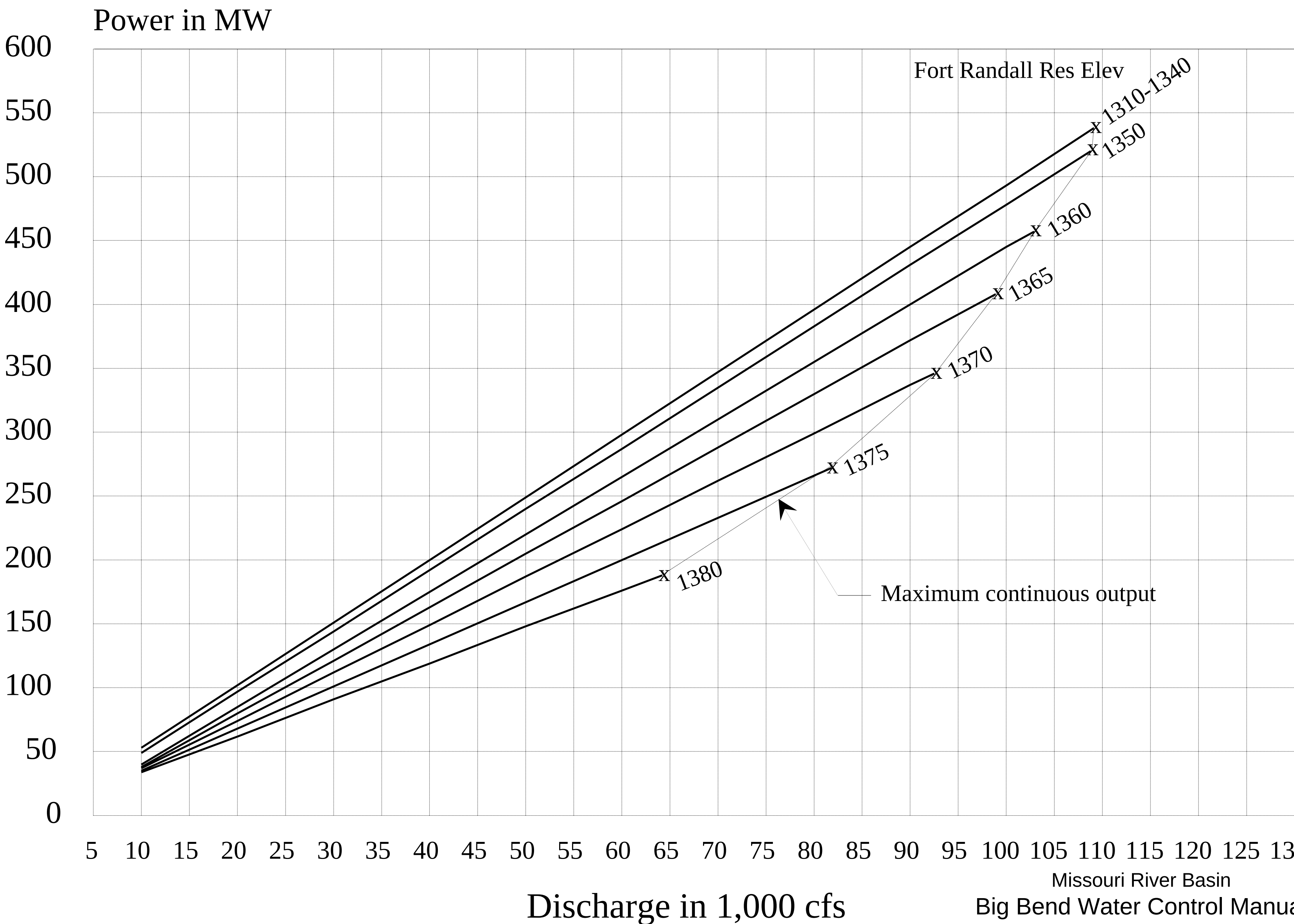
Big Bend Water Control Manual

Tailwater Rating Curves

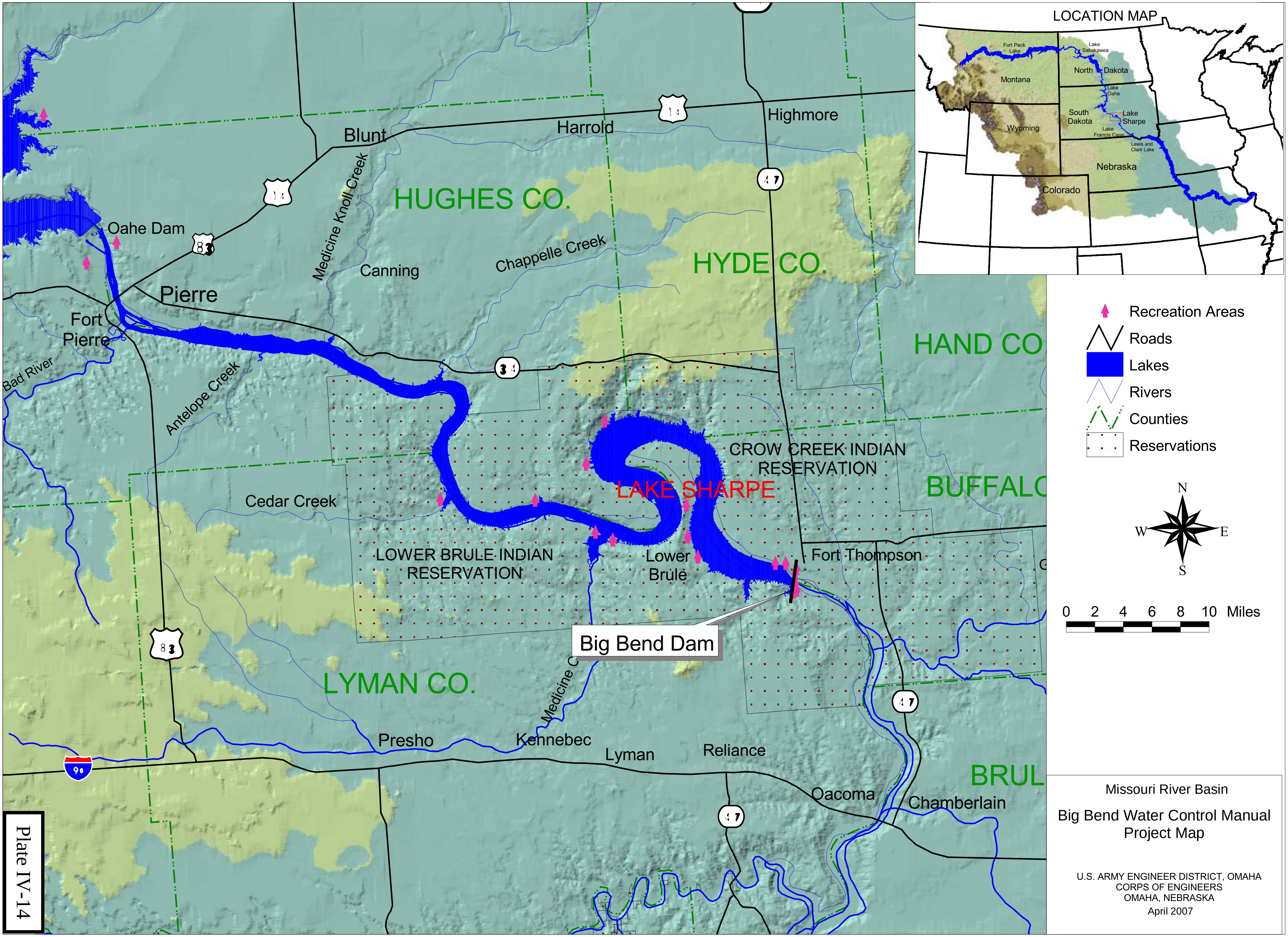
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

Plate IV-12

Big Bend Powerplant



Missouri River Basin
Big Bend Water Control Manual
Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007



Missouri River Basin

Big Bend Water Control Manual
Project Map

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
April 2007

Plate IV-14

BIG BEND PROJECT 1997 RESURVEY **EFFECTIVE 04-MAR-99**

AREA IN ACRES

(1997 SURVEY)

ELEV	0	1	2	3	4	5	6	7	8	9
1340	0	0	0	119	226	273	320	368	415	462
1350	836	1181	1225	1380	1645	2021	2506	3103	3810	4627
1360	5449	6138	6744	7354	7970	8590	9215	9844	10479	11118
1370	11747	12353	12957	13576	14209	14856	15516	16192	16881	17585
1380	18307	19038	19757	20454	21128	21779	22407	23013	23597	24158
1390	24659	25096	25556	26093	26709	27402	28172	29020	29946	30950
1400	31842	32459	33031	33761	34649	35694	36897	38258	39776	41452
1410	43146	44666	46067	47460	48846	50224	51594	52957	54312	55660
1420	57007	58362	59724	61085	62447	63808	65169	66531	67893	69254
1430	70615	0	0	0	0	0	0	0	0	0

BIG BEND PROJECT 1997 RESURVEY **EFFECTIVE 04-MAR-99**

CAPACITY IN ACRE-FEET

(1997 SURVEY)

ELEV	0	1	2	3	4	5	6	7	8	9
1340	0	0	0	35	238	488	785	1129	1521	1959
1350	2445	3631	4807	6082	7567	9373	11609	14386	17815	22006
1360	27069	32905	39345	46393	54054	62333	71235	80763	90924	101721
1370	113160	125215	137867	151130	165019	179548	194731	210581	227115	244344
1380	262285	280958	300362	320473	341270	362729	384828	407544	430855	454739
1390	479172	504057	529364	555169	581551	608587	636355	664932	694396	724825
1400	756297	788510	821216	854573	888739	923872	960128	997666	1036644	1077219
1410	1119548	1163512	1208881	1255647	1303802	1353339	1404250	1456528	1510164	1565152
1420	1621484	1679166	1738209	1798614	1860380	1923508	1987997	2053847	2121059	2189633
1430	2259568	0	0	0	0	0	0	0	0	0

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1380.0	262285	262472	262658	262845	263032	263219	263405	263592	263779	263966
.1	264152	264339	264526	264712	264899	265086	265273	265459	265646	265833
.2	266020	266206	266393	266580	266767	266953	267140	267327	267513	267700
.3	267887	268074	268260	268447	268634	268821	269007	269194	269381	269567
.4	269754	269941	270128	270314	270501	270688	270875	271061	271248	271435
.5	271621	271808	271995	272182	272368	272555	272742	272929	273115	273302
.6	273489	273676	273862	274049	274236	274422	274609	274796	274983	275169
.7	275356	275543	275730	275916	276103	276290	276476	276663	276850	277037
.8	277223	277410	277597	277784	277970	278157	278344	278531	278717	278904
.9	279091	279277	279464	279651	279838	280024	280211	280398	280585	280771
1381.0	280958	281152	281346	281540	281734	281928	282122	282316	282510	282704
.1	282898	283092	283286	283481	283675	283869	284063	284257	284451	284645
.2	284839	285033	285227	285421	285615	285809	286003	286197	286391	286585
.3	286779	286973	287167	287361	287555	287749	287943	288137	288332	288526
.4	288720	288914	289108	289302	289496	289690	289884	290078	290272	290466
.5	290660	290854	291048	291242	291436	291630	291824	292018	292212	292406
.6	292600	292794	292988	293183	293377	293571	293765	293959	294153	294347
.7	294541	294735	294929	295123	295317	295511	295705	295899	296093	296287
.8	296481	296675	296869	297063	297257	297451	297645	297839	298034	298228
.9	298422	298616	298810	299004	299198	299392	299586	299780	299974	300168
1382.0	300362	300563	300764	300965	301166	301368	301569	301770	301971	302172
.1	302373	302574	302775	302976	303178	303379	303580	303781	303982	304183
.2	304384	304585	304786	304988	305189	305390	305591	305792	305993	306194
.3	306395	306596	306798	306999	307200	307401	307602	307803	308004	308205
.4	308406	308608	308809	309010	309211	309412	309613	309814	310015	310216
.5	310417	310619	310820	311021	311222	311423	311624	311825	312026	312227
.6	312429	312630	312831	313032	313233	313434	313635	313836	314037	314239
.7	314440	314641	314842	315043	315244	315445	315646	315847	316049	316250
.8	316451	316652	316853	317054	317255	317456	317657	317859	318060	318261
.9	318462	318663	318864	319065	319266	319467	319669	319870	320071	320272
1383.0	320473	320681	320889	321097	321305	321513	321721	321929	322137	322345
.1	322553	322761	322969	323177	323385	323593	323801	324008	324216	324424
.2	324632	324840	325048	325256	325464	325672	325880	326088	326296	326504
.3	326712	326920	327128	327336	327544	327752	327960	328168	328376	328584
.4	328792	329000	329208	329416	329624	329832	330040	330248	330456	330664
.5	330871	331079	331287	331495	331703	331911	332119	332327	332535	332743
.6	332951	333159	333367	333575	333783	333991	334199	334407	334615	334823
.7	335031	335239	335447	335655	335863	336071	336279	336487	336695	336903
.8	337111	337319	337527	337735	337942	338150	338358	338566	338774	338982
.9	339190	339398	339606	339814	340022	340230	340438	340646	340854	341062
1384.0	341270	341485	341699	341914	342128	342343	342558	342772	342987	343201
.1	343416	343630	343845	344060	344274	344489	344703	344918	345133	345347
.2	345562	345776	345991	346206	346420	346635	346849	347064	347279	347493
.3	347708	347922	348137	348351	348566	348781	348995	349210	349424	349639
.4	349854	350068	350283	350497	350712	350927	351141	351356	351570	351785
.5	351999	352214	352429	352643	352858	353072	353287	353502	353716	353931
.6	354145	354360	354575	354789	355004	355218	355433	355648	355862	356077
.7	356291	356506	356720	356935	357150	357364	357579	357793	358008	358223
.8	358437	358652	358866	359081	359296	359510	359725	359939	360154	360369
.9	360583	360798	361012	361227	361441	361656	361871	362085	362300	362514

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1385.0	362729	362950	363171	363392	363613	363834	364055	364276	364497	364718
.1	364939	365160	365381	365602	365823	366044	366265	366486	366707	366928
.2	367149	367370	367591	367812	368033	368254	368475	368696	368917	369138
.3	369359	369580	369801	370022	370243	370464	370685	370906	371127	371348
.4	371569	371790	372011	372232	372453	372674	372895	373116	373337	373558
.5	373778	373999	374220	374441	374662	374883	375104	375325	375546	375767
.6	375988	376209	376430	376651	376872	377093	377314	377535	377756	377977
.7	378198	378419	378640	378861	379082	379303	379524	379745	379966	380187
.8	380408	380629	380850	381071	381292	381513	381734	381955	382176	382397
.9	382618	382839	383060	383281	383502	383723	383944	384165	384386	384607
1386.0	384828	385055	385282	385509	385737	385964	386191	386418	386645	386872
.1	387100	387327	387554	387781	388008	388235	388463	388690	388917	389144
.2	389371	389598	389826	390053	390280	390507	390734	390961	391188	391416
.3	391643	391870	392097	392324	392551	392779	393006	393233	393460	393687
.4	393914	394142	394369	394596	394823	395050	395277	395505	395732	395959
.5	396186	396413	396640	396867	397095	397322	397549	397776	398003	398230
.6	398458	398685	398912	399139	399366	399593	399821	400048	400275	400502
.7	400729	400956	401184	401411	401638	401865	402092	402319	402546	402774
.8	403001	403228	403455	403682	403909	404137	404364	404591	404818	405045
.9	405272	405500	405727	405954	406181	406408	406635	406863	407090	407317
1387.0	407544	407777	408010	408243	408476	408710	408943	409176	409409	409642
.1	409875	410108	410341	410574	410808	411041	411274	411507	411740	411973
.2	412206	412439	412672	412906	413139	413372	413605	413838	414071	414304
.3	414537	414770	415004	415237	415470	415703	415936	416169	416402	416635
.4	416868	417102	417335	417568	417801	418034	418267	418500	418733	418966
.5	419199	419433	419666	419899	420132	420365	420598	420831	421064	421297
.6	421531	421764	421997	422230	422463	422696	422929	423162	423395	423629
.7	423862	424095	424328	424561	424794	425027	425260	425493	425727	425960
.8	426193	426426	426659	426892	427125	427358	427591	427825	428058	428291
.9	428524	428757	428990	429223	429456	429689	429923	430156	430389	430622
1388.0	430855	431094	431333	431572	431810	432049	432288	432527	432766	433005
.1	433243	433482	433721	433960	434199	434438	434676	434915	435154	435393
.2	435632	435871	436109	436348	436587	436826	437065	437304	437543	437781
.3	438020	438259	438498	438737	438976	439214	439453	439692	439931	440170
.4	440409	440647	440886	441125	441364	441603	441842	442080	442319	442558
.5	442797	443036	443275	443514	443752	443991	444230	444469	444708	444947
.6	445185	445424	445663	445902	446141	446380	446618	446857	447096	447335
.7	447574	447813	448051	448290	448529	448768	449007	449246	449485	449723
.8	449962	450201	450440	450679	450918	451156	451395	451634	451873	452112
.9	452351	452589	452828	453067	453306	453545	453784	454022	454261	454500
1389.0	454739	454983	455228	455472	455716	455961	456205	456449	456694	456938
.1	457182	457427	457671	457915	458160	458404	458648	458893	459137	459381
.2	459626	459870	460114	460359	460603	460847	461092	461336	461580	461825
.3	462069	462313	462558	462802	463046	463291	463535	463779	464024	464268
.4	464512	464757	465001	465245	465490	465734	465978	466223	466467	466711
.5	466955	467200	467444	467688	467933	468177	468421	468666	468910	469154
.6	469399	469643	469887	470132	470376	470620	470865	471109	471353	471598
.7	471842	472086	472331	472575	472819	473064	473308	473552	473797	474041
.8	474285	474530	474774	475018	475263	475507	475751	475996	476240	476484
.9	476729	476973	477217	477462	477706	477950	478195	478439	478683	478928

BIG BEND PROJECT 1997 RESURVEY EFFECTIVE 04-MAR-99

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1390.0	479172	479421	479670	479919	480167	480416	480665	480914	481163	481412
.1	481660	481909	482158	482407	482656	482905	483154	483402	483651	483900
.2	484149	484398	484647	484896	485144	485393	485642	485891	486140	486389
.3	486637	486886	487135	487384	487633	487882	488131	488379	488628	488877
.4	489126	489375	489624	489873	490121	490370	490619	490868	491117	491366
.5	491614	491863	492112	492361	492610	492859	493108	493356	493605	493854
.6	494103	494352	494601	494850	495098	495347	495596	495845	496094	496343
.7	496591	496840	497089	497338	497587	497836	498085	498333	498582	498831
.8	499080	499329	499578	499827	500075	500324	500573	500822	501071	501320
.9	501568	501817	502066	502315	502564	502813	503062	503310	503559	503808
1391.0	504057	504310	504563	504816	505069	505322	505575	505828	506082	506335
.1	506588	506841	507094	507347	507600	507853	508106	508359	508612	508865
.2	509118	509371	509625	509878	510131	510384	510637	510890	511143	511396
.3	511649	511902	512155	512408	512661	512914	513168	513421	513674	513927
.4	514180	514433	514686	514939	515192	515445	515698	515951	516204	516457
.5	516710	516964	517217	517470	517723	517976	518229	518482	518735	518988
.6	519241	519494	519747	520000	520253	520507	520760	521013	521266	521519
.7	521772	522025	522278	522531	522784	523037	523290	523543	523796	524050
.8	524303	524556	524809	525062	525315	525568	525821	526074	526327	526580
.9	526833	527086	527339	527593	527846	528099	528352	528605	528858	529111
1392.0	529364	529622	529880	530138	530396	530654	530912	531170	531428	531686
.1	531944	532203	532461	532719	532977	533235	533493	533751	534009	534267
.2	534525	534783	535041	535299	535557	535815	536073	536331	536589	536847
.3	537105	537364	537622	537880	538138	538396	538654	538912	539170	539428
.4	539686	539944	540202	540460	540718	540976	541234	541492	541750	542008
.5	542266	542525	542783	543041	543299	543557	543815	544073	544331	544589
.6	544847	545105	545363	545621	545879	546137	546395	546653	546911	547169
.7	547427	547686	547944	548202	548460	548718	548976	549234	549492	549750
.8	550008	550266	550524	550782	551040	551298	551556	551814	552072	552330
.9	552588	552847	553105	553363	553621	553879	554137	554395	554653	554911
1393.0	555169	555433	555697	555960	556224	556488	556752	557016	557280	557543
.1	557807	558071	558335	558599	558862	559126	559390	559654	559918	560182
.2	560445	560709	560973	561237	561501	561764	562028	562292	562556	562820
.3	563084	563347	563611	563875	564139	564403	564667	564930	565194	565458
.4	565722	565986	566249	566513	566777	567041	567305	567569	567832	568096
.5	568360	568624	568888	569151	569415	569679	569943	570207	570471	570734
.6	570998	571262	571526	571790	572053	572317	572581	572845	573109	573373
.7	573636	573900	574164	574428	574692	574955	575219	575483	575747	576011
.8	576275	576538	576802	577066	577330	577594	577858	578121	578385	578649
.9	578913	579177	579440	579704	579968	580232	580496	580760	581023	581287
1394.0	581551	581821	582092	582362	582632	582903	583173	583444	583714	583984
.1	584255	584525	584795	585066	585336	585606	585877	586147	586417	586688
.2	586958	587229	587499	587769	588040	588310	588580	588851	589121	589391
.3	589662	589932	590203	590473	590743	591014	591284	591554	591825	592095
.4	592365	592636	592906	593176	593447	593717	593988	594258	594528	594799
.5	595069	595339	595610	595880	596150	596421	596691	596962	597232	597502
.6	597773	598043	598313	598584	598854	599124	599395	599665	599935	600206
.7	600476	600747	601017	601287	601558	601828	602098	602369	602639	602909
.8	603180	603450	603721	603991	604261	604532	604802	605072	605343	605613
.9	605883	606154	606424	606694	606965	607235	607506	607776	608046	608317

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1395.0	608587	608865	609142	609420	609698	609975	610253	610531	610808	611086
.1	611364	611641	611919	612197	612475	612752	613030	613308	613585	613863
.2	614141	614418	614696	614974	615251	615529	615807	616084	616362	616640
.3	616917	617195	617473	617750	618028	618306	618583	618861	619139	619417
.4	619694	619972	620250	620527	620805	621083	621360	621638	621916	622193
.5	622471	622749	623026	623304	623582	623859	624137	624415	624692	624970
.6	625248	625525	625803	626081	626359	626636	626914	627192	627469	627747
.7	628025	628302	628580	628858	629135	629413	629691	629968	630246	630524
.8	630801	631079	631357	631634	631912	632190	632467	632745	633023	633301
.9	633578	633856	634134	634411	634689	634967	635244	635522	635800	636077
1396.0	636355	636641	636927	637212	637498	637784	638070	638355	638641	638927
.1	639213	639498	639784	640070	640356	640642	640927	641213	641499	641785
.2	642070	642356	642642	642928	643213	643499	643785	644071	644357	644642
.3	644928	645214	645500	645785	646071	646357	646643	646928	647214	647500
.4	647786	648072	648357	648643	648929	649215	649500	649786	650072	650358
.5	650643	650929	651215	651501	651787	652072	652358	652644	652930	653215
.6	653501	653787	654073	654359	654644	654930	655216	655502	655787	656073
.7	656359	656645	656930	657216	657502	657788	658074	658359	658645	658931
.8	659217	659502	659788	660074	660360	660645	660931	661217	661503	661789
.9	662074	662360	662646	662932	663217	663503	663789	664075	664360	664646
1397.0	664932	665227	665521	665816	666111	666405	666700	666994	667289	667584
.1	667878	668173	668468	668762	669057	669352	669646	669941	670236	670530
.2	670825	671119	671414	671709	672003	672298	672593	672887	673182	673477
.3	673771	674066	674360	674655	674950	675244	675539	675834	676128	676423
.4	676718	677012	677307	677602	677896	678191	678485	678780	679075	679369
.5	679664	679959	680253	680548	680843	681137	681432	681726	682021	682316
.6	682610	682905	683200	683494	683789	684084	684378	684673	684968	685262
.7	685557	685851	686146	686441	686735	687030	687325	687619	687914	688209
.8	688503	688798	689092	689387	689682	689976	690271	690566	690860	691155
.9	691450	691744	692039	692334	692628	692923	693217	693512	693807	694101
1398.0	694396	694700	695005	695309	695613	695917	696222	696526	696830	697135
.1	697439	697743	698047	698352	698656	698960	699265	699569	699873	700178
.2	700482	700786	701090	701395	701699	702003	702308	702612	702916	703220
.3	703525	703829	704133	704438	704742	705046	705350	705655	705959	706263
.4	706568	706872	707176	707480	707785	708089	708393	708698	709002	709306
.5	709610	709915	710219	710523	710828	711132	711436	711741	712045	712349
.6	712653	712958	713262	713566	713871	714175	714479	714783	715088	715392
.7	715696	716001	716305	716609	716913	717218	717522	717826	718131	718435
.8	718739	719043	719348	719652	719956	720261	720565	720869	721174	721478
.9	721782	722086	722391	722695	722999	723304	723608	723912	724216	724521
1399.0	724825	725140	725454	725769	726084	726399	726713	727028	727343	727657
.1	727972	728287	728602	728916	729231	729546	729861	730175	730490	730805
.2	731119	731434	731749	732064	732378	732693	733008	733322	733637	733952
.3	734267	734581	734896	735211	735525	735840	736155	736470	736784	737099
.4	737414	737729	738043	738358	738673	738987	739302	739617	739932	740246
.5	740561	740876	741190	741505	741820	742135	742449	742764	743079	743393
.6	743708	744023	744338	744652	744967	745282	745597	745911	746226	746541
.7	746855	747170	747485	747800	748114	748429	748744	749058	749373	749688
.8	750003	750317	750632	750947	751261	751576	751891	752206	752520	752835
.9	753150	753465	753779	754094	754409	754723	755038	755353	755668	755982

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1400.0	756297	756619	756941	757263	757586	757908	758230	758552	758874	759196
.1	759518	759840	760163	760485	760807	761129	761451	761773	762095	762417
.2	762740	763062	763384	763706	764028	764350	764672	764995	765317	765639
.3	765961	766283	766605	766927	767249	767572	767894	768216	768538	768860
.4	769182	769504	769826	770149	770471	770793	771115	771437	771759	772081
.5	772403	772726	773048	773370	773692	774014	774336	774658	774981	775303
.6	775625	775947	776269	776591	776913	777235	777558	777880	778202	778524
.7	778846	779168	779490	779812	780135	780457	780779	781101	781423	781745
.8	782067	782390	782712	783034	783356	783678	784000	784322	784644	784967
.9	785289	785611	785933	786255	786577	786899	787221	787544	787866	788188
1401.0	788510	788837	789164	789491	789818	790145	790472	790799	791126	791454
.1	791781	792108	792435	792762	793089	793416	793743	794070	794397	794724
.2	795051	795378	795705	796032	796359	796686	797014	797341	797668	797995
.3	798322	798649	798976	799303	799630	799957	800284	800611	800938	801265
.4	801592	801919	802247	802574	802901	803228	803555	803882	804209	804536
.5	804863	805190	805517	805844	806171	806498	806825	807152	807479	807807
.6	808134	808461	808788	809115	809442	809769	810096	810423	810750	811077
.7	811404	811731	812058	812385	812712	813039	813367	813694	814021	814348
.8	814675	815002	815329	815656	815983	816310	816637	816964	817291	817618
.9	817945	818272	818600	818927	819254	819581	819908	820235	820562	820889
1402.0	821216	821550	821883	822217	822550	822884	823217	823551	823885	824218
.1	824552	824885	825219	825552	825886	826220	826553	826887	827220	827554
.2	827887	828221	828555	828888	829222	829555	829889	830222	830556	830890
.3	831223	831557	831890	832224	832557	832891	833225	833558	833892	834225
.4	834559	834892	835226	835560	835893	836227	836560	836894	837227	837561
.5	837894	838228	838562	838895	839229	839562	839896	840229	840563	840897
.6	841230	841564	841897	842231	842564	842898	843232	843565	843899	844232
.7	844566	844899	845233	845567	845900	846234	846567	846901	847234	847568
.8	847902	848235	848569	848902	849236	849569	849903	850237	850570	850904
.9	851237	851571	851904	852238	852572	852905	853239	853572	853906	854239
1403.0	854573	854915	855256	855598	855940	856281	856623	856965	857306	857648
.1	857990	858331	858673	859015	859356	859698	860040	860381	860723	861065
.2	861406	861748	862090	862431	862773	863114	863456	863798	864139	864481
.3	864823	865164	865506	865848	866189	866531	866873	867214	867556	867898
.4	868239	868581	868923	869264	869606	869948	870289	870631	870973	871314
.5	871656	871998	872339	872681	873023	873364	873706	874048	874389	874731
.6	875073	875414	875756	876098	876439	876781	877123	877464	877806	878148
.7	878489	878831	879173	879514	879856	880197	880539	880881	881222	881564
.8	881906	882247	882589	882931	883272	883614	883956	884297	884639	884981
.9	885322	885664	886006	886347	886689	887031	887372	887714	888056	888397
1404.0	888739	889090	889442	889793	890144	890496	890847	891198	891550	891901
.1	892252	892604	892955	893306	893658	894009	894360	894712	895063	895414
.2	895766	896117	896468	896820	897171	897522	897874	898225	898576	898928
.3	899279	899630	899982	900333	900684	901036	901387	901738	902090	902441
.4	902792	903144	903495	903846	904198	904549	904900	905252	905603	905954
.5	906305	906657	907008	907359	907711	908062	908413	908765	909116	909467
.6	909819	910170	910521	910873	911224	911575	911927	912278	912629	912981
.7	913332	913683	914035	914386	914737	915089	915440	915791	916143	916494
.8	916845	917197	917548	917899	918251	918602	918953	919305	919656	920007
.9	920359	920710	921061	921413	921764	922115	922467	922818	923169	923521

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1405.0	923872	924235	924597	924960	925322	925685	926047	926410	926772	927135
.1	927498	927860	928223	928585	928948	929310	929673	930036	930398	930761
.2	931123	931486	931848	932211	932573	932936	933299	933661	934024	934386
.3	934749	935111	935474	935836	936199	936562	936924	937287	937649	938012
.4	938374	938737	939100	939462	939825	940187	940550	940912	941275	941637
.5	942000	942363	942725	943088	943450	943813	944175	944538	944900	945263
.6	945626	945988	946351	946713	947076	947438	947801	948164	948526	948889
.7	949251	949614	949976	950339	950701	951064	951427	951789	952152	952514
.8	952877	953239	953602	953964	954327	954690	955052	955415	955777	956140
.9	956502	956865	957228	957590	957953	958315	958678	959040	959403	959765
1406.0	960128	960503	960879	961254	961630	962005	962380	962756	963131	963506
.1	963882	964257	964633	965008	965383	965759	966134	966509	966885	967260
.2	967636	968011	968386	968762	969137	969512	969888	970263	970639	971014
.3	971389	971765	972140	972516	972891	973266	973642	974017	974392	974768
.4	975143	975519	975894	976269	976645	977020	977395	977771	978146	978522
.5	978897	979272	979648	980023	980399	980774	981149	981525	981900	982275
.6	982651	983026	983402	983777	984152	984528	984903	985278	985654	986029
.7	986405	986780	987155	987531	987906	988281	988657	989032	989408	989783
.8	990158	990534	990909	991285	991660	992035	992411	992786	993161	993537
.9	993912	994288	994663	995038	995414	995789	996164	996540	996915	997291
1407.0	997666	998056	998446	998835	999225	999615	1000005	1000394	1000784	1001174
.1	1001564	1001954	1002343	1002733	1003123	1003513	1003902	1004292	1004682	1005072
.2	1005462	1005851	1006241	1006631	1007021	1007410	1007800	1008190	1008580	1008970
.3	1009359	1009749	1010139	1010529	1010919	1011308	1011698	1012088	1012478	1012867
.4	1013257	1013647	1014037	1014427	1014816	1015206	1015596	1015986	1016375	1016765
.5	1017155	1017545	1017935	1018324	1018714	1019104	1019494	1019883	1020273	1020663
.6	1021053	1021443	1021832	1022222	1022612	1023002	1023391	1023781	1024171	1024561
.7	1024951	1025340	1025730	1026120	1026510	1026899	1027289	1027679	1028069	1028459
.8	1028848	1029238	1029628	1030018	1030408	1030797	1031187	1031577	1031967	1032356
.9	1032746	1033136	1033526	1033916	1034305	1034695	1035085	1035475	1035864	1036254
1408.0	1036644	1037050	1037456	1037861	1038267	1038673	1039079	1039484	1039890	1040296
.1	1040701	1041107	1041513	1041919	1042324	1042730	1043136	1043542	1043947	1044353
.2	1044759	1045165	1045570	1045976	1046382	1046788	1047193	1047599	1048005	1048411
.3	1048816	1049222	1049628	1050034	1050439	1050845	1051251	1051657	1052062	1052468
.4	1052874	1053280	1053685	1054091	1054497	1054903	1055308	1055714	1056120	1056526
.5	1056931	1057337	1057743	1058149	1058554	1058960	1059366	1059772	1060177	1060583
.6	1060989	1061395	1061800	1062206	1062612	1063018	1063423	1063829	1064235	1064641
.7	1065046	1065452	1065858	1066264	1066669	1067075	1067481	1067887	1068292	1068698
.8	1069104	1069510	1069915	1070321	1070727	1071133	1071538	1071944	1072350	1072756
.9	1073161	1073567	1073973	1074379	1074784	1075190	1075596	1076002	1076407	1076813
1409.0	1077219	1077642	1078066	1078489	1078912	1079335	1079759	1080182	1080605	1081029
.1	1081452	1081875	1082298	1082722	1083145	1083568	1083992	1084415	1084838	1085262
.2	1085685	1086108	1086531	1086955	1087378	1087801	1088225	1088648	1089071	1089494
.3	1089918	1090341	1090764	1091188	1091611	1092034	1092457	1092881	1093304	1093727
.4	1094151	1094574	1094997	1095420	1095844	1096267	1096690	1097114	1097537	1097960
.5	1098383	1098807	1099230	1099653	1100077	1100500	1100923	1101347	1101770	1102193
.6	1102616	1103040	1103463	1103886	1104310	1104733	1105156	1105579	1106003	1106426
.7	1106849	1107273	1107696	1108119	1108542	1108966	1109389	1109812	1110236	1110659
.8	1111082	1111505	1111929	1112352	1112775	1113199	1113622	1114045	1114469	1114892
.9	1115315	1115738	1116162	1116585	1117008	1117432	1117855	1118278	1118701	1119125

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1410.0	1119548	1119988	1120427	1120867	1121307	1121746	1122186	1122625	1123065	1123505
.1	1123944	1124384	1124824	1125263	1125703	1126143	1126582	1127022	1127462	1127901
.2	1128341	1128780	1129220	1129660	1130099	1130539	1130979	1131418	1131858	1132298
.3	1132737	1133177	1133616	1134056	1134496	1134935	1135375	1135815	1136254	1136694
.4	1137134	1137573	1138013	1138453	1138892	1139332	1139771	1140211	1140651	1141090
.5	1141530	1141970	1142409	1142849	1143289	1143728	1144168	1144607	1145047	1145487
.6	1145926	1146366	1146806	1147245	1147685	1148125	1148564	1149004	1149444	1149883
.7	1150323	1150762	1151202	1151642	1152081	1152521	1152961	1153400	1153840	1154280
.8	1154719	1155159	1155598	1156038	1156478	1156917	1157357	1157797	1158236	1158676
.9	1159116	1159555	1159995	1160435	1160874	1161314	1161753	1162193	1162633	1163072
1411.0	1163512	1163966	1164419	1164873	1165327	1165780	1166234	1166688	1167142	1167595
.1	1168049	1168503	1168956	1169410	1169864	1170317	1170771	1171225	1171678	1172132
.2	1172586	1173039	1173493	1173947	1174401	1174854	1175308	1175762	1176215	1176669
.3	1177123	1177576	1178030	1178484	1178937	1179391	1179845	1180299	1180752	1181206
.4	1181660	1182113	1182567	1183021	1183474	1183928	1184382	1184835	1185289	1185743
.5	1186196	1186650	1187104	1187558	1188011	1188465	1188919	1189372	1189826	1190280
.6	1190733	1191187	1191641	1192094	1192548	1193002	1193456	1193909	1194363	1194817
.7	1195270	1195724	1196178	1196631	1197085	1197539	1197992	1198446	1198900	1199354
.8	1199807	1200261	1200715	1201168	1201622	1202076	1202529	1202983	1203437	1203890
.9	1204344	1204798	1205251	1205705	1206159	1206613	1207066	1207520	1207974	1208427
1412.0	1208881	1209349	1209816	1210284	1210752	1211219	1211687	1212155	1212622	1213090
.1	1213558	1214025	1214493	1214961	1215428	1215896	1216364	1216831	1217299	1217767
.2	1218234	1218702	1219170	1219637	1220105	1220572	1221040	1221508	1221975	1222443
.3	1222911	1223378	1223846	1224314	1224781	1225249	1225717	1226184	1226652	1227120
.4	1227587	1228055	1228523	1228990	1229458	1229926	1230393	1230861	1231329	1231796
.5	1232264	1232732	1233199	1233667	1234135	1234602	1235070	1235538	1236005	1236473
.6	1236941	1237408	1237876	1238344	1238811	1239279	1239747	1240214	1240682	1241150
.7	1241617	1242085	1242553	1243020	1243488	1243955	1244423	1244891	1245358	1245826
.8	1246294	1246761	1247229	1247697	1248164	1248632	1249100	1249567	1250035	1250503
.9	1250970	1251438	1251906	1252373	1252841	1253309	1253776	1254244	1254712	1255179
1413.0	1255647	1256129	1256610	1257092	1257573	1258055	1258536	1259018	1259499	1259981
.1	1260462	1260944	1261426	1261907	1262389	1262870	1263352	1263833	1264315	1264796
.2	1265278	1265760	1266241	1266723	1267204	1267686	1268167	1268649	1269130	1269612
.3	1270093	1270575	1271057	1271538	1272020	1272501	1272983	1273464	1273946	1274427
.4	1274909	1275391	1275872	1276354	1276835	1277317	1277798	1278280	1278761	1279243
.5	1279724	1280206	1280688	1281169	1281651	1282132	1282614	1283095	1283577	1284058
.6	1284540	1285022	1285503	1285985	1286466	1286948	1287429	1287911	1288392	1288874
.7	1289355	1289837	1290319	1290800	1291282	1291763	1292245	1292726	1293208	1293689
.8	1294171	1294653	1295134	1295616	1296097	1296579	1297060	1297542	1298023	1298505
.9	1298986	1299468	1299950	1300431	1300913	1301394	1301876	1302357	1302839	1303320
1414.0	1303802	1304297	1304793	1305288	1305783	1306279	1306774	1307270	1307765	1308260
.1	1308756	1309251	1309746	1310242	1310737	1311233	1311728	1312223	1312719	1313214
.2	1313709	1314205	1314700	1315196	1315691	1316186	1316682	1317177	1317672	1318168
.3	1318663	1319158	1319654	1320149	1320645	1321140	1321635	1322131	1322626	1323121
.4	1323617	1324112	1324608	1325103	1325598	1326094	1326589	1327084	1327580	1328075
.5	1328570	1329066	1329561	1330057	1330552	1331047	1331543	1332038	1332533	1333029
.6	1333524	1334020	1334515	1335010	1335506	1336001	1336496	1336992	1337487	1337983
.7	1338478	1338973	1339469	1339964	1340459	1340955	1341450	1341945	1342441	1342936
.8	1343432	1343927	1344422	1344918	1345413	1345908	1346404	1346899	1347395	1347890
.9	1348385	1348881	1349376	1349871	1350367	1350862	1351358	1351853	1352348	1352844

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1415.0	1353339	1353848	1354357	1354866	1355375	1355885	1356394	1356903	1357412	1357921
.1	1358430	1358939	1359448	1359957	1360467	1360976	1361485	1361994	1362503	1363012
.2	1363521	1364030	1364539	1365049	1365558	1366067	1366576	1367085	1367594	1368103
.3	1368612	1369121	1369631	1370140	1370649	1371158	1371667	1372176	1372685	1373194
.4	1373703	1374213	1374722	1375231	1375740	1376249	1376758	1377267	1377776	1378285
.5	1378794	1379304	1379813	1380322	1380831	1381340	1381849	1382358	1382867	1383376
.6	1383886	1384395	1384904	1385413	1385922	1386431	1386940	1387449	1387958	1388468
.7	1388977	1389486	1389995	1390504	1391013	1391522	1392031	1392540	1393050	1393559
.8	1394068	1394577	1395086	1395595	1396104	1396613	1397122	1397632	1398141	1398650
.9	1399159	1399668	1400177	1400686	1401195	1401704	1402214	1402723	1403232	1403741
1416.0	1404250	1404773	1405296	1405818	1406341	1406864	1407387	1407909	1408432	1408955
.1	1409478	1410001	1410523	1411046	1411569	1412092	1412614	1413137	1413660	1414183
.2	1414706	1415228	1415751	1416274	1416797	1417319	1417842	1418365	1418888	1419411
.3	1419933	1420456	1420979	1421502	1422025	1422547	1423070	1423593	1424116	1424638
.4	1425161	1425684	1426207	1426730	1427252	1427775	1428298	1428821	1429343	1429866
.5	1430389	1430912	1431435	1431957	1432480	1433003	1433526	1434048	1434571	1435094
.6	1435617	1436140	1436662	1437185	1437708	1438231	1438753	1439276	1439799	1440322
.7	1440845	1441367	1441890	1442413	1442936	1443458	1443981	1444504	1445027	1445550
.8	1446072	1446595	1447118	1447641	1448164	1448686	1449209	1449732	1450255	1450777
.9	1451300	1451823	1452346	1452869	1453391	1453914	1454437	1454960	1455482	1456005
1417.0	1456528	1457064	1457601	1458137	1458673	1459210	1459746	1460283	1460819	1461355
.1	1461892	1462428	1462964	1463501	1464037	1464573	1465110	1465646	1466182	1466719
.2	1467255	1467792	1468328	1468864	1469401	1469937	1470473	1471010	1471546	1472082
.3	1472619	1473155	1473692	1474228	1474764	1475301	1475837	1476373	1476910	1477446
.4	1477982	1478519	1479055	1479591	1480128	1480664	1481201	1481737	1482273	1482810
.5	1483346	1483882	1484419	1484955	1485491	1486028	1486564	1487101	1487637	1488173
.6	1488710	1489246	1489782	1490319	1490855	1491391	1491928	1492464	1493000	1493537
.7	1494073	1494610	1495146	1495682	1496219	1496755	1497291	1497828	1498364	1498900
.8	1499437	1499973	1500510	1501046	1501582	1502119	1502655	1503191	1503728	1504264
.9	1504800	1505337	1505873	1506409	1506946	1507482	1508019	1508555	1509091	1509628
1418.0	1510164	1510714	1511264	1511814	1512364	1512913	1513463	1514013	1514563	1515113
.1	1515663	1516213	1516763	1517312	1517862	1518412	1518962	1519512	1520062	1520612
.2	1521162	1521711	1522261	1522811	1523361	1523911	1524461	1525011	1525561	1526111
.3	1526660	1527210	1527760	1528310	1528860	1529410	1529960	1530510	1531059	1531609
.4	1532159	1532709	1533259	1533809	1534359	1534909	1535458	1536008	1536558	1537108
.5	1537658	1538208	1538758	1539308	1539858	1540407	1540957	1541507	1542057	1542607
.6	1543157	1543707	1544257	1544806	1545356	1545906	1546456	1547006	1547556	1548106
.7	1548656	1549205	1549755	1550305	1550855	1551405	1551955	1552505	1553055	1553605
.8	1554154	1554704	1555254	1555804	1556354	1556904	1557454	1558004	1558553	1559103
.9	1559653	1560203	1560753	1561303	1561853	1562403	1562952	1563502	1564052	1564602
1419.0	1565152	1565715	1566279	1566842	1567405	1567969	1568532	1569095	1569659	1570222
.1	1570785	1571349	1571912	1572475	1573038	1573602	1574165	1574728	1575292	1575855
.2	1576418	1576982	1577545	1578108	1578672	1579235	1579798	1580362	1580925	1581488
.3	1582052	1582615	1583178	1583742	1584305	1584868	1585432	1585995	1586558	1587121
.4	1587685	1588248	1588811	1589375	1589938	1590501	1591065	1591628	1592191	1592755
.5	1593318	1593881	1594445	1595008	1595571	1596135	1596698	1597261	1597825	1598388
.6	1598951	1599515	1600078	1600641	1601204	1601768	1602331	1602894	1603458	1604021
.7	1604584	1605148	1605711	1606274	1606838	1607401	1607964	1608528	1609091	1609654
.8	1610218	1610781	1611344	1611908	1612471	1613034	1613598	1614161	1614724	1615287
.9	1615851	1616414	1616977	1617541	1618104	1618667	1619231	1619794	1620357	1620921

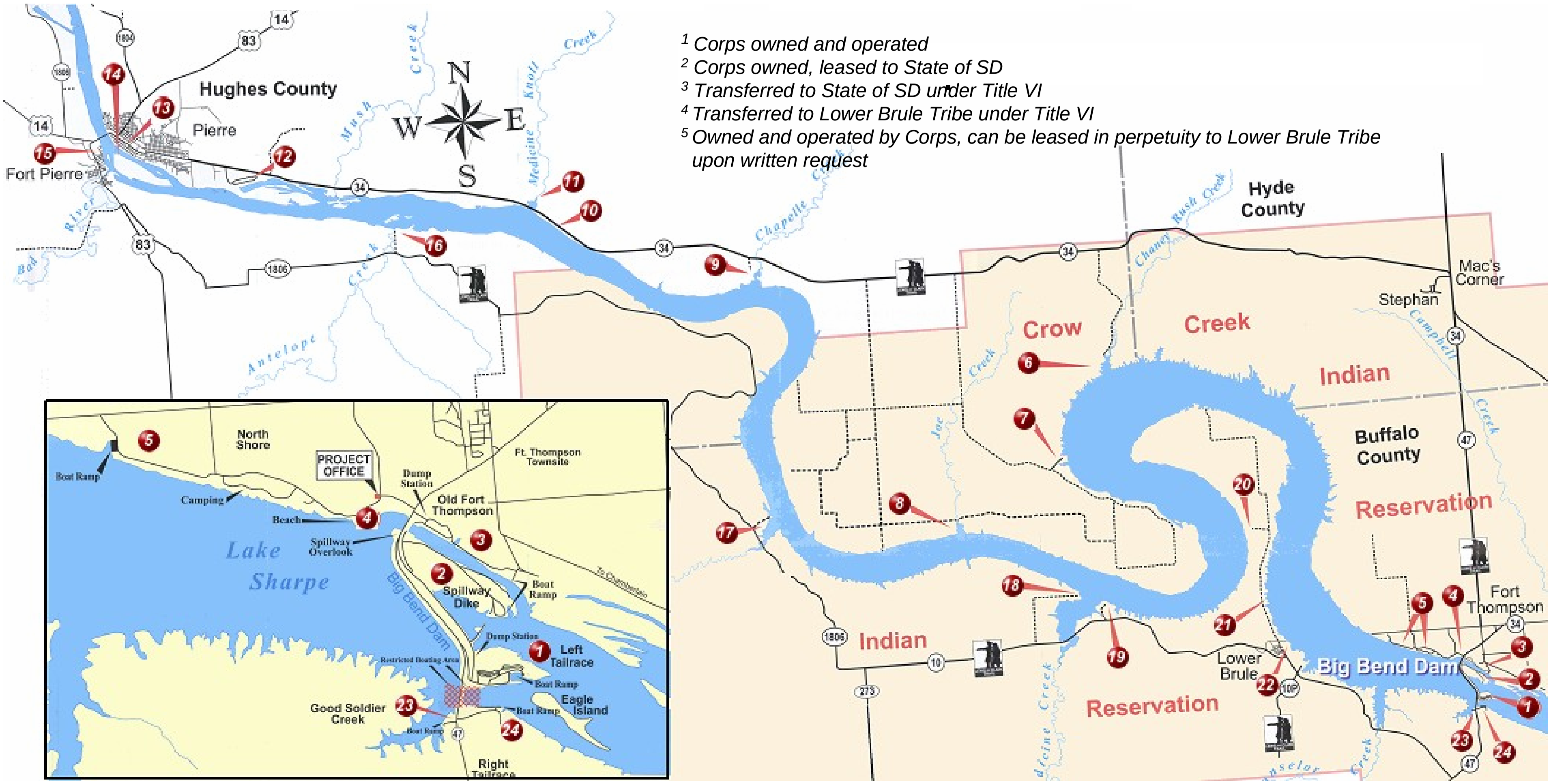
CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1420.0	1621484	1622061	1622638	1623214	1623791	1624368	1624945	1625522	1626099	1626675
.1	1627252	1627829	1628406	1628983	1629559	1630136	1630713	1631290	1631867	1632444
.2	1633020	1633597	1634174	1634751	1635328	1635904	1636481	1637058	1637635	1638212
.3	1638789	1639365	1639942	1640519	1641096	1641673	1642250	1642826	1643403	1643980
.4	1644557	1645134	1645710	1646287	1646864	1647441	1648018	1648595	1649171	1649748
.5	1650325	1650902	1651479	1652055	1652632	1653209	1653786	1654363	1654940	1655516
.6	1656093	1656670	1657247	1657824	1658400	1658977	1659554	1660131	1660708	1661285
.7	1661861	1662438	1663015	1663592	1664169	1664745	1665322	1665899	1666476	1667053
.8	1667630	1668206	1668783	1669360	1669937	1670514	1671091	1671667	1672244	1672821
.9	1673398	1673975	1674551	1675128	1675705	1676282	1676859	1677436	1678012	1678589
1421.0	1679166	1679756	1680347	1680937	1681528	1682118	1682709	1683299	1683889	1684480
.1	1685070	1685661	1686251	1686842	1687432	1688022	1688613	1689203	1689794	1690384
.2	1690975	1691565	1692155	1692746	1693336	1693927	1694517	1695108	1695698	1696288
.3	1696879	1697469	1698060	1698650	1699241	1699831	1700421	1701012	1701602	1702193
.4	1702783	1703374	1703964	1704554	1705145	1705735	1706326	1706916	1707507	1708097
.5	1708687	1709278	1709868	1710459	1711049	1711640	1712230	1712821	1713411	1714001
.6	1714592	1715182	1715773	1716363	1716954	1717544	1718134	1718725	1719315	1719906
.7	1720496	1721087	1721677	1722267	1722858	1723448	1724039	1724629	1725220	1725810
.8	1726400	1726991	1727581	1728172	1728762	1729353	1729943	1730533	1731124	1731714
.9	1732305	1732895	1733486	1734076	1734666	1735257	1735847	1736438	1737028	1737619
1422.0	1738209	1738813	1739417	1740021	1740625	1741229	1741833	1742437	1743041	1743645
.1	1744249	1744854	1745458	1746062	1746666	1747270	1747874	1748478	1749082	1749686
.2	1750290	1750894	1751498	1752102	1752706	1753310	1753914	1754518	1755122	1755726
.3	1756330	1756935	1757539	1758143	1758747	1759351	1759955	1760559	1761163	1761767
.4	1762371	1762975	1763579	1764183	1764787	1765391	1765995	1766599	1767203	1767807
.5	1768411	1769016	1769620	1770224	1770828	1771432	1772036	1772640	1773244	1773848
.6	1774452	1775056	1775660	1776264	1776868	1777472	1778076	1778680	1779284	1779888
.7	1780492	1781097	1781701	1782305	1782909	1783513	1784117	1784721	1785325	1785929
.8	1786533	1787137	1787741	1788345	1788949	1789553	1790157	1790761	1791365	1791969
.9	1792573	1793178	1793782	1794386	1794990	1795594	1796198	1796802	1797406	1798010
1423.0	1798614	1799232	1799849	1800467	1801085	1801702	1802320	1802938	1803555	1804173
.1	1804791	1805408	1806026	1806644	1807261	1807879	1808497	1809114	1809732	1810350
.2	1810967	1811585	1812203	1812820	1813438	1814055	1814673	1815291	1815908	1816526
.3	1817144	1817761	1818379	1818997	1819614	1820232	1820850	1821467	1822085	1822703
.4	1823320	1823938	1824556	1825173	1825791	1826409	1827026	1827644	1828262	1828879
.5	1829497	1830115	1830732	1831350	1831968	1832585	1833203	1833821	1834438	1835056
.6	1835674	1836291	1836909	1837527	1838144	1838762	1839380	1839997	1840615	1841233
.7	1841850	1842468	1843086	1843703	1844321	1844938	1845556	1846174	1846791	1847409
.8	1848027	1848644	1849262	1849880	1850497	1851115	1851733	1852350	1852968	1853586
.9	1854203	1854821	1855439	1856056	1856674	1857292	1857909	1858527	1859145	1859762
1424.0	1860380	1861011	1861643	1862274	1862905	1863536	1864168	1864799	1865430	1866062
.1	1866693	1867324	1867955	1868587	1869218	1869849	1870480	1871112	1871743	1872374
.2	1873006	1873637	1874268	1874899	1875531	1876162	1876793	1877425	1878056	1878687
.3	1879318	1879950	1880581	1881212	1881844	1882475	1883106	1883737	1884369	1885000
.4	1885631	1886262	1886894	1887525	1888156	1888788	1889419	1890050	1890681	1891313
.5	1891944	1892575	1893207	1893838	1894469	1895100	1895732	1896363	1896994	1897626
.6	1898257	1898888	1899519	1900151	1900782	1901413	1902044	1902676	1903307	1903938
.7	1904570	1905201	1905832	1906463	1907095	1907726	1908357	1908989	1909620	1910251
.8	1910882	1911514	1912145	1912776	1913408	1914039	1914670	1915301	1915933	1916564
.9	1917195	1917826	1918458	1919089	1919720	1920352	1920983	1921614	1922245	1922877

CAPACITY IN ACRE-FEET
(1997 SURVEY)

ELEV	.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1425.0	1923508	1924153	1924798	1925443	1926088	1926732	1927377	1928022	1928667	1929312
.1	1929957	1930602	1931247	1931892	1932536	1933181	1933826	1934471	1935116	1935761
.2	1936406	1937051	1937696	1938340	1938985	1939630	1940275	1940920	1941565	1942210
.3	1942855	1943500	1944144	1944789	1945434	1946079	1946724	1947369	1948014	1948659
.4	1949304	1949948	1950593	1951238	1951883	1952528	1953173	1953818	1954463	1955108
.5	1955752	1956397	1957042	1957687	1958332	1958977	1959622	1960267	1960912	1961557
.6	1962201	1962846	1963491	1964136	1964781	1965426	1966071	1966716	1967361	1968005
.7	1968650	1969295	1969940	1970585	1971230	1971875	1972520	1973165	1973809	1974454
.8	1975099	1975744	1976389	1977034	1977679	1978324	1978969	1979613	1980258	1980903
.9	1981548	1982193	1982838	1983483	1984128	1984773	1985417	1986062	1986707	1987352
1426.0	1987997	1988656	1989314	1989973	1990631	1991290	1991948	1992607	1993265	1993924
.1	1994582	1995240	1995899	1996557	1997216	1997874	1998533	1999191	1999850	2000508
.2	2001167	2001825	2002484	2003142	2003801	2004459	2005118	2005776	2006435	2007093
.3	2007752	2008410	2009069	2009727	2010386	2011044	2011703	2012361	2013020	2013678
.4	2014337	2014995	2015654	2016312	2016971	2017629	2018288	2018946	2019605	2020263
.5	2020922	2021580	2022239	2022897	2023556	2024214	2024873	2025531	2026190	2026848
.6	2027507	2028165	2028824	2029482	2030141	2030799	2031458	2032116	2032775	2033433
.7	2034092	2034750	2035409	2036067	2036726	2037384	2038043	2038701	2039360	2040018
.8	2040677	2041335	2041994	2042652	2043311	2043969	2044628	2045286	2045945	2046603
.9	2047262	2047920	2048579	2049237	2049896	2050554	2051213	2051871	2052530	2053188
1427.0	2053847	2054519	2055191	2055863	2056535	2057208	2057880	2058552	2059224	2059896
.1	2060568	2061240	2061912	2062585	2063257	2063929	2064601	2065273	2065945	2066617
.2	2067289	2067962	2068634	2069306	2069978	2070650	2071322	2071994	2072666	2073338
.3	2074011	2074683	2075355	2076027	2076699	2077371	2078043	2078715	2079388	2080060
.4	2080732	2081404	2082076	2082748	2083420	2084092	2084765	2085437	2086109	2086781
.5	2087453	2088125	2088797	2089469	2090141	2090814	2091486	2092158	2092830	2093502
.6	2094174	2094846	2095518	2096191	2096863	2097535	2098207	2098879	2099551	2100223
.7	2100895	2101568	2102240	2102912	2103584	2104256	2104928	2105600	2106272	2106944
.8	2107617	2108289	2108961	2109633	2110305	2110977	2111649	2112321	2112994	2113666
.9	2114338	2115010	2115682	2116354	2117026	2117698	2118371	2119043	2119715	2120387
1428.0	2121059	2121745	2122430	2123116	2123802	2124488	2125173	2125859	2126545	2127231
.1	2127916	2128602	2129288	2129974	2130659	2131345	2132031	2132717	2133402	2134088
.2	2134774	2135460	2136145	2136831	2137517	2138202	2138888	2139574	2140260	2140945
.3	2141631	2142317	2143003	2143688	2144374	2145060	2145746	2146431	2147117	2147803
.4	2148489	2149174	2149860	2150546	2151232	2151917	2152603	2153289	2153975	2154660
.5	2155346	2156032	2156717	2157403	2158089	2158775	2159460	2160146	2160832	2161518
.6	2162203	2162889	2163575	2164261	2164946	2165632	2166318	2167004	2167689	2168375
.7	2169061	2169747	2170432	2171118	2171804	2172489	2173175	2173861	2174547	2175232
.8	2175918	2176604	2177290	2177975	2178661	2179347	2180033	2180718	2181404	2182090
.9	2182776	2183461	2184147	2184833	2185519	2186204	2186890	2187576	2188262	2188947
1429.0	2189633	2190332	2191032	2191731	2192430	2193130	2193829	2194528	2195228	2195927
.1	2196626	2197326	2198025	2198725	2199424	2200123	2200823	2201522	2202221	2202921
.2	2203620	2204319	2205019	2205718	2206417	2207117	2207816	2208515	2209215	2209914
.3	2210613	2211313	2212012	2212712	2213411	2214110	2214810	2215509	2216208	2216908
.4	2217607	2218306	2219006	2219705	2220404	2221104	2221803	2222502	2223202	2223901
.5	2224600	2225300	2225999	2226699	2227398	2228097	2228797	2229496	2230195	2230895
.6	2231594	2232293	2232993	2233692	2234391	2235091	2235790	2236489	2237189	2237888
.7	2238587	2239287	2239986	2240686	2241385	2242084	2242784	2243483	2244182	2244882
.8	2245581	2246280	2246980	2247679	2248378	2249078	2249777	2250476	2251176	2251875
.9	2252574	2253274	2253973	2254673	2255372	2256071	2256771	2257470	2258169	2258869

1. Left Tailrace[5]
2. Spillway Dike[1]
3. Old Fort Thompson[1]
4. North Shore Beach[1]
5. North Shore[1]
6. North Bend[2]
7. West Bend[2]
8. Joe Creek[2]
9. DeGrey[3]
10. Fort George[3]
11. Rousseau Overlook[3]
12. Farm Island[3]
13. Pierre Waterfront[3]
14. LaFramboise Island[3]
15. Fort Pierre Waterfront[3]
16. Antelope Creek[3]
17. Cedar Creek[4]
18. North Iron Nation[4]
19. South Iron Nation[4]
20. Narrows[4]
21. Lower Brule Ramp[4]
22. Lower Brule Campground[4]
23. Good Soldier[5]
24. Right Tailrace[5]



[1] Corps owned and operated
[2] Corps owned, leased to State of SD
[3] Transferred to State of SD under Title VI
[4] Transferred to Lower Brule Tribe under Title VI
[5] Owned and operated by Corps, can be leased in perpetuity to Lower Brule Tribe upon written request

Missouri River Basin
Big Bend Water Control Manual
Recreation Facilities
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Area Number	Recreation Area	Boat Ramp	Camping	Electric Hookup	Drinking Water	Showers	Flush Toilets	Vault Toilets	Picnic Shelters	Tables/Grills	Swimming Beach	Playground	Dump Station	Fish Cleaning	Telephone	Marina	Trail
1.	Left Tailrace	●	●	●	●	●	●	●	●	●		●	●	●	●		
2.	Spillway Dike	●						●	●	●							
3.	Old Fort Thompson	●	●		●	●	●	●	●	●		●	●				
4.	North Shore Beach				●	●	●	●	●	●	●	●			●		
5.	North Shore	●	●		●			●	●	●				●			
6.	North Bend	●	●					●									
7.	West Bend	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
8.	Joe Creek	●	●					●	●	●							
9.	DeGrey	●	●					●									
10.	Fort George	●						●									
11.	Rousseau Overlook							●	●								
12.	Farm Island	●	●	●	●	●	●	●	●	●	●	●	●	●			●
13.	Pierre Waterfront	●			●			●	●	●	●			●	●	●	●
14.	LaFramboise Island	●			●		●	●	●	●							●
15.	Fort Pierre Waterfront	●															●
16.	Antelope Creek	●															
17.	Cedar Creek	●															
18.	North Iron Nation		●					●	●	●				●			
19.	South Iron Nation	●	●					●	●	●		●		●			
20.	Narrows																
21.	Lower Brule Ramp	●															
22.	Lower Brule Campground		●	●	●	●	●	●	●	●		●			●		
23.	Good Soldier	●						●	●	●		●					
24.	Right Tailrace	●	●		●		●	●	●	●		●		●			

To determine if the facility listed is accessible for your needs, please call (605) 245-2255

Missouri River Basin

Big Bend Water Control Manual

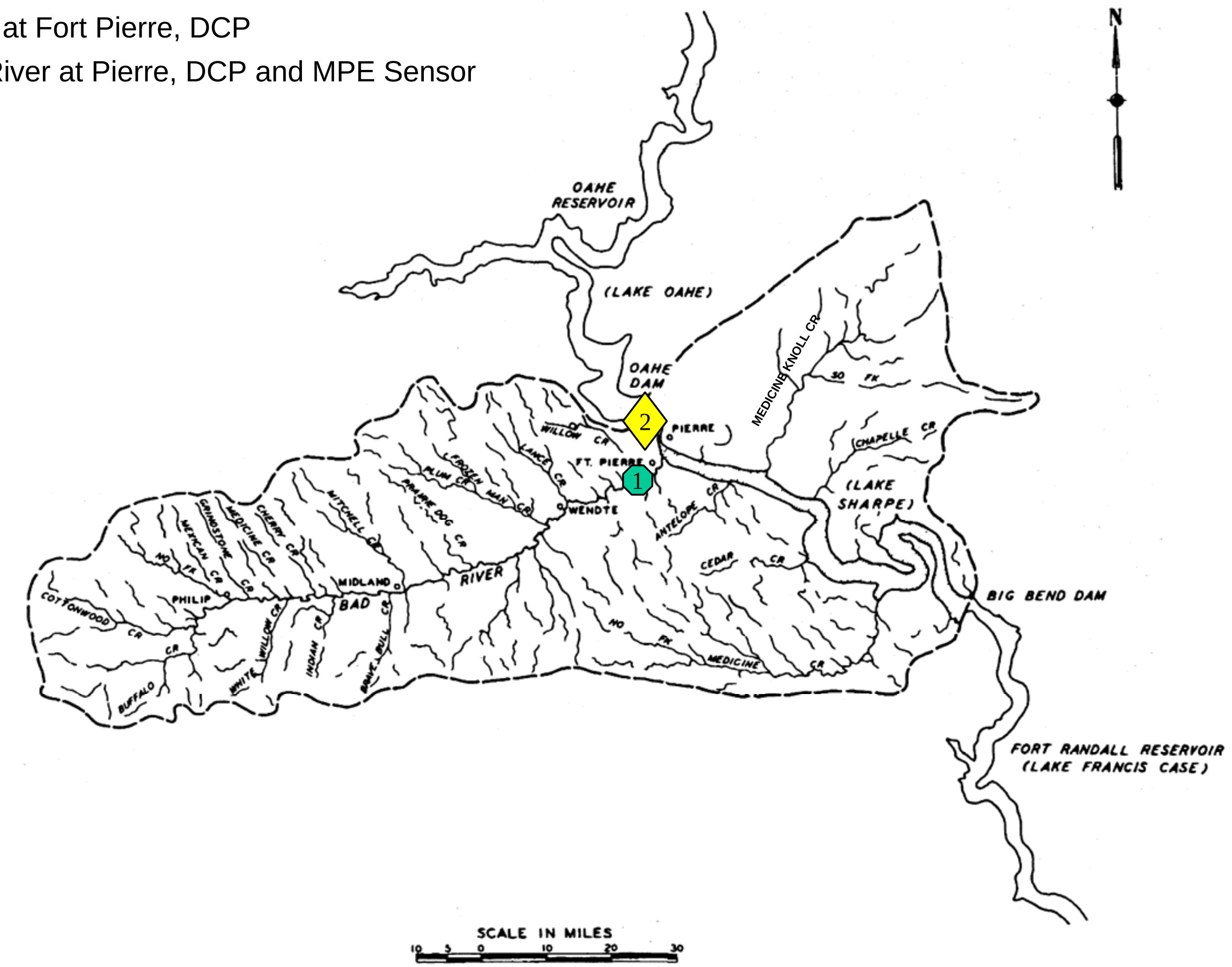
Recreation Activities

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Plate IV-18

1 Bad River at Fort Pierre, DCP

2 Missouri River at Pierre, DCP and MPE Sensor



Missouri River Basin

Big Bend Water Control Manual

Precipitation Stations

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

1 Bad River at Midland (D.A = 1460 sq. mi.)

2 Bad River at Fort Pierre (D.A. = 3107 sq. mi.)

3 Medicine Knoll Creek near Blunt, 1950-1997 (D.A. = 455 sq. mi.)

4 Medicine Creek at Kennebec, 1955-1990 (D.A. = 465 sq. mi.)

5 Missouri River at Pierre

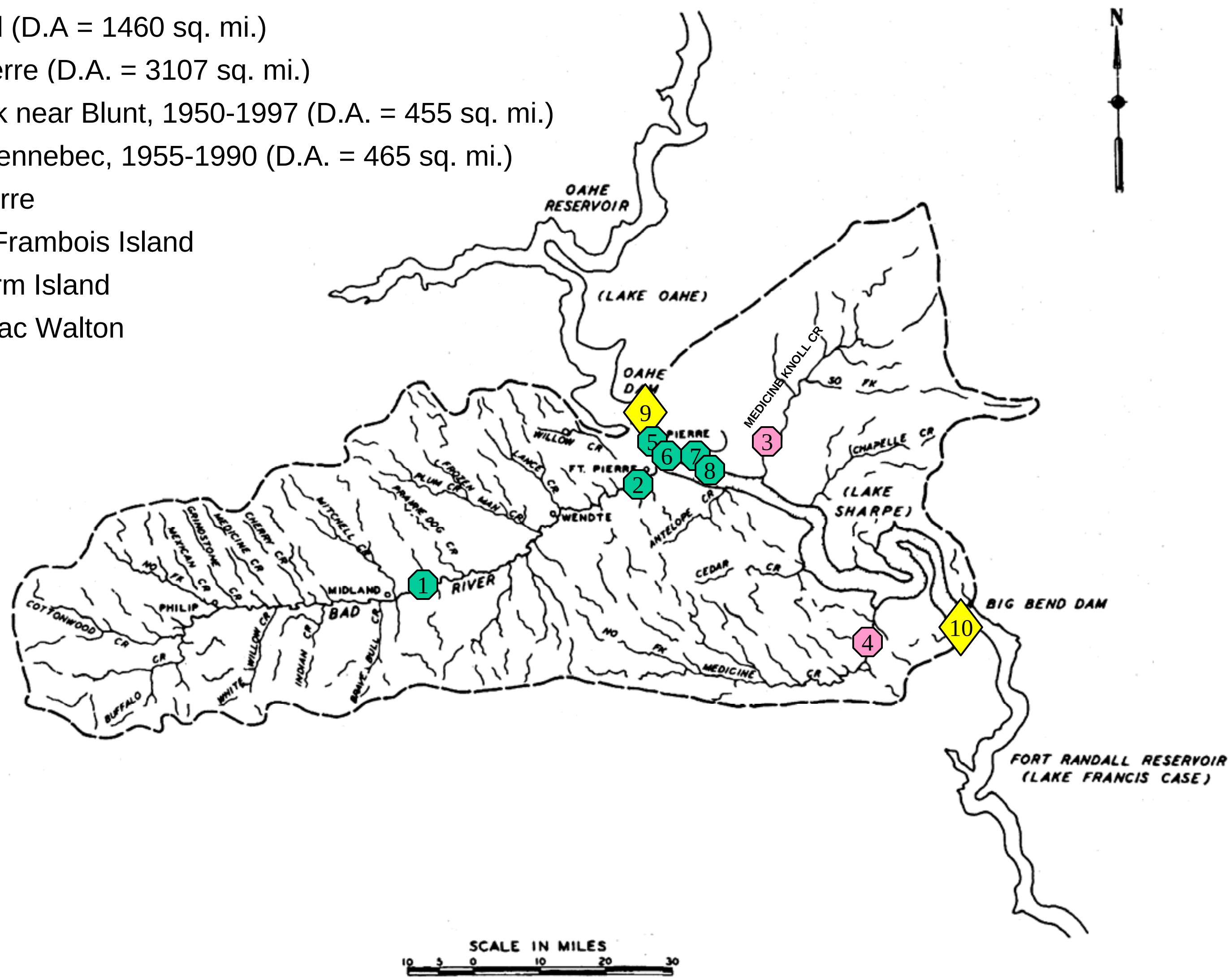
6 Missouri River at LaFrambois Island

7 Missouri River at Farm Island

8 Missouri River at Isaac Walton

9 Oahe Dam

10 Big Bend Dam

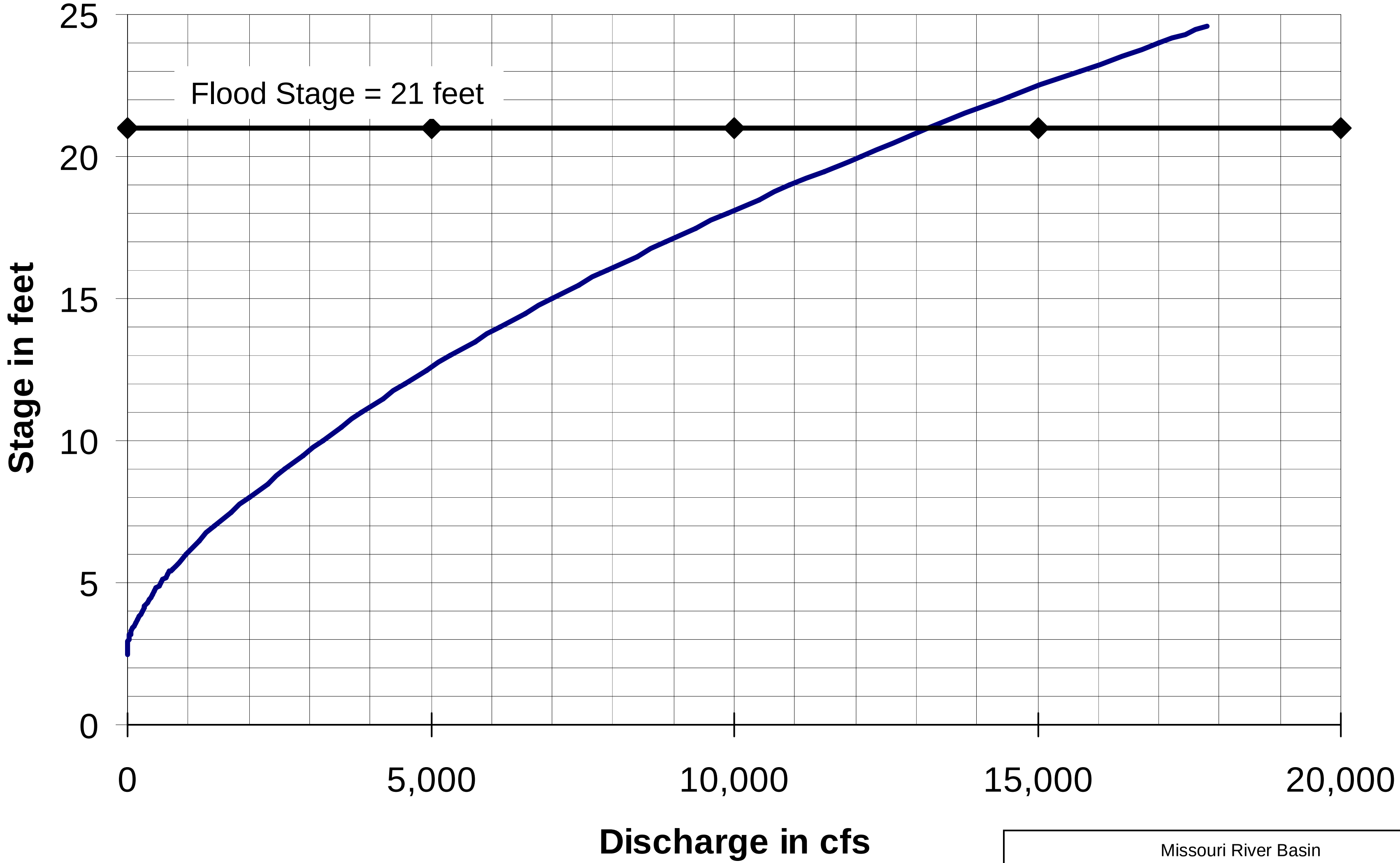


Missouri River Basin

Big Bend Water Control Manual
Stream and Reservoir Gaging Stations

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

Rating Curve - Bad River at Fort Pierre, SD

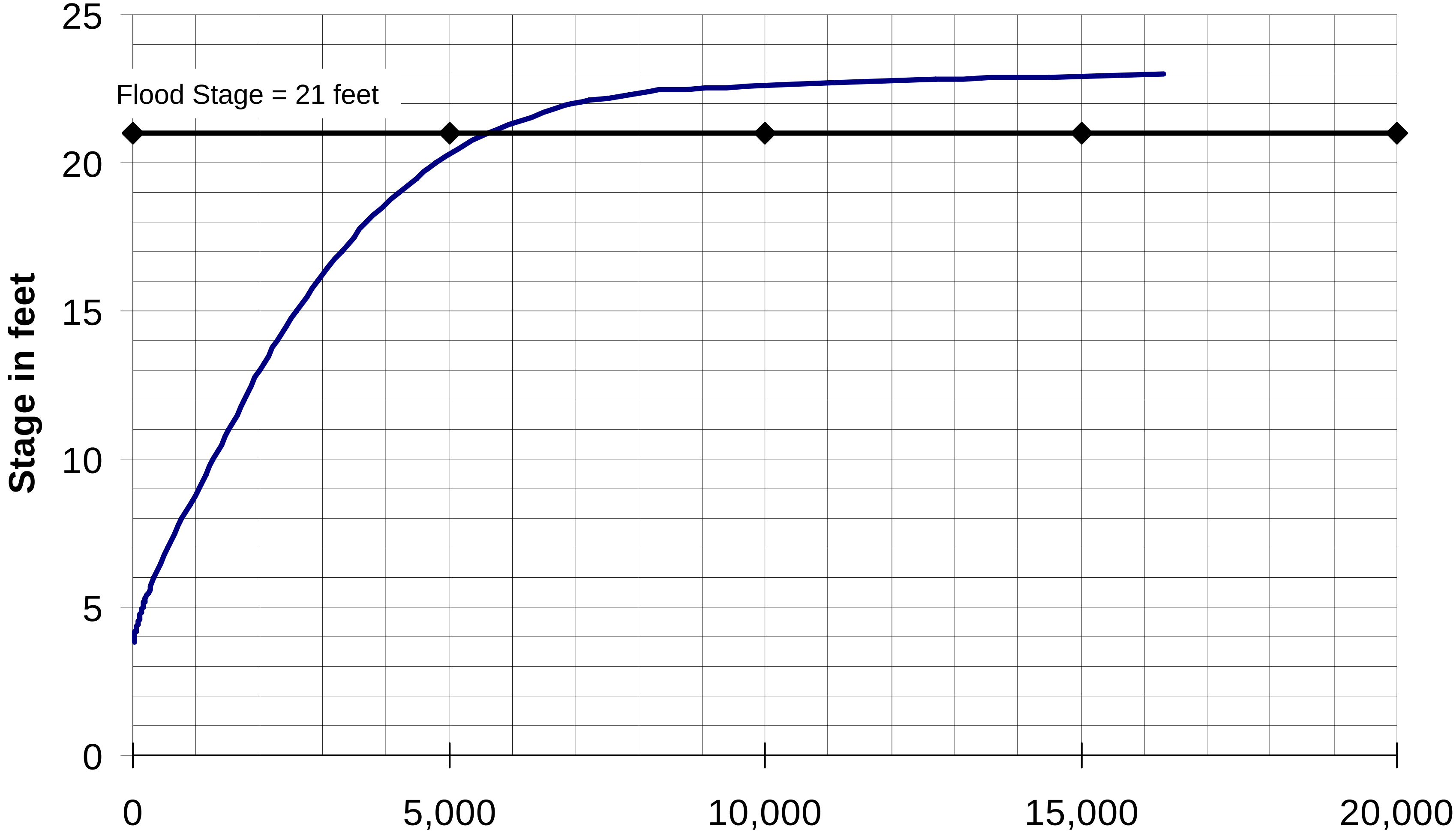


Datum of gage is 1427.83 feet above sea level NGVD29.

Missouri River Basin
Big Bend Water Control Manual
Rating Curve – Bad River at Fort Pierre, SD

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

Rating Curve - Bad River at Midland, SD



Datum of gage is 1849.14 feet above sea level NGVD29.

Missouri River Basin
Big Bend Water Control Manual
Rating Curve – Bad River at Midland, SD

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

Reservoir Elevation Corrections at Big Bend to Allow for Wind Effects

(True Elevation = Reported Pool Elevation* + Correction)

Wind Speed in Miles Per Hour

Wind Direction	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70
360	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.5	-0.7	-1.0	-1.3	-1.6	-1.9
10	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-0.9	-1.1
20	-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
30	-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
40	+0.0	+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
50	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.7	+0.8	+1.0	+1.2	+1.5	+1.7
60	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+1.0	+1.3	+1.5	+1.8	+2.0	+2.3
70	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.0	+1.3	+1.6	+1.9	+2.2	+2.6	+3.0
80	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.5	+1.9	+2.2	+2.6	+3.1	+3.5
90	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.8	+1.1	+1.4	+1.7	+2.1	+2.5	+2.9	+3.4	+3.9
100	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.5	+1.9	+2.3	+2.7	+3.2	+3.7	+4.3
110	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+1.9	+2.3	+2.8	+3.3	+3.9	+4.4
120	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+2.0	+2.4	+2.8	+3.4	+3.9	+4.5
130	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.9	+1.2	+1.6	+1.9	+2.3	+2.8	+3.3	+3.9	+4.4
140	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.1	+1.5	+1.9	+2.3	+2.7	+3.2	+3.7	+4.3
150	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.8	+1.1	+1.4	+1.7	+2.1	+2.5	+2.9	+3.4	+3.9
160	+0.0	+0.0	+0.1	+0.2	+0.3	+0.5	+0.7	+0.9	+1.2	+1.5	+1.9	+2.2	+2.6	+3.1	+3.5
170	+0.0	+0.0	+0.0	+0.1	+0.2	+0.4	+0.6	+0.8	+1.0	+1.3	+1.6	+1.9	+2.2	+2.6	+3.0
180	+0.0	+0.0	+0.0	+0.1	+0.2	+0.3	+0.4	+0.6	+0.8	+1.0	+1.3	+1.5	+1.8	+2.0	+2.3
190	+0.0	+0.0	+0.0	+0.1	+0.1	+0.2	+0.3	+0.4	+0.5	+0.7	+0.8	+1.0	+1.2	+1.5	+1.7
200	+0.0	+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
210	-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
220	-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
230	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.4	-0.6	-0.7	-0.9	-1.1
240	-0.0	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.2	-0.3	-0.5	-0.7	-1.0	-1.3	-1.6	-1.9
250	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.4	-1.8	-2.2	-2.6
260	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.4	-1.8	-2.3	-2.7	-3.1
270	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.6	-0.9	-1.2	-1.6	-2.1	-2.6	-3.0	-3.5
280	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.6	-1.0	-1.4	-1.8	-2.3	-2.8	-3.3	-3.8
290	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.7	-1.1	-1.5	-1.9	-2.5	-2.9	-3.5	-4.0
300	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.7	-1.1	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0
310	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.7	-1.1	-1.5	-1.9	-2.5	-2.9	-3.5	-4.0
320	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.4	-0.6	-1.0	-1.4	-1.8	-2.3	-2.8	-3.3	-3.8
330	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.6	-0.9	-1.2	-1.6	-2.1	-2.6	-3.0	-3.5
340	-0.0	-0.0	-0.0	-0.1	-0.1	-0.2	-0.3	-0.5	-0.7	-1.0	-1.4	-1.8	-2.3	-2.7	-3.1
350	-0.0	-0.0	-0.0	-0.0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.4	-1.8	-2.2	-2.6

Reservoir Elevation Wind Corrections in Feet

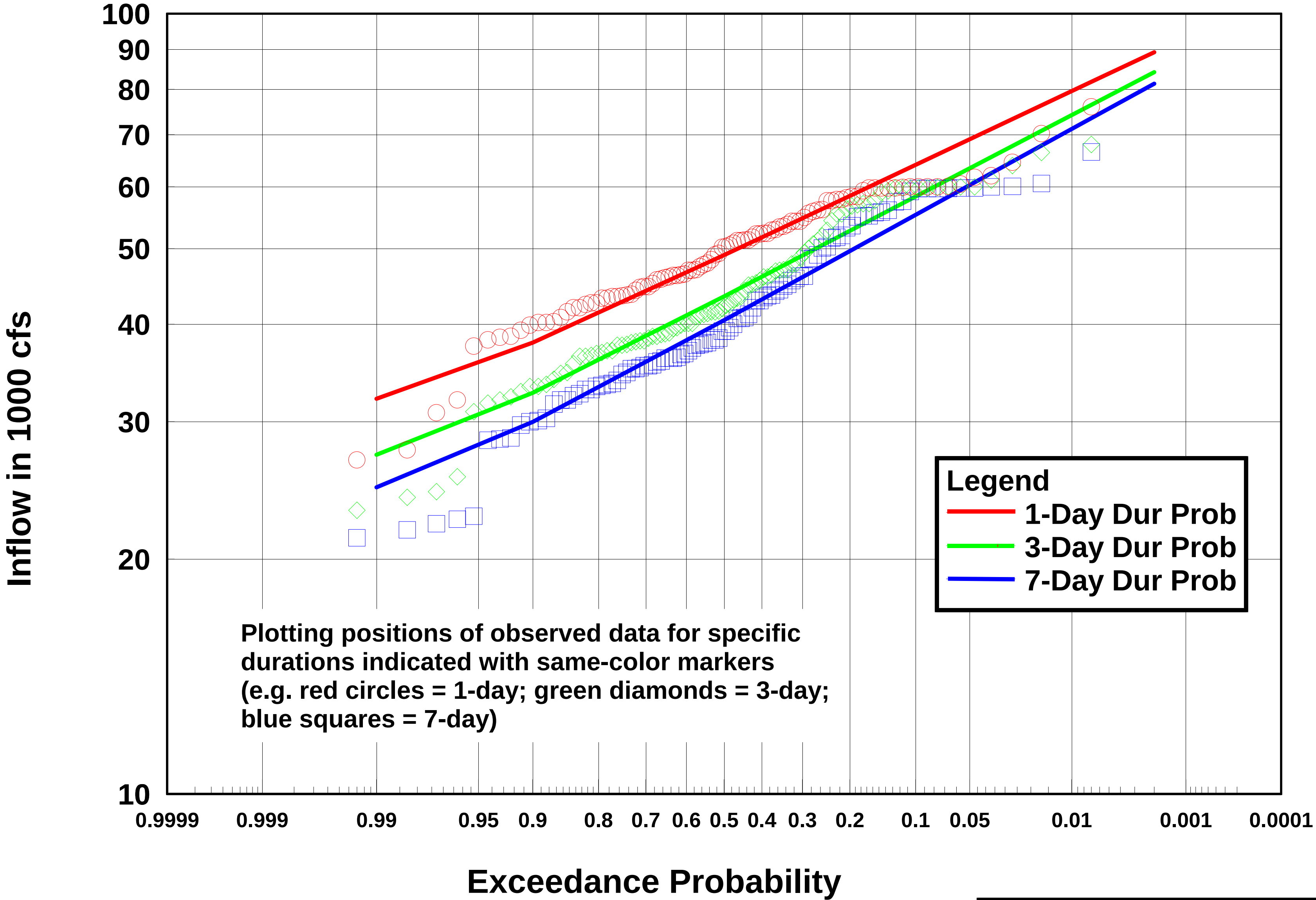
*** Pool elevation as measured at the dam.**

Missouri River Basin
Big Bend Water Control Manual
Reservoir Elevation Wind Correction Table

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Plate VI-3

Big Bend - Regulated Inflows

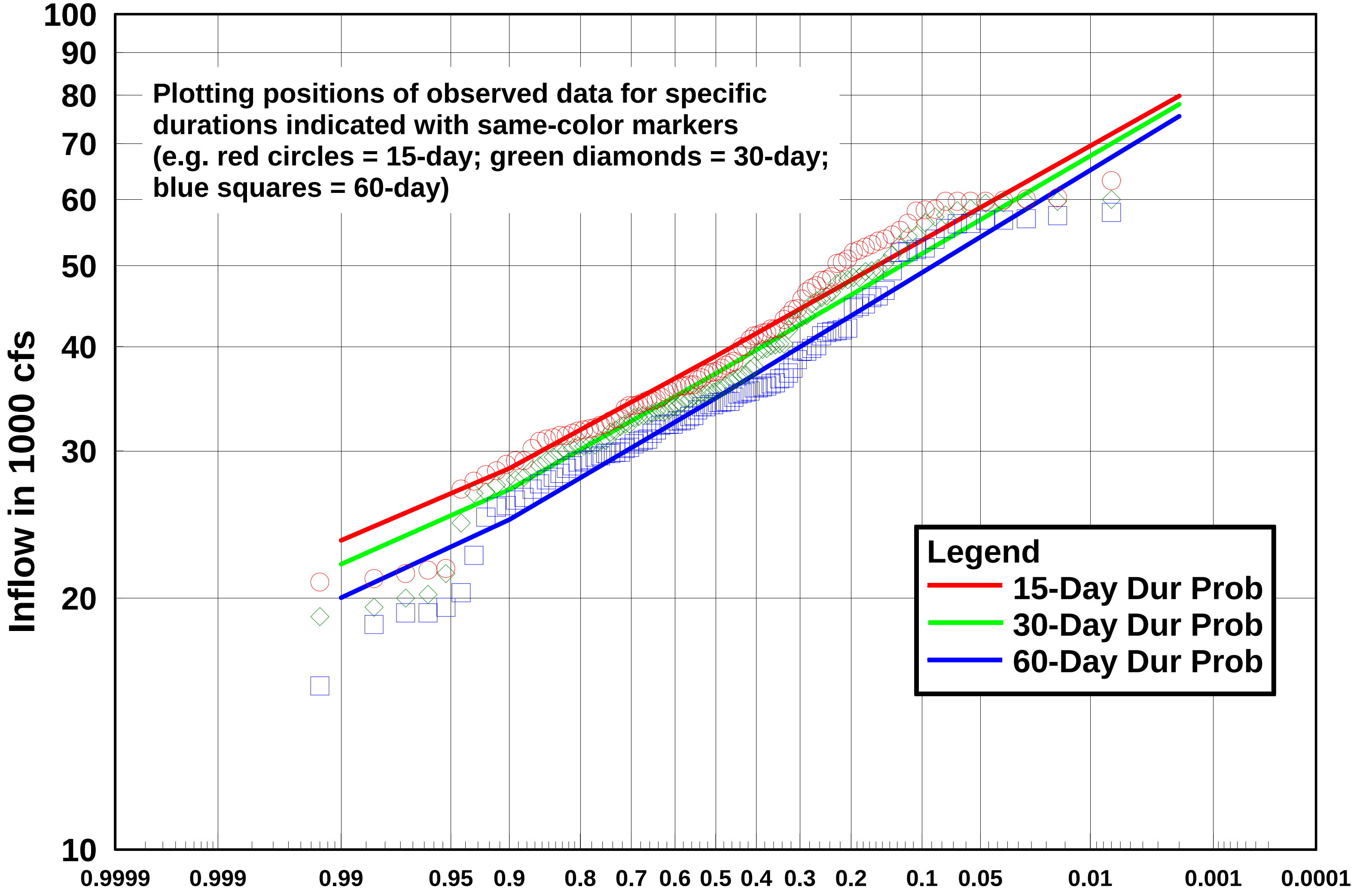


Note:
Regulated Inflows = Incremental Inflows + Oahe Releases

Missouri River Basin
Big Bend Water Control Manual
Regulated Inflow Volume Probabilities for 1-, 3- and 7-Day Durations

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Big Bend - Regulated Inflows



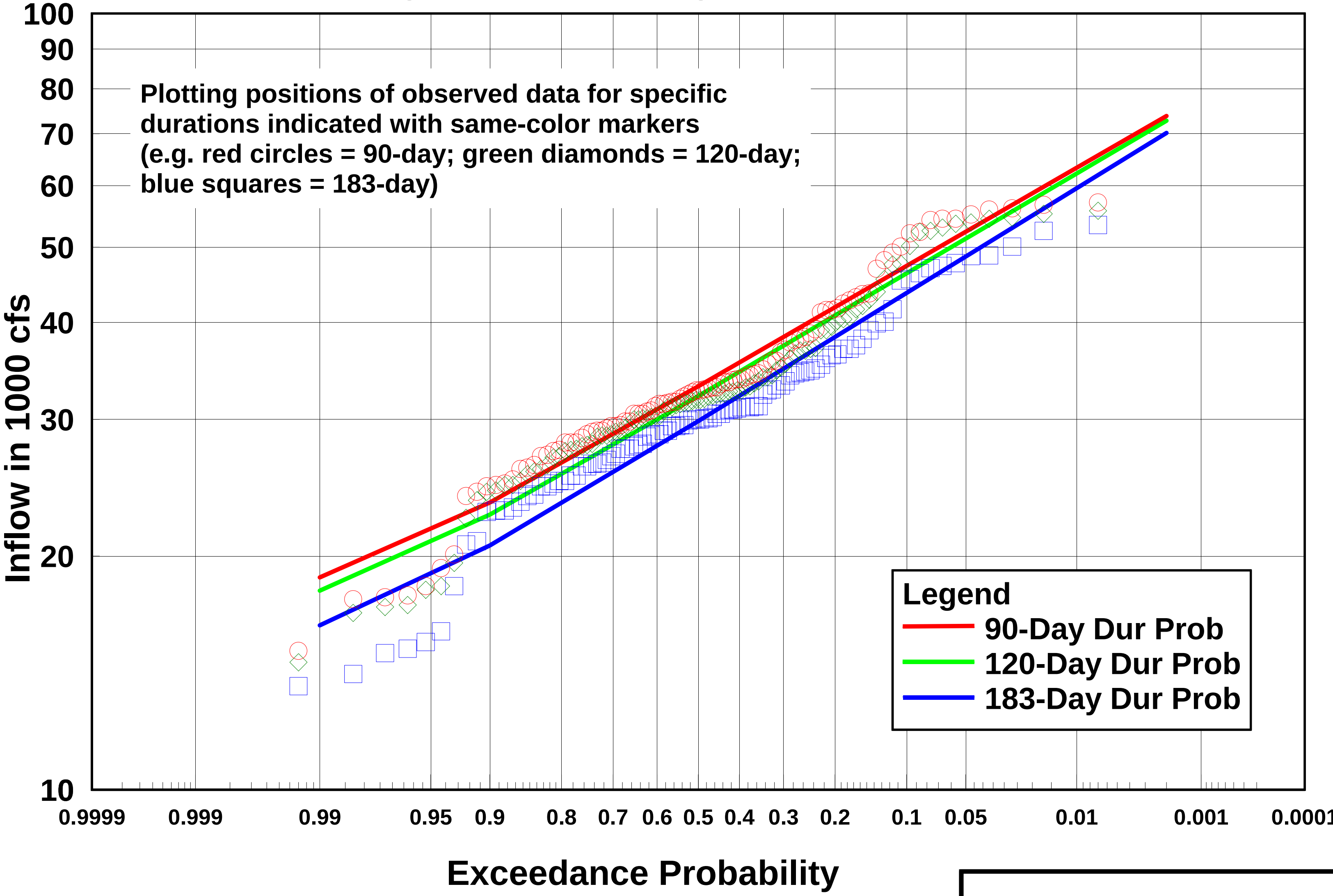
Exceedance Probability

Note:
Regulated Inflows = Incremental Inflows + Oahe Releases

Missouri River Basin
Big Bend Water Control Manual
Regulated Inflow Volume Probabilities for 15-, 30- and 60-Day Durations

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

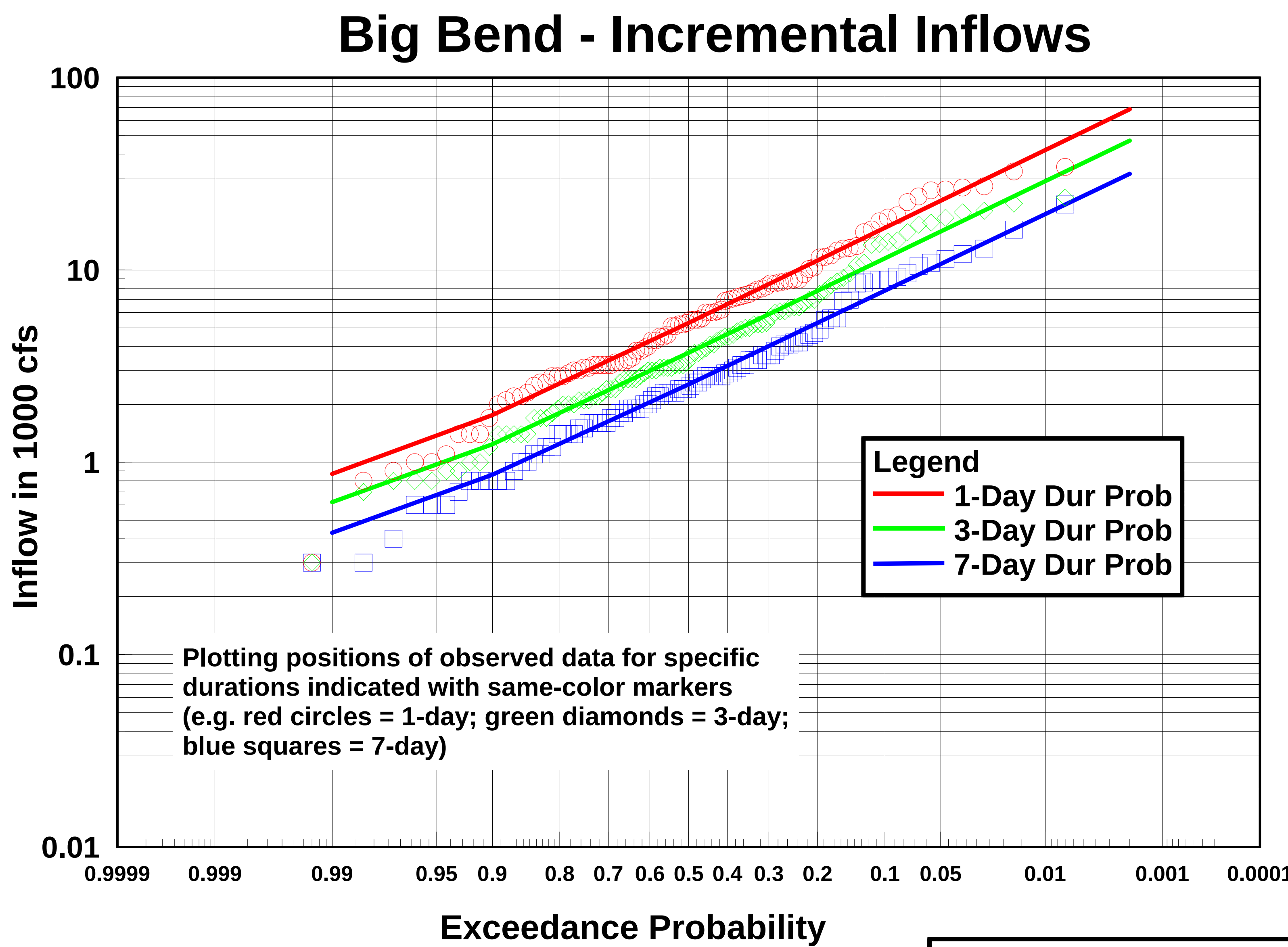
Big Bend - Regulated Inflows



Note:
Regulated Inflows = Incremental Inflows + Oahe Releases

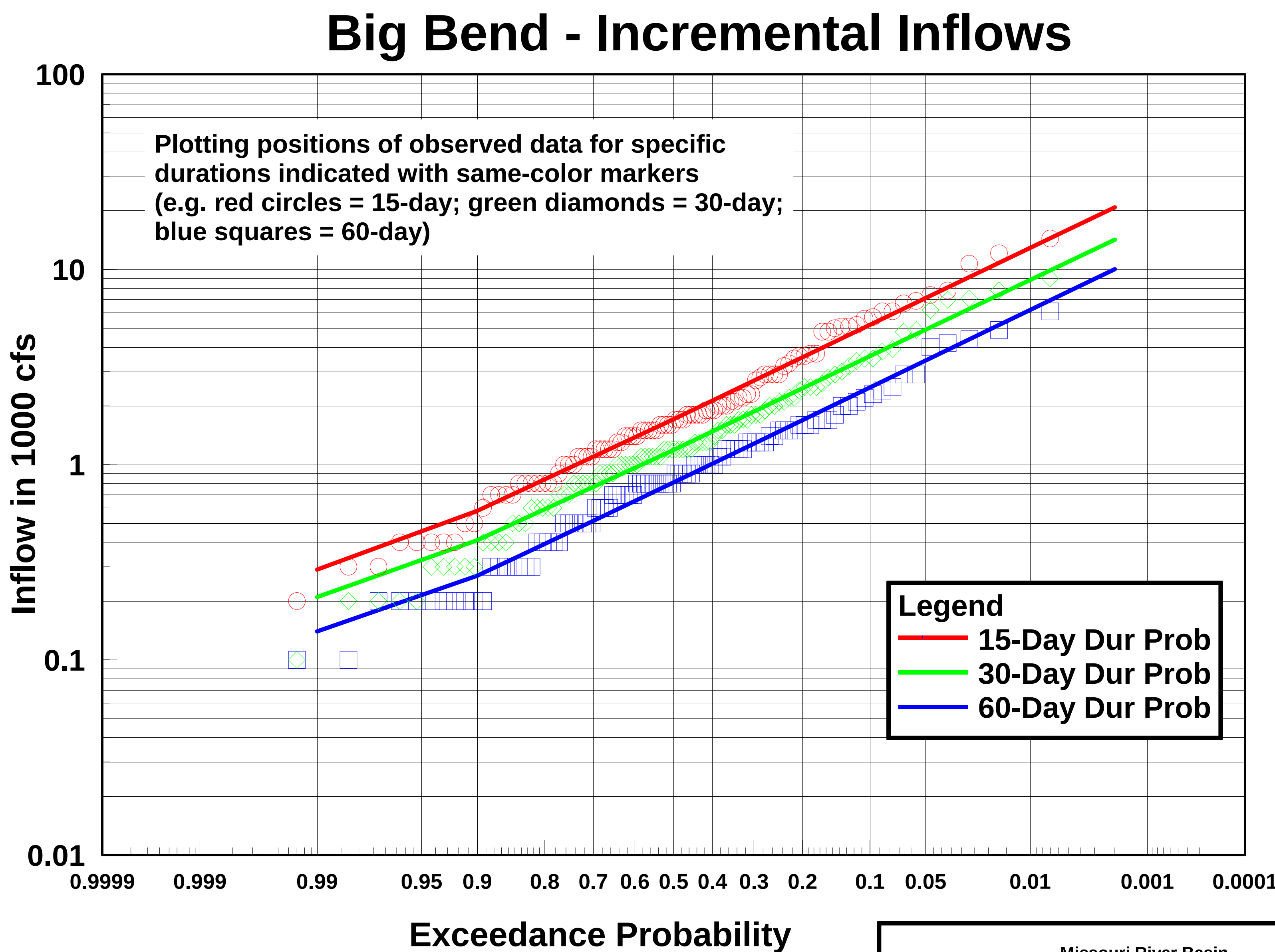
Missouri River Basin
Big Bend Water Control Manual
Regulated Inflow Volume Probabilities for
90-, 120- and 183-Day Durations

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007



Missouri River Basin
Big Bend Water Control Manual
Incremental Inflow Volume Probabilities for 1-, 3- and 7-Day Durations

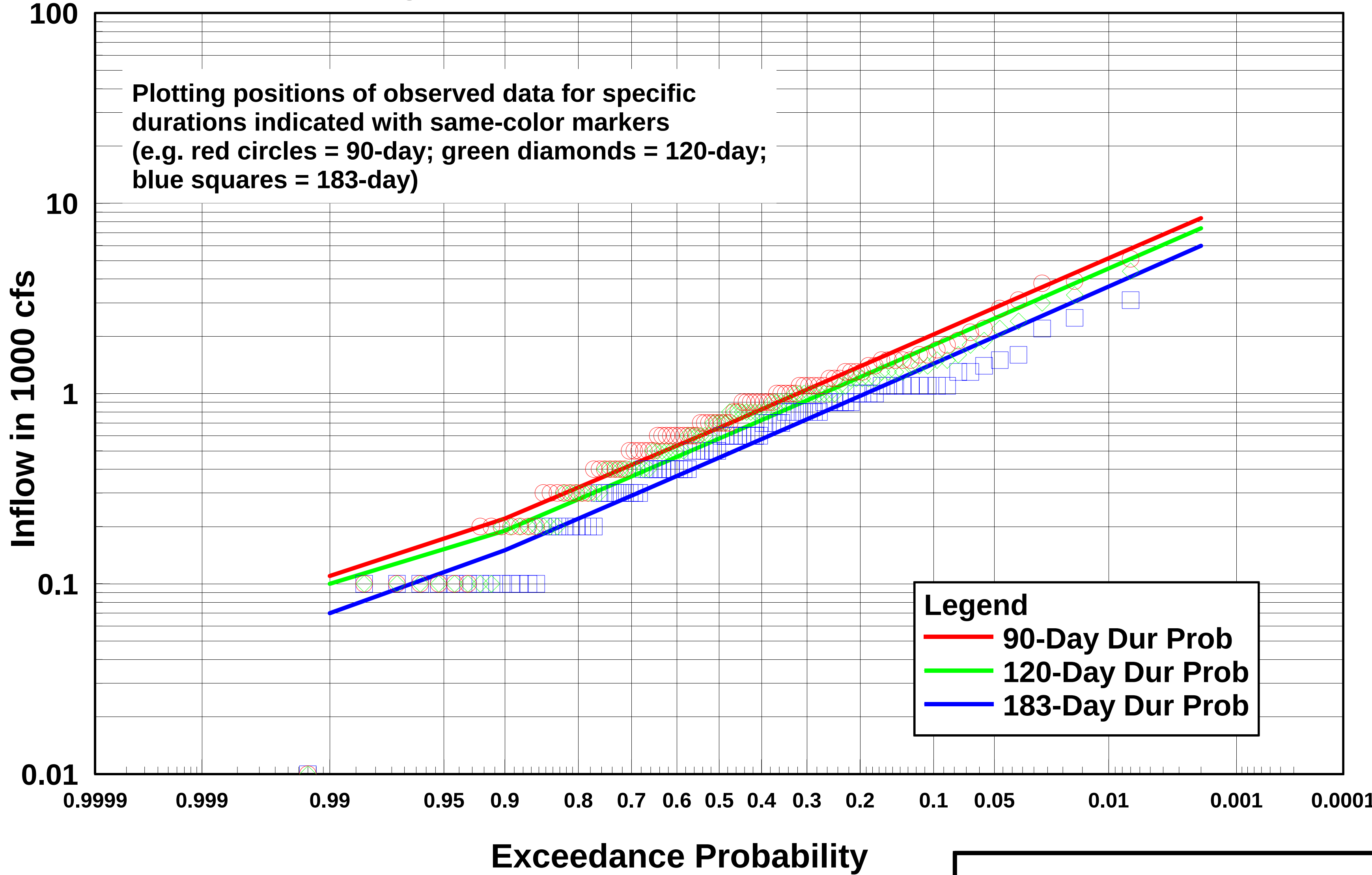
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007



Missouri River Basin
Big Bend Water Control Manual
Incremental Inflow Volume Probabilities for 15-, 30- and 45-Day Durations

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

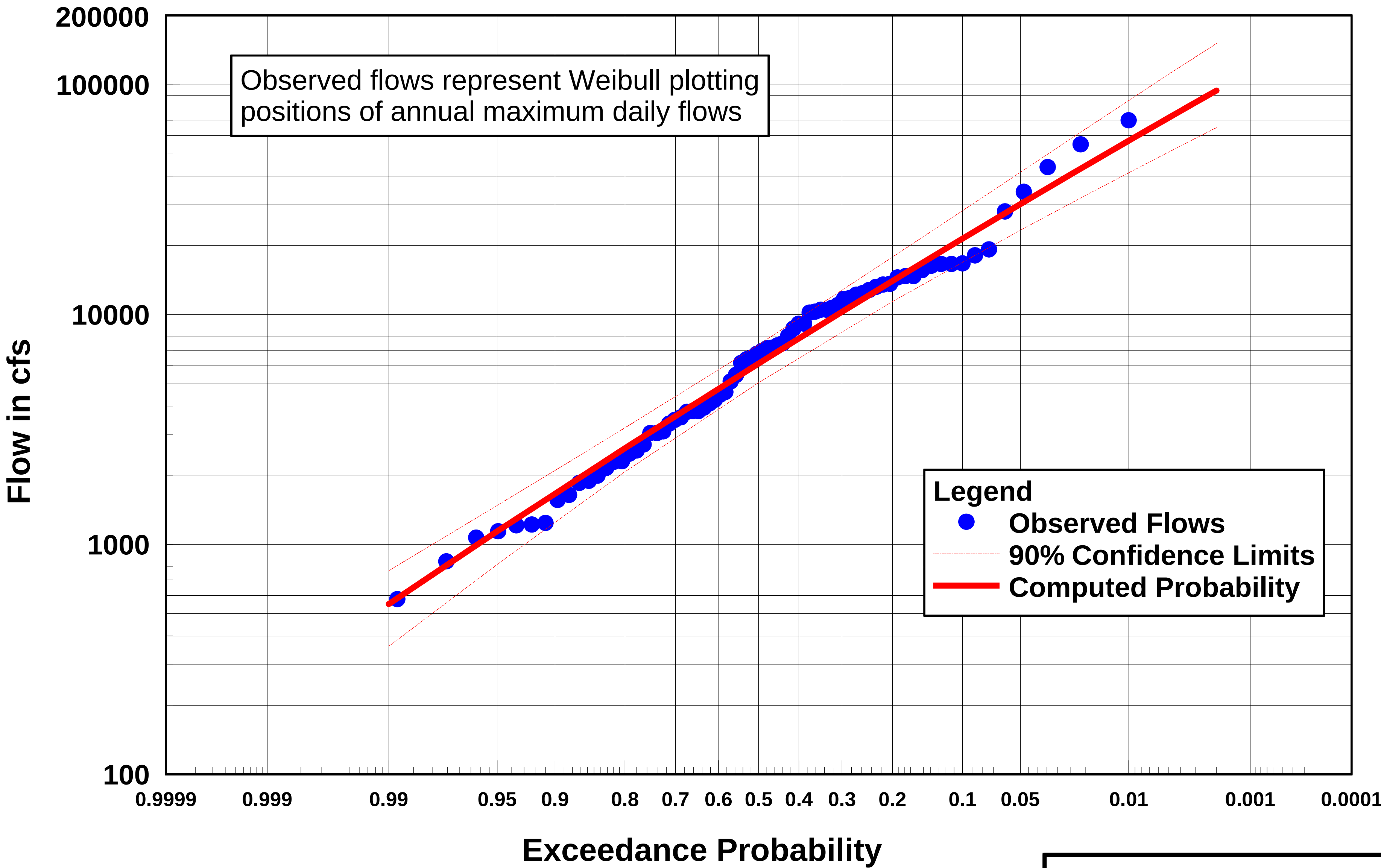
Big Bend - Incremental Inflows



Missouri River Basin
Big Bend Water Control Manual
Incremental Inflow Volume Probabilities for 90-, 120- and 183-Day Durations

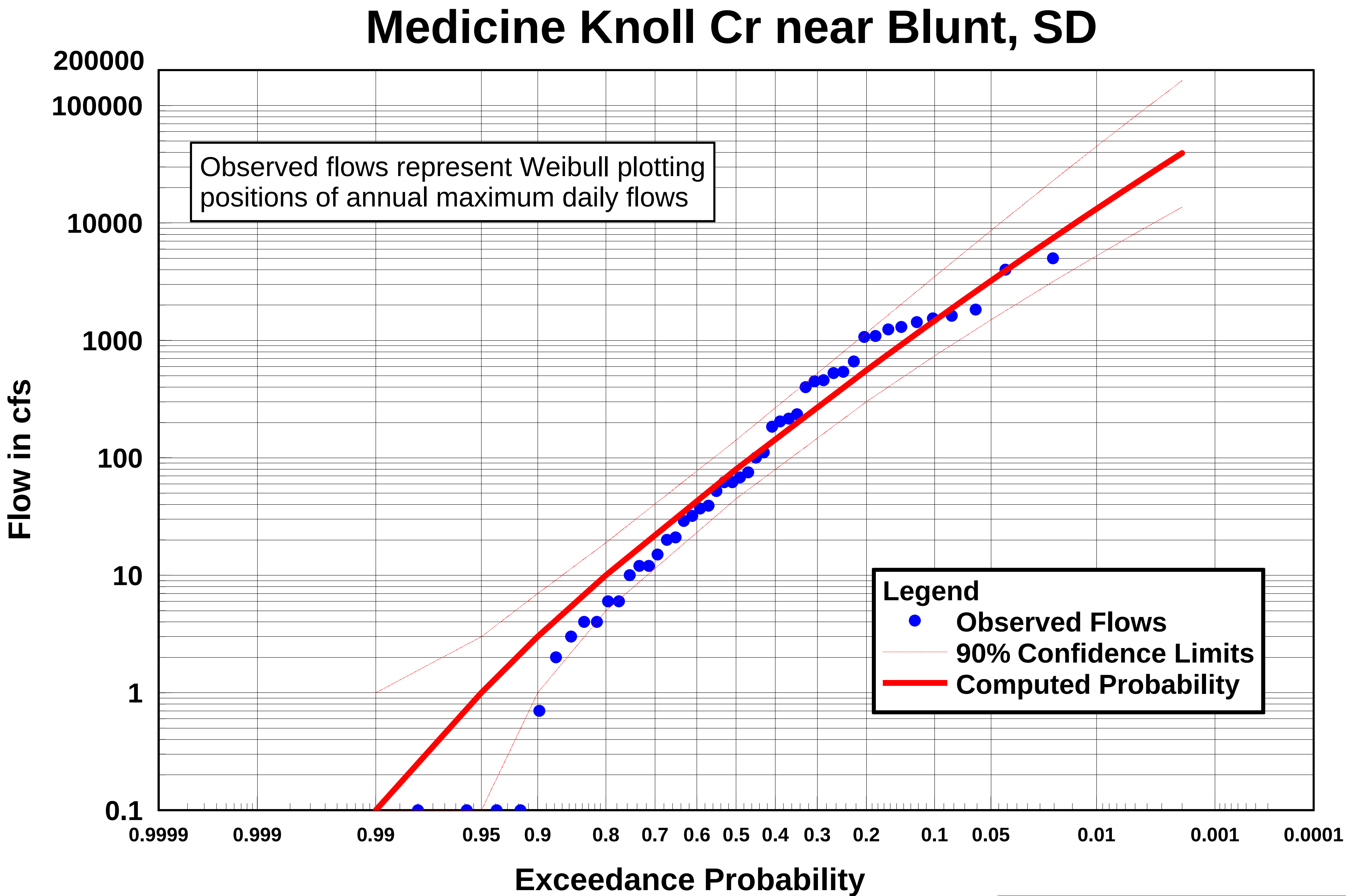
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Bad River near Fort Pierre, SD



Missouri River Basin
Big Bend Water Control Manual
Bad River near Fort Pierre, SD
Probability Curve

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

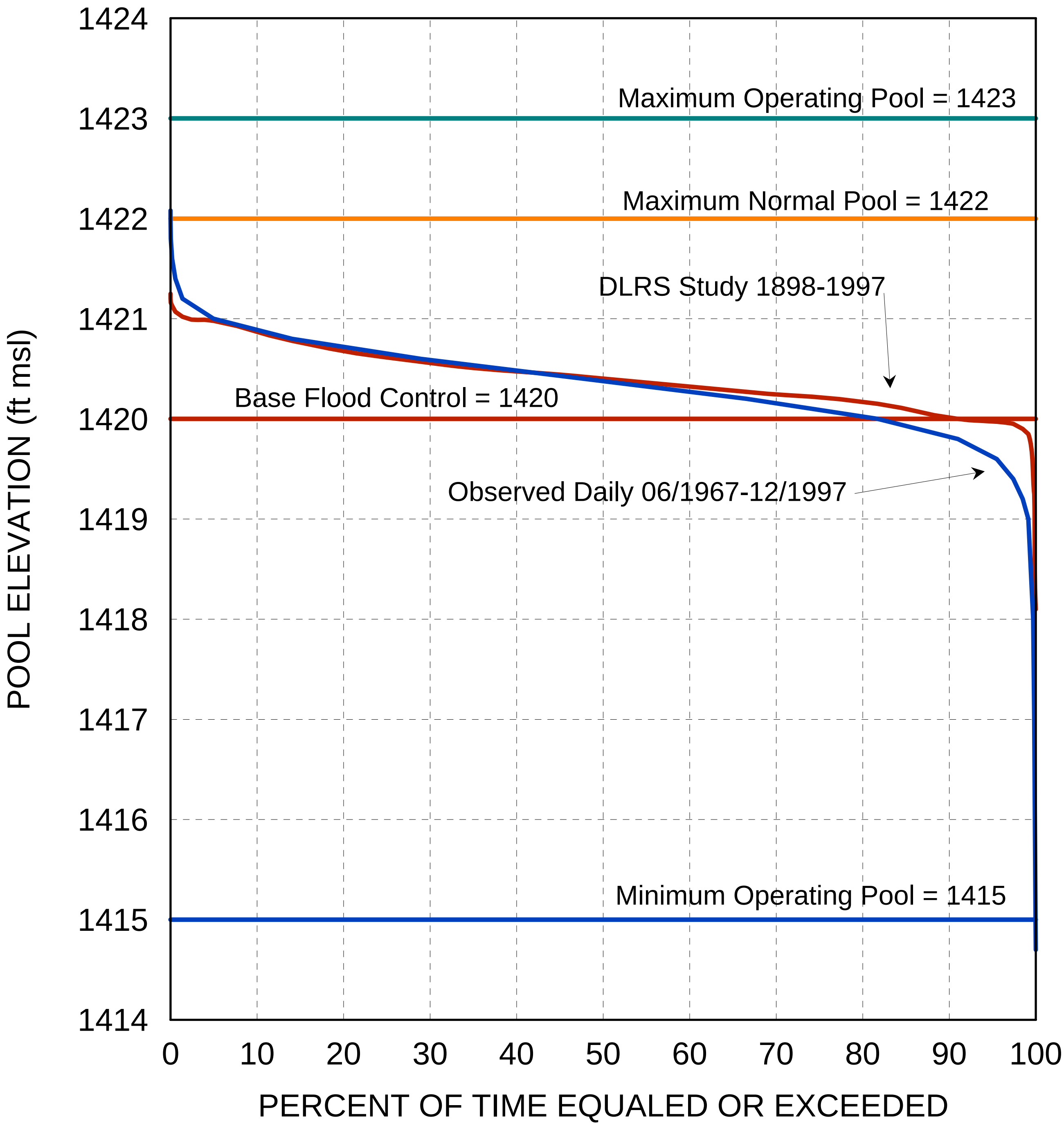


Missouri River Basin
Big Bend Water Control Manual
Medicine Knoll Cr near Blunt, SD
Probability Curve

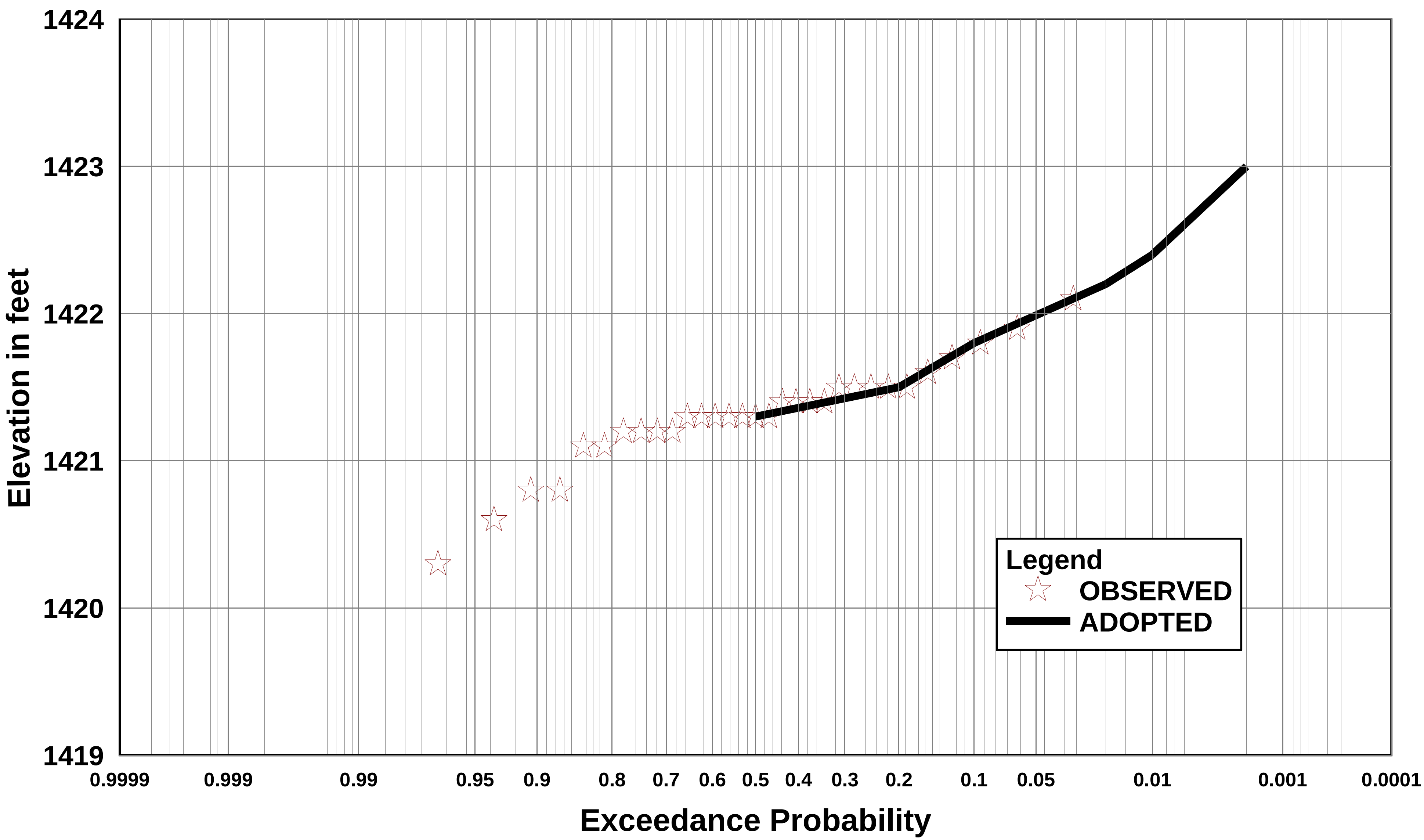
U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Big Bend - Lake Sharpe

POOL DURATION RELATIONSHIP

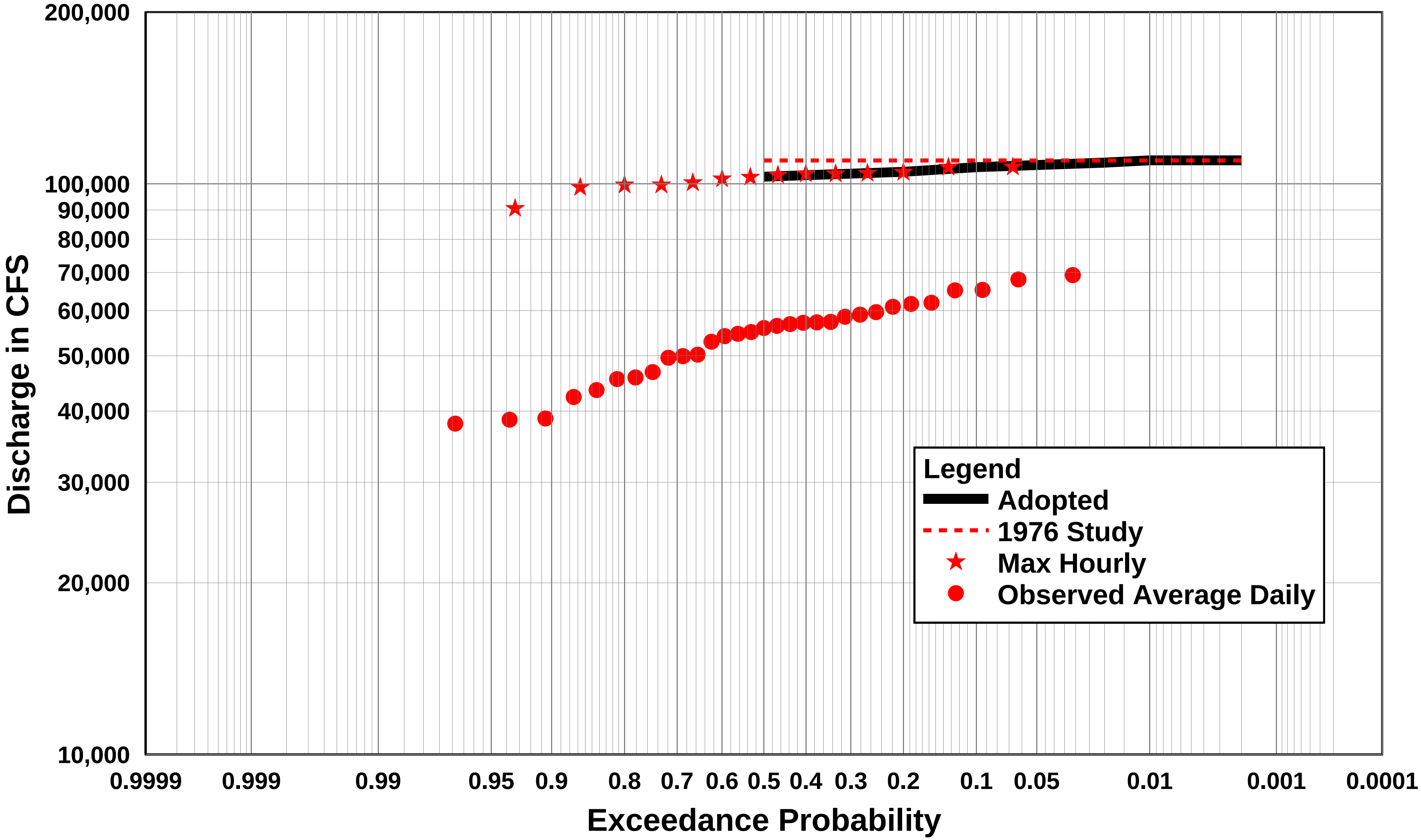


Missouri River Basin
Big Bend Water Control Manual
Reservoir Pool Duration
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007



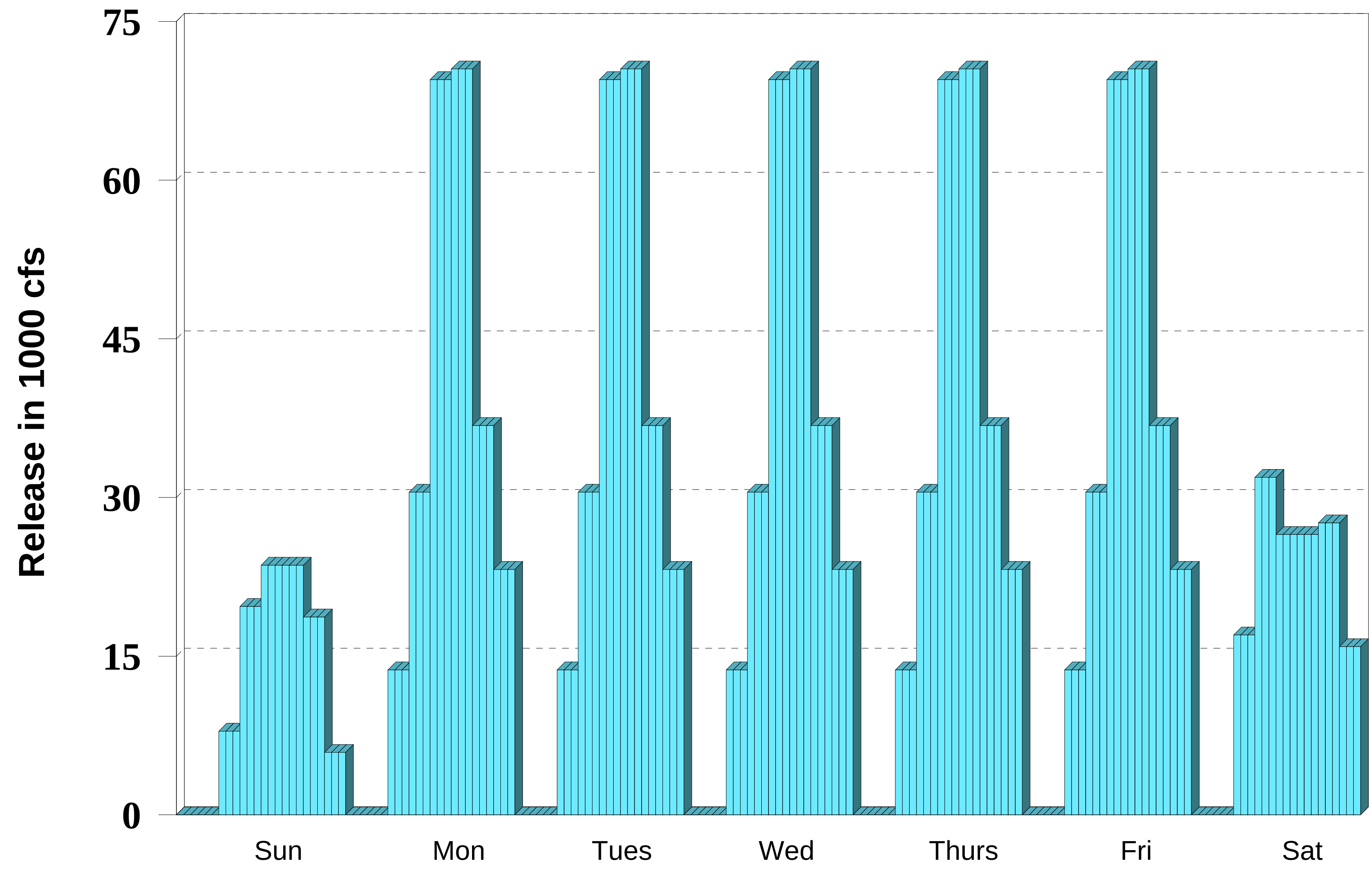
Missouri River Basin
Big Bend Water Control Manual
Big Bend Reservoir - Lake Sharpe
Pool Probablity Relationship

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007



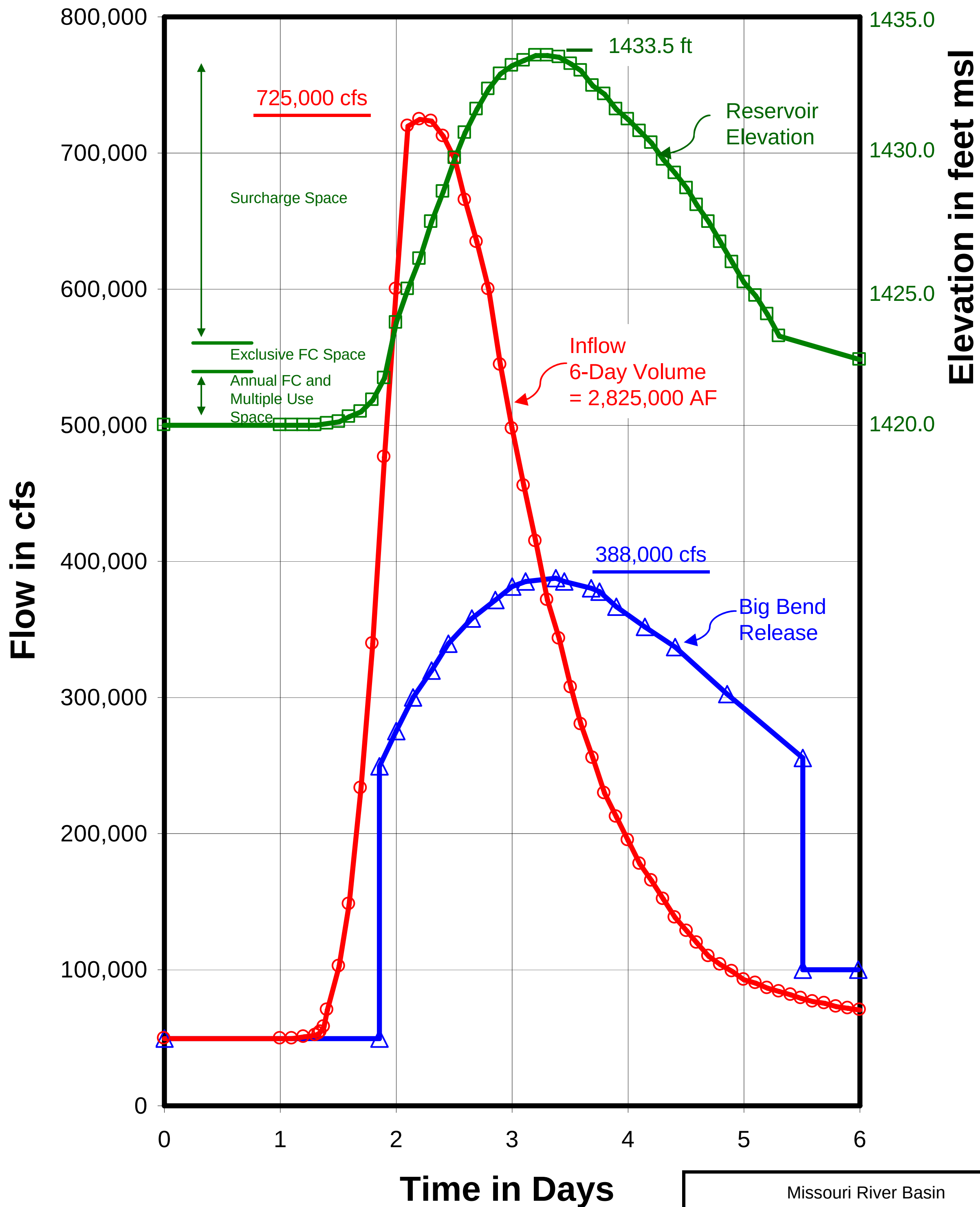
Missouri River Basin
Big Bend Water Control Manual
Big Bend Dam and Reservoir
Release Probablity Relationship

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007



Missouri River Basin
Big Bend Water Control Manual
Typical Weekly Release Pattern

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

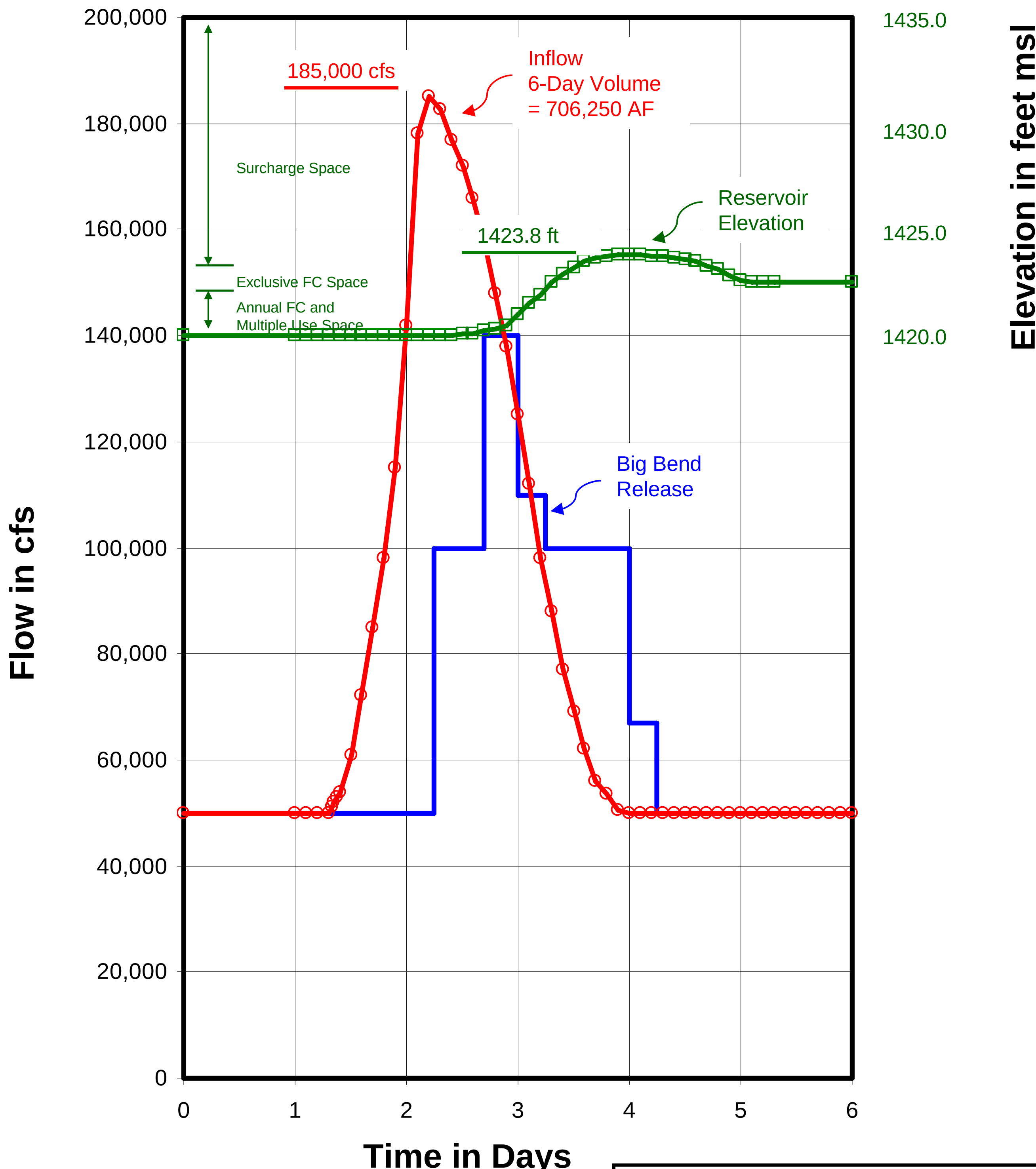


Note: Routing assumes 50,000 cfs release from Oahe Dam over the 6-day period.

Missouri River Basin
Big Bend Water Control Manual
Spillway Design Flood Routing

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Plate VII-2



Note: Routing assumes 50,000 cfs release from Oahe Dam over the 6-day period.

Missouri River Basin

Big Bend Water Control Manual

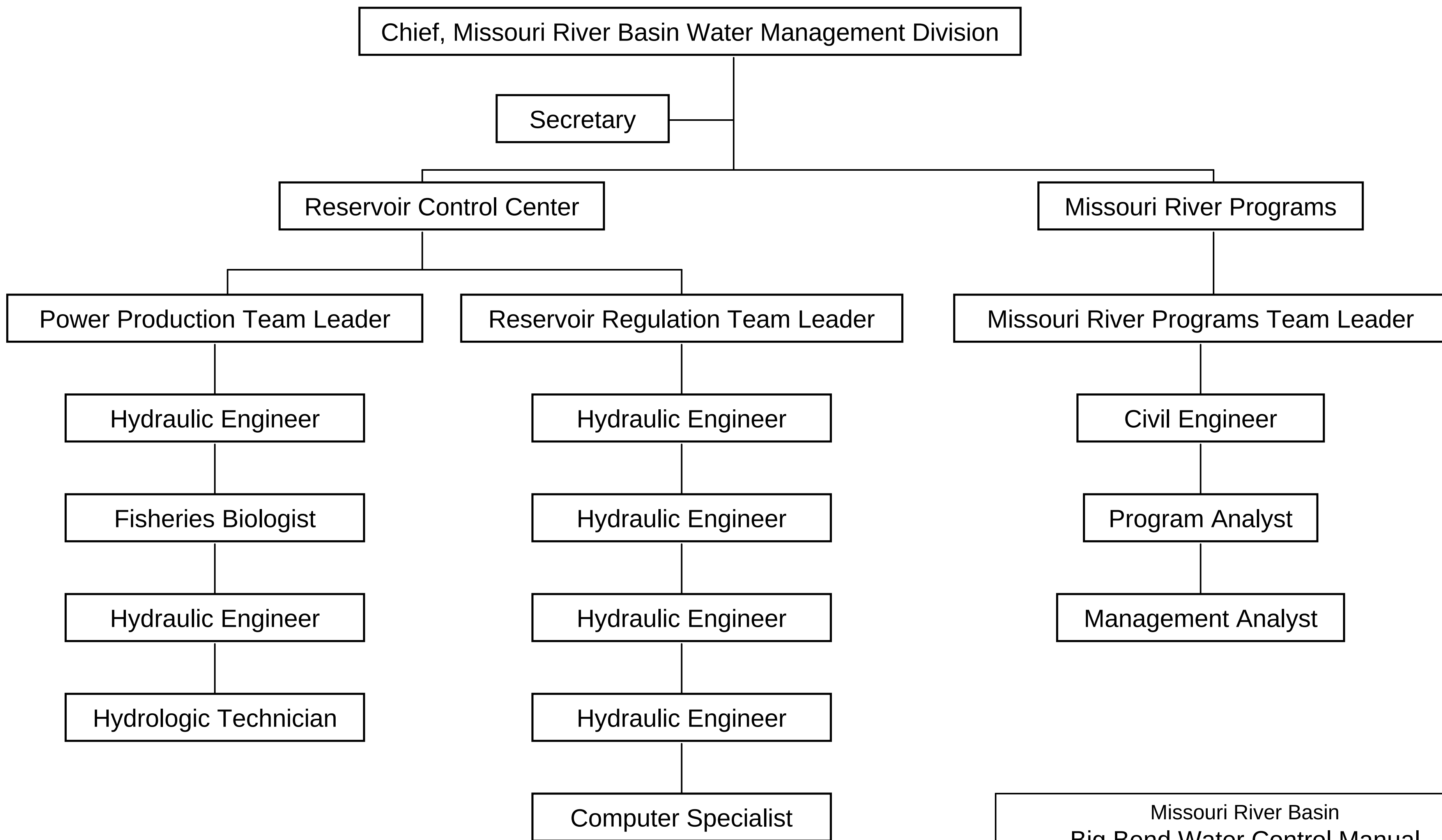
One-Quarter Spillway Design Flood Routing

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007

Plate VII-3

NWD-Omaha

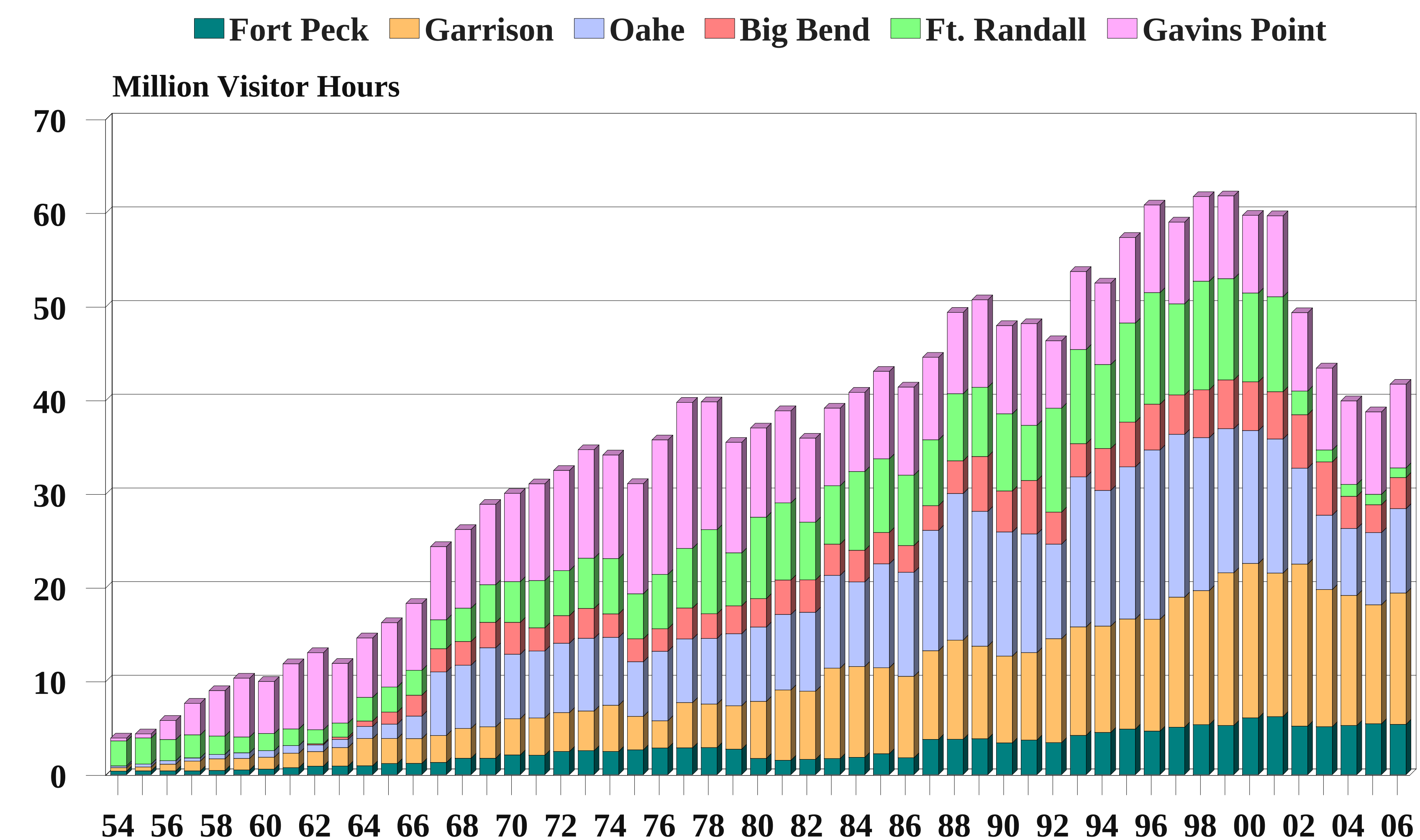
Missouri River Basin Water Management Division



Missouri River Basin
Big Bend Water Control Manual
Water Management Organization Chart

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
April 2007

System Project Visits
1954 to 2006



1954 through 1988 data in Calendar Years
1989 to 1991 in Fiscal Years
1992 to present in VERS System
2002 to present reflect changed accounting due to Title VI land transfer to State of South Dakota

Missouri River Basin
Big Bend Water Control Manual
Mainstem Project Visitation

U.S. Army Engineer Division, Northwestern
Corps of Engineers, Omaha, Nebraska
April 2007