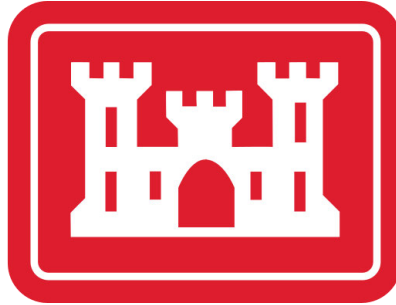


Interim Water Control Manual

Big Sandy Lake Dam and Reservoir

Mississippi River Headwaters Project



U.S. Army Corps of Engineers
St. Paul District
St. Paul, Minnesota



December 21, 2020

FOR OFFICIAL USE ONLY

RECORD OF CHANGES

- April 1963 – Master Reservoir Regulation Manual
- February 1968 – Revised Master Reservoir Regulation Manual
- January 2003 – Water Control Manual, Big Sandy Lake Dam and Reservoir
- December 2020 – Interim Water Control Manual, Big Sandy Lake Dam and Reservoir

NOTICE TO USERS OF THIS MANUAL

Regulations specify that this Water Control Manual be published in digital form in the central repository located at the following link:

<https://maps.crrel.usace.army.mil/apex/f?p=875>

The Water Control Manual at the central repository will be considered the official manual and will be kept current at all times. Also please note that USACE Corporate Information may move the central repository link to a new location.



EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise during normal business hours, contact Water Management by telephone at 651-290-5693. During non-duty hours, assistance can be obtained by contacting one of the following persons, in the order listed below.

Water Management Regulation Assistance		
Brian Johnson, PE	Hydraulic Engineer, Mississippi River Headwaters Regulator, Brian.Ke.Johnson@usace.army.mil	651-290-5652 [REDACTED]
Elizabeth Nelsen, PE	Chief, Water Management Section Elizabeth.A.Nelsen@usace.army.mil	651-290-5306 [REDACTED]
Mike Knoff, PE	Chief, Hydraulics & Hydrology Branch Michael.R.Knoff@usace.army.mil	651-290-5600
Michael Bart, PE	Chief, Engineering & Construction Division Michael.J.Bart@usace.army.mil	651-290-5303
Emergency Operations Center	24 Hour Line	651-290-5210

Other Emergency Contacts		
Point of Contact	Business Hours	After Hours
Aitkin County Emergency Management Aitkin County Sheriff	1-218-927-7420 1-218-927-7417	218-927-2138
Emergency Operations Center Mississippi Valley Division U.S. Army Corps of Engineers	1-601-634-5026	---
North Central River Forecast Center National Weather Service, Duluth, MN	1-952-361-6650 1-218-729-0651	---
Homeland Security and Emergency Mgmt. Minnesota Department of Public Safety	1-651-201-7400	24 Hours

Project Office Points of Contact		
Tammy Frauenshuh, Site Manager	Big Sandy Lake Dam 22205 531 st Lane McGregor, MN 55760	651-290-5845
Courtney Kinnett, Park Ranger	Big Sandy Lake Dam 22205 531 st Lane McGregor, MN 55760	651-290-5846
Jeff Steere, Supervisory Park Ranger	Northern Headwaters Project Office Pokegama Lake Dam 34385 Hwy 2 West Grand Rapids, MN 55744	651-290-5808

Interim Water Control Manual
Big Sandy Lake Dam and Reservoir
Mississippi River Headwaters Project

U.S. Army Corps of Engineers
St. Paul District

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Pertinent Data

(also see Appendix A)

Project Location: Big Sandy Lake Dam is on the Sandy River near Libby, Minnesota, 1.2 miles upstream of the confluence with the Mississippi River. The confluence is at river mile 1105.6 above the Ohio River. The dam is 14 miles north of McGregor, Minnesota in Aitkin County. It is at Lat. 46° 47' 20", Long. 93° 19' 10", in Section 25, T50 N, R24 W.

Drainage Area: 421 square miles

Datum and Conversion: All elevations use the 1929 National Geodetic Vertical Datum (1929 NGVD) unless otherwise stated. To convert to the 1988 North American Vertical Datum NAVD 88, use the following: 1929 NGVD + 0.69 feet = NAVD 88.

Embankment Type:	Earth Fill with timber diaphragm
Embankment Length:	1,586 feet (total, left and right)
Embankment Height:	20.5 feet
Embankment Top Width:	22 feet

	Elevation (feet)	Capacity (acre-feet)	Area (acres)
Big Sandy Reservoir			
Gate Sill	1207.31	--	--
Min. Operating Limit/Winter Drawdown	1214.31	44,000	8,100
Normal Summer Pool Level	1216.31	62,000	9,400
Max. Operating Limit	1218.31	82,000	10,700
Top of Dam	1221.31	118,000	12,900

1 Introduction

1-01 Authorization for Manual

This manual was prepared in compliance with the following:

- a. Engineering Manual 1110-2-3600 titled "Management of Water Control Systems" dated 10 October 2017;
- b. Engineering Regulation 1110-2-240 titled "Water Control Management" dated 30 May 2016;
- c. Engineering Regulation 1110-2-8156 titled "Preparation of Water Control Manuals" dated 30 September 2018;
- d. 33 CFR 208.11;
- e. 33 CFR 222.5.

This manual supersedes the previous manual dated January 2003 which superseded the previous manual dated 1963. It incorporates changes to the water control plan in accordance with the rehabilitation of the Big Sandy Lake Dam structure.

1-02 Purpose and Scope

The purpose of this manual is to provide guidance and instruction for project personnel and to serve as a reference for others who may be involved with or affected by the regulation of water by this project. The manual is for daily use by project personnel for essentially all foreseeable conditions affecting the project. The scope of this manual covers all water control management activities as they relate to the hydraulic and hydrologic aspects of the project.

1-03 Related Manuals and Reports

Prior reports pertinent to this manual are as follows:

- a. Headwaters Reservoirs Operations Study, Mississippi River, Minnesota, U.S. Army Corps of Engineers, St. Paul District, 29 October 1956 (Flood Control Guide Curve Study for Aitkin, MN).
- b. The Engineer Corps Manages Water: Problems of the Mississippi River and Six Reservoir Lakes, Conservation Volunteer, Minnesota Conservation Department, Robert Bulesmeier, Chief, Reservoir Management Section, St. Paul District, U.S. Army Corps of Engineers, July-August 1957.
- c. The Upper Mississippi River Reservoirs, Gopher Historian, Lucile M. Kane, Manuscripts Curator, Minnesota Historical Society, Spring 1962.
- d. Master Reservoir Regulation Manual, Headwaters Dams and Reservoirs, U.S. Army Engineer District, St. Paul, Corps of Engineers, St. Paul, Minnesota, April 1963.
- e. Multiple Use Survey, Winnibigoshish and Leech Reservoirs, Report prepared by Chippewa National Forest, North Central Region, Milwaukee, Wisconsin, in cooperation with the Corps

of Engineers, United States Department of the Army, (undated, however received by the Corps on 25 August 1965).

- f. Master Reservoir Regulation Manual, Headwaters Dams and Reservoirs, U.S. Army Engineer District, St. Paul, Corps of Engineers, St. Paul, Minnesota, April 1963 (revised 19 February 1968).
- g. Environmental Review of the Headwaters of the Mississippi River Reservoir Projects, Bemidji College, 1973.
- h. Review of Design Features of Existing Dams at Mississippi River Headwaters Reservoirs, RCA ENG CW-(OT)761, St. Paul District, Corps of Engineers, March 1974.
- i. Finding of Fact, Environmental Impacts of Operation and Maintenance Activities, Mississippi Headwaters Reservoirs, North Central Minnesota, Prepared in accordance with paragraph 4b(2) of Engineer Regulation 1105-2-507, Conclusion: an Environmental Impact Statement (EIS) was not required under the provisions of Section 102 of the 1969 National Environmental Policy Act (NEPA), Public Law 91-190, Signed by Colonel Max W. Noah, St. Paul District Commander, U.S. Army Corps of Engineers, 18 April 1975.
- j. Mississippi River Headwaters - Master Plan for Public Use Development, St. Paul District, Corps of Engineers, August 1977.
- k. Effect of Different Operating Plans for the Six Mississippi River Headwaters Dams, Saint Anthony Falls Hydraulic Laboratory Project Report No. 184, University of Minnesota, 1979.
- l. Creativity, Conflict and Controversy: A History of the St. Paul District, U.S. Army Corps of Engineers, Raymond H. Merritt, U.S. Government Printing Office, 1979, 667-718.
- m. Limnological Study of Reservoirs in Minnesota, North Dakota and Wisconsin Operated by the St. Paul District, U.S. Army Corps of Engineers, Robert O. Megard, Department of Ecology and Behavioral Biology, University of Minnesota, Final Report for Government Contract No. DACW37-78-C-0167, November 1980.
- n. Mississippi River Headwaters Lakes Feasibility Study, Main Report and Appendices, Two Volumes, St. Paul District, Army Corps of Engineers, 1982.
- o. Computer Operations Study of Reservoir Operations for Six Mississippi River Headwaters Dams, Final Report and Appendices, Three Volumes, St. Paul District, Corps of Engineers, 1982.

- p.** Area-capacity Table Reevaluation for the Mississippi River Headwaters Study, St. Paul District, Corps of Engineers, August 1983.
- q.** Emergency Plan for Big Sandy Lake Dam and Reservoir, St. Paul District, Corps of Engineers, June 1987.
- r.** Reservoir Regulation Contingency Plan, Mississippi River Headwaters Reservoirs, Prepared to Comply with the Water Resources Development Act of 1988, Public Law 100-676 (November 17, 1988), Section 21, Department of the Army, Corps of Engineers, St. Paul District, St. Paul, Minnesota, April 1989.
- s.** Mississippi River Headwaters Lakes in Minnesota - Low Flow Review, St. Paul District, Corps of Engineers, October 1990.
- t.** Dam and Damages: The Ojibway, the United States, and the Mississippi Headwaters Reservoirs, Minnesota History, Minnesota Historical Society, Jane Lamm Carroll, Historian, St. Paul District, U.S. Army Corps of Engineers, Spring 1990.
- u.** Operational Management Plan, Big Sandy Lake Dam and Reservoir, Corps of Engineers, St. Paul District, May 1994.
- v.** Water Available from the Mississippi River at Minneapolis and Other Upstream Minnesota Locations During Low Flow Conditions, Section 22 Report, Corps of Engineers, St. Paul District, September 1994.
- w.** The Rhetoric of Reservoirs, Minnesota History, Minnesota Historical Society, David R. Treuer, Leech Lake Reservation, Leech Lake Tribe of Ojibway, Winter 1992.
- x.** System-Wide Low-Flow Management Plan, Mississippi River above St. Paul, Minnesota, Interagency Agreement, September 1996, revised March 11, 2004, revised June 2015.
- y.** Water Control Manual, Mississippi River Headwaters Project, Big Sandy Lake Dam and Reservoir, Sandy River, January 2003.
- z.** Mississippi River Headwaters Reservoir Operating Plan Evaluation (ROPE), Upper Mississippi River Headwaters Bemidji to St. Paul, Minnesota Final Integrated Reservoir Operating Plan and Environmental Impact Statement, U.S. Army Corps of Engineers, St. Paul District, September 2009. ROPE Record of Decision was signed January 19, 2010.
- aa.** Mississippi River Headwaters, Master Plan, October 2016.

1-04 Project Owner

The United States Government is the owner of this project.

1-05 Operating Agency

The U.S. Army Corps of Engineers, St. Paul District, Operations Division, is responsible for the operation and maintenance of the Big Sandy Lake Dam and Reservoir Project. Regulation instructions for the project are provided by the District's Engineering and Construction Division, Water Management Section.

The Site Manager and Park Ranger are stationed at Big Sandy Lake Dam during normal duty hours, Monday through Friday. Typically, they are on-site from 8:00 am until 4:30 pm, throughout the year. During the summer recreation season, rangers are on-site on the weekends. The Supervisory Park Manager, Northern Headwaters Project Office is located at Pokegama Lake Dam and works normal duty hours. Information on contacting these personnel is listed in the introduction to this manual.

1-06 Regulating Agency

The regulation of the project is under the supervision of the Water Management and Hydrology Section within the Hydraulics and Hydrologic Branch, Engineering and Construction Division of the St. Paul District, U.S. Army Corps of Engineers. Water Management has the direct responsibility to manage the lake level, outflow from the dam, and provide information to the National Weather Service and other agencies, all within the scope of the authorized project purposes.

1-07 Vertical Datum

All vertical datum with in this manual is in NGVD 29. To convert to NAVD 88 apply the following formula: $NGVD\ 29 + 0.69\ ft. = NAVD\ 88$

2 Description of Project

2-01 Location

Big Sandy Lake Dam and Reservoir are part of the Mississippi River Headwaters Basin. The dam is located in Aitkin County, Minnesota, on the Sandy River, 1.25 miles upstream of the junction of the Sandy and Mississippi Rivers, at Mississippi River mile 1106.85 above the Ohio River. It is 264.2 Mississippi River miles above St. Paul, 50.2 Mississippi River miles above Aitkin, MN, and 77.7 Mississippi River miles below Pokegama Dam. Libby, MN is a nearby community. See **Plate 2-1 (General Location Map)**, **Plate 2-1a (General Watershed Plan)**, and **Plate 2-2 (Vicinity Map)**.

2-02 Purpose

- a. **Tribal Trust:** The federal government’s tribal trust responsibility must be considered in the operation and regulation of the project. See **Chapters 7 and 9** for additional information.
- b. **Flow Augmentation for Navigation:** The original authorized purpose of the six Headwaters Reservoirs, as authorized in the Rivers and Harbors Act of 1881, 21 Stat. 468, was to increase Mississippi River discharges during low-flow periods to aid navigation between St. Paul, MN, and Lake Pepin, near Lake City, MN. See **Section 3-02** for additional details.
- c. **Other Purposes:** Other authorized purposes of the reservoir include flood risk management, recreation, water supply, and enhanced fish and wildlife production. The reservoir purpose is discussed further in **Chapter 7**. The above, and other project purposes assigned by Congress following completion of the project, are listed in **Table 2-1**.

Authorized Purpose	Public Law No.	Description
Navigation		Rivers and Harbors Act of 1881
Flood Control, Recreation, and Surplus Water	78-534	Flood Control Act of 1944
Fish and Wildlife	85-624	Fish and Wildlife Coordination Act of 1958
Water Supply	85-500	Water Supply Act of 1958
Recreation	89-72	Federal Water Project Recreation Act of 1965
Water Quality (general policy)	92-500	Federal Water Pollution Control Act Amendments of 1973
Threatened or Endangered Fish and Wildlife	93-205	Endangered Species Act of 1973

Conservation, Recreation, and Timber	86-717	Forest Cover Act of 1960
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2-03 Physical Components

- a. **Current Control Structure:** The control structure consists of reinforced concrete abutments and piers supported by the original timber pilings. The total length of the structure between abutments is 109 feet (see **Plates 2-3, 2-4, and 2-5**). There are a total of 12 bays with a net width of 67 feet. This consists of 1 log sluice 11-foot wide, 6 gated bays, each 5-foot wide, and the previous lock chamber, now divided into 5 bays, each with an approximate width of 5.2 feet and sill elevation of 1216.81 feet. The sill elevations of the log sluice and gated bays are 1207.31 feet. Additionally, 6 small openings above each of the gated bays allow uncontrolled discharge to occur whenever the lake level is above elevation 1218.31 feet. An 8-foot wide roadway with a top elevation of 1223.5 feet is supported by the structure. The top of the control structure (top of the curb on roadway) is at elevation 1224.17 feet. There is a concrete spillway apron below Big Sandy Lake Dam with a top elevation of 1207.31 feet. The lock chamber is no longer operable as a lock. See also **Exhibit A**.
- b. **Proposed Control Structure:** The control structure consists of reinforced concrete abutments and piers supported by the original timber pilings. The total length of the structure between abutments is 109 feet (see **Plates 2-3b, 2-4b, and 2-5b-place holders for new drawings from final design**). There are a total of 10 bays with a net width of 65 feet. This consists of 1 dual leaf slide gate bay (11-foot wide), 6 slide gate bays (each 4.5-foot wide), and 3 aluminum stoplog bays (each 9-foot wide). Stoplog bays have a sill elevation of 1216.81 feet. The sill elevations of gated bays are 1207.31 feet. Additionally, 6 small openings above each of the gated bays allow uncontrolled discharge to occur whenever the lake level is above elevation 1218.31 feet. An 8-foot wide roadway with a top elevation of 1223.5 feet is supported by the structure. The top of the control structure (top of the curb on roadway) is at elevation 1224.17 feet. There is a concrete spillway apron below Big Sandy Lake Dam with a top elevation of 1207.31 feet. The lock chamber is no longer operable as a lock. See also **Exhibit A**.
- c. **Emergency Spillway:** There is no emergency spillway at Big Sandy Lake Dam. All flow is through the main control structure
- d. **Embankments and Dikes:** Big Sandy Lake Reservoir is contained by one main embankment and four perimeter dikes. The main embankments at Big Sandy Lake Dam consist of earth fill with a timber diaphragm. The right and left sections are 75 feet and 30 feet long with top elevations of 1225.31 feet and 1227.81 feet, respectively.

The 4 perimeter dikes are in low areas and have a minimum top elevation of 1225.1 feet. They are designed to prevent an uncontrolled overflow of stored water during extreme flood events. The locations of the perimeter dikes are shown on **Plate 2-6**. Pertinent data for these dikes are listed in **Table 2-2**.

An evaluation of the safety of the perimeter dikes was made for the 1982 Mississippi River

Headwaters Lakes Feasibility Study completed by the District. Design standards state that the dikes should be high enough to avoid overtopping during a Standard Project Flood (SPF), including appropriate freeboard allowances for wave action. Based on the SPF series developed for Big Sandy Lake all the dikes should be raised. However, this would not be effective without raising or replacing the control structure. Economic justification for the above measures was not found; however, it was recommended that the dikes should be included for further evaluation under the Dam Safety Assurance Program of the Corps of Engineers.

Dike No.	Description	Top Width (ft)	Length (ft)	Original Top Elevation (ft, 1929 NGVD)	Existing Controlling Dike Elevation (ft, 1929 NGVD)	Top Surface Material	Side Slope	Condition
1	Main Access Road	20	1386	1227.81	1227.8	Bituminous	1:3	Satisfactory
2	Tieback to Right Embankment	10	200	1225.31	1225.1	Grass	1:3	Satisfactory
3	Access Road to Camping Area	10	913	1225.31	1225.7	Bituminous	2:3	Satisfactory
4	Aitkin Lake Road	20	1200	1226.81	1227.2	Gravel	1:3	Satisfactory

Normal Pool Elevation, Highest Summer Range = 1216.56 ft
Maximum Observed Pool Elevation = 1224.82 ft

- e. **Reservoir:** The Big Sandy Lake Dam and Reservoir controls runoff from 421 square miles of the Big Sandy Lake drainage basin. The backwater effect from the dam affects eight lakes, which are connected to the reservoir (see Table 2-3). Information on reservoir storage can be found in Error! Reference source not found..

1. Big Sandy Lake	5. Round
2. Aitkin Lake	6. Tiesen
3. Sandy River Flowage	7. Sandy River
4. Davis	8. Rat

2-04 Related Control Facilities

The Big Sandy Lake Project does not contain any additional integrated components.

2-05 Real Estate Acquisition

- a. **Dam Site Recreation Area:** the Federal Government holds fee title to 1,116 acres of land associated with the project. The Big Sandy Lake Dam and Recreation Area is located on the north shore of Big Sandy Lake and includes approximately 118 acres of land, of which 85 acres is for recreation and 33 acres have been developed as campgrounds.
- b. **Flowage Rights:** In addition to the above, the Corps has flowage rights to 9,785 acres of land around Big Sandy Lake. The Bureau of Indian Affairs administers two parcels of land. See **Plates 2-7 to 2-12**.

2-06 Public Facilities

Situated on the western edge of the Savanna State Forest, the Big Sandy Lake Dam and Recreation Area is located on the northwest shore of Big Sandy Lake. This Corps-owned area includes 118 acres of land, of which 33 acres has been developed as campgrounds. A portion of the area downstream from the dam is low, marshy, and subject to flooding. The makeup of the 85 acres north of the dam, is relatively level and includes an extensive amount of marshland not usable for conventional recreation. Most of the developed areas have a park-like appearance with mowed grass and scattered trees being the only vegetation. The fringes of the developed areas are deciduous forest made up of oak, aspen, white pine, and birch, with relatively dense underbrush. The Big Sandy Lake recreation area and features are shown in **Figure 2-1** and listed in **Table 2-4**.

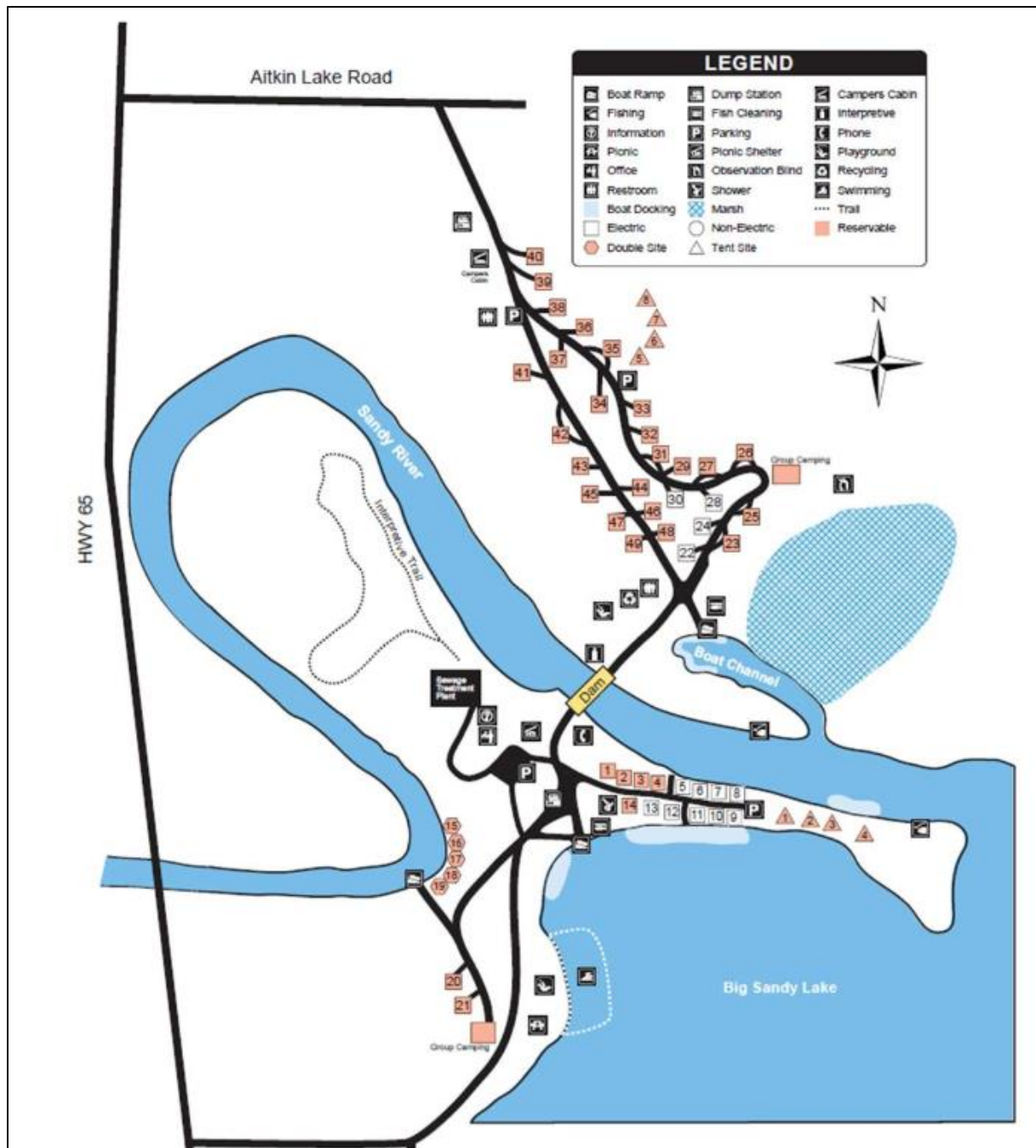


Figure 2-1. Big Sandy Lake Recreation Area

Description	Facility	Description	Facility
Mixed Camping	59	Maintenance Facility	X
Camping w/ Electric Hookup	55	Residence	0
Tent Camping	8	Access to the Recreation Areas	X
Picnic Units	5	Internal Vehicular Circulation	X
Swimming Beach	1	Walkways	X
Camper Cabins	1	Cemetery	0
Boat Launch	3	Bulletin Boards	X
Boat Dock	2	Camp Cleaning Tools	X
Canoe Launch	X	Picnic Tables	X
Fishing Docks	1	Fish Cleaning Facility	1
Day Use Area	X	Picnic Shelters	1
Playground	2	Fireplace	X
Parking Spots	80	Firewood	0
Ranger Station	X	Barbecue Units	X
Interpretive Facilities	X	Trash Receptacles	X
Interpretive Trails	1	Movie Screen	0
Concessions	0	Lighting	X
Potable Water Supply	X	Signage	X
Shower Building	X	Water Traffic Controls	X
Flush Toilets	X	Fences	X
Vault Toilets	X	Landscaping Practices	X
Sanitary Dumping Station	2	Telephones	X
Sewage Treatment Plant	X		

64 = No. Of Units X = Available 0 = Not Available
Group Campsites - 2; used for 2 RVS & up to 30 people w/ tents
Double Campsites - 5; used for two RVs or two families

3 History of Project

3-01 Authorization for Project

The River and Harbor Act of 1881 (21 Stat. 468) authorized the construction of a dam at Big Sandy Lake. Other lakes affected include Leech, Pokegama, Sandy, Cross (Pine River) and Gull. Winnibigoshish was authorized by the River and Harbors Act of 1880. Following authorization of the reservoirs, Congress directed the Secretary of War to establish regulations governing their operation through the River and Harbor Act of 1888.

3-02 Planning and Design

A plan to build a network of dams in the Headwaters region of the Mississippi River dates back to 1850. In that year, Congress asked Charles Ellet Jr., a civilian engineer, to conduct a survey and prepare a report on flood control and navigation on the Mississippi and Ohio Rivers. Ellet recommended, in his 1852 report, that a series of dams be constructed to regulate the erratic flow of the Mississippi. Ellet's report was sent to the Corps of Engineers who in turn reported to Congress that the effort would be too expensive in comparison to the benefits.

In the meantime William D. Washburn, who has often times been called the "father of the [Headwaters] reservoir system", moved from Maine to Minnesota in 1857. His brother Cadwallader had acquired mining and lumber interests in both Wisconsin and Minnesota. William would go on to represent Minnesota in the state Legislature and both houses in Congress, and Cadwallader would become governor of Wisconsin. The Washburns invested in power development on the west side of St. Anthony Falls. By 1865 they owned a controlling interest in the Minneapolis Mill Company and were actively promoting Minneapolis as a manufacturing center. However, their grand manufacturing plans were threatened in 1863 and 1864 when the flow of water in the Mississippi dropped to its lowest level in 25 years. The Washburns, and their consulting engineer, concluded that a constant flow in the river could be aided by an upstream reservoir system. In 1869, they directed a survey of the Upper Mississippi River to look for dam sites. Later that year they purchased 40 acres at Pokegama Falls above Grand Rapids as it presented a good location for a dam site.

At about the same time, in 1868, the St. Paul District engineer, Major Gouverneur K. Warren, recommended a survey be conducted above St. Anthony Falls to ascertain "the practicability of forming large reservoirs on the headwaters of the Mississippi to aid in keeping navigation at low stages". His report of April 30, 1870 suggested the construction of 41 reservoirs on the St. Croix, Chippewa, Wisconsin and Mississippi Rivers. The various watersheds covered a wilderness area of approximately 25,000 square miles. However, in the 1870's, the proponents of a reservoir system met strong opposition in Congress who were concerned that the dams would primarily benefit the logging, milling and water power industries. Congress resisted the efforts to stretch the "commerce clause" of the constitution beyond navigation. Thus, in 1878, Congress asked for an examination of the impact of a reservoir system on navigation below St. Paul to Lake Pepin. The report proposed that an experimental dam be constructed at the outlet of Lake Winnibigoshish to increase water levels below St. Paul during the summer.

In the meantime, William Washburn was elected to Congress in 1878 where he continued his fight for a federally-funded reservoir system. In turn, communities along the river pressured their Congressman to take measures to support steamboat traffic as a means to prevent a railroad monopoly. In 1879, the River Impoundment Association Convention strongly endorsed the reservoir system promoted by Congressman Washburn.

The St. Paul business community saw through the intentions of Washburn and others. Even though the argument for the reservoir system was based on improving navigation from St. Paul to Lake Pepin, and on down to St. Louis, the St. Paul Board of Trade sent resolutions to Congress condemning the plan. The city opposed the scheme to obtain federally supplied water for industrial use while using navigation below St. Paul as a smoke screen. However, Congressman Washburn's argument that there was little utility in dredging, building wing dams and making other improvements "unless there was adequate water in the channel" prevailed. As a result, in 1880, Congress approved funds for the construction of the dam at Lake Winnibigoshish and construction began in the winter of 1881. Additional funding soon followed. The construction of Leech and Pokegama dams commenced in 1883 with all three operating by 1884. The construction of Pine River Dam commenced in 1885 and was completed in 1886. When the water released from the first 3 reservoirs backed up into Big Sandy Lake; a fifth reservoir was constructed there (1891-1895) in an attempt to keep the Sandy River from running backwards. There were clear benefits to the water power interests at St. Anthony Falls. The reservoirs increased the flow during August and September by forty percent and during October and November by fifty percent. Although the effect that these reservoirs had on navigation is not as easy to document; the increased flow helped navigation to some degree. Prior to the construction of the lock and dam system on the Mississippi River, water from the reservoirs was released for navigation when the stage at St. Paul dropped below specified levels.

An engineer named William de la Barre was instrumental in taking advantage of the reservoirs for water power. De la Barre worked for the Minneapolis Mill Company (for which William Washburn was a majority owner). Under his direction, and supplemented by a steadier flow in the river, millpower was more than tripled from 1883 through 1889. In 1889, Washburn merged his company with Pillsbury and De la Barre took over direction of the combined interest. De la Barre increased the revenue of the new company fivefold over the next 20 years and more than quadrupled the horsepower of the mills. He did this in part by coordinating the companies' water needs with the regulation of the reservoirs by the Corps. Soon the power interests needed additional water so they asked the federal government to construct more reservoirs. The Corps of Engineers, however, could not justify more reservoirs and recommended that the system be limited to the existing five impoundments. The power interests, however, insisted on having one more dam at Gull Lake. The site had been studied by the Corps in 1898 but abandoned because the flowage rights were too expensive. The Corps instead began rebuilding the existing dams. The push for a dam at Gull was kept alive, however, by De la Barre and his political associates. Finally, in 1900, John S. Pillsbury deeded 1,000 acres of land on Gull Lake to the federal government and subsequently Congress authorized the dam in 1907. The St. Anthony Power Company began to obtain leases from the numerous property owners around

the lake and deeded them over to the federal government in 1911 and the dam was put into operation the following year.

For additional information on the Headwaters reservoirs, see Merritt: 1979 (see **Section 1-03**). For information on the effects that the reservoir project had on Indian Tribes see Carroll: 1990 and Treuer: 1992 (see **Section 1-03**).

3-03 Construction

The construction of the dam at Big Sandy Lake commenced early in May of 1891 and was completed in October of 1895. Native timber and other materials were used in the construction of the original dam due to the remote nature of the site in the wilderness. However, the timber materials were subject to rot. Replacement of Big Sandy Lake Dam began in 1907 and was complete by 1912. The Headwaters area had become more populated since the time the original structure was built, and with the roads greatly improved, it was decided that the replacement structure for the old timber dam could profitably be built of concrete.

The basic structure remains in place except: the downstream apron was replaced in 1958, the lock chamber was converted into a stoplog control structure in 1958 (later replaced with a concrete curtain wall to elev. 1216.81 feet with stoplogs from there up to elev. 1219.31 feet), and installation of slide gates in 1971. The embankment sections were raised and lengthened because of high stages experienced during the 1950, 1969, and 1971 floods.

3-04 Related Projects

Lake Winnibigoshish Dam, Leech Lake Dam, and Pokegama Lake Dam: Big Sandy Lake reservoir is one of the six Mississippi River Headwaters reservoirs (**Plate 2-1**) all of which are regulated by the Corps. Control facilities related to Big Sandy Lake Dam include: Lake Winnibigoshish and Lake Pokegama Dams on the Mississippi River, Leech Lake Dam on the Leech Lake River. Lake Winnibigoshish Dam and Leech Lake Dam are always operated so that, if possible, the combined outflow from these reservoirs does not exceed the Mississippi River channel capacity below the confluence of the Leech Lake River with the Mississippi River. During flood periods, Winnibigoshish, Leech, and Pokegama reservoirs are regulated to provide storage so that outflow can be reduced as necessary during high stages on the Mississippi River near Aitkin, Minnesota, and other areas downstream.

Winnibigoshish, Leech Lake and Pokegama Dams control approximately 80 percent of the water impounded by the six Headwaters dams. The operation of Big Sandy Lake Dam is not related to the operation of Pine River or Gull Lake Dam. Also, no upstream nor downstream structures exist for Big Sandy Lake Dam or Sandy River.

Aitkin, Minnesota Diversion Channel: A diversion channel upstream of Aitkin, Minnesota, assists in the flood risk management operation for Aitkin, Minnesota.

As early as 1906, the annual report of the Chief of Engineers discussed the flood situation at Aitkin with particular reference to the Headwaters lakes regulation. Several plans had been suggested over the years to alleviate the flood condition in the Aitkin area, which included

dredging and channel straightening, building a dike system, a diversion channel, building a dam, and use of the Headwaters reservoirs solely for flood prevention. The dredging of the river channel and the dike systems were rejected for economic reasons. Investigations in the uncontrolled area indicated that there were no suitable dam sites. This left the only apparent solution to the problem, that of a diversion channel in conjunction with using Winnibigoshish, Leech, Pokegama, and Sandy reservoirs to store flood waters.

A flood diversion channel at Aitkin was authorized by the Flood Control Act approved 30 June 1948 (H.D. 599, 80th Cong., 2d session). Construction was started 21 August 1952 on a channel having a general east-west alignment between river miles 1064 and 1040.4 on the Mississippi River. The channel is about 6 miles in length with a bottom width of 90 feet and 1 on 3 side slopes except for a contracted section at each end of the main diversion channel. Also included were a channel about 1,100 feet in length leading the Little Willow River into the main diversion channel, a 2,800 foot channel diverting Wakefield Creek into the main diversion channel, and erosion control structures at the mouth of the Little Willow and Wakefield Creek diversions and at one other point.

In addition, two supplementary cutoff channels are located downstream, the 800-foot Pine Knoll cutoff between miles 1040.9 and 1040.1 and the 1,300-foot Tow Head Rapids cutoff located between miles 1031.4 and 1030.5. The project was completed in June 1956. The responsibility for local cooperation was assumed by the Aitkin Drainage and Conservancy District which furnished assurances and provided necessary right-of-entry to lands required for construction. The project was transferred to local interests on 24 December 1956.

In addition, by 1956, guide curves for the regulation of the Big Sandy Lake and Pokegama Lake reservoirs were developed to distribute, between Aitkin, Pokegama Lake and Big Sandy Lake, the total damages during flood periods (see **Chapter 7**). Lake Winnibigoshish and Leech Lake are regulated to assist Pokegama Lake during flood risk management operations.

3-05 Dam Safety History/Issues

- a. **Historical Conditions:** The original dam was constructed during 1891 to 1895 and has gone through numerous alterations or repairs. Some of the alterations or repair measures with the respective date of construction and a brief description of the work are listed in [Table 3-1](#). More detail about the alteration or repairs can be found in Chapter 2 of the Periodic Inspection for Big Sandy Lake Dam.

Big Sandy Lake Dam is currently categorized as Dam Safety Action Classification (DSAC) DSAC 4 (low urgency). This classification was determined from a 2009 Screening for Portfolio Risk Analysis (SPRA). Since the project is currently categorized as DSAC 4, an Interim Risk-Reduction Measures Plan (IRRMP) is not required. A quantitative risk analysis for the existing condition has not been performed for the project.

A preliminary screening-level risk assessment was performed as part of the 2009 SPRA. This risk assessment did not capture any of the major concerns being used to recommend a design analysis report. The loading conditions considered by the SPRA included three

hydrologic loading conditions: normal (less than a 10- year flood), unusual (10- to 300-year flood); and extreme (300-year flood to Probable Maximum Flood or PMF). Two seismic loadings were also considered: Operating Basis Earthquake (OBE) with an annual exceedance probability (AEP) of 1/144; and a Maximum Design Earthquake (MDE) with an AEP of 1/950 for non-critical structures and an AEP of 1/ 2,475 for critical structures. The loading conditions used for SPRA are summarized below in . The primary concerns identified by the SPRA included: 1) embankment erosion for the unusual and extreme loadings and 2) dike reliability for the unusual and extreme loadings.

Hydrologic Loading Condition	Reservoir Level (ft)	Seismic Loading Condition	Peak Ground Acceleration (g)
Normal	1216.31	OBE	0.001
Unusual	1223.00	MDE (non-critical)	0.0134
Extreme	1228.7	MDE (critical)	0.0274

The computed maximum pool elevations due to the Probable Maximum Flood (PMF) without and with dam failure are 1228.7 and 1228.6 respectively. The starting pool elevation for the routing of a failure at normal high pool elevation is 1218.3. The computed maximum pool elevations given respectively without and with dam failure for the 70% PMF are 1226.9 and 1226.8, the 40% PMF elevations are 1224.5 and 1224.1 and the Threshold Flood elevations are 1219.3 and 1219.7. In the case of the Threshold flood with failure, the slide gates were assumed to become inoperable, preventing increased discharge and causing the water level to rise. Breach was assumed to occur when the reservoir reached maximum elevation due to the Threshold flood inflow.

Gage zero for Big Sandy Lake Reservoir is 1207.31. At the maximum operating pool elevation of 1218.31, the reservoir storage is 81,900 acre feet. During summer, the reservoir is maintained at elevation 1216.32 + 0.2 feet and contains 62,400 acre-feet storage. Winter drawdown pool level is at elevation 1214.31, 7.0 feet above the outlet sill elevation, with 44,400 acre-feet of water in the pool.

The adopted Probable Maximum Flood has a peak inflow of 40,500 cfs. The computed maximum peak outflow for the case of Probable Maximum Flood with failure is 19,300 cfs. The hydraulic depth of Big Sandy Lake Dam from Probable Maximum Flood level to invert of outlet is approximately 21 feet. The value of the envelope curve for hydraulic depth of 21 feet is approximately 18,000 cfs which is 1,300 cfs less than the maximum outflow computed for Big Sandy Lake Dam. This difference is approximately 7 percent of the computed maximum outflow. Several failure scenarios for Big Sandy Lake Dam were studied. The case of failure concurrent with a Probable Maximum Flood represents a compounding of extremely unlikely events. The case of failure at normal high pool elevation represents much less severe conditions that might occur under normal non-flood

conditions. All outflow hydrographs were computed using the dam break component of the U.S. Army Corps of Engineers' HEC-1 model.

- b. Current Project Conditions:** The 2016 Periodic Inspection revealed widespread concrete and timber apron deterioration both upstream and downstream of the dam. The vertical surfaces along the upstream right headwall, stop log slots and sluice gate sidewalls have significant spalling and exposed rebar. The downstream concrete floor in sluice gate bays #1 through #6 are deteriorated and scoured. The upstream timber apron is significantly deteriorated and there are multiple areas where timber beams are missing. The full 2015 Diving Inspection is located in Appendix F of the 2016 Sandy Periodic Inspection Report. The aprons are severely degraded and need repair.

The scour hole underneath the timber apron upstream of Gate Bay No. 6 could potentially affect the continued safe operation of the project, and it is recommended that a fix is designed and implemented before the next Periodic Inspection.

The Earthen embankments have all been inspected and appear to be in good condition, with no degradation or displacement. There were adequate levels of sod cover, and minimal vegetation within the riprap. The main inlet and outlet channels were also concluded to be satisfactory, with only small amounts of cracking from the grouted riprap. Latest soundings in 2011 showed a small scour hole which has not progressed from historical sounding but should still be monitored.

The upstream face of the concrete control structure above the water line is in good condition. Below the water line, many areas of concern were identified in the 2015 diving inspection. The concrete surfaces at or below the pool water elevation were found to be in poor condition. There are holes in the concrete, seven to fourteen inches deep, with exposed rebar throughout the entire length of the curtain wall. The right abutment wall and concrete curtain wall has large areas of spalling. The membrane between the two faces of curtain wall were exposed and coming out of the joint. The structure had significant erosion along the piers and stop log slots. Areas of previous concrete repair are about fifty percent delaminated. The rubberized joint sealant is in good condition however.

Various areas of seepage were noted during the 2015 diving inspection. The left downstream wingwall had multiple areas of seepage at the wall and slabs as well as between the walls and apron. Rusting was a key indicator the seepage is occurring at the stop logs. There was active seepage at the time of the 2015 inspection.

The stop logs paint system is failing. There was corrosion coincident with the paint failure although there was no section loss noted. The current stop logs allow for significant leakage. The bottom logs cannot be removed by staff and as such, are of unknown condition.

3-06 Principal Regulation Issues

Throughout the history of the dam there has been several associated issues with the structure. There has been significant erosion of the original concrete and timber apron. The embankment has been overtopped while temporary dikes were constructed during the 2012 flood. The

original stop logs when loaded have allowed significant leakage. More information of flooding, past and current condition can be found in section 4-06, 3-05 and the Periodic Inspection for Big Sandy Lake Dam. There has been no known channel deterioration or encroachment.

- a. **Bank Erosion:** Bank erosion due to higher than normal pool levels and wave action causes destruction to shoreline archaeological and cultural sites, damages recreation and commercial interests, and contributes to degraded water quality. Big Sandy Lake experiences considerable shoreline erosion due to its circular shoreline configuration and large range of lake level fluctuations. Of particular concern is erosion along the Big Sandy Lake shoreline near an Indian burial site. At the request of the Big Sandy Lake Reservation (see **Chapter 9**), the eroded shoreline near this site was repaired in the winter of 1983-1984. The repairs consisted of a pervious fill bank with a rock base, set at a slope of 1 vertical on 2 horizontal. The top of the bank has settled, up to 2 feet in some places. Shoreline erosion around the six Mississippi River Headwaters lakes is the most serious on Winnibigoshish, Leech, and Big Sandy Lakes.
- b. **Control Structure Overtopped:** During the 1950 flood, Big Sandy Lake Dam was overtopped by 3.5 feet (see **Section 4-06**). Temporary dikes were constructed on the embankment to prevent erosion and loss of the structure. See **Section 3-05**. A temporary dike was constructed on the left side of the structure in 2012.
- c. **Water Supply for Low Downstream Conditions/Navigation:** Severe drought and low water conditions below St. Louis existed in fall of 2012. A directive to deviate from approved water control plans, dated 26 October 2012, was received from Mississippi Valley Division. The directive required the storage of up to 10% above the approved guide curves. In a coordinated plan, the stored water was released to minimize drought conditions. Sandy was included in a Mississippi Headwaters release plan which estimated a release of over 3,200 cfs for six days and over 2,000 cfs for 11 days. The actual release was two days (over 3,200 cfs) and 15 days (over 2,000 cfs). The Mississippi Headwaters release plan appears to have provided an additional outflow of approximately 2,000 cfs at Lock and Dam No. 10 for two days. It was only minimally successful in the St. Louis area. The principal regulation issue was timing. With the reservoir drawdown to begin on October 1 and normal ice formation by late October or early November, the ice on the reservoir had the potential of forming higher on the shoreline and causing damage. See 1-03 r, 1-03 u, and 2-02 b.

3-07 Modifications to Regulations

General regulations for the Mississippi Headwaters reservoirs were first established by the War Department in 1889 and were formally modified in 1931, 1935, 1936, 1944 and 1988.

The first regulation governing the operation of the Headwaters dams (dated 1889) did not contain any information on water levels. The area surrounding the Headwaters lakes was largely undeveloped when the dams were first built in the late 1800's and early 1900's, consequently there were no serious objections to widely fluctuating lake elevations. However, as recreation on the reservoirs and downstream agriculture developed in the first quarter of the 1900's, local

landowner interests became more important in determining reservoir regulation. In addition, the need for supplemental releases from the six Headwaters lakes for navigation, hydropower and water supply was greatly reduced during and after the 1930's. As a result, the Secretary of War issued new regulations for the six Headwaters reservoirs during the period 1931-1944. The headwaters regulation is codified at 33 CFR 207.340. Section 21 of the Water Resources Development Act of 1988 (Public Law 100-676) and Section 3175 of the Water Resources Development Act of 2007 (Public Law 110-114) provided additional requirements. A description of the various regulation orders, as well as various other rules, guidelines and deviations that have occurred, are listed below. Also see _____ and **Chapter 7**.

- a. **1889 Regulation Order:** The River and Harbor Act of Congress, dated 11 August 1888, directed the Secretary of War to establish regulations governing the operation of the Mississippi River Headwaters reservoirs. This request resulted in the 12 February 1889 regulation orders, a copy of which can be found in the 1896 Annual Report of the Chief of Engineers, Part 3, pages 1829-1831. The 1889 regulations were probably republished in 1896 due to the recently completed dam at Big Sandy Lake in October 1895.

The 1889 regulation does not list specific reservoir levels or discharge requirements; nor does it mention specific reservoirs. [By 1896, only Lake Winnibigoshish, Leech Lake, Pokegama Lake, Big Sandy Lake and Pine River Dam were completed.] In general the regulation provided:

- i. Penalties for violating the orders
- ii. Authority to the officer-in-charge to store water for use in downstream navigation “until the limit of capacity or safety of the reservoirs is reached”
- iii. Rules for the sluicing of logs
- iv. Sole discretion for the operation of gates to the officer-in-charge.

Operating levels, however, were developed by the officer-in-charge based on physical limitations and engineering judgment. These levels through usage became known as the “Original Operating Limits” (see _____ and **Chapter 7**). The lower limits were usually the sill elevation of the dam or some other physical limitation that governed releases. The upper limits were set, with the later exception of Gull, at a point lower than the flowage rights acquired for each dam while still providing some freeboard below the top of the dam. Sandy’s “Original Operating Limits” are 1207.91 ft. to 1218.31 ft. (0.6 ft. to 11.0 ft. stage).

- b. **1931 Regulation Order:** In 1929 and 1930 the Headwaters reservoirs were lowered in an effort to test their capabilities to increase flows below St. Paul. Subsequent dry weather (low inflows) resulted in continued low water levels. Resort owners and local residents organized and demanded the establishment of minimum operating levels to provide them with more reliable conditions. As a result, on 11 February 1931, the Secretary of War revoked the 1889 regulations and issued the 1931 order which included both high and low water operating limits (see _____). A minimum discharge of 10 cfs was prescribed for Big Sandy Lake and, at the request of the Minnesota Lake Levels Association, the lower operating limit was raised 6.4 feet to 1214.31 feet (7.0 ft. stage). An upper operating limit

was also specified (1218.31 feet, 11.0 ft. stage) and rules regarding the release of water for navigation and the sluicing of logs were clarified in addition to other details.

- c. **1935 Regulation Order:** In the years 1930 through 1934 many protests were received in the District office in regards to low water levels. As a result, on 14 May 1935, the Acting Secretary of War modified the 1931 regulations reducing Pokegama’s minimum flow value and changing the values at Pokegama, Sandy, Pine and Gull to an “average annual discharge”. This allowed the dams to be completely closed at times for various reasons to include low inflows or maintenance. These minimum flow changes did not affect Lake Winnibigoshish or Leech Lake. However, a clarification to the operational limits was added to minimize the range of fluctuations in levels in any reservoir in a single year. See .
- d. **1936 Regulation Order:** Hearings were held in 1935 due to the failure of the Winnibigoshish, Leech and Pokegama to reach desirable levels. As a result, on 4 February 1936, the Secretary of War issued new regulations which changed, among other things, the minimum flow value at Winnibigoshish and Leech to an average annual value (all 6 reservoirs now had average annual minimum discharges). The average annual discharge of 10 cfs at Sandy (stated in the 1935 order) was changed to 80 cfs. Only minimum operating limits are listed in this regulation. However, the regulation does not preclude the reservoirs from being operated up to the upper limits listed in both the 1931 and 1935 regulations. Correspondence indicates that storage up to the maximum limits could be used “should extremely wet years necessitate this action” See .
- e. **1944 Regulation Order:** This order for the Headwaters reservoirs did not affect Big Sandy Lake. The order lowered the minimum elevation for Leech Lake one foot, from 1293.70 feet (1.0 ft. stage) to 1292.70 feet (0.0 ft. stage) in order to allow the “normal” (ordinary) upper limit to be reduced from 3.5 feet to 3.0 feet. A minimum stage of 0.0 feet was not possible without an official change in the regulations. This proposal came as a result of a meeting held in Walker, Minnesota on 25 October 1944, which was hosted by Congressman Harold Knutson. The meeting was held following 4 months of very wet weather conditions. See .
- f. **Title 33, Section 207.340, Code of Federal Regulations:** This regulation codifies all of the orders affecting the Headwaters reservoirs through the 1944 Regulation Order. Section 21 of the Water Resources Development Act of 1988 (Public Law 100-676) and Section 3175 of the Water Resources Development Act of 2007 (Public Law 110-114), as well as the referenced Reservoir Regulation Contingency Plan, provide additional direction.
- g. **1963 Findings of Fact Conclusions Order, State of Minnesota and Plan of Operation:** The 1963 Findings of Fact from the State of Minnesota, Department of Conservation, Commissioner of Conservation, dated 19 April 1963, and the Plan of Operation from the Division of Game and Fish, dated 15 August 1963, outline some recommendations regarding the operation of the Headwaters reservoirs. The Commissioner lists various operation guidelines in the 19 April 1963 Findings of Fact and mentions that recommendations from

the Division of Game and Fish will be developed and kept on file. The subsequent 15 August 1963 Plan of Operation outlines the recommendations from the earlier Findings of Fact, while adding guidelines related to changes in discharge, spring spawning, springtime operation and clarifying minimum releases, among other things. No reference is made, of course, to these guidelines in Appendix D, Table G-10 of the Headwaters Master Reservoir Regulation Manual, dated April 1963. However, Appendix D, Table G-10 of the revised Master Manual, dated 19 February 1968, references the State's Plan of Operation as it relates to maximum and low-flow discharges.

No formal agreement exists between the State of Minnesota and the Corps of Engineers regarding the 1963 recommendations and they are not legally binding upon the Corps. In actual practice, the Corps makes a good faith effort to regulate the Headwaters lakes in conformance with the 1963 maximum and low-flow discharge guidelines whenever possible and when not in conflict with the authorized project purposes or other federal mandates. Some small adjustments have been made to the guidelines. Following is a summary of the guidelines adopted and/or considered from the 19 April 1963 Findings of Fact and the subsequent Plan of Operation signed on 15 August 1963. Also see **Chapter 7**.

1. Maximum discharges from the reservoir were recommended for elevations ranging from 1207.31 feet to 1218.31 feet (0.0 ft. to 11.0 ft. stage). See **Chapter 7** for details.
 2. A minimum discharge from the reservoir was recommended for periods when the pool was at or below critical elevations. See **Chapter 7** for details.
- h.** 1988, Public Law 100-676, Section 21, Water Resources Development Act of 1988. This Public Law, dated 17 November 1988, was a result of the drought of 1987-1988. In 1988, Minnesota Governor Rudy Perpich asked the Corps of Engineers to make supplemental releases from the Headwaters reservoirs to meet downstream water use requirements. When rainfall returned to the region in early August of 1988, the Corps denied the request. Congressman Oberstar however, determined that some Congressional oversight was needed related to the use of the water contained within the reservoirs for the benefit of upstream and downstream uses. As a result, the Public Law states that the Secretary of the Army must notify Congress 14 days in advance of any reservoir going outside prescribed minimum and maximum operating limits. In addition, a Reservoir Regulation Contingency Plan was provided to Congress in compliance with the Public Law (see **Section 1-03**). The Congressional notification elevations for Big Sandy Lake reservoir are elevations 1214.31 feet and 1218.31 feet (see _____ and **Chapter 7**). Since the law was enacted, a situation requiring Congressional notification has not occurred.
- i.** **2007, Public Law 110-114, Section 3175, Water Resources Development Act Of 2007:** WRDA 2007 amended Section 21 of WRDA 1988 by adjusting elevations and allowing the Secretary to operate the headwaters reservoirs below the minimum or above the maximum water levels in accordance with water control manuals, after consultation with the Governor

of Minnesota and other stakeholders. Water control manuals become effective when the Secretary transmits them to Congress, and Congress must be notified at least 14 days before operating any headwaters reservoir above or below specified water level limits, unless such operations are necessary to prevent loss of life, to ensure dam safety, or in anticipation of flood risk management.

- j. **2010, Mississippi River Headwaters Reservoir Operating Plan Evaluation (ROPE) Study and Record of Decision:** The ROPE study showed that Sandy had little to no effect on helping with the balanced flood damages from the 1956 guide curves. The ROPE study removed Sandy from the guide curves and stated, for the maximum benefit, Sandy should release as much water as possible prior the backwater from the Mississippi River. The ROPE low flow requirements fulfill Federal requirements and supersede the Minnesota DNR guidelines.

4 Watershed Characteristics

4-01 General Characteristics

Big Sandy Lake reservoir controls the runoff from 421 square miles. The basin is located 70 miles west of Duluth and 120 miles north of Minneapolis, Minnesota, and is the most easterly watershed of the six Headwaters basins. It is the only Headwaters reservoir basin not sharing a common boundary with another Headwaters reservoir watershed. The basin extends eastward from the Mississippi River approximately 26 miles and is about 18 miles wide in the north-south direction (see **Plate 2-1a**).

The water in Big Sandy Lake originates from four main rivers: the West Savanna from the north, the Prairie and Tamarack from the east, and the Sandy River from the south. The Prairie River is the longest stretching approximately 30 miles. The average river slope is about 3.3 feet per mile. The land elevation ranges from a high point of 1,575 feet in the far eastern portion of the watershed to an elevation of 1217 feet.

The Mississippi River Headwaters basin lies within the Minnesota section of the hemlock-white pine-northern hardwoods region of the deciduous forest in eastern North America. Sugar maple and basswood dominate in the southern portion; white spruce, balsam fir, and paper birch dominate the northeastern reaches; and intermediate communities occupy the central areas. Pine subclimaxes are common throughout the region. Pines often occupy sites which have light-textured soils, while hardwoods prefer the heavier soils. Oaks and aspen form successional communities on upland sites, while elms and ash form communities on low-lying areas. Lowland conifers occupy wet areas having organic soils. Forest communities dominate the shoreline vegetation of the six Headwaters lakes; lesser amounts of bog, marsh, and grassy areas are present. Upland sites are occupied by birch-aspen and pine-mixed hardwoods communities, while elm-ash is common in the lowlands. Maple-basswood communities are found on higher ground behind elm-ash stands. Marsh communities are also abundant. The marsh vegetation consists mainly of cattail with scattered alder, willow, ash, aspen, and birch.

4-02 Topography

The topography of the Big Sandy Lake watershed is predominantly flat with gentle rolling hills characteristic of glacial effects. Much of the area to the south and east is marshland. The hills rise from 80 to 200 feet above the low areas. The land elevation ranges from a high point of 1,575 feet in the far eastern portion of the watershed to an elevation of 1217 feet at Big Sandy Lake. Elevations in the Prairie River basin range from elevation 1315 feet at its origin to elevation 1217 feet at the mouth at Big Sandy Lake. The runoff from Big Sandy Lake watershed is slow and significantly attenuated as a result of the relatively flat topography and the presence of many lakes and wetlands.

4-03 Geology and Soils

The area surrounding Big Sandy Lake in Aitkin County is primarily glacial till plain with a large outwash area characterized by surface deposits of sand and gravel to the northwest. The soil of

the till plain area is brownish, slightly acidic, with pebbles and boulders of granite and gneiss incorporated into it.

Aitkin County is relatively flat and includes numerous lakes and large areas of poorly drained swamplands. A thick mantle of glacial drift covers the entire surface of Aitkin County and overlies older rock formations. This glacial mantle is 100 to 150 feet thick. This material was deposited over two to three glacial periods. The low land lying north of Aitkin was the site of glacial Lake Aitkin, which was formed by the partial barrier of glacial material deposited across the Mississippi River channel. Melting water breached the barrier, and allowed the lake to drain, leaving remnants of beach ridges and lacustrine deposits of silt and clay in the old lake area. Extensive peat lands cover approximately 40 percent of the county and average 5 feet in thickness. A large peat or muskeg area extends over 75 to 100 square miles and is located north of Aitkin. Due to the presence of wetlands with high organic material, the runoff from Big Sandy Lake watershed is slow with low amounts of sediment.

4-04 Sediment

Erosion and sediment production from rivers within the watershed is a relatively minor problem due to the forest cover, soil types and land topography in the area. Sediment production from shoreline erosion within the reservoir boundaries is of concern for the loss of real estate and water quality reasons, but has only a very minor impact on the elevation-storage characteristics of the reservoir. Shoreline erosion within the Mississippi River Headwaters lakes is caused primarily by high lake levels combined with wind and wave action which accelerate erosion. The progressive loss and deterioration of lakeshore lands and related vegetation can destroy shoreline archaeological and cultural sites, damage recreational, residential, and commercial interests and contribute to reduced water quality. Sedimentation surveys have never been performed due to physical and fiscal restrictions and a perceived lack of need. A more complete discussion of bank erosion problems can be found in **Section 3-06b**.

4-05 Climate

The Headwaters lakes area has warm, short summers which can be followed by long, severe winters with snow on the ground from November to March. The growing season, between the last killing frost in the spring and the first killing frost in late summer or early fall, varies from about 143 days in Aitkin and Itasca Counties (Leech, Winnibigoshish and Pokegama Dam area) to 148 days in Aitkin and Crow Wing Counties (Sandy, Pine and Gull Dam area). Warm summer days and cool evenings during the growing season contribute to favorable conditions for production of soybeans, oats, barley, flax, hay and wild rice.

- a. **Temperature:** At the northern end of the Headwaters region, temperatures average approximately +5 degrees Fahrenheit in January and +65 degrees Fahrenheit in the summer months. In the southern portion of the Headwaters area, temperatures are typically about 5 degrees Fahrenheit warmer. Great extremes can occur, and temperatures below -50 degrees Fahrenheit and above +100 degrees Fahrenheit have been recorded.

- b. **Precipitation:** Annual precipitation in the eastern half of the Headwaters lakes area varies from 17 to 38 inches and averages 28 inches. On the western side, precipitation varies from 15 to 34 inches yearly, with an annual average of 22 inches. Annual snowfall in the area is typically 43 to 60 inches, and the average annual runoff of about 3 inches in the western half of the region is approximately half of that in the east. Normally, the winter months of December, January and February are the driest, while the greatest amount of precipitation occurs during June and July. A general description of the climate for the Big Sandy Lake area can be drawn from **Table Table** and **Table** .
- c. **Evaporation:** The seasonal (May-October) average evaporation of 24.4 inches in **Table Table** corresponds very well with Free Water Surface (FWS) seasonal evaporation of 24 to 26 inches from the National Weather Service Technical Report 33. The monthly values will deviate somewhat since the model data used in **Table Table** accounts for the heat storage effects of the reservoir water.
- d. **Wind:** The average wind speed in this area is about 8 miles per hour. The prevailing winds are from the north, but southwest winds are very common during the summer months. Wind speeds are usually highest during the afternoon and lowest at night. See **Plate 4-1**.

Extremes	Temperature ¹ Degrees, F	Annual Precipitation ² Inches	Lake Evaporation ³ Inches	
			Annual	July
Minimum	-52 (Jan. 31, 1899)	14.92 (1976)	24.8 (1928)	3.7 (1950)
Maximum	102 (July 28, 1988)	44.36 (1953)	36.2 (1974)	8.1 (1936)

1. Big Sandy Lake Dam, National Oceanic and Atmospheric Administration, Climatological Data, 1896-2020. (NOAA Station No. 217460)
2. Big Sandy Lake Dam, National Oceanic and Atmospheric Administration, Climatological Data, 1892-2020. (NOAA Station No. 217460)
3. Watershed Study in Northeastern Minnesota, 1916-1980 (Meyer Model, Barr Engineering Co.)

Month	Normal Temperature ¹ Degrees F	Normal Precipitation ¹ Inches	Normal Snowfall ² Inches	Lake Evaporation ³ Inches	Wind ⁴	
					Speed MPH	Prevailing Direction
January	8.4	0.75	15.9	0.3	8	WNW
February	13.9	0.56	8.4	0.5	8	NNW
March	26.4	1.23	9.6	0.9	9	WNW
April	41.7	1.95	2.7	1.3	10	NW
May	54.5	3.03	0.2	3.2	9	NW
June	63.5	4.74	--	5.0	8	WNW
July	68.2	4.53	--	5.4	7	NW
August	66.7	3.28	--	4.7	6	S
September	57.6	3.38	--	3.6	7	NW
October	44.5	2.60	1.0	2.5	8	NNW
November	29.0	1.14	8.1	2.2	8	NNW
December	13.6	0.79	10.6	0.4	8	WNW
Annual	40.8	27.88	56.5	30.0	8	NW

1. Big Sandy Lake Dam, National Oceanic and Atmospheric Administration, Climatological Data, 1981-2010, (NOAA Station No. 217460)
2. Big Sandy Lake Dam, National Oceanic and Atmospheric Administration, Climatological Data, 1971-2000, (NOAA Station No. 217460)
3. Watershed Study in Northeastern Minnesota, 1916-1980 (Meyer Model, Barr Engineering Co.), Note: evaporation data was collected at Lake Winnibigoshish, Leech Lake, and Pine River Dam from 1931 through 1934.
4. St. Cloud, Minnesota Records, Climatic Atlas of the United States.

- e. **Climate Change Assessment:** Engineering Construction Bulletin (ECB) No. 2018-14 (USACE 2018) provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate change adaption policy. It calls for a qualitative analysis. The goal of a qualitative analysis of potential climate threats and impacts to USACE hydrology-related projects and operations is to describe the observed present and possible future climate threats, vulnerabilities, and impacts of climate change specific to the study goals or engineering designs. This includes consideration of both past (observed) changes as well as potential future (projected) changes to relevant climatic and hydrologic variables.

The important hydrologic variables affecting the proposed Big Sandy Lake project include water surface elevation (stage). Besides fluctuations in climate, stage can be influenced by long-term geomorphic change, changes to the operation of hydraulic structures, and gage relocation. These factors can make it difficult to determine the role of climate change in affecting the hydrologic signal at the project scale. The relevant question to answer for this project is whether there has been, or will be a change that affects ecological conditions and flood risk in the study area and how this change would impact the resilience and operation

and maintenance of the proposed project. Lake stage was chosen as the primary hydrologic variable to analyze for this project with discharge as its proxy.

The Mississippi River Headwaters ROPE (Reservoir Operating Plan Evaluation) study states “experience has shown that as the snow melts and stages at Aitkin rise, the maximum flood damage reduction benefit for both Big Sandy Lake and Aitkin is obtained by releasing as much water as possible through the dam prior to the backwater effect from the Mississippi River restricting the outflow through the gates. Even though the gates are often wide open by this time, the outflow approaches zero as the tailwater level below the dam rises with very little flow from the Sandy River making its way to Aitkin. By releasing as much water as possible early on, Big Sandy Lake retains as much storage as possible to assist Aitkin while keeping its ultimate peak lake elevation as low as possible.” The maximum discharge does not influence flooding because the tailwater from the Mississippi River is higher than lake levels during flooding. Lake Discharge will not be analyzed for this project as lake discharge does not affect flooding in regard to climate change.

- f. Literature Review: Climate Change Trends at a Regional Scale:** Both historic, observed hydrometeorological datasets, as well as projected, climate changed hydrometeorological data was looked at to support some broader statements about how the climate may change over the 50 year project life and 100 year, project performance horizon. Important, driving hydrometeorological variables include precipitation and temperature. The magnitude, seasonal and interannual variation, duration, and rate of change of these variables can affect physical, chemical, and biological characteristics of ecosystems.

A series of regional summary reports on trends in both observed and projected hydrometeorological variables were published by the USACE in 2015. In Water Resources Region Hydrologic Unit Code (HUC) 07, the Upper Mississippi Region, the report concludes that “increased air temperatures and increased frequencies of drought, particularly in the summer months, will result in increased water temperatures. This may lead to water quality concerns, particularly for the dissolved oxygen levels, which are an important water quality parameter for aquatic life. Increased air temperatures are associated with the growth of nuisance algal blooms and influence wildlife and supporting food supplies. Increased mean annual precipitation in the region may pose complication to planning for ecosystem needs and lead to [increased] variation in flows (Civil Works Technical Report CWTS-2015-13, USACE (2015)).” These conclusions were based on a large body of research cited in the report, some of which is summarized below.

In the Upper Mississippi Region, a statistically significant trend of increasing air temperature was found based on observed temperature data for the winter, spring, and summer months; however, a slight decreasing trend was observed in fall temperatures based on the 1950 to 2000 time period (Wang et al. 2009, Westby et al. 2013). A study by Westby et al. conducted in 2013, quantified statistically significant warming for the most northern portion of the Upper Mississippi Region and a general cooling trend for the southern region. A study by

Johnson and Stefan (2006) identified numerous trends in 20th century hydro-climate data for sites across Minnesota suggestive of a warming climate. These include earlier ice-out dates and later ice-in dates for lakes and earlier spring runoff.

Multiple authors have identified significant, increasing trends in total precipitation in historical records for the study region. Palecki et al. (2005) quantified statistically significant increases in winter storm precipitation totals for the 1972 to 2002 time period. Grundstein (2009) identified significant, positive linear trends (period 1895 – 2006) in both annual precipitation and the soil moisture index for multiple sites within the Upper Mississippi Region. Wang et al. (2009) identified a significant increasing trend in precipitation for the Upper Mississippi Region, particularly in the summer and fall (1950 to 2000). For the northern half of the region, a mild decreasing trend was identified during the winter and spring. A study by McRoberts and Nielsen-Gammon (2011) found that the positive trend in annual precipitation indicates an increase on the order of 5 – 20% per century (1895 to 2009 time period).

Streamflow/discharge and duration are the most important hydrometeorological variable affecting ecological conditions and engineering resilience for the project. Elevated water surface elevations, which are directly related to streamflow, can affect all of the project's objectives - increase the diversity and percent cover of desirable emergent and submergent aquatic plant species and provide quality feeding and resting habitat for a wide variety of waterfowl and waterbirds. Trends in streamflow and the corresponding water surface elevations will be considered when designing project features. The 2015 USACE literature synopsis cites a number of studies that identified trends of increasing flow metrics in the Upper Mississippi River Basin (Mauget 2004, Small 2006, Novotny and Stefan 2007, Kalra 2008, Xu 2013). Mauget (2004) analyzed 42 daily streamflow gages throughout the U.S., nine of which are located within the Upper Mississippi Region. He identified an increasing trend (1939 – 1998) in observed, mean annual river flow in the Mississippi watershed as a whole, including the Upper Mississippi and a significant increase in "surplus" flow days and a decrease in drought incidences for the latter part of the record compared to earlier years. Xu et al. (2013) identified statistically significant positive trends in both observed annual streamflow and baseflow for multiple stream gages in the Upper Mississippi Region. Novotny and Stefan (2007) analyzed 20th century historic streamflow data from 36 gages scattered across Minnesota, most of which were located in the Upper Mississippi Region. Novotny and Stefan (2007) applied trend analysis to a number of different flow metrics, including mean flow, 7-day low flow, and peak flows and found statistically significant (p-value <0.1) increasing trends for the period of 1913 to 2002.

In addition to consulting the USACE literature synthesis for Water Resources Region 07, the Upper Mississippi Region, results from the US Global Research Program's Third National Climate Assessment for the Upper Midwest were evaluated. **Figure 4-1**, from the US Global Research Program's Third National Climate Assessment completed in 2014, shows estimates of increased precipitation throughout the Upper Midwest for the middle of the current

century (2041-2070) relative to the end of the last century (1971-2000). Across the entire Midwest, the total amount of water from rainfall and snowfall is projected to increase. The Third National Climate Assessment states that “in the Upper Midwest extreme heat, heavy downpours, and flooding will affect infrastructure, health, agriculture, forestry, transportation, air and water quality, and more. Climate change will tend to amplify existing risks climate poses to people, ecosystems, and infrastructure. Direct effects will include increased heat stress, flooding, drought, and late spring freezes.”

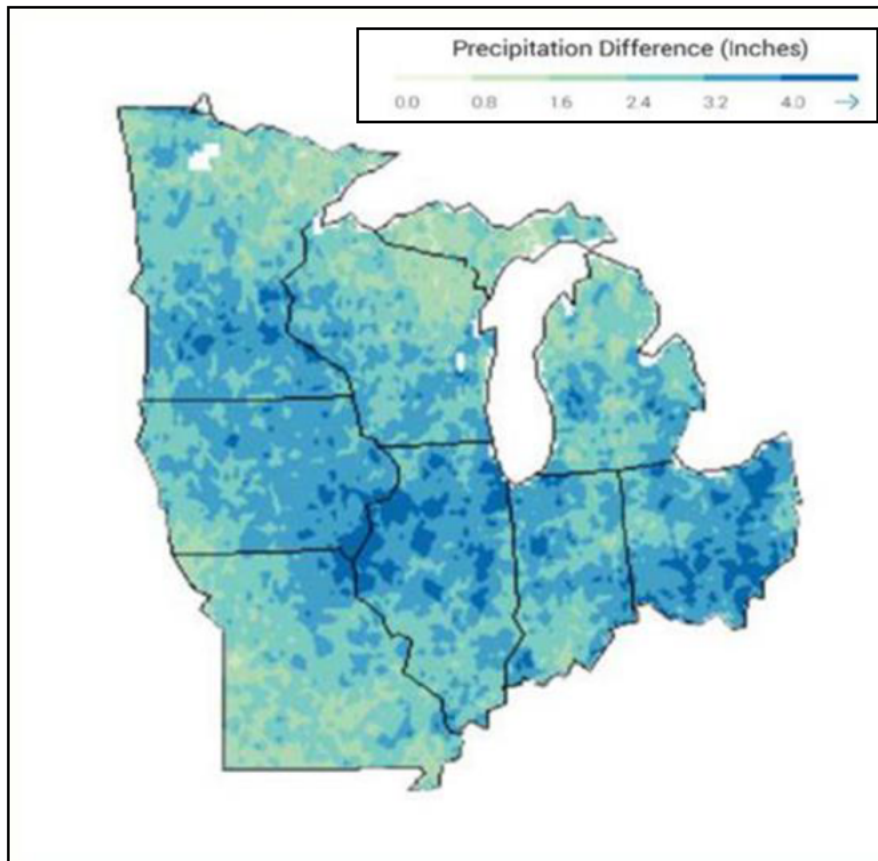


Figure 4-1. Projected Changes for the Middle of the Current Century (2041 – 2070) Relative to the End of the Last Century (1971 – 2000). (Figure Source: NOAA NCDC/CICS-NC)

According to the Third National Climate Assessment (NCA), projected future air temperatures are expected to trend upward, as will annual precipitation. Future increases in the frequency and magnitude of large storm events is expected. Projected changes in temperature, soil moisture and precipitation indicate an increase in the severity of droughts and extreme precipitation events. As a result of projected temperature increases the number of frost-free days is anticipated to rise. Streamflow has increased over the past century; however, a clear consensus is lacking with regards to projections in future hydrology. Some studies predict increases in projected streamflow and others predict decreases. Figure 4-2 shows a summary of observed and projected trends in climate

variables as well as an indication of the level of consensus within the literature according to the USACE literature synthesis.

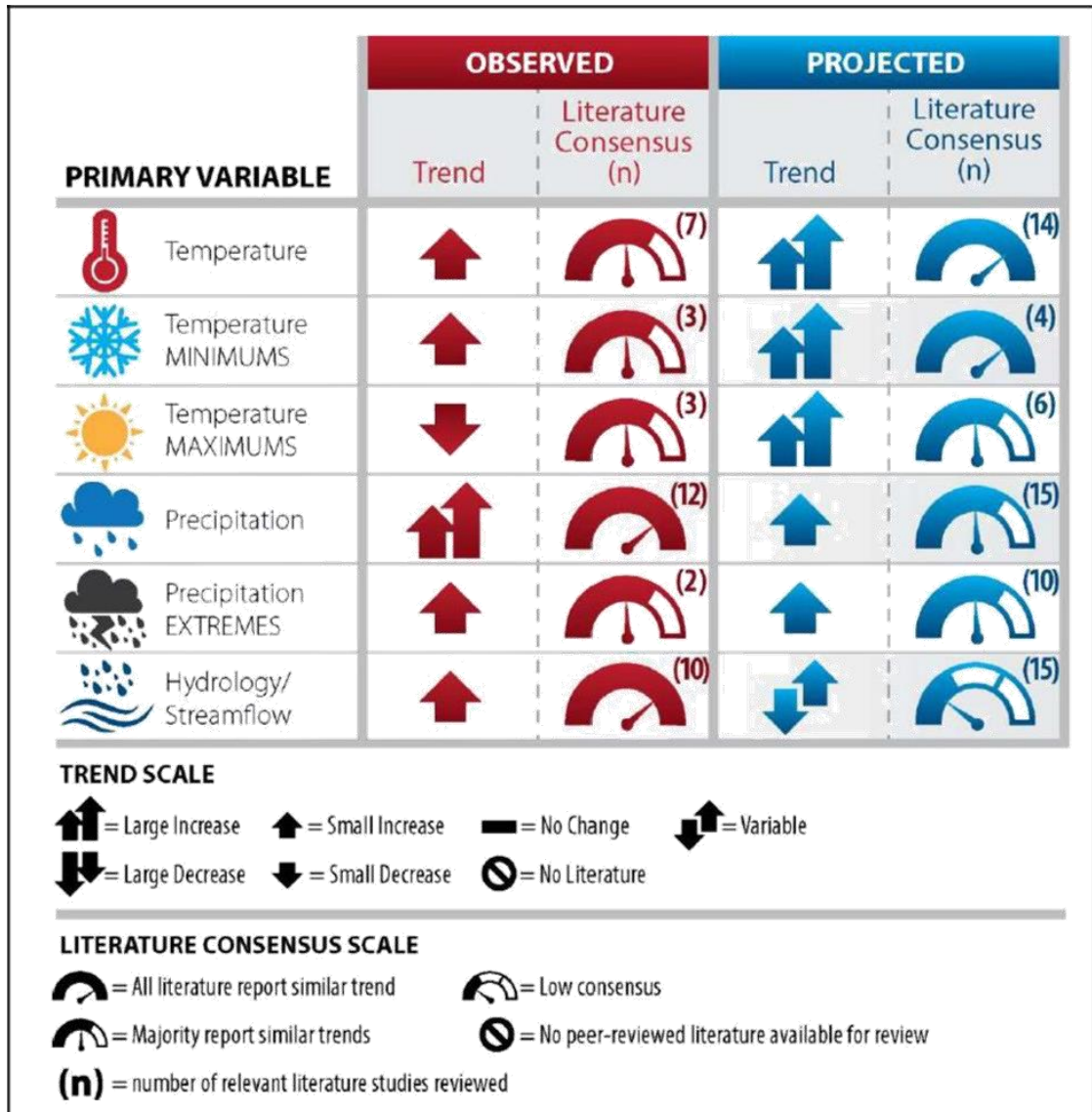


Figure 4-2. Summary of climate trends and literary consensus (USACE, 2015)

These observed and projected increasing trends in air temperature and precipitation as well as observed streamflow could affect ecosystem conditions in the project area and the engineering resilience of project features and should be considered during planning and design.

- g. **First Order Statistical Analysis, Trends in Streamflow & Climate Change at a Regional Scale:**
The USACE Climate Hydrology Assessment Tool was used to investigate potential future

trends in streamflow for HUC 0701, the Mississippi Headwaters watershed. Figure 4-3 below shows the location of the project area relative to the HUC02 and HUC04 watershed delineations, while Figure 4-4 displays the range of projected, mean annual maximum monthly stream flows computed from 93 different climate changed hydrologic model runs for the period of 1951-2099. This mean annual maximum monthly discharge variable is relevant to this project because the ecological conditions in the study area and the study objectives are most significantly impacted by high flow conditions and because one of the constraints to this project is the need to maintain the current level of flood risk in the study area.

Climate changed hydrology output is generated using various greenhouse gas mission scenarios (Representative Concentration Pathways, RCPs) and global circulation models (GCM) to project precipitation and temperature data into the future. These meteorological outputs are spatially downscaled using the BCSD statistical method and then inputted in the U.S. Bureau of Reclamation's (USBR) Variable Infiltration Capacity (VIC) precipitation-runoff model to generate a streamflow response. The effects of regulation are not included within the USBR VIC model.

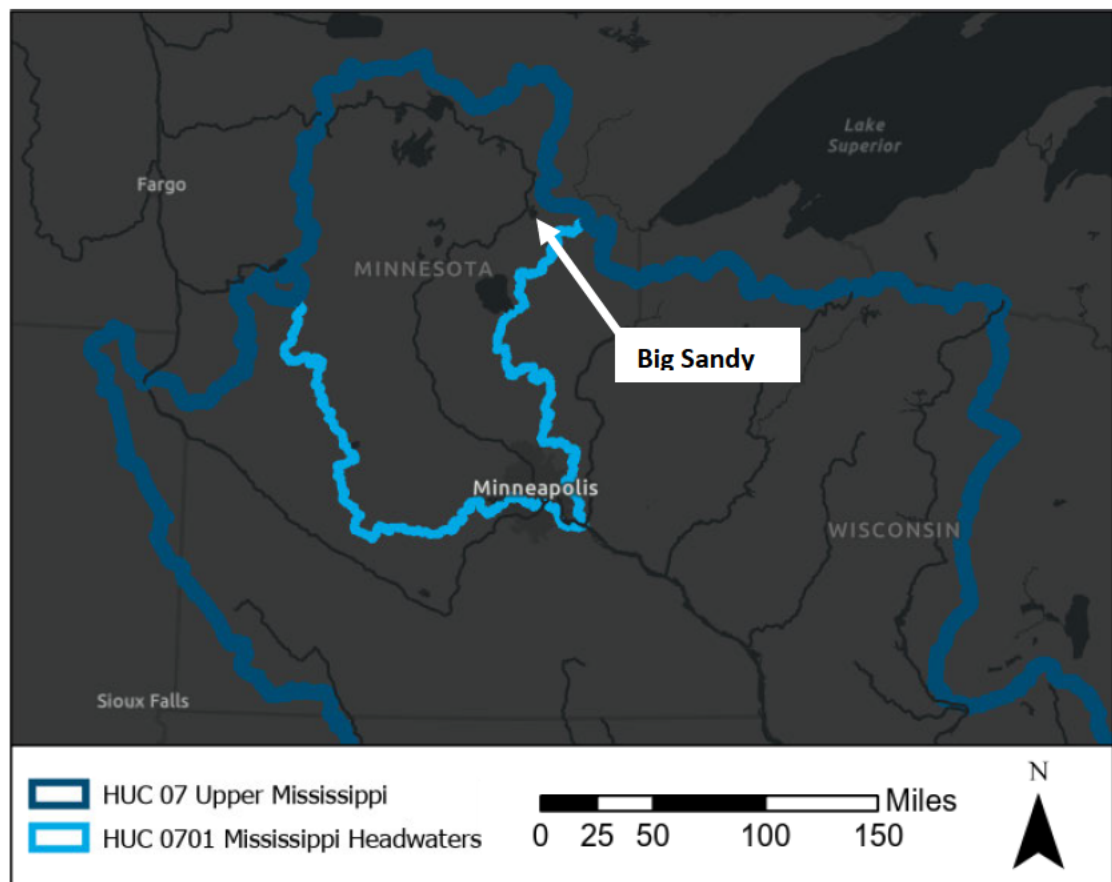


Figure 4-3. Location of Project Area within its HUC 2 and HUC 4

As expected for this type of qualitative analysis, there is considerable, but consistent spread in the projected annual maximum monthly flows. The spread in the projected annual maximum monthly flows is indicative of the high degree of uncertainty associated with projected, climate changed hydrology. See **Figure 4-4**.

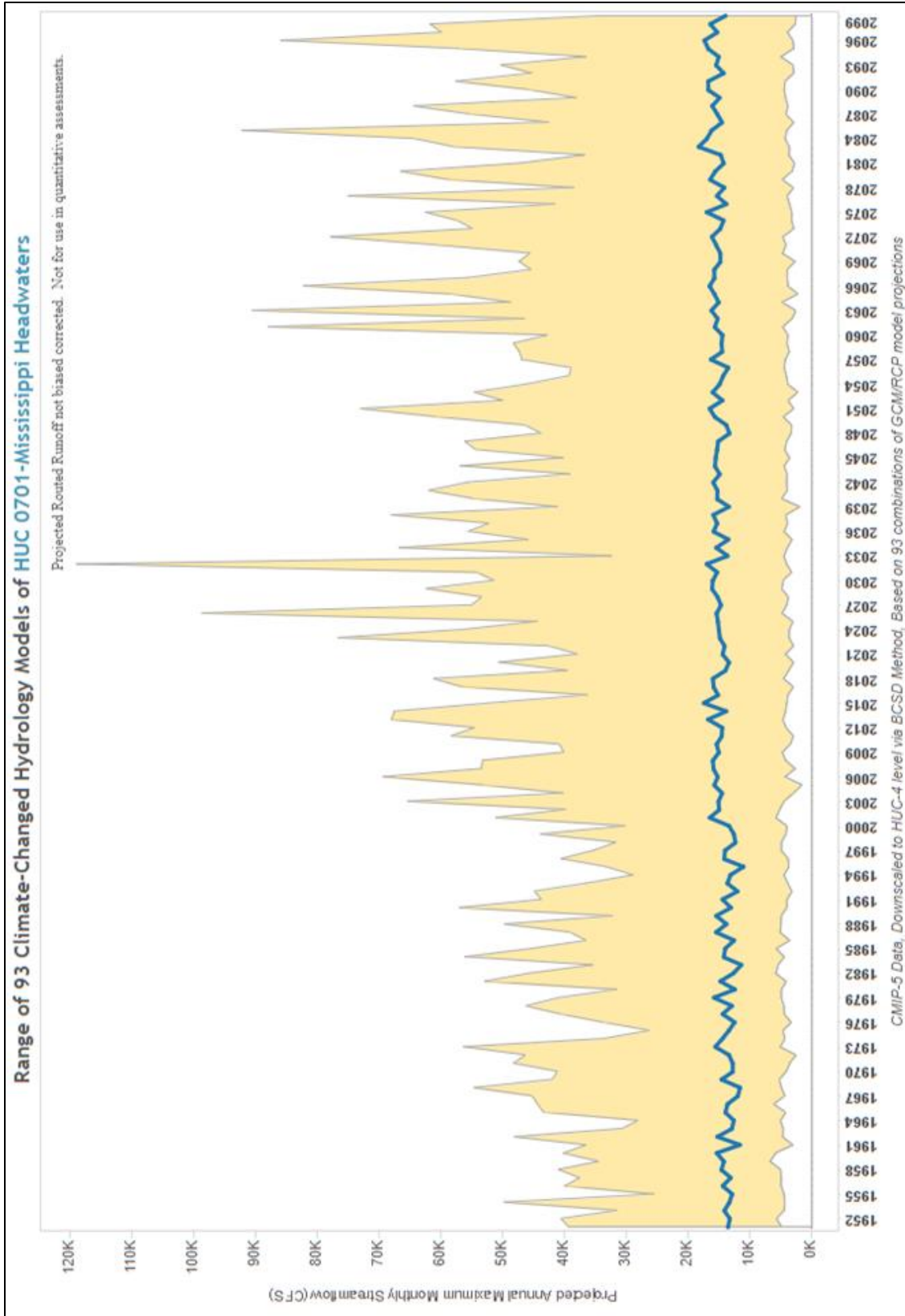


Figure 4-4. Range of Projected Annual Maximum Monthly Streamflow among Ensemble of 93 Climate-Changed Hydrology Models, HUC 0701 Mississippi Headwaters

As shown in **Figure 4-5** below, there is a statistically significant increasing trend in the mean projected annual maximum monthly streamflow. The p- value associated with this trend is less than 0.02. This is less than the generally accepted threshold for significance of 0.05. This finding suggests that there is potential for annual maximum monthly streamflows to increase in the future in the study area, relative to the current conditions.

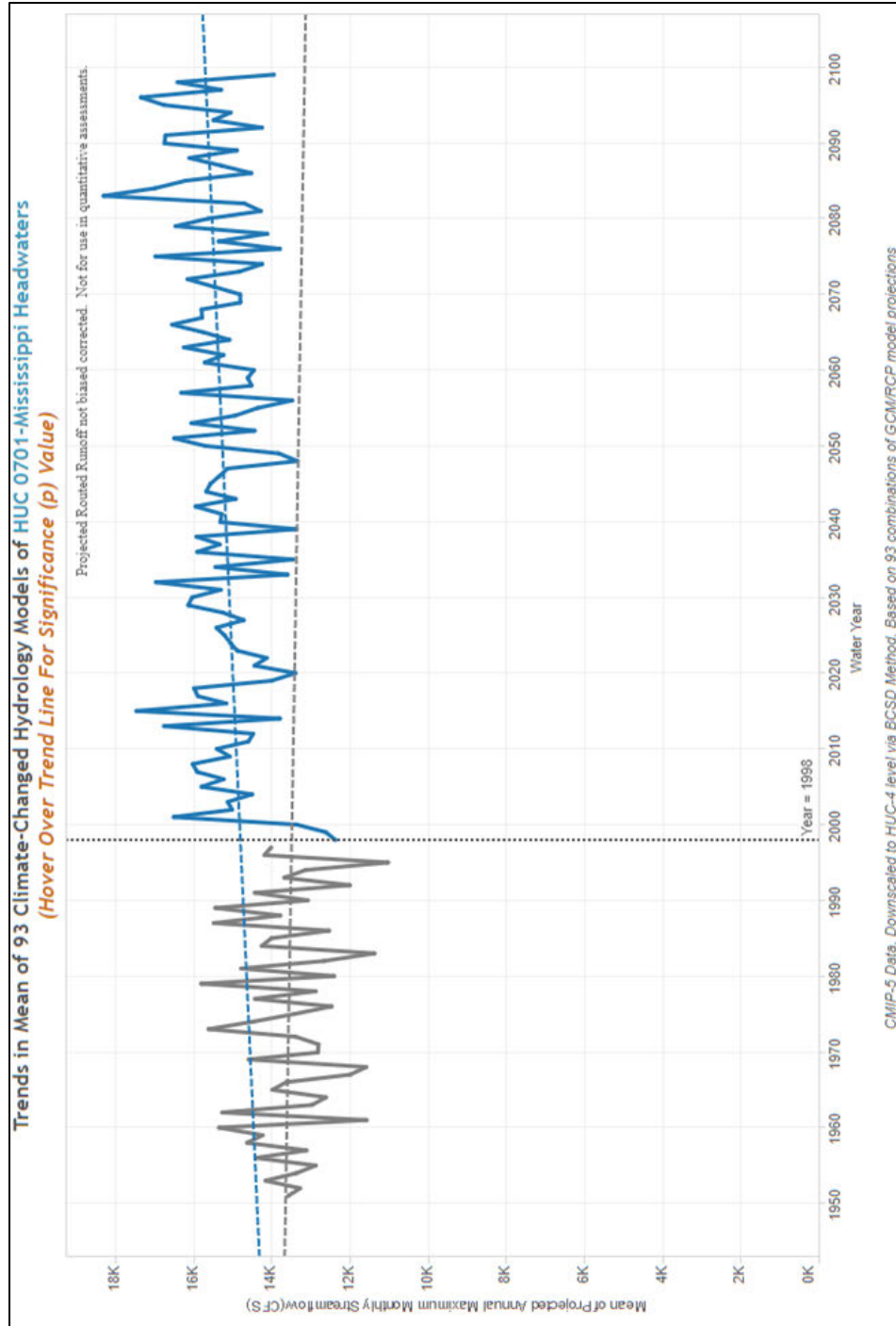


Figure 4-5. Mean Projected Annual Maximum Monthly Streamflow, HUC 0701 Mississippi Headwaters. Trendline Equation: $Q = 8.84568 * [\text{Water Year}] - 2884.03, p < 0.05$

- h. **Screening Level Vulnerability Assessment to Climate Change Impacts:** The USACE Watershed Climate Vulnerability Assessment Tool was also used to compare the relative vulnerability of the HUC 0702, the Minnesota watershed, to climate change to the other 201 HUC- 04 watersheds across the continental United States (CONUS). The tool facilitates a

screening level, comparative assessment of how vulnerable a given HUC-04 watershed is to the impacts of climate change. The tool can be used to assess the vulnerability of a specific USACE study to project climate change impacts. For this study both the Ecosystem Restoration and Flood Risk Reduction business lines were analyzed. This project is related to ecosystem restoration, but because of the flood stage impacts constraints, flood risk reduction is also relevant. Assessments using this tool help to identify and characterize specific climate threats and particular sensitivities or vulnerabilities, at least in a relative sense, across regions and business lines. The tool uses the Weighted Order Weighted Average (WOWA) method to represent a composite index of how vulnerable a given HUC-4 watershed (Vulnerability Score) is to climate change specific to a given business line. The HUC-4 watersheds with the top 20% of WOWA scores are flagged as being vulnerable.

Indicators considered within the WOWA score for Ecosystem Restoration include: change in sediment load, short-term variability in hydrology, runoff elasticity (ratio of streamflow runoff to precipitation), macroinvertebrate index (sum score of six metrics indicating biotic condition), two indicators of flood magnification (indicator of how much high flows are projected to change overtime), mean annual runoff, change in low runoff, and percent of at risk freshwater plant communities.

Indicators considered within the WOWA score for Flood Risk Reduction include: long-term variability in hydrology, runoff elasticity (ratio of streamflow runoff to precipitation), two indicators of flood magnification (indicator of how much high flows are projected to change overtime) and urban area (acres) within the 500 year floodplain.

When assessing future risk projected by climate change, the USACE Climate Vulnerability Assessment Tool makes an assessment for two 30-year epochs of analysis centered at 2050 and 2085. These two periods were selected to be consistent with many of the other national and international analyses. The tool assesses how vulnerable a given HUC-04 watershed is to the impacts of climate change for a given business line using climate changed hydrology based on a combination of projected climate outputs from the general climate models (GCMs) and representative concentration pathway (RCPs) resulting in 100 traces per watershed per time period. The top 50% of the traces by flow volume are called the “wet” subset of traces and the bottom 50% of the traces are called the “dry” subset of traces. Meteorological data projected by the GCMs is translated into runoff using the USBR Variable Infiltration Capacity (VIC) Macroscale hydrologic model. For this assessment, the default, National Standards Settings are used to carry out the vulnerability assessment.

- 1) Ecosystem Restoration Vulnerability Assessment:** Based on the results of the USACE Watershed Climate Vulnerability Assessment Tool presented in **Figure 4-6** below, relative to the other 201 HUC04 watersheds in the CONUS, the Mississippi Headwater watershed (HUC 0701) is relatively more vulnerable to the impacts of climate change on ecosystem restoration. For the Mississippi Headwater watershed, the major drivers of the computed vulnerability score are, “At Risk Freshwater

Plant”, “Runoff Precipitation”, and “Monthly CV of Unregulated Runoff”. shows the vulnerability scores for the two 30-year epochs and the scores are relatively constant between both epochs and their wet and dry subsets of traces. Additionally, shows the vulnerability score contributions of the different indicators for the 2050 epoch.

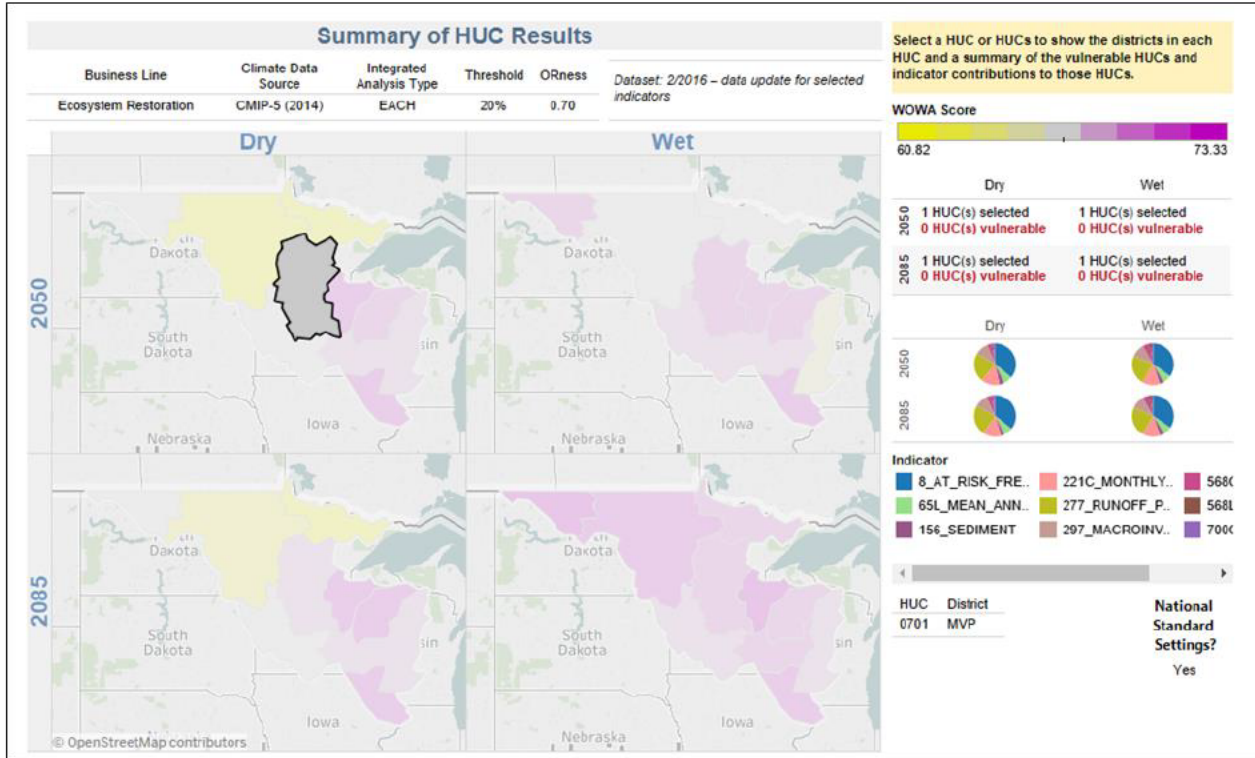


Figure 4-6. Projected Vulnerability for the Mississippi Headwaters (0701) with Respect to Ecosystem Restoration

HUC 4 Watershed	Ecosystem Reduction Vulnerability			
	2050 Dry	2050 Wet	2085 Dry	2085 Wet
Mississippi Headwaters (0701)	67.45	69.52	67.97	70.16

2050 Epoch	Mississippi Headwaters (0701)

Indicator	Contribution to WOWA Ecosystem Restoration Vulnerability Score			
	Dry		Wet	
At Risk Freshwater Plants	24.21	35.89%	24.21	34.82%
Monthly Coefficient of Variation (CV) of Unregulated Runoff	9.46	14.03%	9.57	13.76%
Flood Magnification	1.92	2.84%	3.41	4.90%
Mean Annual Runoff	4.78	7.08%	4.60	6.61%
Runoff Precipitation	15.72	23.31%	16.31	23.46%
Flood Magnification Local	0.76	1.12%	1.35	1.94%
Sediment	1.89	2.80%	2.41	3.47%
Macroinvertebrates	7.04	10.43%	7.09	10.20%
Low Flow Reduction	1.34	1.98%	0.90	1.30%

2) **Flood Risk Reduction Vulnerability Assessment:** Based on the results of the USACE Watershed Climate Vulnerability Assessment Tool presented in Figure 4-7 below, relative to the other 201 HUC04 watersheds in the CONUS, the Mississippi Headwater watershed (HUC 0701) is relatively more vulnerable to the impacts of climate change on flood risk reduction. For the Minnesota watershed, the major drivers of the computed vulnerability score are, “Runoff Precipitation”, “Annual CV of Unregulated Runoff”, and “Flood Magnification”. shows the vulnerability scores for the two 30-year epochs. Additionally, shows the vulnerability score contributions of the different indicators for the 2050 epoch.

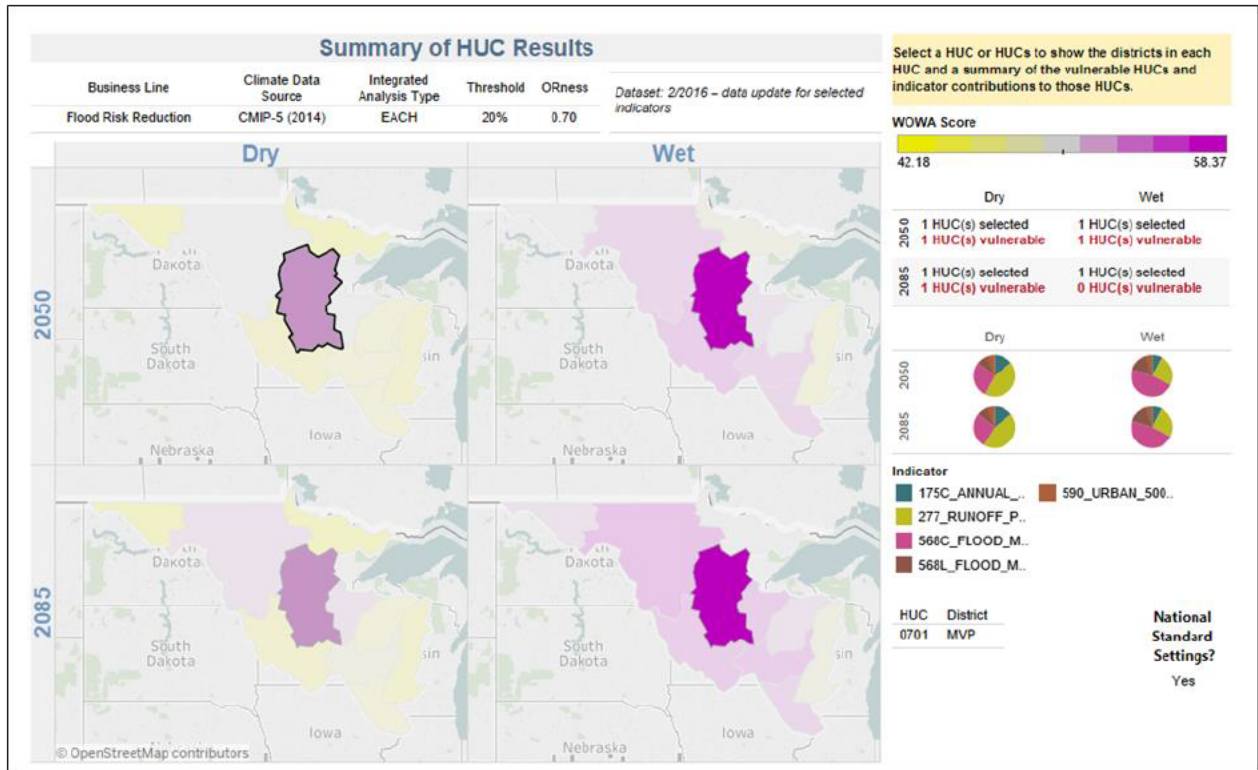


Figure 4-7. Projected Vulnerability for the Mississippi Headwater Watershed (0701) with Respect to Flood Risk Reduction

Table 4-5 Projected Vulnerability with Respect to Flood Risk Reduction				
HUC 4 Watershed	Flood Risk Reduction Vulnerability Score			
	2050 Dry	2050 Wet	2085 Dry	2085 Wet
Mississippi Headwaters (0701)	51.85	58.14	52.90	58.37

Table 4-6 Comparison of Different Indicators for the Mississippi Headwaters Watershed with Respect to Flood Reduction				
2050 Epoch	Mississippi Headwaters (0701)			
Indicator	Contribution to WOWA Ecosystem Flood Risk Reduction Vulnerability Score			
	Dry		Wet	
Runoff Precipitation	22.51	43.41%	14.19	24.40%
Annual CV of Unregulated Runoff	7.42	14.31%	4.51	7.76%
Flood Magnification	18.95	36.54%	36.70	63.13%
500 YR Urban Floodplain	2.98	5.74%	2.73	4.70%

- i. **First Order Statistical Analysis: Site Specific Trends in Observed Precipitation and Air Temperature Data:** In addition to analyzing river discharge, ECB 2018-14 requires the climate change analysis to include information for other variables relevant to hydro-climatic conditions such as temperature, evaporation rates and precipitation. The qualitative analysis required by this ECB should focus on those aspects of climate and hydrology relevant to the project’s problems, opportunities, and alternatives. The primary variables relevant to this project, besides discharge would include precipitation and air temperature. Trends in total annual precipitation and average annual air temperature are evaluated.

The data for these two variables is collected from the NOAA National Climatic Data Center (NCDC) station USC00211630 (Cloquet, MN US). The datasets cover 97% of the years between 1912 and 2015. The location of the station in relation to the project can be viewed in **Figure 4-8**. This is the closest station near Big Sandy Lake with evaporation data and a high percentage of data covered.

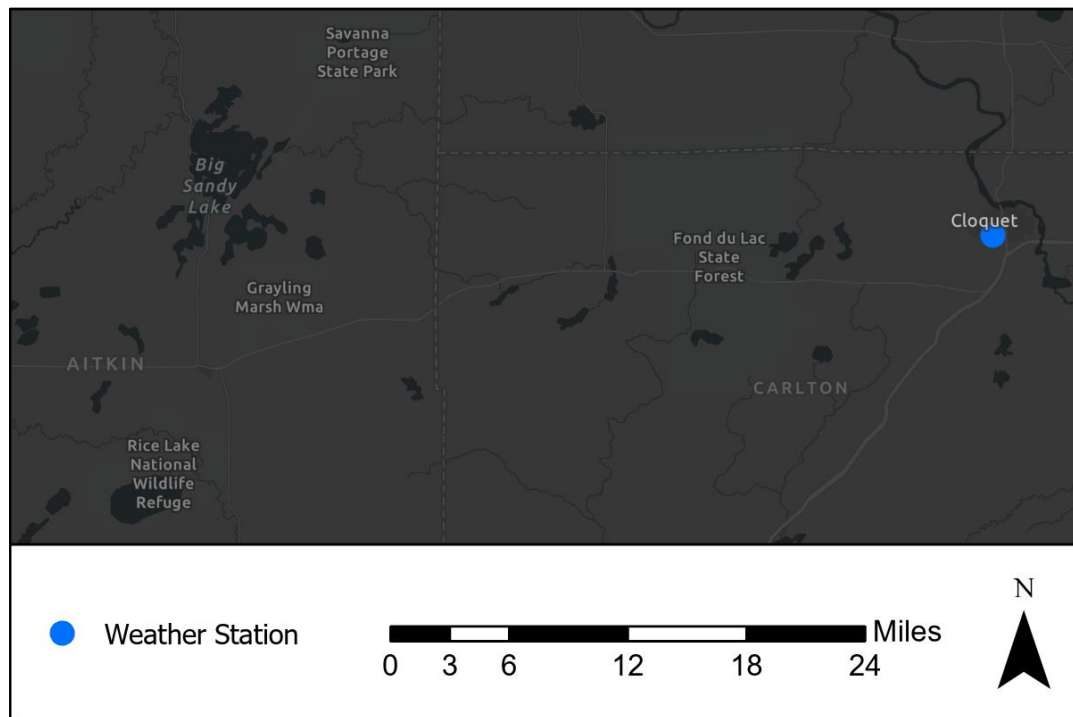


Figure 4-8. NOAA National Climactic Data Center Location in Cloquet, MN

- a. **First Order Statistical Analysis: Total Annual Precipitation:** The USACE Timeseries Toolbox application is used to assess the stationarity of the precipitation record recorded by the Cloquet, MN gage near the Minnesota River Basin. Four of the twelve non-stationarity detection tests included within the Timeseries Toolbox indicate that there is a statistically significant, non-stationarity in the year 1963 (see , below). Two different statistical tests are indicating a change in mean and two tests are indicating a change in overall statistical distribution. Thus, there is

consensus between tests. Because multiple tests, targeting different statistical properties are indicating a nonstationarity it can be considered robust. There is a significant increase in the magnitude of the mean if the data collected pre-and post-1939 is compared. As shown in Figure 4-9, it can be concluded that there is an operationally significant nonstationarity in the total annual precipitation record at this site (Friedman, et al. 2017). Figure 4-10 shows the results of a linear trend analysis for the entire period of record and for the subsets of data collected prior to and post 1939. There is a statistical significant positive trend in the dataset collected between 1912 and 2015 (p-value<0.05). If the dataset is broken up into two subsets of data collected pre- and post- 1939, there are no statistically significant trends (p-values>0.05).

Method	Year
Cramer-Von-Mises (CVM)	1963
Energy Divisive (END)	1963
Lombard Wilcoxon (LW)	1939
Mann-Whitney (MW)	1940

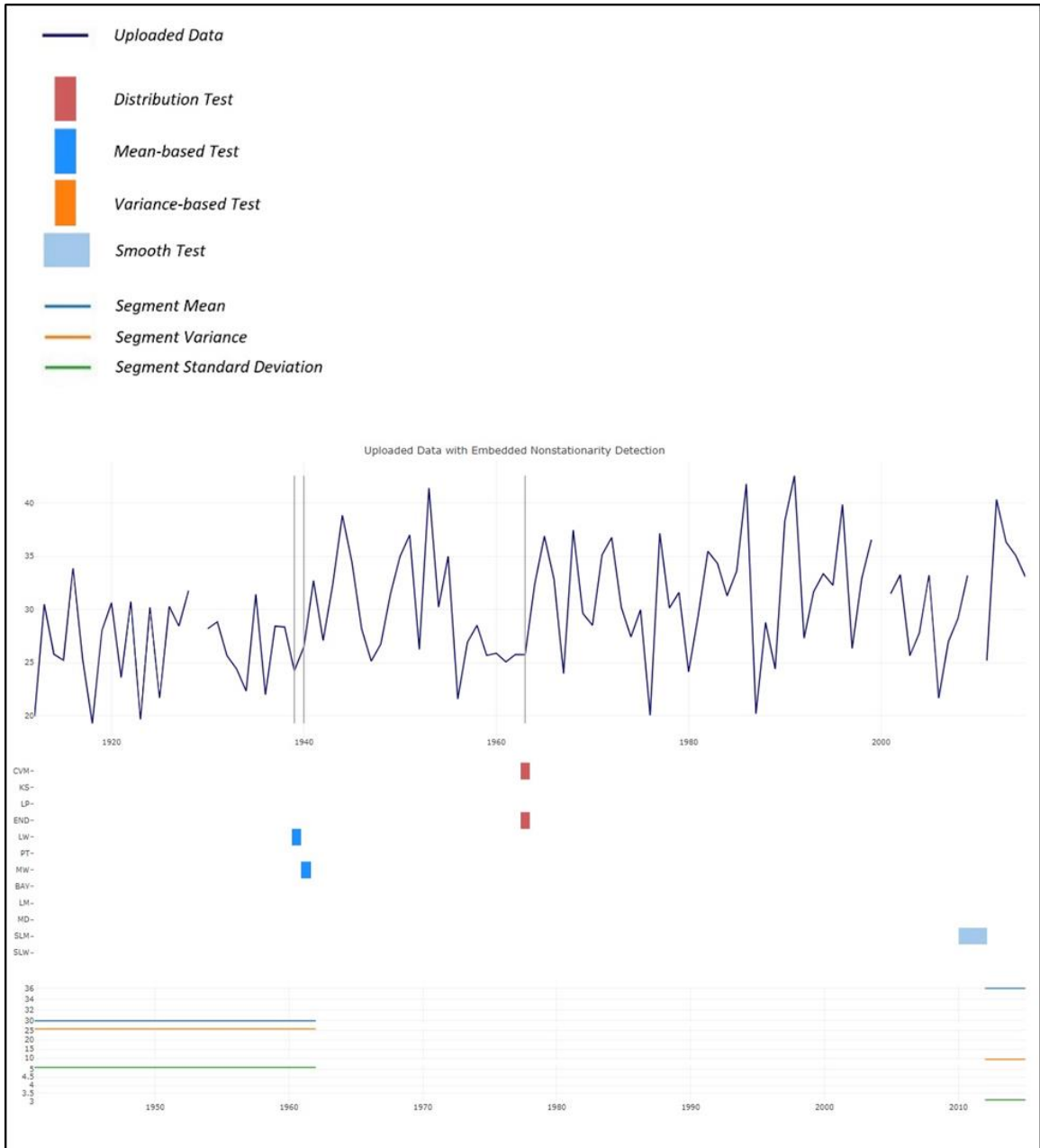


Figure 4-9. Nonstationary Analysis of Total Annual Precipitation at the Cloquet, MN Climatic Gage from 1912 to 2015 using the Time Series Toolbox

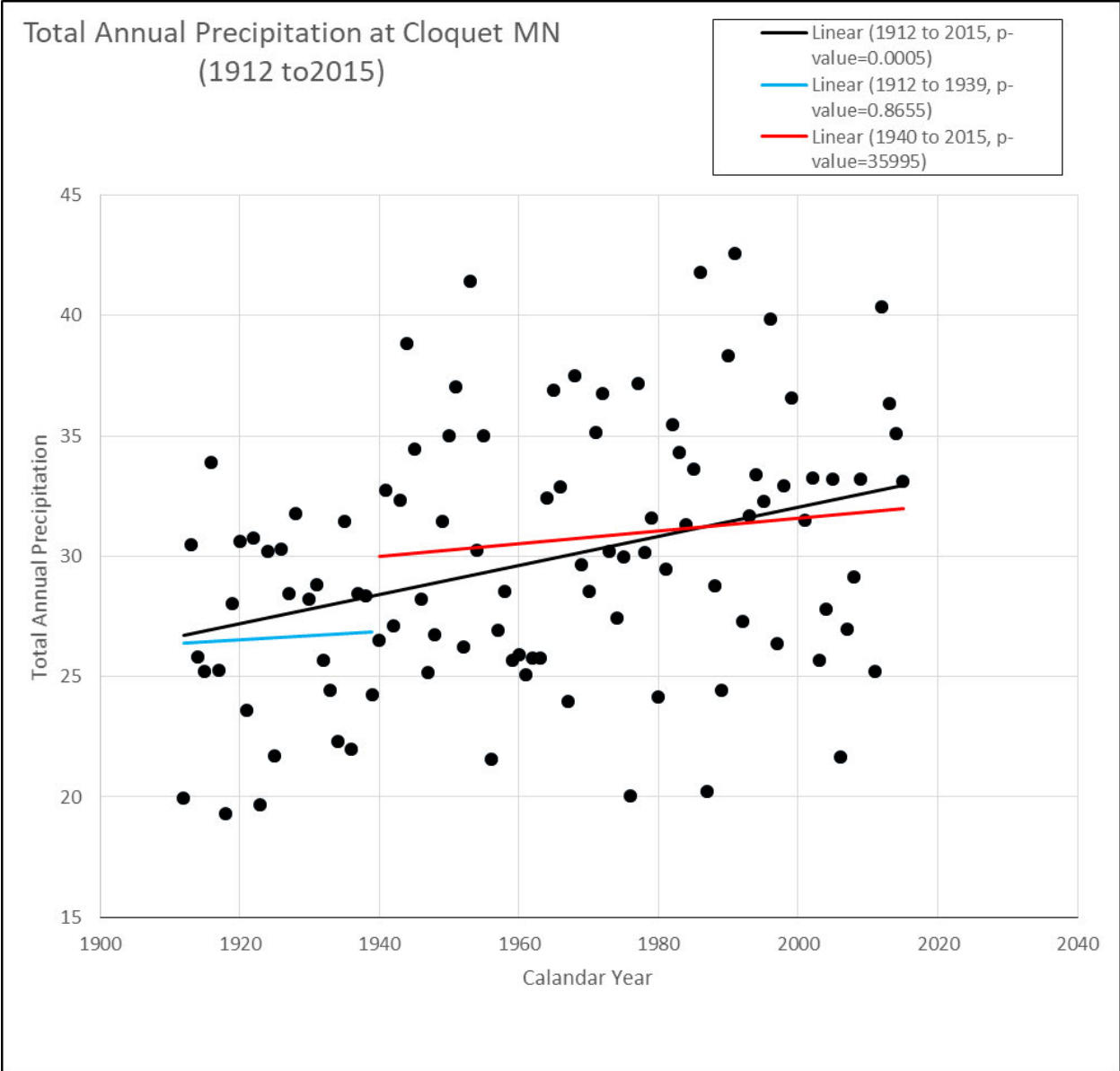


Figure 4-10. Total Annual Precipitation at the Cloquet, MN Climatic Gage from 1912 to 2015 & Subsets of Data Selected Based on the 1976 Nonstationarity

b. Air Temperature Nonstationarity Detection Tests: The USACE Timeseries Toolbox application is used to assess the stationarity of the average annual air temperature record recorded by the Cloquet, Minnesota gage near the Big Sandy Lake Basin. Four of the twelve different non-stationarity detection tests applied by the tool indicate a nonstationarity in 1997 (below). Cramer-Von-Mises (CVM), LePage (LP), Bayesian CPD (BAY), Mood (MD) detect nonstationarities in 1997. The

year 1983 was used as a breakpoint however because it was the only date located in the breakpoint analysis. Two different statistical tests are indicating a change in mean and two tests are indicating a change in overall statistical distribution. Thus, there is consensus between tests. Because multiple tests, targeting different statistical properties are indicating a nonstationarity it can be considered robust. There is a significant increase in the magnitude of the mean if the data collected pre- and post- 1983 is compared. As shown in Figure 4-11 below, it can be concluded that there is an operationally significant nonstationarity in the average annual air temperature record at this site (Friedman, et al. 2017). Figure 4-12 shows the results of a linear trend analysis for the entire period of record and for the subsets of data collected prior to and post 1983. There is a statistical significant positive trend in the dataset collected between 1912 and 2015 (p-value<0.05). If the dataset is broken up into two subsets of data collected pre- and post- 1983 there are no statistically significant trends (p-values>0.05).

Method	Year
Cramer-Von-Mises (CVM)	1979
Cramer-Von-Mises (CVM)	1997
LePage (LP)	1997
Energy Divisive (END)	1972
Lombard Wilcoxon (LW)	1984
Mann-Whitney (MW)	1919
Mann-Whitney (MW)	1985
Bayesian CPD (BAY)	1997
Bayesian CPD (BAY)	2012
Lombard Mood (LM)	1996
Mood (MD)	1997

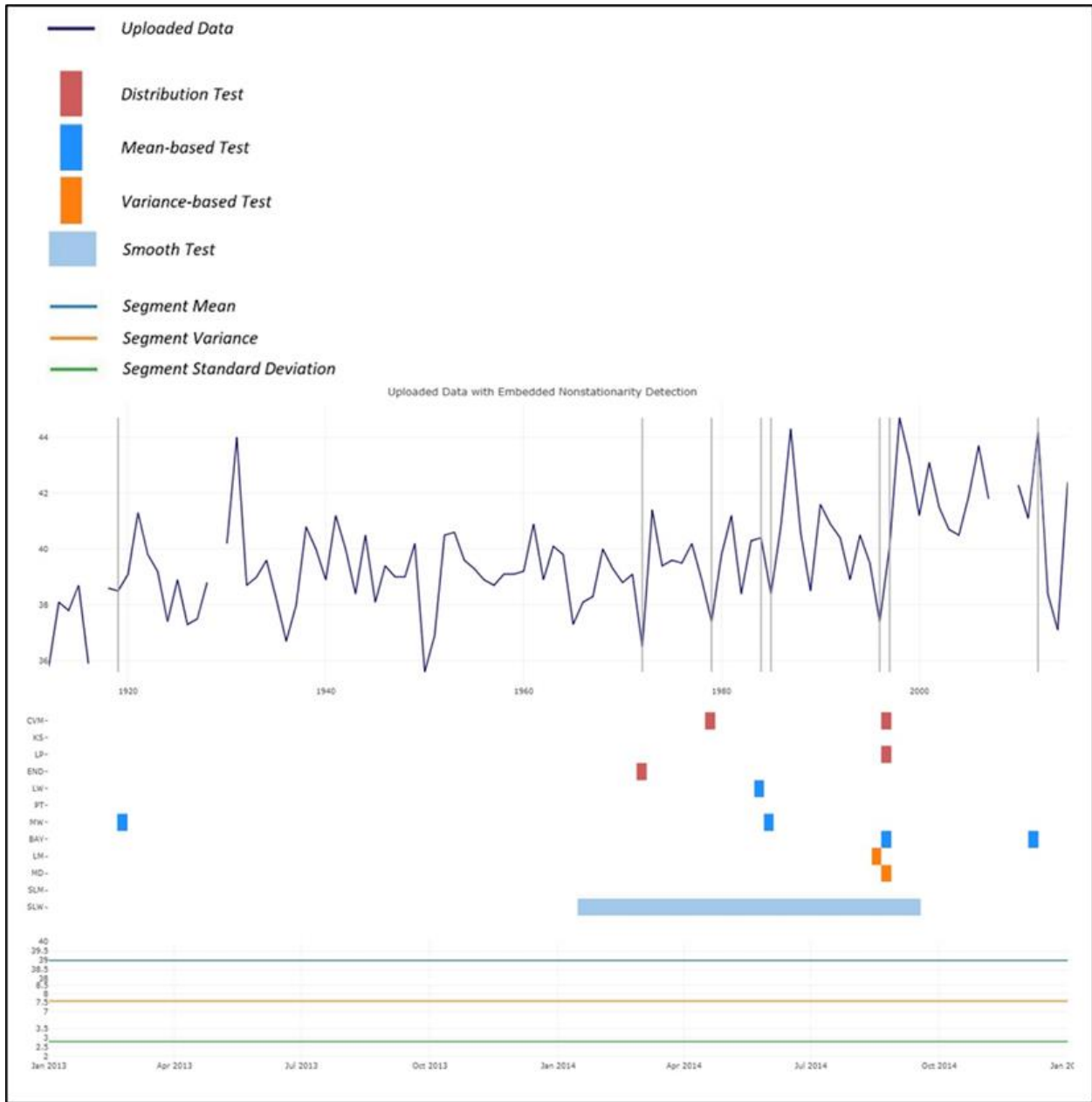


Figure 4-11. Nonstationary Analysis of Average Annual Air Temperature at the MSP Climatic Gage from 1939 to 2017 using the Time Series Toolbox

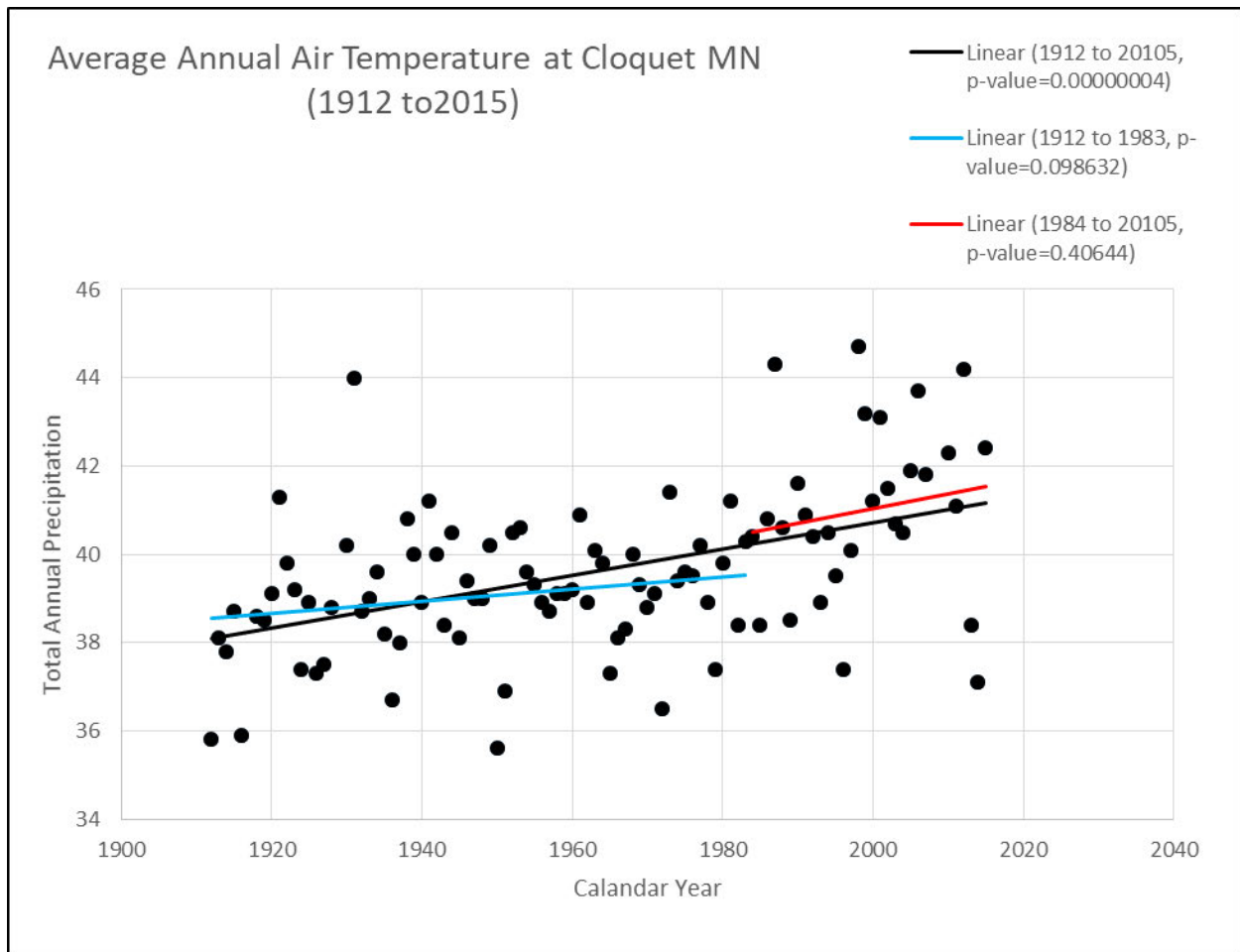


Figure 4-12. Average Annual Air Temperature at the Cloquet, MN Climatic Gage from 1912 to 2015 with Trend Lines for the 1983 Breakpoint

- j. **Summary and Conclusion:** The USACE Watershed Climate Vulnerability Tool indicating that the Mississippi River watershed is vulnerable to the impacts of climate change on ecosystem restoration or flood risk management relative to other 201 HUC-04 watersheds in CONUS, and available climate change literature suggests a wetter and warmer climate in the future. A first order statistical analysis using the USACE Climate Hydrology Assessment Tool, Nonstationarity Detection Tool and Timeseries Toolbox confirms that overall, observed flows have been increasing and will likely continue to increase in the Mississippi Headwater River Basin. With the proposed, repaired design of the water management structures, the project will be given the best chance at completing annual drawdowns safely.

The trends and nonstationarities detected in the annual peak flow and the average annual flow records cannot be attributed to a specific driver like the construction of a water management structure or a known, abrupt change in land use. Thus, trends and nonstationarities are likely caused by a less easily identifiable source like anthropogenic

climate change, long-term, persistent natural fluctuations in climate or distributed changes to the basin's land cover/land use/geomorphology overtime.

Climate change and extreme flooding should not affect the operation of this structure as the tailwater from the Mississippi River “submerges the Big Sandy Lake Dam gates, restricting the outflow due to reduced head across the dam” states the ROPE Study. There are studies being done to understand the relationship for flood risk management from Big Sandy Lake on the Mississippi River and this section will be updated accordingly. The Lake will have more inflow from the basin as well as receiving more water from a higher Mississippi River over time

4-06 Storms and Floods

- a. **Storms and Floods:** Floods of damaging proportions occur in the Mississippi River Headwaters basin above Brainerd, Minnesota, as a result of rapid snowmelt, heavy spring rains, or prolonged periods of above-normal summer rainfall. Although large areas of poorly-drained marsh and timberlands throughout the basin have been frequently flooded, the focal point of repeated damaging floods was in the vicinity of the City of Aitkin, Minnesota. Since the latest ROPE Study there is no current flood damage center for Big Sandy Lake Dam because “a water control regulator cannot proactively operate Sandy Dam over a large portion of the existing guide curves”. The National Weather Service flood stage at Aitkin is 12.0 feet (reduced from 15.0 feet in November 1978).

When flooding subsides in the Aitkin area, large volumes of stored water are released from the upstream reservoirs (Winnibigoshish, Leech, Pokegama and Big Sandy Lake) which, when combined with local runoff, can lead to prolonged high river levels.

Selected floods at Big Sandy Lake are tabulated in **Table 4-9**. A brief description of these floods follows.

**Table 4-9
Peak Elevations and Discharges for Selected Events at Big Sandy Lake Dam and Reservoir¹**

Date ²	Lake Elevation ³ (ft)	Pool Elevation ³ (ft)	Discharge (cfs)
13 July 1897	1222.36	1222.36	3,697 (Peak for WY = 3,738 on 12 July)
10 July 1905	1220.25	1220.21	743 (Peak for WY = 1,709 on 26 June)
30 April 1916	1220.51	1220.43	1,910 (Peak for WY = 2,091 on 6 May)
19 May 1950	1224.82 ⁴	1224.80	2,067 (Peak for WY = 3,400 on 23 May) ^{4,5}
25 April 1969	Not Available ⁶	1221.75 (1300 hrs)	394 (Peak for WY = 1,940 on 8 May) ⁵
6 May 1975	Not Available	1222.10 (1200 hrs)	1,370 (Peak for WY = 1,850 on 15 May) ⁵
30 April 2001	Not Available	1221.76	1,250 (Peak WY = 1,534 on 3 May)
28 June 2012	Not Available	1222.93	2,427 (Peak WY = 2,548 on 3 July)

1. Unless otherwise noted, values are from Corps log sheets and are assumed to be AM readings.
2. The period of record is not homogeneous. The current operating plan began in 1936. Caution must be exercised when comparing pre-1936 events to later events. See Section 3-07. Backwater from the Mississippi River can affect Sandy L. outflow. Due to regulation effects, Water Years may not provide hydrologically independent events.
3. Gage zero = 1207.31 feet (1929 NGVD). Pool elevations, which can be affected by head loss in the approach channel, are recorded at the dam. Lake elevations were recorded on the lake proper (not affected by head loss). In some years, lake elevations were not recorded daily. Morning pool readings are shown. Most of the time, afternoon pool values were also recorded on the log sheets and, in some cases, those values are slightly higher than the morning pool values. The log sheets and USGS records should be consulted for additional information to include the time when the values were recorded and other details. There currently is no lake gage (see Note No. 6).
4. Maximum lake elevation of record through 2020. Recorded at 1800 hours. See USGS 1950 Water Supply Paper No. 1175 and Corps log sheets. Maximum outflow of record for the period 1936 - 2020. See the 1897 peak outflow and Note No. 2. See Chapter 7 for info on Aitkin, MN. The control structure was overtopped in 1950 by 3.5 ft.
5. From records supplied to the United States Geologic Survey. See USGS Water Supply Paper (WSP) No. 1175 (for 1950), Water Resource Data for MN, 1969 and Water Resource Data for MN, 1975. Also see Corps log sheets and Chapter 5.
6. The lake gage was discontinued after December 1962. See Corps log sheets.

- a. **The Flood of July 1905:** The first major flood for which reliable records are available at Aitkin occurred in 1905 and followed a prolonged period of above normal summer rainfall. Outflow from Big Sandy Lake Dam peaked at 1,709 cfs on 26 June and remained high until mid-July. The maximum lake elevation attained was 1220.25 feet on 10 July.
- b. **The Flood of April 1916:** Rapidly rising temperatures during April, accompanied by light rains, melted the snow cover around Big Sandy Lake. Subsequent rains in May resulted in damaging stages which persisted into June. The flood discharge at Big Sandy Lake rose rapidly at the end of April, peaked at 2,091 cfs on 6 May, and receded in mid-May. The maximum lake elevation was 1220.51 feet on 30 April.

- c. **The Flood of April 1950:** Precipitation during the winter of 1949-50 was considerably above normal and the snow cover remained on the ground late into the spring as April temperatures averaged about 10 degrees below normal. Deeply frozen ground conditions, together with the heavy snow cover, were conducive to high runoff which, when combined with the above-normal rainfall of April and May, produced the greatest flood in the history of the area. During the 1950 flood, the reservoir capacity, measured to the top of the outlet dam, was exceeded. The dam was overtopped by 3.5 feet and temporary dikes were built to prevent erosion. After the flood, the earth dam sections on both banks were raised above the flood level.

Winnibigoshish and Leech Lake reservoirs were able to contain most of their inflows during the flood period; however, Pokegama reservoir was filled to near maximum height and at the peak of the flood was discharging about 2,500 cfs. The unprecedented high stages on the Mississippi River raised the tailwater elevation at Big Sandy Lake Dam, retarded the outflow from the reservoir, and contributed to a record maximum reservoir lake elevation of 1224.82 feet and a maximum discharge of 3,400 cfs (the maximum discharge of record is 3,740 cfs in 1897). During these high stages, some flow left the Mississippi River upstream of the reservoir and flowed into Big Sandy Lake. Since this flood, a road in that area was raised to prevent this diversion from reoccurring. Damages in the reservoir areas were approximately \$500,000 and brought the estimated total damages, to about \$2.5 million.

- d. **The Flood of April 1969:** The fall of 1968 had 3 to 4 inches more precipitation than normal. This, added to the 5.6 inches-above-normal precipitation in the spring of 1969, was cause for increased public awareness of a flood situation. The high waters of 1965, which caused very severe flooding in downstream reaches of the Mississippi River, were still very much remembered. Records show that the snow on the ground at Big Sandy Lake Dam was 20.0 inches deep on the first of April and that it was completely melted in 11 days. The peak flow at Big Sandy Lake Dam was 1,940 cfs on 8 May and the maximum pool elevation was 1221.75 feet on 25 April.
- e. **The Flood of May 1975:** There was approximately 3 inches more than normal precipitation for the January through March period of 1975. The snow depth at Big Sandy Lake was 26.0 inches on the first of April and was completely gone by 22 April. A spring rain storm on 23 April contributed 0.85 inches. At Big Sandy Lake, the maximum lake elevation was 1222.10 feet on 6 May and the maximum discharge was 1,850 cfs on 15 May.
- f. **The Flood of Spring 2001:** The spring flooding was the result of four contributing climatic factors: 1) significant autumn precipitation (heavy early November rains before soil freeze-up), 2) heavy winter snowfall (above average in some locations),

3) less than ideal snowmelt scenario (below normal March temperatures), 4) record-breaking April precipitation. April precipitation totals were extraordinarily high across the Headwaters region as well as most of Minnesota. Portions of the Headwaters region received over six inches of precipitation in the month of April. Precipitation totals surpassed the historical average by more than four inches in many areas.

Lake Winnibigoshish, Leech Lake, Pokegama Lake and Big Sandy Lake all experienced high water which affected recreation activities and caused shoreline erosion. Big Sandy Lake reservoir peaked at elevation 1221.76 feet on 30 April 2001.

- g. The Flood of Summer 2012:** During the winter of 2011/2012, Sandy achieved its “normal” drawdown. After the snow melted in spring, favorable rains occurred. All Headwaters sites were in their summer operating bands by late April/early May. From May 19 to May 29, 2012, the Headwaters region received more-than-normal precipitation. Gull recorded 7.71 inches, Cross Lake 6.74 inches, Sandy 7.37 inches, Pokegama 5.75 inches, Leech 2.95 inches and Winnibigoshish 3.15 inches. Gull Lake quickly rose and eventually crested at elevation 1195.09 feet (1.09 feet above normal) which tied the record crest set in 1952. On June 13, the lake level was back in the summer band. Sandy crested at elevation 1218.96 feet (2.65 feet above center of band). On June 20, the lake level was still 1 foot above the summer band. Pokegama was regulated according to the guide curves from the approved Water Control Manual and the National Weather Service’s flood forecast at Aitkin, MN. Retention at Pokegama allowed the reservoir to eventually crest at elevation 1274.85 feet (1.43 feet above center of summer band). On June 17, 2012, the reservoir was back in the summer band. Cross Lake, Leech, and Winnibigoshish remained in their normal summer operating bands.

From June 17 to June 24, 2012, torrential rains fell in the eastern Headwaters basin. Gull recorded 3.33 inches, Cross Lake 7.42 inches, Sandy 8.80 inches, Pokegama 5.32 inches, Leech 5.84 inches and Winnibigoshish 3.81 inches. The first NWS prediction at Aitkin, MN was stage 20.5 which would have been 2nd highest all time. Per the operating plans, outflow was reduced at Pokegama (from 2,100 cfs to 320 cfs), Leech (from 380 cfs to 130 cfs), and Winnibigoshish (from 675 cfs to 100 cfs). Pokegama crested on July 2 at elevation 1276.45 feet (2.78 feet above top of summer operating band) and returned to the band on July 28. Leech crested about 0.35 feet above the top of summer operating band. Winnibigoshish crested about 0.25 feet above summer operating band. Sandy was hardest hit, eventually cresting at 6.37 feet above the summer band (elevation 1222.93 feet) on June 28. Gates had been fully open since May 24th. Sandy returned to the summer band on July 30. Gull crested on June 24 at elevation 1194.71 feet and Cross Lake crested on June 25 at elevation 1230.09 feet (0.52 feet above top of summer operating band). All

stated elevations are in 1929 NGVD.

h. The Flood of Spring 2019: During March, a maximum 24 inches of snow and 4.8 inches of snow water equivalent (SWE) were recorded at the site. The entire Sandy watershed had higher than normal snow and SWE quantities. The initial NWS forecast for Aitkin was over stage 17 feet. The full 2 feet drawdown on Sandy was maintained until 23 March, when the warming temperatures produced more runoff. The slide gates were fully opened on 29 March, and on 5 April, the stop logs were removed. After an initial crest and cooling period, the lake eventually crested at elevation 1217.57 feet, 1.26 feet above center of summer band, on 4 May. The peak outflow of 1,276 cfs occurred on 19 May. The lake returned to summer band on 24 May, and the slide gates were cut on 27 May, while the stop logs were replaced on 29 May.

b. Droughts and Requested Releases:

- a. The Drought of 1940 – 1944:** Vessels needed for the war effort could not get through the Soo Locks on the Great Lakes. The traffic (over 2,000 vessels) was instead diverted down the Illinois River to the Mississippi River and on to New Orleans. Water from the Headwaters reservoirs was released during this period (primarily in the fall and winter months) in an effort to provide sufficient water depth for navigation over the Chain of Rocks in St. Louis, Missouri. At this same time, additional water was needed to cover the industrial water intakes in the St. Louis area. At various times, water was also released to help with power generation at Keokuk, IA due to a shortage of coal and to assist in the movement of oil up the Ohio River from the St. Louis refineries.
- b. Emergency Repairs in 1953:** The discharge from the Headwaters reservoirs was adjusted to facilitate emergency repairs of the locks and dams in the Twin Cities.
- c. The Drought of 1956:** After the winter of 1943-44, additional releases from the Headwaters reservoirs for the St. Louis area were not needed until 1956, when a water shortage occurred again. This resulted in not only the release of water from the Headwaters but also the release of water from Lake Michigan by executive order.
- d. 1956 Aitkin Flood Control Guide Curves:** Moderate to severe floods occurred in the Aitkin, Minnesota area in 1950, 1952, 1953 and 1954 (and earlier). Concerns about flooding resulted in the construction of the Aitkin Diversion Channel (see **Section 3-04b**). The project was completed in June 1956. In addition, flood control guide curves were developed to distribute damages between Pokegama Lake, Big Sandy Lake, and Aitkin during flood periods. Lake Winnibigoshish and Leech Lake Dam are operated in conjunction with Pokegama Lake Dam in order to make an attempt to follow the guide curves. As part of this study effort, the upper operating limit for

Sandy was raised from elevation 1218.31 feet to the top of the control structure at elevation 1221.31 feet (by agreement rather than an official change in the Congressional regulations). Pokegama's upper operating limit was also raised from elevation 1276.42 feet to the top of its control structure at elevation 1278.42 feet. See _____ and **Chapter 7** for additional details on the flood control operation for Aitkin.

- e. **The Drought of 1958:** The discharge in the Mississippi River at St. Paul reached a mean daily low of 1,950 cfs in August of 1958. In a letter dated 20 August 1958, Mr. Kerwin L. Mick, Chief Engineer and Superintendent of the Minneapolis-St. Paul Sanitary District, requested that the Corps release water from the Headwaters reservoirs to aid in the dilution of sewage in the Twin Cities area. In a letter to Mr. Mick dated 22 August 1958, Colonel Brown indicated that, in response to the request, the discharge from the reservoirs was increased about 80 percent for the benefit of all the interests below the dams. Additional water was released from the reservoirs on approximately August 27.
- f. **The Drought of 1959:** The discharge in the Mississippi River at St. Paul had reached a mean daily low of 1,970 cfs in August of 1959 and was forecasted to go as low as 1,000 cfs. In a letter dated 18 August 1959, Mr. Kerwin L. Mick, Chief Engineer and Superintendent of the Minneapolis-St. Paul Sanitary District, requested that the Corps release water from the Headwaters reservoirs to aid in the dilution of sewage in the Twin Cities area. In a letter to Mr. Mick dated 12 September 1959, Colonel Brown indicated that, in response to the request, the discharge from the reservoirs was increased on 25 August in advance of the normal fall drawdown period.
- g. **The Drought of 1960:** The discharge in the Mississippi River at St. Paul had reached a mean daily discharge of 2,330 cfs in August of 1960. In a letter dated 16 August 1960, Mr. Kerwin L. Mick, Chief Engineer and Superintendent of the Minneapolis-St. Paul Sanitary District, requested that the Corps release water from the Headwaters reservoirs to aid in the dilution of sewage in the Twin Cities area. In a letter to Mr. Mick dated 19 August 1960, Colonel Strandberg indicated that, in response to the request, the discharge from the reservoirs was increased on 17 August in advance of the normal fall drawdown period.
- h. **2012, Directive to Deviate, Memorandum to the St. Paul District, the Rock Island District, and the St. Louis District from the Mississippi Valley Division:** This directive required the storage of water of up to 10% above the approved guide curve storage to be released at a later date to mitigate downstream drought impacts. This directive was suspended on 11 February 2013.

4-07 Runoff Characteristics

The runoff from Big Sandy Lake watershed is slow and significantly attenuated as a result of the relatively flat topography and the presence of many lakes and wetlands. Big Sandy Lake Dam controls the runoff from a 421 square mile area, of which 31 percent is dry land, 12 percent is water, and 57 percent is wetlands. In general, the land not covered by wetlands is forested. The average overland slope is 14.78 feet per mile.

During the development of this Water Control Manual, information about the runoff characteristics of the watershed was obtained by utilization of the reservoir's hydrologic records together with computer modeling of the basin. A computer model of the watershed was developed and calibrated using computed inflows for selected floods together with corresponding storm or snowmelt data (see **Chapter 6**). Flow duration curves, exceedence-frequency curves and streamflow distributions were derived from observed data and the data resulting from the model. These curves give a graphical display of important watershed runoff characteristics.

The elevation and outflow records from 1899 to 2018 as well as average lake evaporation from were utilized in a reverse routing procedure to estimate daily inflows to the reservoir. The exceedence frequency of a given average monthly inflow can be determined for each month from **Plate 4-2**. The monthly exceedence frequency curves show a wide variation due to the unique weather conditions of each month, although seasonal patterns are evident. The percent time a given inflow or outflow is equaled or exceeded is given on the flow duration curves, **Plate 4-3** and **4-4**. See also **Section 8-11**.

The monthly streamflow distribution determined from the period of record at Big Sandy Lake is presented on **Plate 4-5**. Minimum monthly discharges occur in late winter. The maximum monthly inflow occurs in April from snowmelt and spring rain runoff. Maximum monthly outflows as a result are significantly lower and occur in May. Monthly inflows generally exceed outflows during spring and summer as the reservoir is filling and evaporation losses occur. The inverse is true during the fall and winter as the reservoir level is drawn down for use in spring flood protection.

The annual streamflow distribution for Big Sandy Lake is shown on **Plate 4-6**. The peak annual inflow and outflow occurred in 1953. The year of 1934 is the driest on record. A cyclic pattern is evident in the 119 years of record (1899-2018).

4-08 Water Quality

Big Sandy Lake is a highly colored eutrophic lake in the north central Minnesota in the Northern Lakes and Forests (NLF) ecoregion. Sandy is composed of several bays with a relatively large and shallow main bay. Two bays, Bill Horn and Webster Bays, exhibit characteristics of a classically stratified dimictic lake. The large main bay is windswept and rarely stratifies except for short periods on hot calm summer days. During these times anoxia at the sediment-water interface may occur, liberating phosphorus into the bottom waters. Upon mixing, the additional phosphorus may be circulated to the surface waters for utilization by algae.

Both point and non-point source pollution are attributable to the eutrophication of Big Sandy Lake. Big Sandy Lake's mean summer total phosphorus, chlorophyll a, and secchi transparency are 40 ppb, 9 ppb, and 1 meters (3.3 feet), respectively. Bog staining or coloration of the water from the surrounding wetlands results in slightly lower secchi transparency than expected based on chlorophyll a concentrations. Phosphorus and chlorophyll a values are high compared to those of a "typical" NLF ecoregion lake, but resemble that of a "typical" North Central Hardwood Forest (NCHF) ecoregion lake as shown in **Table 4-10**. An estimated 95% of phosphorus loading to Big Sandy Lake is derived from the major tributaries in the watershed, the Sandy and Prairie-Savanna Rivers. Typical stream total phosphorus concentrations are in the range expected in the NCHF ecoregion.

The Minnesota Pollution Control Agency (MPCA) placed the lake on the MN 303(d) list of impaired waters in 2006. The lake has an approved TMDL since 2011. Sandy only partially supports swimming use during the summer months as impaired swimming conditions, based on the frequency of nuisance algal blooms, are estimated to occur between 26-50 percent of the time. MPCA studies have indicated that a 10 percent reduction in phosphorus loading would result in perceptible reductions in nuisance algae blooms and aquatic plant growth. In response to the lake's current condition, the Big Sandy Lakes Association has adopted a non-degradation water quality policy and plan to reduce total phosphorus loading to Big Sandy Lake by 10 percent. In addition, the two point source dischargers in the watershed, the McGregor and Cromwell publicly owned treatment works, are being upgraded to meet current MPCA standards. The Corps Water Quality Management Program supports local initiatives by cooperating in efforts to track, control, and limit the cultural-induced eutrophication in Big Sandy Lake.

In addition to land use changes from natural conditions, the Sandy watershed has been altered in other ways. Extensive ditching of wetlands in portions of the watershed has occurred as early as the early 1900s when an effort was made to establish increased farmlands (MN DNR Fisheries 2002). More recently, wetlands have been ditched and drained to allow for peat and wild rice farming. The ditches have likely affected the hydrology and nutrient transport dynamics of the watershed. Peat soils and wetlands that typically remained flooded before ditching may now drain to a greater depth or more frequently during dry periods, thereby allowing them to become more oxygenated. The increase in oxygen is expected to increase decomposition of the nutrient rich organic material in the peat soil, thereby releasing phosphorus. Decomposition of wetland and peat materials is evidenced by the highly colored water of the rivers in the watershed, which is a result of high concentrations of organic compounds that result from decomposition of peat.

A limnological survey of the Headwaters reservoirs was conducted in 1980 (see **Section 1-03**). Also see **Sections 5-02, 7-07, and 8-04**.

Water Quality Parameter	Big Sandy Lake	Typical Northern Lakes and Forest Ecoregion Lake	Typical North Central Hardwood Forest Ecoregion Lake
Mean Total Phosphorus (ppb)	40	14-27	23-50
Mean Chlorophyll a (ppb)	9	<10	5-22
Maximum Chlorophyll a (ppb)	57	<15	7-37
Mean Secchi Transparency (meters)	1.33 (low due to natural staining of water)	2.5-4.5	1.5-3.2
Trophic State	Eutrophic	Mesotrophic to Mildly Eutrophic	Eutrophic

4-09 Channel and Floodway Characteristics

The downstream channel of Big Sandy Lake Dam consists of a 1.25 mile stretch of the Sandy River before its mouth at the Mississippi River. During flood events, the backwater from the Mississippi River has a significant effect on the outflow from the dam. This was evident before the construction of the dam. The structure has been designed to withstand a reversal of head due to the Mississippi River backing up the channel when the level of Big Sandy Lake is lower than that of the river below the dam.

The Big Sandy Lake Dam during floods has no damage center because it does not influence the flood and only reacts to the Mississippi River flooding. The travel time to Aitkin, roughly 43 river miles downstream, is approximately 1 day. The Aitkin diversion channel inlet, described in Section 3-04b, is approximately 21 river miles downstream.

It was reported that the upstream channel was in good condition, with no significant difference between the 2005 and 2011 sounding. The observable features of the outlet channel are generally in satisfactory condition, with the exception of the cracked grouted riprap, located downstream of the control structure on the right bank of the channel. The observable features of the inlet channel are in satisfactory condition. The inlet and outlet channels can be seen in Figure 4-13 Figure 4-14 respectively. The time of water travel is omitted because the structure is not operated for flooding the channel and is only acted upon by the Mississippi River.



Figure 4-13. General View of Downstream Channel



Figure 4-14. General View of Upstream Channel

4-10 Upstream Structures

There are no water control structures upstream of Big Sandy Lake Dam.

4-11 Downstream Structures

There are no water control structures below Big Sandy Lake Dam on the Sandy River. The nearest downstream structure on the Mississippi River is the Aitkin diversion channel. See Section 3-04b for information about the Aitkin diversion.

4-12 Economic Data

- a. **Population:** The Big Sandy Lake watershed includes small portions of St. Louis and Carlton Counties to the east, but primarily is in Aitkin County. Census information for Aitkin County is given in . The town of Aitkin is the largest community in the county, with 2,165 people in 2010. There are approximately 20 other small communities, averaging about 400 people each, scattered throughout the county. 93.3 percent of the residents in this area, though rural, are classified as rural non-farm because they do not reside on farms but live in the small towns or in homes in the country. The remaining 6.7 percent of the residents are farmers. There is no urban classification for the county.

Year of Census	Population
1910	10,371
1920	15,043
1930	15,009
1940	17,865
1950	14,327
1960	12,162
1970	11,403
1980	13,404
1990	12,425
2000	15,301
2010	16,202
Est. 2018	15,902

- b. **Agriculture:** Agriculture continues to be economically important despite a steady decline in rural population. Of the various agricultural sectors, the greatest growth has been in beef production, while the output of other agricultural products has remained relatively static. One potentially bright spot, economically, is the development of wild rice paddies in recent years. In Aitkin County, as well as in the other Headwaters counties, the demand for rice paddy land has been growing each year, reflecting the growth in the wild rice industry. presents an agricultural profile Aitkin County (2012 data).

Table 4-12 2012 Agricultural Profile of Aitkin County	
Item	Number
Cattle and Calves (head)	10,444
Layers (number of)	1,366
Horses and Ponies (head)	601
Broilers (number of)	309
Pullets (number of)	193
Hay (acres)	34,513
Wheat, Barley, & Oats for Grain (acres)	1,076
Corn for Grain or Seed (acres)	1,967
Soybeans (acres)	7,930
Farms (number of)	471
Farmland (acres)	122,591

- c. **Industry:** Industry in Aitkin County includes tourism, lumber, and mining. A survey of businesses in communities near lakes indicated that 50 percent of summer retail business was attributed to tourism. In 2015, approximately 65,000 visits were made to Big Sandy Lake Recreational Area. The scenery and numerous lakes and streams make the area a fine vacation and sporting location.

The industries of agriculture, forestry and fishing have been shown to be more important to Aitkin County than they are state-wide. Nevertheless, employment in these sectors has fallen in recent years. shows basis statistics on establishments in Aitkin County.

Item	Number
Agriculture, Forestry, Fishing, and Hunting	5
Mining, Quarrying, and Oil and Gas Extraction	2
Utilities	1
Construction	65
Manufacturing	24
Wholesale Trade	9
Retail Trade	73
Transportation and Warehousing	13
Information	5
Finance and Insurance	19
Real Estate and Rental and Leasing	7
Professional, Scientific, and Technical Services	15
Management of Companies and Enterprises	2
Admin, Support, and WM Services	18
Educational Services	1
Health Care and Social Assistance	28
Arts, Entertainment, and Recreation	12
Accommodation and Food Services	51
Other Services (Except Public Administration)	49

- d. **Flood Damages:** Because of the large amount of storage provided by the many lakes and swamps in the basin and the regulation of the Headwaters reservoirs, floods are not of a flashy nature. Floods in the Aitkin area are characteristically of long duration, rising gradually to crest and receding slowly. This area of about 30,000 acres of rich black loam and peat is the best agricultural land in the Headwaters basin. In 1915, an extensive system of ditches was constructed to turn the entire area into a highly productive agricultural area. At the established flood stage of 12.0 feet, about 2,000 acres of land are flooded and at a 20.0 foot stage, most of the 30,000 acres is under water, including the outskirts of the City of Aitkin. The drainage area above Aitkin, which produces these floods, covers 6,140 square miles. Of this area, only 3,686 square miles, or about 60 percent of the total drainage area, are controlled by the Headwaters reservoirs. Hence, a flood may easily be produced entirely from the uncontrolled area. For example, 95 percent of the initial 1975 flood peak at Aitkin resulted from the drainage area below Pokegama and Big Sandy Lakes Dams.

High water damages consist of flood fight or preparedness measures, damage and loss of personal property, and clean-up and repair for both residential and commercial units. In addition to the above damages, commercial establishments experience a decline in net income because of the high water. High water damages also include the effects of high stages, wave action and ice movement on reservoir shorelines, permanent residences,

summer homes, resorts, cottages, roads, bridges, and farmlands. High water losses are greatest during the 1 June to 30 September peak resort period. Approximately 100 structures are subject to damage from flooding.

The low water damages for Big Sandy Lake occur during the May-September recreation season. These low water losses consist of changes in net income to commercial activities. Some of these losses are increased expenditures for harbor maintenance, reduced or canceled reservations because of access problems to fishing areas, shortened stays because of poor fishing, and damaged equipment because of shallow depths. Private landowners also experience increased expenses and equipment damage from low water. Low water damages are especially severe on lakes with very gradually sloping bottoms, such as Big Sandy Lake.

The elevation-damage curve for Big Sandy Lake shows both the low and high water damage relationships. The damage-frequency curves for Big Sandy Lake area were developed using data from 1936 to 1976 and 2018 pricing levels. Average annual damages are derived from these curves.

Detailed high water damage surveys were conducted on Big Sandy Lake. A summary is given below.

- a.** A substantial reduction in the number of commercial establishments has occurred so that low water damages (loss of business) will be minimal (23 commercial units in 1962 versus 12 commercial units in 1977).
- b.** Approximately 79 homes will receive some damage from a lake level elevation of 1223.9 feet. Approximately 8.6 percent of the residential units are flooded at this elevation.
- c.** At the 1975 flood elevation of 1222.1 feet, approximately \$134,000 in October, 2018 price levels, damage would occur from damages to buildings and contents and from clean-up costs.
- d.** The estimated average annual high water loss in Big Sandy Lake area shoreline value due to current erosion is \$157,586 in October, 2018 price levels.
- e.** In summary, average annual high water damage on Big Sandy Lake is \$347,971 in October, 2018 price levels. This amount includes all physical damage to property from high water levels, such as repair costs to docks and shore facilities and loss of business to commercial units, and \$157,586 in October, 2018 price levels, estimated annual shoreline property erosion loss.

5 Data Collection and Communication Networks

5-01 Hydrometeorologic Stations

Several hydrometeorological stations are utilized to collect the various hydraulic and hydrologic parameters used in the regulation of the project.

Facilities

Table 5-1 lists the data collection facilities at the dam. **Plate 5-1** shows the locations of the facilities in the area. **Plate 5-2** lists some of the gages in the watershed. Locations for the snow survey sites are shown on **Plate 5-2** and listed in **Table 5-3**.

Table 5-1 Big Sandy Lake Streamflow & Hydrometeorological Stations			
Location	Data Type	Equipment	Ownership
Big Sandy Lake Dam	Pool Elevation ^{1,3}	DCP ²	Corps of Engineers
	Tailwater Elevation ⁴	DCP ²	Corps of Engineers
	Precipitation	Recording and Non-recording Gages	National Weather Service
	Temperature	Thermometer	Corps of Engineers
	Wind Direction	Manual Estimate	Corps of Engineers
	Snow Depth and Water Equivalent	Snow Tube	Corps of Engineers
	Frost Depth	Frost Tube	Corps of Engineers
Big Sandy Lake	Ice Thickness	Manual Estimate	Corps of Engineers

1. The "Pool" gage is located at the dam. The "Lake" gage was on the main body of the reservoir before being discontinued after December 1961. See the Corps log sheets. Data is available on Corps log sheets dating back to January 1982.
2. One DCP transmits both pool and tailwater readings.
3. Some elevation data was published by the U.S. Geological Survey (Gage No. 05218500) from October 1941 through 1997 based on records provided by the Corps of Engineers.
4. Discharge data was published by the U.S. Geological Survey from July 1893 to September 1916 and from October 1941 through 1994 (Gage No. 052190000) based on records provided by the Corps of Engineers.

Location	Drainage Area, mi ²	Equipment	Ownership
USGS Gage No. 05227500	6,140	Mississippi River at Aitkin, MN	On the right bank upstream side of the bridge at the north edge of Aitkin
USGS Gage No. 05227530		Mississippi River Diversion near Aitkin, MN	On the left bank by the Osprey Ave. bridge over the diversion channel
USGS Gage No. 05242300	7,320	Mississippi River at Brainerd, MN	On the left bank in the Brainerd Public Utilities hydropower plant in Brainerd, MN
USGS Gage No. 052610000	11,010	Mississippi River near Fort Ripley, MN	On the left bank, 600 ft. upstream from Nokasippi River, 1.0 miles north of Fort Ripley

Note: USGS gage number 05220500, Mississippi River below Sandy River near Libby, MN (Drainage Area = 5,600 sq. mi.) was discontinued in 1991. Data is available from 1930 - 1990).

Reporting

The information needed to operate the dam and regulate the reservoir is reported to the Water Management Section by the project staff. Daily (8:00 a.m.) readings for the pool, tailwater and outflow are provided as well as precipitation and wind readings. The pool and tailwater elevations are also recorded by DCPs and transmitted via satellite directly to Water Management's Local Readout Ground Station (LRGS). At each DCP gage, the correspondence between the gage and DCP readings is checked visually by project personnel at regular intervals. Daily inflow to the reservoir is calculated by Water Management from the change in reservoir elevation and the outflow. Copies of the official site log sheets are copied to Water Management's folder on the District server.

On Monday mornings, from approximately the end of November until the end of March, the project staff report "winter conditions" at the dam along with the normal data reports. The reports consist of the amount of snow on the ground, the water content of the snow, the thickness of the ice on the lake and the ground frost depth. The snow and frost information are also provided to the National Weather Service and the State Minnesota Climatology Office.

Prior to the spring snowmelt, the project staff conducts a snow survey in the basin. The survey is normally conducted during the last week of February or the first week of March. Instructions as to the exact date to start are issued by the Water Management Section. A report of this survey is forwarded to Water Management as soon as possible after completion. Prior to conducting the snow survey, the project staff might perform a snow reconnaissance in the basin to determine if a detailed snow survey is necessary. The project staff drives through the watershed making a visual inspection the general area. If an appreciable amount of snow should fall after the survey has been completed, another survey may be required. See Plate 5-2 and .

Number and Name	Location
1. Big Sandy Lake Dam	200 ft. West of the Office Building; N 46.7860°, W 93.3197°
2. McGregor	1 mile north of McGregor, east of MN 65 near Airport; N 46.6093°, W 93.3168°
3. Tamarack	0.5 miles north of Tamarack, east of Main St; N 46.6608°, W 93.1227°
4. Cromwell	1 mile north of Cromwell, east of MN 73; N 46.6857°, W 92.8837°
5. Floodwood	1 mile south of Floodwood, west of MN 73; N 46.9065°, W 92.9073°
6. Jacobson	0.5 miles west of Jacobson on MN 200 in County Park; N 47.0045°, W 93.4498°
7. Hill City	3.5 miles east of Hill City on Hwy 200 at Haypoint Trail; N 46.9913°, W 93.5242°
8. Waukenabo	1.3 miles west of US 169 and Grove St intersection; N 46.7062°, W 93.6240°
9. Palisade	East end of Palisade in City Park along Miss. River; N 46.7103°, W 93.4860°
10. Aitkin	0.4 miles south of Hwy 210 on 422 nd Pl; N 46.5228°, W 93.7338°
11. McGrath	0.7 Mile south of McGrath, east of Hwy 65 and 150 th Ln; N 46.2315°, W 93.2755°
12. Onamia	Intersection of Wall St and Soo Line ATV Trail; N 46.0708°, W 93.6603°

Maintenance

The gages associated with this reservoir are maintained by Corps personnel and the U.S.G.S. on a periodic or as-needed basis. Snow survey equipment repair is the responsibility of the Corps' gage crew.

5-02 Water Quality Stations

Also see Sections 4-08, 7-07, and 8-04.

Facilities

The Corps regularly maintains three (3) water quality data collection stations on Big Sandy Lake. Stations locations are shown on Plate 5-3. Data collected is used to define baseline water quality conditions, identify water quality trends, support locally sponsored lake management programs, and to analyze water quality problems and concerns as they relate to natural conditions and to reservoir operations. Data collection is routinely performed by field staff with the help of local

volunteers from The Sandy Area Lakes Association. Staff and volunteers are trained by Water Quality Unit personnel.

The current data collection program is a cooperative effort between the Corps of Engineers, Minnesota Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MDNR), and the Big Sandy Lake Association in support of the Sandy Area Lakes Clean Water Partnership. The Corps maintains the lake water quality stations and the MPCA and MDNR maintain the stream water quality stations. Vertical profiles of water temperature, dissolved oxygen, pH, and specific conductance are electronically monitored on a regular basis at each lake station. In addition, two meter integrated surface samples are collected analyzed for total and ortho phosphorus, total kjeldahl nitrogen, nitrate-nitrite nitrogen, ammonia nitrogen, chlorophyll a, and color. Additional depth specific samples and parameters are obtained at sporadic intervals to further define water quality relationships. Laboratory analyses are performed by Corps inspected and approved laboratories.

The MPCA and MDNR are monitoring streams in Big Sandy Lake's watershed as part of a Clean Water Partnership Project. The temporary program is designed to identify nutrient loads and pollution sources to Big Sandy Lake. Data collected by the MPCA and Corps will be used to set water quality goals for the lake and to identify, prioritize, and design best management programs (BMP's) to be used in the watershed to control the rate of cultural-induced eutrophication.

Reporting

In-situ lake water quality data is electronically recorded and is available on the St. Paul District's Water Control site. Lake samples analyzed for nutrients and chlorophyll are processed at the project site and shipped to a Corps- approved laboratory for analysis. All chemical analysis follow recommended Environmental Protection Agency (EPA) or equivalent procedures. Laboratory results are forwarded to the Water Quality Unit in the District office. Both in-situ and nutrient data is reviewed and entered into DBASE. The data is also provided to the MPCA who enter the data into the EPA STORET data storage system under the agency code 21MINNL. The Corps produces periodic data reports describing data collection activities and laboratory results for the project. All lake water quality data is available upon request.

The MPCA and MDNR currently maintain the stream water quality data program. Stream data is available through the USEPA's STORET water quality database under the agency code 21MINN. Stream water quality stations are temporary and are shifted often depending on current study needs. Stream data is used to identify pollution sources, compute pollutant loadings, and assess the effectiveness of BMP's.

Maintenance

Project personnel are trained to do routine calibration and maintenance of equipment. Any additional maintenance required is performed by Water Quality Unit staff.

5-03 Sediment Stations

There are no sediment monitoring stations in the Mississippi River Headwaters region.

5-04 Recording Hydrologic Data

The project staff obtain river elevations, reservoir elevations, precipitation, and other data from gages in the vicinity of the dam and other pertinent locations. The staff connect to the computers in the Water Management Section to enter the project data into the electronic database. This data is also recorded on a log sheet which is stored on the server. The pool, tailwater and various river elevations and hydrometeorological data are also recorded by Data Collection Platforms (DCP) and transmitted via satellite to Water Management's electronic database. At some DCP gages, the correspondence between the gage and DCP readings is checked visually by project personnel at regular intervals.

An NWS precipitation gage is used at the dam to record daily precipitation. The 24 hour precipitation and weather observations are recorded daily. The data are archived by the National Climatic Data Center in Asheville, NC. The U.S. Geological Survey and various contractors conduct streamflow measurements as requested by the District office. The data from USGS gages in the area is available on the National Water Information System site: <https://waterdata.usgs.gov/nwis/sw>.

During the annual snow survey, five snow samples are recorded at each station (see **Plate 5-2** and **Table 5-3**). The average snow depth and water content of the snow in inches is recorded and sent to the District office for analysis of the probable runoff to be expected. In addition to the snow samples, notes are recorded on the general conditions of snow cover in fields, timbered areas, river channels, dry runs and ditches both at the stations where measurements are taken and between the stations. The water content of the snow is determined by instructions contained in the National Weather Service Observing Handbook No. 2. Frost depths from power company crews and construction crews, or from anyone who may have occasion to penetrate the ground surface, are obtained and recorded.

5-05 Communication Network

The staff can transmit hydrologic data and information by computer, telephone, facsimile, or via the United States mail. The main method of transmitting data to the St. Paul District Office is to directly enter data into the dss files using a secure terminal and a DWINDO program (Water Management's CRT program). Backup method is for the project office to call or email the district office with the information. The data path to the Water Management website starts at the DCP. The DCP sends a signal to the U.S. Geostationary Operational Environmental Satellite (GOES). The GOES satellite sends the signal to the Direct Readout Ground Station (DRGS) at Wallops Island, Virginia. The data is reformatted and sent to the Domestic Communication Satellite (DOMSAT), which transmits the data to the Local Readout Ground Station (LRGS) located on the roof of the St. Paul District Office. All of the project related data is available on the internet. The project data is also provided to the National Weather Service via a dedicated communication line.

5-06 Communication with Project

Between Regulating Office and Project Office

Water Management communicates with the project via the telephone and email. Also, the introduction to this Water Control manual contains emergency regulation contact procedures. If the project staff cannot connect with anyone in the District office, they will follow the regulations in **Chapter 7** with due consideration for any unusual circumstances that might prevail.

- a. **Weekly Log Sheets:** CEMVP Form 405B, "Weekly Log Sheet" is used to record all pertinent data at the Big Sandy Lake project, including gage readings noted or requested and local weather conditions. The sheet is scanned in and placed in the Water Management folder on the district server. The original is kept at the project office.
- b. **Water Quality Data:** Water quality data is recorded on data sheets and e-mailed to the Water Quality Unit in the District office.
- c. **Emergency Reports:** During floods or other emergencies, the Resource Manager enters data into Water Management's CRT program as soon after 8:00 a.m. as possible.

Between Regulating/Project Office and Others

- a. **The National Weather Service:** As CWMS becomes more implemented, data and forecasts will be automatically shared. The current methods to share data and information is thorough NWSSChat, email, or telephone.
- b. **Others:** Local residents and the Big Sandy Lake Association have access to project-related information from the project staff either by telephone, in person, on the internet or through the local news media. Press releases are issued when conditions warrant. Flash-flooding is not a problem in this area. Notifications of severe weather or impending unusual conditions are handled by the National Weather Service and through local law enforcement and civil defense authorities. The Project office and the District office communicate with the City of Aitkin, Potlach Corporation (Potlach Dam, Brainerd) and the National Weather Service and others as needed.

5-07 Project Reporting Instructions

The pool and tailwater elevations that are recorded on the project's log sheet are followed by a letter code to indicate the source of the data. Sources include visual readings of float tapes or staff gages, data from voice modems, data from Data Collection Platforms (sometimes obtained from a website) and wire weight gage data. It is preferred that the data recorded on the project log sheet be obtained from a float tape, staff gage or wire weight gage daily or at a minimum once or twice a week.

5-08 Warnings

In the event of impending emergency conditions, or advisories requiring interim gate changes, Water Management will call the project staff. The introduction to this manual contains phone numbers for Water Management and various District personnel. In the event of emergencies affecting project regulation and concerns downstream, the officials listed on page iv **Error! Reference source not found.** will be contacted (also see **Sections 7-13** and **8-10**).

6 Hydrologic Forecasts

6-01 General

Role of USACE

The Water Management Section prepares flood forecasts of reservoir inflow/outflow and pool elevation for internal use during critical flood periods (see **Chapter 7**). During non-critical periods of reservoir regulation, forecasts are not required for regulation. Corps' forecasts may arise from either wet or dry conditions, and are used to assist the National Weather Service (NWS), Water Management regulators and the Project Resource Manager in their work. The St. Paul District may provide water quality data through its Water Quality Unit.

Role of Other Agencies

The National Weather Service (NWS) River Forecast Center in Chanhassen, Minnesota is the official source for all stream-stage forecast information. The water quality divisions of the various state agencies within the St. Paul District forecasts water quality conditions when warranted.

6-02 Flood Condition Forecasts

Requirements

National Weather Service (NWS) Model uses a six hour time step. The important gages to monitor include lake elevation at Pokegama, Leech, and Winnibigoshish, and river stage at Aitkin.

Methods

During floods, Water Management will work with the NWS to determine desired outflow. A CWMS model was developed for the Upper Mississippi River Headwaters. The model was completed and transferred in November 2019. Implementation funds and processing are ongoing. The normal procedure until the Corps has non-excel models, is to use the NWS 28-day inflow and peak pool elevation with current forecast, including the run-off forecasted from snow melt. Water Management will forecast outflow, adjustments, and share data with the NWS. Through NWS Chat, discuss finer points of conditions and make additional forecast iterations. Adjust outflow as needed to keep the pool elevation or control points at desired target.

6-03 Conservation Purpose Forecasts

Forecasting for water-related activities such as hydropower regulation, recreation, fish spawning, water supply and water quality are not a part of the daily Water Management routine. Short-term projections of water level, flows, temperature and local hydrologic conditions may be obtained from Water Management upon request.

6-04 Long-Range Forecasts

Long-range forecasts of reservoir inflows and levels are not normally required due to the very limited water supply use of the reservoir. A seasonal drawdown is required to prepare the reservoir for spring runoff. The difference in storage between the average fall elevation of the lake and the spring lake level is adequate to store the average spring inflow. Predictions of pool levels for project purposes are based on current precipitation trends.

6-05 Drought Forecast

The Minnesota Department of Natural Resources and the NWS routinely monitor and report drought indicators. Hydrologic and meteorological forecasts are issued by the National Weather Service (see **Section 6-01**). During drought conditions, the regulation of the project will be in accordance with **Section 7-12**.

6-06 Water Quality Forecasting

Forecasting for water quality is not part of the daily Water Management routine.

7 Water Control Plan

7-01 General Objectives

The original authorized purpose of Big Sandy was to increase Mississippi River discharges during low-flow periods to aid navigation. As use for navigation diminished, the reservoir is now regulated primarily for flood risk management, fish and wildlife, recreation, and Tribal Trust. The Water Control Plan supports recreation by maintaining, when possible, stable reservoir levels within a specified elevation band during the summer. Flood risk management objectives are met by a fall/winter drawdown schedule and a designated flood control storage pool, which provides storage capacity for spring and summer flood events. Water levels are managed, when conditions permit, for various fish and wildlife and Tribal Trust concerns. The low-flow plan manages water resources both upstream and downstream of the dam during critical periods. See **Section 2-02** for information on these and other authorized purposes.

7-02 Constraints

- a. **Tribal Trust:** A portion of the Big Sandy Lake drainage area is within the boundary of the Big Sandy Lake Indian Reservation, whose residents are formally represented by the government of the Mille Lacs Band of the Minnesota Chippewa Tribe, a Federally Recognized Tribe. The implementation of the Water Control Plan must consider the issue of the Tribal Trust relationship between the Federal Government and the Tribe. Any deviation from the authorized Water Control Plan must be coordinated with the Tribe. See **Chapter 9**.
- b. **Reverse Flow (Backwater) into Big Sandy Lake:** The confluence of the Big Sandy Lake River and the Mississippi River is a short distance downstream of the dam (see Plate 2-2). When the water level in the Mississippi River is high the backwater effect extends all the way up to the tailwater of Big Sandy Lake Dam. When water levels on the Mississippi River are extremely high, Big Sandy Lake dam is inundated and the Sandy River can reverse directions and flow back into Big Sandy Lake. During flooding conditions, the tailwater elevation (due to backwater) can restrict releases or result in flow into Big Sandy Lake.
- c. **High Water: Flowage Rights and Impacts to Shoreline Property:** The Corps has flowage rights around Big Sandy Lake reservoir to approximately elevation 1222.31 feet (see **Section 2-05**). Of all the Headwaters reservoirs, due to the backwater from the Mississippi River (see above), Big Sandy Lake has the greatest potential to approach or exceed its flowage rights elevation. There are a number of structures below the flowage rights elevation. See ROPE study for impacted first floor survey.

7-03 Overall Plan for Water Control Management

Big Sandy Lake reservoir is regulated between a minimum elevation of 1214.31 feet and a maximum elevation of 1221.31 feet. If possible, the reservoir level should be within its summer range/band of 1216.06 feet to 1216.56 feet by the first day of the fishing season (approx. mid-

May). The winter drawdown of the reservoir for spring flood risk management begins in the fall. The ordinary (normal) spring drawdown elevation is 1214.31 feet, which is the lower operating limit of the reservoir. Significant shoreline erosion begins to occur at approximately elevation 1218.31 feet but storage to elevation 1221.31 feet can be used if needed to prevent flooding downstream. Details of the water control plan are given in the following paragraphs.

7-04 Standing Instructions to Project Operator

The project is to be regulated in accordance with **Section 7-05**. For information on data collection and transmission of reports, refer to **Chapter 5**. For procedures to be followed in the event of lost communications, refer to **Section 7-14**. In the event of a communication failure, the procedures outlined in this chapter should be followed as far as practicable until communication channels are restored. An emergency contact list, and other points of contact, can be found in the introduction to this manual, and in **Chapter 1**.

7-05 Flood Risk Management

The regulation of the reservoir and the operation of the dam is done in accordance with the water control plan described below.

a. **Information Sources:** A description of the project, to include the control structure, and other pertinent project data can be found in **Chapter 2** and **Exhibit A**. A brief history and changes that have been made to the Water Control Plan, since the project was authorized, are discussed in **Chapter 3**. A description of the watershed, climate and past floods can be found in **Chapter 4**. **Chapter 5** contains information on the project's data collection and communication networks, while **Chapter 6** discusses hydrologic forecasts. Frequency and duration curves and flood hydrographs are referenced in **Chapters 4** and **8**. See **Chapter 9** for information related to the coordination of Water Management activities.

1) **Water Control Plan Summaries:** The Water Control Plan that is currently in use is described below. The following discussion uses terms like Normal Summer Range/Band, Present Ordinary Operating Limit and Present/Total Operating Limit. These terms were carried over from the previous manual (dated 2003) in order to provide consistency with the earlier manual and are defined in **Section 7-17**. **Table 7-1** provides a summary of the regulation for Big Sandy Lake only. **Table Nos. 7-2 and 7-3** provide a summary of the regulation parameters for the entire Mississippi River Headwaters system for comparison and easy reference. **Plate 7-1** contains drawdown information.

**Table 7-1
Big Sandy Lake Regulation Parameters**

Date or Period	Reservoir Elevation (ft)	Discharge (cfs)	Comments
Full Summer Pool Start of Fishing Season into September, Approximately 15 May to 10 Sep.	1216.06 – 1216.56 Normal Summer Band Middle = 1216.31	As needed to maintain the band, but not less than 20 cfs	The summer band is usually held until October.
Fall/Winter Drawdown Approx. 1 Oct. to 1 Mar. (Varies)	1216.31 down to 1214.21 (Varies ¹)	Approx. 60 cfs above inflow	A drawdown to 1214.31 ft is needed most years.
Flood Risk Management Operation Approx. 1 Mar to 15 May → Approx. 15 May to Fall →	Can go up to 1221.31 1214.31 up to 1221.31 1216.56 up to 1221.31	At initial melt runoff, release and maintain drawdown ³ .	Coordinate operations with Winnibigoshish, Leech, and Pokegama.
Wet Conditions/High Inflow 1 Jan. to 31 Dec.	Above 1221.31 ² 14 Days Prior to 1221.31 notify Secretary of the Army	Dam wide open until reservoir below 1221.31 to insure the safety of the structure.	Coordinate operation with Winnibigoshish, Leech, and Pokegama.
Dry Conditions/Low Inflow 1 Jan. to 31 Dec.	≥1214.31, 14 Days Prior to 1214.31 notify the Secretary of the Army	20 cfs	The minimum flow is 20 cfs when the pool is ≥1214.31 ft.
Very Dry Cond./Low Inflow 1 Jan. to 31 Dec.	Less than 1214.31	10 cfs	Reservoir is below minimum operating limit

1. Elevation 1214.31 feet is the normal drawdown target elevation. The drawdown elevation can be higher than this depending on runoff/snowpack conditions. Elevation 1214.31 feet is also the lower Total Operating Limit.
2. Shoreline erosion intensifies above elevation 1218.31 to 1221.31 feet.
3. See ROPE Study, pages 97-98.

**Table 7-2
Mississippi River Headwater Reservoir System
Operating Elevations and Stages in Feet**

	Lake Winni- bigoshish	Leech Lake	Lake Pokegama	Sandy Lake	Cross Lake Pine River	Gull Lake
1. Normal Summer Range/Band (stage in feet)	1297.94-1298.44	1294.50-1294.90	1273.17-1273.67	1216.06-1216.56	1229.07-1229.57	1193.85-1194.15
Middle of the Summer Band Elev.	9.0 - 9.5 1298.19	1.8 - 2.2 1294.70	8.75 - 9.25 1273.42	8.75 - 9.25 1216.31	12.75 - 13.25 1229.32	6.1 - 6.40 1194.00
2. Ordinary Operating Limits (stage in feet)	1296.94-1300.94 8.0 - 12.0	1293.20-1295.70 0.5 - 3.0	1270.42-1274.42 6.0 - 10.0	1214.31-1218.31 7.0 - 11.0	1227.32-1230.32 11.0 - 14.0	1192.75-1194.75 5.0 - 7.0
3. Present/Total Operating Limit (stage in feet)	1294.94-1303.14 6.0 - 14.2	1292.70-1297.94 0.0 - 5.24	1270.42-1278.42 6.0 - 14.0	1214.31-1221.31 7.0 - 14.0	1225.32-1235.30 9.0 - 18.98	1192.75-1194.75 5.0 - 7.0
4. Congressional Notification Levels Public Law 110-114, Sect. 3175, WRDA 07	1296.94/1303.14 8.0 / 14.2	1293.20/1297.94 0.5 / 5.24	1270.42/1278.42 6.0 / 14.0	1214.31/1221.31 7.0 / 14.0	1227.32/1235.30 11.0 / 18.98	1192.75/1194.75 5.0 / 7.0
5. ROPE Low Flow	$\geq 1294.94 / 6.0$ 100 cfs, < 1294.94 50 cfs	$\geq 1292.70 / 0.0$ 120 cfs, < 1292.70 60 cfs	$\geq 1273.17 / 8.75$ 200 cfs, < 1273.17 Winni + Leech	$\geq 1214.31 / 7.0$ 20 cfs, < 1214.31 10 cfs	$\geq 1225.32 / 9.0$ 30 cfs, < 1225.32 15 cfs	$\geq 1192.75 / 5.0$ 20 cfs, < 1192.75 10 cfs
6. Flowage Rights Acquired to Elevation: (stage in feet)	1306.86 17.92 +	1301.94 9.24 +	1280.42 16 +	1222.31 15 +	1238.82 22.5 +	1194.75 7.0
7. Estimated Downstream Channel Capacity (cfs)	2,000	1,500	6,000	(8.)	2,000-2,500	950
Gage Zero Elevation, 1912 MSL, adj.	1289.47	1293.23	1264.89	1207.70	(8)	1188.14
Gage Zero Elevation, USE Datum	1290.08	1293.76	1265.27	1209.00	1218.20	1190.00
Gage Zero Elevation, 1929 NGVD	1288.94	1292.70	1264.42	1207.31	1216.32	1187.75

1. The most desirable levels for the summer season.
2. The Ordinary Operating Limits represent the range which minimizes the degree of high and low water damages. The lower Ordinary Limit is the normal/maximum spring drawdown level.
3. Sandy's Present/Total Operating Limits are in accordance with the latest Water Control Plan. The upper and lower limits provide maximum storage for flood risk management and other purposes.
4. Section 21 of the Water Resources Development Act of 1988 (Public Law 100-676) and Section 3175 of the Water Resources Development Act of 2007 (Public Law 110-114) require the Secretary of the Army to notify Congress 14 days prior to a reservoir being below the minimum or above the maximum listed here.
5. The ROPE 2009 supersedes the previous MNDNR low flow Guidelines.
6. See **Section 2-05** for information. Flowage rights on the Cass L. Chain obtained to elev. 1307.86 (18.92 ft stage).
7. The channel below Big Sandy Lake is affected by backwater from the Miss. River. The channel capacity below the confluence of the Miss. River and the Leech Lake River is 2,200 cfs. High flows in the 2,000 to 2,500 cfs range from Pine River Dam cause high water problems on Big Pine Lake.
8. The channel below Big Sandy Lake is affected by backwater from the Miss. River. The channel capacity below the confluence of the Miss. River and the Leech Lake River is 2,200 cfs. High flows in the 2,000 to 2,500 cfs range from Pine River Dam cause high water problems on Big Pine Lake.
9. 1912 M.S.L. adjustment information for the Pine River Dam gage zero is not available.

Dam/Reservoir	Drainage Area (square miles)	Surface Area at Maximum Operating Limit (square miles)	Ratio of Drainage Area to Surface Area
Winnibigoshish	1,442	179 at 1303.14 ft	8.06
Leech	1,163	250 at 1297.94 ft	4.65
Pokegama	660 ^{1,2}	38 at 1278.42 ft	17.37
Sandy	421 ²	20 at 1221.31 ft	21.05
Pine/Cross Lake	562	24 at 1235.30 ft	23.42
Gull	287	20 at 1194.75 ft	14.35

1. The local drainage between Lake Winnibigoshish/Leech Lake and Pokegama Lake = 660 sq. mi. Total Drainage Area = 3,265 sq. mi. (see note 2).

2. Of the 6,240 sq. mi. of drainage area above Aitkin, MN, 3265 sq. mi. are controlled by Lake Winnibigoshish, Leech Lake, and Lake Pokegama (see note 1), 421 sq. mi. are controlled by Big Sandy Lake, and 2,544 sq. mi. are uncontrolled.

- 2) **Rating Curves/Tables and Project Information: Plate 7-2 (Free/Submerged Flow Decision Matrix)** should always be consulted prior to determining the outflow from the dam. The following rating curves, tables and guidelines are useful for the operation of the project.

Old (Existing Configuration of the Dam and Plates as Shown in the January 2003 WCM)	
Location	Description
Plate 7-1	Drawdown Curve
Plate 7-2	Free/Submerged Flow Decision Matrix
Plate 7-3	Slide Gate Rating Table
Plate 7-4	Stop Log Bays (in old lock chamber) Rating Tables
Plate 7-5	11-Foot Log Bay Rating Table
Plate 7-6	Submerged Flow Slide Gate Rating Curve
Plate 7-6a	Discharge Measurements for Various Slide Gate Openings
Plate 7-6b	Rating Curve for Openings Above Slide Gates
Plate 7-7	Stop Log Bays (in old lock chamber) Rating Curves
Plate 7-8	11-Foot Stop Log Bay Rating Curve
Exhibit A	Elevation-Storage Curve/Table and Area-Capacity Curve

New	
Location	Description
Plate 7-1	Drawdown Curve
Plate 7-2	Free/Submerged Flow Decision Matrix
Plate 7-3a	Slide Gate Rating Table
Plate 7-4b	Stop Log Bays (in old lock chamber) Rating Tables
Plate 7-5b	11-Foot Log Bay Rating Table
Plate 7-6	Submerged Flow Slide Gate Rating Curve
Plate 7-6a	Discharge Measurements for Various Slide Gate Openings
Plate 7-6b	Rating Curve for Openings Above Slide Gates
Plate 7-7	Stop Log Bays (in old lock chamber) Rating Curves
Plate 7-8b	11-Foot Stop Log Bay Rating Curve
Exhibit A	Elevation-Storage Curve/Table and Area-Capacity Curve

- b. **Emergency Regulation:** See Section 7-13.
- c. **Flood Risk Management:** The spring melt can occur as early as March or as late as May with runoff extending into early June. As such, the 1 March drawdown target date allows for an early spring runoff (see Plate 7-1). Unlike spring floods, the flood events that occur during the other three seasons do not benefit from advanced drawdown measures. In the summer, fall or winter, if it is evident that downstream areas will require flood risk management operation, the applicable procedures below will be followed.
- 1) **Flood Risk Management: Regulation and Operation:** It is prudent to release as much water as possible prior to the backwater from the Mississippi River drowning out the outflow from the dam (see ROPE study pg. 97). Storage is available in Sandy reservoir between the elevations of 1214.31 feet (max. drawdown level) and 1221.31 feet (Upper Operating Limit) with a drawdown target elevation determined each year based on conditions.

Once the reservoir fills from the drawdown elevation to the summer band (1216.06 to 1216.56 ft.), the discharge should match the inflow.

During floods, daily estimates of the remaining inflow volume will be made (see Chapter 6). When the reservoir exceeds elevation 1221.31 feet. Open river conditions will then exist until the reservoir drops below elevation 1221.31 feet and regulation is again possible.

The Big Sandy Lake Dam control structure must be opened completely when the reservoir is above elevation 1221.31 feet, and on the recession down to below elevation 1221.31 feet, to insure the safety of the dam. After it is no longer necessary to operate for flood risk management, the reservoir will be returned to the summer band by the first day of the fishing season (approx. Mid-May),

whenever possible, at a rate that will not endanger wildlife or cause other issues within the reservoir or downstream. The Secretary of the Army must notify Congress 14 days prior to the reservoir level going above elevation 1221.31 feet.

- 2) Flood Risk Management: Travel Times:** When outflows from Big Sandy Lake reservoir are effective, the travel time from Big Sandy Lake reservoir to Aitkin is approximately 1 day. Travel time during flood conditions may be different or nonexistent as there is a backwater effect on Big Sandy Lake.
- 3) Flood Risk Management: Flood Forecasts:** The National Weather Service (NWS) river forecasts extend 5 days into the future, which allows time to reduce the discharge at Big Sandy Lake Dam for the benefit of points downstream (e.g. approx. 1-day travel time to Aitkin). The NWS should be contacted daily during flood periods to ensure that the Corps' operation decisions coincide with the NWS forecasts. See also **Chapter 6**.
- 4) Flood Risk Management: Fall/Winter Drawdown:** The fall/winter drawdown of the reservoir normally begins on 1 October, however, if necessary, it can begin any time after Labor Day (approx. 10 Sept.). The 1 October start of the drawdown allows for an extended recreation season through the end of September (see **Plate 7-1**). The timing of the start of the drawdown may vary from year to year depending on the magnitude of the inflow and other variables. However, the drawdown of the reservoir requires a careful consideration of the attendant hydrometeorological variables as discussed below. The drawdown (combined with that at Winnibigoshish, Leech and Pokegama reservoirs), provides storage for flood risk management at Aitkin, Minnesota and, if necessary, other areas downstream.
- 5) Flood Risk Management: Drawdown Discharge:** In the fall, the total discharge and the length of time required to lower the pool to the normal drawdown level (elev. 1214.31 ft.) by 1 March, are determined. An average discharge from 1 October to 1 March of approximately 60 cfs above inflow is required for a drawdown from elevation 1216.31 (mid-summer band) to 1214.31 feet. However, the required drawdown discharge may change as the winter/snowpack progresses. The area-capacity curves and storage tables in **Exhibit A** and the drawdown curve on **Plate 7-1** can be used to assist in this calculation and to adjust for different dates and target elevation ranges as the fall and winter hydrometeorologic conditions materialize.
- 6) Flood Risk Management: Drawdown Target Elevations:** The final drawdown target level, which may be higher than 1214.31 feet, is based on inflow projections, expected storage requirements, snow surveys (see **Chapter 5**), the precipitation outlook forecast and other variables, all of which may change as the winter progresses. Periodic checks of inflow, and the hydrologic conditions in the basin (e.g. snowpack), are made and the outflows are adjusted as necessary to accomplish

the goal. In periods of drought, or when light snow cover (low water content) exists, the reservoir may be drawn down only as far as conditions warrant. It is recommended that the drawdown be reviewed after the January snow survey results have been published. A drawdown to approximately 1214.31 feet is necessary most years due to Sandy's relatively large drainage area versus its storage (see) and the fact that backwater from the Mississippi River can drown out Sandy's tailwater, which restricts the outflow during periods of high inflow. Elevation 1214.31 feet is the lower operating limit of the reservoir. See **Plate 7-1**.

7) Flood Risk Management: Drawdown, Travel Time, and Snowmelt Run-Off: The travel time from Sandy to Aitkin is approximately 1 day. If possible, the discharge from Sandy Dam should be reduced in time to allow all the drawdown discharges (if any) to pass through Aitkin prior to the peak occurring there. If the drawdown is completed before the spring snowmelt begins, discharge inflows to maintain the drawdown level. See the ROPE Study, pages 97-98.

d. Management During Construction and Rehabilitation: In order to access the features requiring rehabilitation and in order to pass flows, phased construction with cofferdams will be used. The project construction is over two years, with each phase of construction scheduled from June to September, a period of time when there is a better likelihood of lower flows.

For Phase 1, an upstream coffer dam will isolate the upstream side of the lock bay area, while a downstream coffer dam will be placed on the apron. Phase 1 construction will occur within the dewatered lock bay. The lock bulkhead wall will be removed and replaced with three stop log bays that span the 30 foot width. A new concrete sill will be installed to reduce the number of stop logs required. During Phase 1 construction, all flows will be passed through the slide gates and the log sluice bay.

For Phase 2, an upstream coffer dam will isolate the upstream side of the slide gates and the log sluice bay, while a downstream coffer dam will be placed on the apron. Phase 2 will replace the existing slide gates with new gates and will also replace the stop logs of the log sluice bay with a motorized full width dual leaf gate. During Phase 2 construction, all flows will be passed through the lock bay.

At the present time in the design process, the most current hydraulic design is provided by the contract documents. From the Design Documentation Report (DDR) Interim Submittal, the following is presented for the operations during the construction phases (Note the vertical datum is NAV 1988): The hydraulic analysis builds upon previous review of USACE supplied gage and reference data as detailed in the Big Sandy Lake Preliminary Engineering Report (PER). The focus of this analysis continues to be on:

- Providing sufficient capacity for a 10-year frequency event ($Q = 2100$ CFS) flow bypass during construction.

- Providing adequate control of flow bypass during construction under varying operating conditions.
- Analyzing scour potential under proposed improvements and construction bypass.
- Overall improvement of hydraulic capacity and operation at Big Sandy Lake Dam.

1) Management During Construction and Rehabilitation: Pertinent Structure

Elevations: The pool at Big Sandy Lake Dam is maintained at 1217.0 feet (NAV 1988) during normal flow conditions in the summer. Under normal operations the pool is reduced throughout the winter months to elevation 1215.0 feet (NAV 1988) to provide additional spring flood storage. This begins on October 1 in a typical year.

Key pool elevations, all in NAV 1988, are provided below:

- Top of Control Structure: 1224.86 ft
- Maximum Operating Limit: 1219.00 ft
- Normal Summer Pool: 1217.00 ft
- Minimum Operating Limit (Winter Pool): 1215.00 ft
- 2-Year Flood Pool: 1218.29 ft, Q = 1400 cfs
- 5-Year Flood Pool: 1220.69 ft, Q = 1800 cfs
- 10-Year Flood Pool: 1221.69 ft, Q = 2100 cfs
- 50-Year Flood Pool: 1222.99 ft, Q = 2900 cfs

Normal flows are in the range of 100 cfs, but as shown by the design flood values above, they can reach 1000-2000 cfs during higher magnitude flood conditions. Previously, the 5-year flow of 1800 cfs and pool elevation of 1220.69 feet were used as benchmarks for hydraulic capacity and upstream cofferdam elevation requirements during construction, respectively. Subsequent discussions with the USACE regarding more frequent observation of higher flows at Big Sandy lead to increasing the level of protection (and required hydraulic capacity) provided by the upstream cofferdam to the 10-year flood pool elevation of 1221.69 ft. The sheet pile wall will be given an additional 1-foot of freeboard resulting in a top elevation of 1222.69 feet which is approximately equal to the 30-year (3.33% exceedance) flood pool. **Figure 7-1** Figure 7-2 below show the discharge and headwater duration curves.

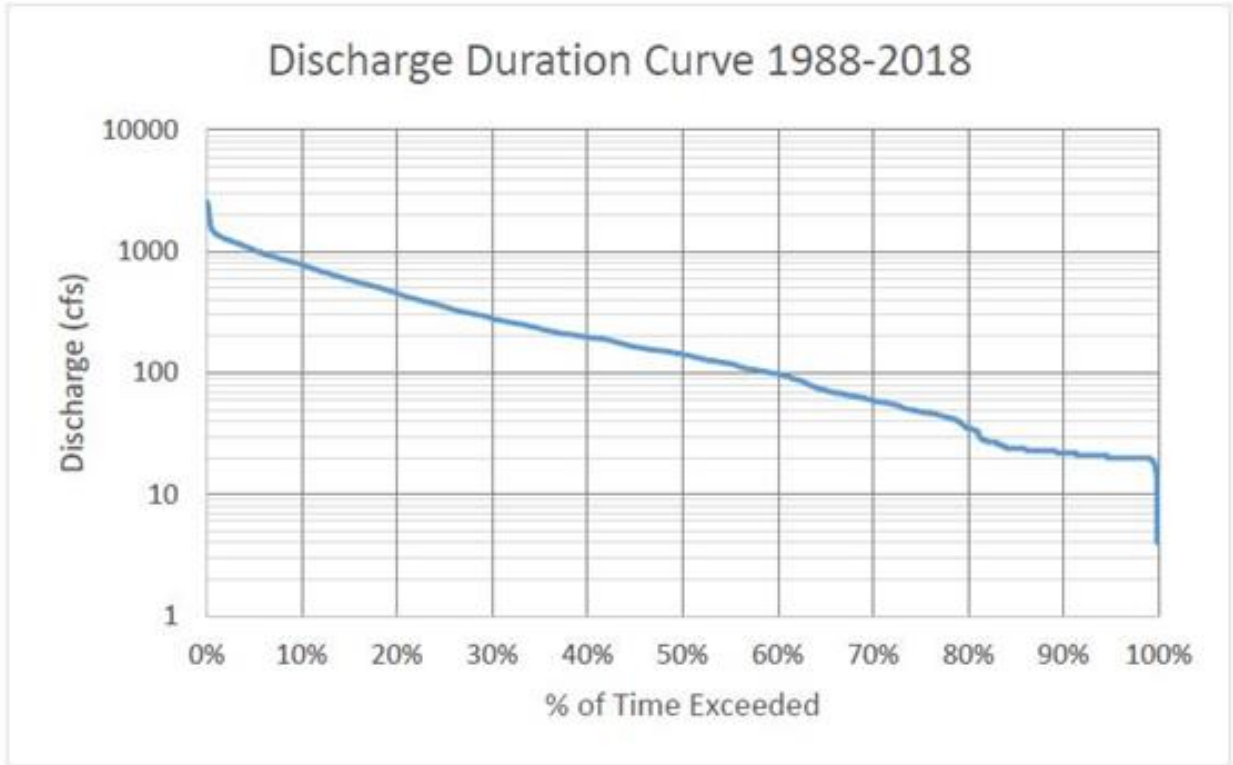


Figure 7-1. Discharge Duration Curve at Big Sandy Lake Dam

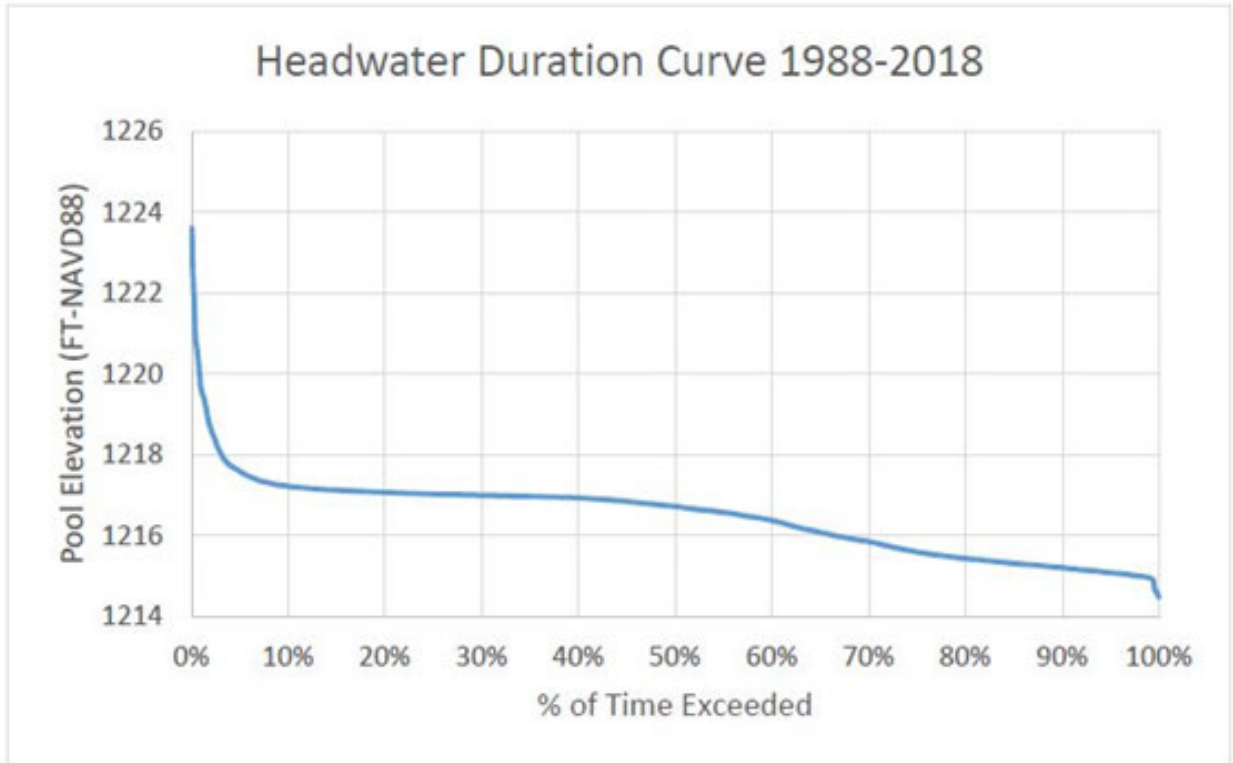


Figure 7-2. Headwater Duration Curve at Big Sandy Lake Dam

As shown by the discharge duration curve graph, the average flow is roughly 150 cfs. Flows exceed 300 cfs approximately 30% of the time. It is assumed that construction phases will span several months, so the 5-year and 10-year flood flows of 1400 cfs and 1800 cfs, respectively, were used as benchmarks for bypass and pool elevations during construction.

The temporary downstream cofferdam design elevation will be determined by the contractor and require government approval prior to construction. Historic Big Sandy Lake Dam pool and tailwater elevation, duration and frequency data will be provided in the form of reference drawings.

2) Management During Construction and Rehabilitation: Construction Bypass

Capacity and Flow Control: A spreadsheet model was created to establish the dam’s current hydraulic capacity. A proposed spreadsheet model was also created and has been updated to reflect the new stoplog bay dimensions. Increasing the hydraulic capacity needed for bypass flow during construction from the 5-year event to the 10-year event requires removal of the existing concrete sill within the lock bay. As such, the bottom of the proposed stoplog bay will be at elevation 1206.0 feet and provide more than sufficient capacity to pass normal and flood flows during construction. **Figure 7-3** below shows the spreadsheet model layout. Detailed

computations are provided in Contractor submittal.

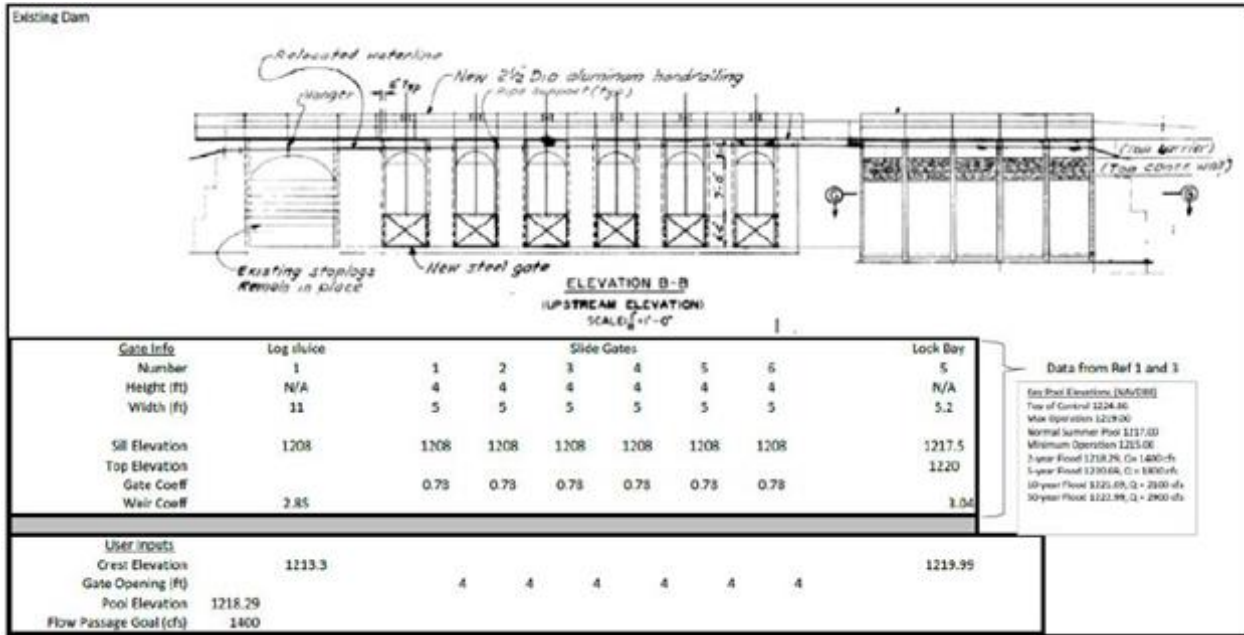


Figure 7-3. Hydraulic Capacity Spreadsheet Model

3) Management During Construction and Rehabilitation: Flow Management During Construction: Phase 1 of construction includes cofferdam systems around the lock bay. Constructing the lock bay improvements first establishes the flow bypass system for Phase 2. During Phase 1, normal and high flows will continue to be passed through the slide gates and log sluice bay as they are currently, and all construction of the lock bay portion of the dam will be completed.

Phase 2 will include cofferdam systems around the sluice gate and log sluice bays. During this time, all flow will be diverted through the new stoplog bays and construction of the sluice gate and log sluice bay will be completed.

As discussed in the previous section, the completed lock bay will increase the dam’s existing hydraulic capacity and allow for passage of larger magnitude flow events if required during construction. For normal operation during construction, it’s anticipated that one of the bays will be equipped with stoplogs of varying height to allow for the passage of low-flow increments all the way down to the minimum flow requirement of 20 cfs. USACE personnel will be responsible for removing and replacing stoplogs in the lock bay. **Figure 7-4** below shows a configuration of stoplogs within the lock bay that would allow the operator to precisely control the pool elevation by re-configuring the 12”, 10”, 8” and 6” stoplogs in various combinations to achieve the desired outflow. The addition of a spare 6” stoplog would allow the operator to easily lower the elevation within the bay in 2”

increments if necessary.

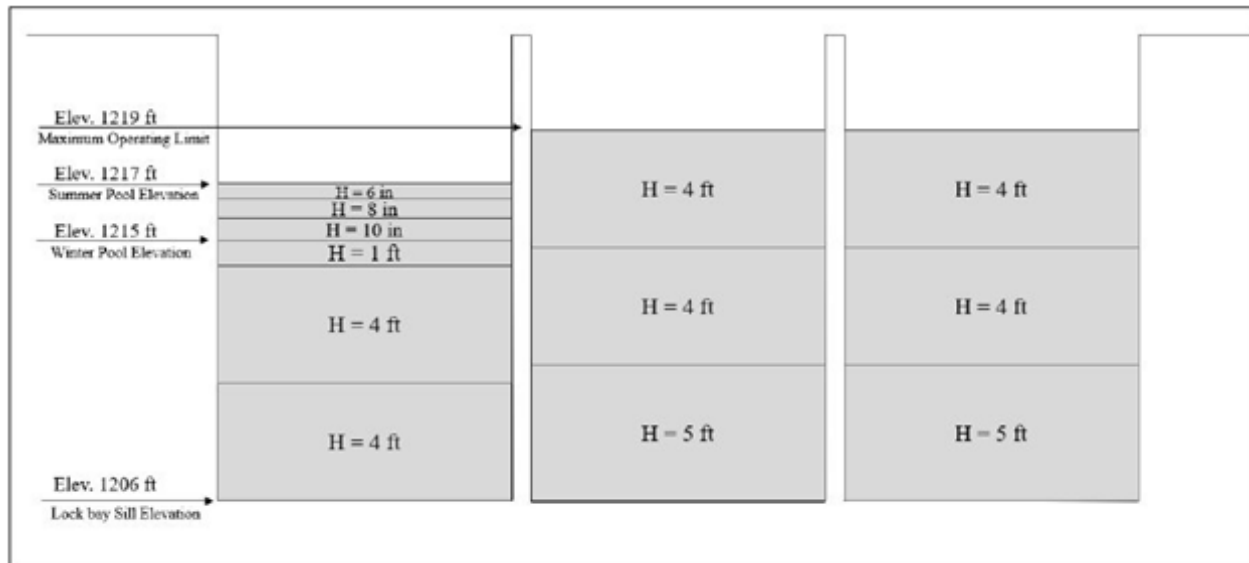


Figure 7-4. Lock Bay Stoplog Configuration During Construction

- 4) **Management During Construction and Rehabilitation:** Scour Control: The potential for scour was reviewed in the following locations where hydraulic conditions are expected to change:
- Directly downstream of the lock bay's concrete apron during construction bypass.
 - Downstream of the log sluice bay during operation of the lower dual leaf gate.

Lock Bay: A HEC-RAS steady flow model of the lock bay and downstream channel was developed in the PER to evaluate velocity, hydraulic parameters, and downstream riprap stability for the 2-year and 5-year flood events. The model was updated with the pool/flow conditions anticipated during a 10-year event. The peak velocity computed was 7.62 ft/s, which was lower than both the 2-year and 5-year peak velocities computed in the PER. A riprap stability analysis was performed in accordance with USACE's MVP Riprap design (Rev 2 March 2015) document to determine the size of riprap considered stable under flood discharge conditions. The analysis determined that a R20 gradation would be stable under the velocities computed by HEC-RAS. The specific size of the existing downstream riprap is unknown but prior inspection reports indicated the thickness of the riprap layer is 15 inches. This falls within the typical R20 placement thickness of 12 to 18 inches, so a similar sizing to the R20 gradation appears likely. Detailed computations are provided in the Contractor submittal.

Log Sluice Bay: The potential for scour downstream of the log sluice bay was reviewed in the PER and found that an increase in scour risk for the riprap at the downstream end of the concrete apron is not anticipated due to the minimal use of the lower leaf gate during normal operation. Raising the bottom leaf may be performed periodically to exercise and test the gates as part of routine inspection and maintenance, or during flood events when additional hydraulic capacity is required. However, stoplog channels are being provided upstream and downstream of the gate which would allow for placement of stoplogs on the downstream side to exercise the gate without significant discharge.

- 5) **Management During Construction and Rehabilitation: Improved Hydraulic Capacity and Operation:** The proposed improvements will result in an overall increase in the structure’s hydraulic capacity and simplify day-to-day operation of the dam. The table below summarizes the proposed changes to the log sluice bay, slide gates, and lock bay from a hydraulics and operations perspective.

Table 7-4. Summary of Hydraulic Features

	Log Sluice Bay	Slide Gates (6)	Lock Bay Stoplogs
Issues	Existing 11-foot log sluice bay operated by flood-mounted jib cranes and a lifting beam. Handling stoplogs is cumbersome and requires at least two people.	Manually operated gates nearing end of 50-year design life	Concrete wall and steel columns in poor condition. No way to pass required flow during construction.
Proposed Feature	Remove and replace existing with 11' x 10' high dual leaf slide gate. Independent 5' gates with UHMWPE side seals.	Remove and replace existing slide gates with new SS gates. Heating element in gate frame and UHMWPE side seals.	Remove existing stoplogs structural beams, walkway, and concrete bulkhead walls, and replace with three 9-foot wide aluminum stop log bays.
Hydraulics	Used periodically for high flow events and passing debris. Increased	Size of gates and hydraulic opening remains the same.	Primary purpose is to bypass flows during construction. Not

	hydraulic capacity compared to existing stoplogs. Lower gate only used for extreme flood events.		anticipated for use under normal conditions except for extreme flood events.
Operation	Motorized push button control system that can operate the two gates independently.	Motorized push button control with option for manual operation, operable from either pumphouse or catwalk. Gate heaters can be turned on/off individually at the gate.	Lifting beam used in conjunction with USACE supplied hoist/machinery to pull individual stoplogs during major flood events.

7-06 Recreation

Recreation is an important feature of Big Sandy Lake reservoir. There are numerous lakeshore homes and resorts around the lakes and a public recreation area. Excessive inflows can cause the reservoir level to exceed the Normal Summer Band due to the relatively small outlet capacity of the dam and the limited downstream channel capacity.

The main portion of the recreation season encompasses the period from the first day of the fishing season through Labor Day weekend (approx. mid-May to early Sept.). When runoff conditions permit, the reservoir level should be within the Normal Summer Band of 1216.06 to 1216.56 feet by the first day of the fishing season, and held there by discharging inflow until October, after which the fall/winter drawdown can begin. As the recreation industry has grown, the number of people using the resource in the late fall (thru Sept.) has also increased. A gradual drawdown, beginning on approximately 1 October, keeps the pool within the summer band through September to accommodate late season recreation (see drawdown discussion for details).

7-07 Water Quality

The Federal Water Pollution Control Act Amendments of 1972 requires Federal facilities to comply with applicable Federal, State, and local standards. The only water quality concern relates to the threat of eutrophication. At this time no physical routine regulation procedures are identified that would improve reservoir water quality.

7-08 Fish and Wildlife

The Fish and Wildlife Coordination Act, as amended, provides that certain Federal reservoirs should be managed for the conservation, maintenance, and management of wildlife resources.

7-09 Water Conservation/Water Supply

The reservoir is not used for water supply. There is no provision in the Water Control Plan for the use of water in or from the reservoir for water supply. An analysis of the feasibility of using

water from the Headwaters region to supplement downstream needs is contained in the September 1994 Section 22 report.

The ROPE Study provides that, if the reservoir is at or above elevation 1214.31 feet (7.0 ft. stage), the minimum discharge is 20 cfs. Furthermore, if the reservoir is below elevation of 1214.31 feet, the minimum discharge is reduced to 10 cfs. Area-capacity curves and a storage table for Big Sandy Lake are in **Exhibit A**. See **Section 7-12** for information on the draft Drought Contingency Plan and other applicable reference documents.

7-10 Hydroelectric Power

In the Big Sandy Lake basin area, there is no existing or planned Federal hydropower development. Also, Big Sandy Lake does not operate for any non-Federal hydropower in the area.

7-11 Navigation

The need for flow augmentation from the reservoirs for navigation was greatly reduced after completion, in the 1930's, of the Mississippi River 9-foot channel project (i.e., locks and dams). The project has rarely been operated for this purpose since then. See **Sections 2-02** and **3-07**.

7-12 Drought Contingency Plans

The Drought Contingency Plan (DCP) is a stand-alone document (ER 1110-2-1941, dated 02 February 2018). A DCP specifically for Big Sandy has not been prepared, however, numerous drought considerations have been finalized over the years, particularly since the devastating drought of 1988.

Minimum Flow toward Drought: The Big Sandy Lake level should be held at normal summer range (1216.56 to 1216.06 NGVD 1929). During dry periods, the outflow is reduced to minimum outflow of 20 cfs () in order to keep the lake at the normal summer range. If the lake level continues to recede and go below the 1216.06, the minimum outflow of 20 cfs is maintained. Once the lake level recedes all the way to the lowest total operating limit (1214.31 NGVD 1929), the outflow is reduced to 10 cfs (Table 5.5.6, ROPE Study).

Congressional Notification: The Secretary of the Army shall report to Congress at least 14 days prior to the Big Sandy Lake level going lower than 1214.31 (NGVD 1929).

Regional Drought: Often the extent of a drought covers more than a single Mississippi River headwaters site. The Minnesota Department of Natural Resources, in coordination with the St Paul District, formulated a Low Flow Management Plan. The Plan sets trigger elevations and flow rate restrictions in order to provide steady, non-surfing levels during low flows. While Lake Winnibigoshish and Lake Pokegama are specifically listed, Big Sandy is not. In addition, the October 1990 "Mississippi River Low-Flow Review" report and the September 1994 "Water Available from Upstream Locations" Section 22 Report (see **Section 1-03**) should be consulted for further guidance during low-flow conditions.

Coordination: Federal, State, local, and tribal entities should coordinate beginning at the start of drought or abnormally dry conditions. The St Paul District has a tribal trust responsibility to the Mille Lacs Band of the Minnesota Chippewa Tribe.

7-13 Flood Emergency Action Plans

The Emergency Action Plan is a stand-alone document (see **Section 1-03**). It outlines procedures to be followed under various emergency conditions to include a dam failure. A copy of the plan is kept in the Water Management Section and at the project office. The report includes: an emergency identification plan, an emergency operations and repair plan, an emergency notification list, and an inundation map. See also **Sections 5-08** and **8-10**. The Emergency Regulation Assistance Procedures are discussed in the introduction to this manual preceding the Table of Contents. See also **Section 7-05**.

7-14 Other – Loss of Communication

In the event of failure of normal (telephone) communications, the project staff will maintain contact with the District Office by any other means available, including radio, alternate telephone services, the internet or by sending a messenger to the nearest point where communication is available. The messenger will then transmit written or verbal instructions from Water Management if special operation is required. If Water Management cannot be contacted at the District Office, one of the regulators, in order of preference as shown in the introduction to this manual, is to be contacted.

If contact cannot be made the primary objective of the project staff will be to ensure the safety of the dam and provide the most effective operation of the project by following the guidance in this chapter. It may also be necessary for the project staff to monitor the effects of any reservoir releases on downstream damage centers. During flood risk management or emergency operation, the appropriate procedure in this chapter will be followed until contact with the District Office is re-established.

7-15 Deviation from Normal Regulation

It may be necessary on occasions to deviate from the normal regulation procedures described in this manual. The District Office normally classifies deviations as major or minor on a case-by-case basis with concurrence from the Division Office. If a deviation is classified as minor, the District Water Management Office will provide the senior Division Water Management manager the deviation request explaining the need for the deviation. This request is normally sent via e-mail when there is adequate time. If the minor deviation request is considered time critical, the request can be made orally and once the approval is given by the Division Office an e-mail request should be sent for the record. If a deviation is determined to be major, a formal recommendation is required from the District by the Chief, Engineering and Construction Division. All deviation requests should be coordinated within the District Office as well as the appropriate Federal and State Agencies and local interests. Deviations may be implemented prior to reporting to higher authority for catastrophic incidents that involve the protection of human life, public property and the safety of project structures.

7-16 Rate of Release Change

Under normal operating conditions rate of release change should be between 20% and 30%. See table 5.5.6 in the ROPE study. Two or three gate changes per day may be necessary during critical flow periods to alleviate stress to fish and wildlife resources.

7-17 Definitions and Operation Levels

The following terms are used in **Section 7-05** (e.g. see) and elsewhere in this manual. This information is provided here to assist in interpreting the regulations and other historical references (see **Section 3-07**).

- a. **Normal Summer Range/Band:** (Sometimes called Desirable Summer Range/Band)
Investigations were made of desirable levels for the Headwaters Reservoirs through public consultation. The Normal Summer Range/Band represents the reservoir level which is the most beneficial to a majority of the users during the summer months (see **Table 7-2**).
- b. **Ordinary Operating Limits:** (Sometimes called Present Ordinary Operating Limits) This represents the range that the reservoir is ordinarily operated in during an annual cycle, which minimizes the degree of high and low water damages (see **Section 3-07** and). The full range, of course, is not experienced every year.
- c. **Present/Total Operating Limits:** The term “Total Operating Limits” (in addition to Present Operating Limits) is used in this manual (e.g. in and). This is due to the fact that Pokegama, Sandy and Pine, due to subsequent flood risk management studies involving Pokegama and Sandy and, in the case of Pine, a dam safety upgrade, are operated above the limits specified in the various regulations (see **Section 3-07** in the respective manuals). These limits represent the absolute upper and lower reservoir levels that the Corps can operate within (see **Table 7-2**). The term “Present Operating Limits” is used when it is felt that it will provide the easiest reference back to historic documents (e.g. primarily at Winnibigoshish, Leech and Gull). The Present Operating Limits were established and/or modified in regulations dated 1931, 1935, 1936 and 1944. Modifications to the upper limits at Pokegama and Sandy were published in the 1963 (revised 1968) Master Regulation Manual (see **Section 1-03**) and Cross Lake/Pine’s upper limit was modified in the 1997 Design Memorandum (see also **Section 1-03**). Congressional notification of upper and lower reservoir levels is required by Public Law 100-676, Section 21, of the Water Resources and Development Act (WRDA) of 1988. See **Section 3-07** of this manual for more information.

8 Effect of Water Control Plan

8-01 General

The Water Control Plan primarily affects flood risk management, recreation and fish and wildlife. The plan strives to maintain stable water levels during the summer months which provides many benefits related to recreation, fish, wildlife, bank erosion, preservation of archaeological and cultural sites, and water quality (see also **Chapter 2** and **Section 3-06b**).

8-02 Flood Risk Management

Spillway Design Flood

The dam was constructed prior to the development of current spillway design flood standards. As a result, the original design of the dam was not based upon Probable Maximum Flood (PMF) criteria. A PMF was developed, however, for the June 1987 Emergency Plan report (see **Section 1-03**), and has been incorporated into this manual for comparative purposes. The computed peak inflow from the PMF is 40,500 cfs. Routing of the PMF through the reservoir, resulted in a computed peak pool elevation of 1228.7 feet and a maximum outflow through the spillway and over the dam of 20,300 cfs. The PMF hydrograph for without dam failure scenario is presented on **Plates 8-1**.

Inflow Design Flood

The dam was constructed before the advent of current Spillway Design Flood criteria (see next paragraph).

Reservoir Design Flood

A Standard Project Flood (SPF) for Big Sandy Lake Dam was developed and presented in the Corps of Engineers report titled, "Review of Design Features of Existing Dams (RCS ENG CW-(OT) 761; Supplement No. 1), Mississippi River Headwaters Reservoirs", in March 1974 (see **Section 1-03**). The purpose of this report was to determine a Spillway Design Flood (SDF) for each of the Headwaters reservoirs. The term "Spillway Design Flood" as used in the report does not refer to the design used to construct the dam but rather to a flood derived by means of the criteria available at the time (i.e. 1974). The report adopted the SPF as the SDF. See **Plate 8-2**.

Big Sandy Lake Dam is only 1.25 miles upstream of the mouth of the Sandy River, which discharges into the Mississippi River. At Big Sandy Lake Dam the tailwater stage is greatly affected by a variable backwater from moderate to high stages on the Mississippi River. During large floods Big Sandy Lake Dam can be completely inundated by backwater from the Mississippi River. Consequently, the adopted SPF flood series for Big Sandy Lake Dam was derived from the Mississippi River at a location immediately above the mouth of the Sandy River. This condition, due to the Mississippi River backwater effect, was found to be more critical than an SPF derived for the area above Big Sandy Lake Dam. The SPF was based upon the 1950 flood.

The SPF peak discharge is estimated to be 29,000 cfs. This is equivalent to an elevation of 1226.81 feet at the U.S.G.S. gage on the Mississippi River at Libby, Minnesota, just below the

mouth of Sandy River (this gage has been discontinued). Assuming a flat pool into Big Sandy Lake, this is the SPF maximum pool elevation for the reservoir.

An index Standard Project Storm rainfall of 9.0 inches was used. An initial loss rate of 1.0 inch was satisfied by placing the second largest day of rainfall before the maximum day. A uniform loss rate of 0.20 inch per hour was used and only one six-hour period had rainfall greater than the loss rate. The rainfall excess during that period was 5.25 inches.

Other Floods

Selected floods are described in **Section 4-06** and are listed in _____ along with some corresponding information for the reservoir.

8-03 Recreation

The current Water Control Plan for the reservoir provides dependable and stable summer lake levels, which benefit resort owners, lakeshore residents and area commerce. Stable summer levels reduce shoreline erosion, improve wildlife habitat and provide a known reference for land owners to use for cabins and docks. See **Sections 2-06 and 7-06**.

8-04 Water Quality

This Water Control Plan does not significantly impact the rate or level of eutrophication of Big Sandy Lake, which is the only water quality problem at Big Sandy Lake. Eutrophication is primarily due to both point and non-point nutrient loadings from the watershed. Big Sandy Lake is currently listed on the Minnesota Pollution Control Agency's (MPCA) 2008 303(d) Impaired Waters List due to excessive nutrients (phosphorus). A Total Maximum Daily Load (TMDL) Report was completed for Big Sandy Lake in January 2010. As of 2018, Big Sandy remains on the Impaired Waters List. Phosphorus load reductions to Big Sandy Lake will be achieved by targeting multiple nonpoint sources.

See Sections **4-08, 5-02, 7-07**.

8-05 Fish and Wildlife

The U.S. Fish and Wildlife Service has performed studies of the water levels maintained during the operation of Big Sandy Lake and has concluded that the present reservoir regulation schedules are generally satisfactory from the wildlife point of view. The current Water Control Plan provides for stable summer levels and consistent recurring year round levels, which benefit fish and wildlife. See **Section 7-08**.

8-06 Water Conservation/Water Supply

The headwaters reservoirs are not used for water supply under normal operations. The Drought Contingency Plan should be referenced for information on water supply issues in the region. See **Sections 1-03, 7-09, and 7-12**.

8-07 Hydroelectric Power

The Water Control Plan's streamflow regulation provides flow- duration characteristics, which benefit downstream hydropower plants. See also **Section 7-10**.

8-08 Navigation

The benefits of the Water Control Plan, with respect to navigation, occurred primarily in the years prior to the 1930's. After this time, the 9-foot channel project below Minneapolis eliminated the need for releases to aid navigation. See **Section 2-02**.

8-09 Drought Contingency Plans

A Drought Contingency Plan (DCP) specifically for Big Sandy has not been prepared, however, numerous drought considerations have been finalized over the years, particularly since the devastating drought of 1988 and 2012.

8-10 Flood Emergency Action Plans

The Emergency Action Plan provides a guide for the necessary actions to identify, mitigate and respond to various types of emergencies, which while rare, could occur in the operation of the dam. The plan is a stand-alone document (see **Section 1-03**).

8-11 Frequency

Also see **Section 4-07**.

Peak Inflow Probability

Plate 8-3 illustrates the probability of given inflow volumes into Big Sandy Lake for durations of 1, 3, 10, 30 and 90 days. The inflow curves are based on data developed by reverse routing using daily lake elevation and discharge records from 1899 through 1985. The one-day volume-frequency curve, as well as the remaining curves, were developed in accordance with the methods presented in Water Resources Council Bulletin 17B. The curves were smoothed graphically to correlate with the one-day curve. Lake elevations used in the reverse routing analysis are likely to have been affected by wind speed and direction. No smoothing was done to the reverse routed hydrographs prior to the statistical analysis to account for wind-related and other data irregularities and resulting "negative inflows".

Pool Elevation Duration and Frequency

The annual probability of a given peak pool elevation is given on **Plate 8-4**. The percent of the time the pool is at, or above, a given elevation is presented on **Plate 8-5**. These curves were developed for the period 1936 through 1985. Outflow values prior to 1936 are nonhomogeneous due to a change in the reservoir regulation schedule.

Key Control Points

The frequency curve for Big Sandy Lake Dam outflows and tailwater elevation are given on **Plates 8-6 and 8-7**, respectively. These curves were developed for the period 1936 through 1985. Outflow values prior to 1936 are nonhomogeneous due to a change in the reservoir regulation schedule. See **Section 3-04** for a description of the flood risk management project at Aitkin.

8-12 Other Studies

Examples of Regulation

The House Committee on Rivers and Harbors passed a resolution on June 7, 1945 requesting a review of the Mississippi River Headwaters reservoirs. Since then, several studies have been completed to determine the effectiveness of the present regulation plan for each reservoir. These studies include:

- 1) Mississippi River Headwaters Lakes Feasibility Study, 1982, Main Report and Appendices, Two Volumes.
- 2) Computer Operations Study of Reservoir Operations for Six Mississippi River Headwaters Dams, 1982, Final Report and Appendices, Three Volumes.
- 3) Environmental Review of the Headwaters of the Mississippi River Reservoir Projects, Bemidji College, 1975.
- 4) Review of Design Features of Existing Dams at Mississippi River Headwaters Reservoirs, RCS ENG CW-(OT)761, March 1974.
- 5) Mississippi River Headwaters- Master Plan for Public Use Development, August 1977.

Studies 1 and 2 resulted from several earlier studies, in which the effects of regulation plans at the Mississippi Headwaters Reservoirs were examined. Study 3 is devoted entirely to environmental aspects of the headwaters reservoirs. In general, the conclusions of reports 1, 2, and 3 favored the present regulation plan as the best means of meeting the existing problems. The purpose of study 4 was to determine the Spillway Design Flood for each of the headwaters reservoirs using 1974 criteria. Study 5 describes and evaluates resource management at the six Corps of Engineers' administered recreation areas.

Channel and Floodway Studies

Floodplain studies have been performed for several communities in the Mississippi River Headwaters region below Big Sandy Lake. The flood discharge was computed for each city for the 10-, 50-, 100- and 500-year floods. In some cases, corresponding elevations were also tabulated. Such studies are referenced in .

Community	Study Number	County	Comments
Aitkin	270001	Aitkin	Mississippi River and Ripple River
Brainerd	270093	Crow Wing	Mississippi River and Rice Lake
Crosby	270094	Crow Wing	Serpent Creek and Lake

Palisade	270004	Aitkin	Mississippi River at State Hwy 232
Riverton	270100	Crow Wing	Mississippi River at Little Rabbit Lake

Miscellaneous Studies

The Mississippi River Headwaters, Reservoir Operating Plan Evaluation (ROPE) Study began in 2001 and was completed in September 2009 (Record of Decision signed 19 January 2010). It included evaluation of various operating plans and an Environmental Impact Statement. The ROPE Study considered numerous factors and produced minimal changes to the current reservoir operations.

9 Water Control Management

9-01 Responsibilities and Organization

USACE

The Corps of Engineers is the owner, operator and regulator of the Big Sandy Lake Dam and Reservoir. The Water Management Section has direct day-to-day responsibility for the regulation, and the Operations Division has responsibility for the operation and maintenance of the project. A portion of Big Sandy Lake is within the boundary of the Big Sandy Lake Indian Reservation, whose residents are formally represented by the Government of the Mille Lacs Band of the Minnesota Chippewa Tribe, a Federally Recognized Tribe. As stated in *Cherokee Nation vs. Georgia (1831)*, a unique relationship exists between the United States Government and Federally Recognized Tribes. Several treaties exist between the Mille Lacs Band and the Federal Government. Treaties signed in 1826, 1837, 1847 and 1855; court cases; administrative law; and statute define the legal obligations of the Federal Government to the Mille Lacs Band. The legal trust relationship predates the Headwaters Lakes project and the existence of Minnesota as a state. The Corps of Engineers, as an agency of the Federal Government, is a party to such relationships. It shall, to the best of its ability, strive to fulfill such obligations inasmuch as they do not conflict with the rights of the United States Government, which are paramount, to use the waters of Big Sandy Lake for its authorized purposes. An additional consideration at Big Sandy Lake is the presence of a burial area near the lakeshore, which could be subject to damage from flooding and/or erosion. This burial area is on land held in trust by the Federal Government "for the benefit of the Indians living in the area. The USACE assumes all authority in the operation and maintenance responsibilities for the Big Sandy Dam. Day-to-day operation generally follow guidance provided in the Standing Instructions to Project Operator (**Section 7-04**).

Other Federal Agencies

The National Weather Service has the responsibility for official hydrologic forecasts within the Upper Mississippi River Basin. The U.S. Geological Survey collects data on the discharges at various stations within this basin (see map, **Plate 5-1**).

State, County, and Local Agencies

State agencies having an interest in Big Sandy Lake regulation are the Minnesota Pollution Control Agency, Minnesota Department of Natural Resources, and Mississippi Headwaters Board. Interested local agencies include the City of Aitkin and the power utilities downstream of Aitkin. There are no State and/or local agencies that have direct or indirect responsibilities in the operation and maintenance of the Big Sandy Reservoir.

Private Organizations

The Big Sandy Lake Association is one private organization that has a role or responsibilities for the operation and maintenance of the Big Sandy Reservoir. Other local private interests include area resorts, homeowners, and recreational users.

9-02 Interagency Coordination

Local Press and USACE Bulletins

Information concerning the regulation of the reservoir is provided by the St. Paul District's Public Affairs Office (PAO) through social media and to the local news media in response to their requests. Additionally, the PAO provides news releases of an advisory nature to the local news media regarding important aspects of project regulation. These news releases do not provide public forecasts of river stages or flows however, because such forecasts are a congressionally mandated responsibility of the National Weather Service.

National Weather Service

Current readings from the headwaters reservoirs are supplied to the National Weather Service on a regular basis. These readings include discharges, reservoir levels, snow depth/water content, frost depths and precipitation. The National Weather Service uses this information in developing their river forecasts.

U.S. Geological Survey

This agency receives data from its own and co-operative observer gages, the DCP network, as well as from the Water Management Section on a regular schedule and other times on request.

Power Marketing Agency

Power generation is not applicable to this project.

Other Federal, State, or Local Agencies

The U.S. Fish and Wildlife Service, National Resource Conservation Service, U.S. Forest Service, and the Environmental Protection Agency, all have an ongoing interest in Big Sandy Lake, and assist in the regulation of the reservoir through data sharing and coordination.

9-03 Interagency Agreements

There are no formal inter-agency agreements for the operation and maintenance of the Big Sandy Reservoir. However, the St. Paul District works to resolve issues in regulatory matters affecting Tribal or state interests by informal coordination with the Indian Tribes and the Minnesota Department of Natural Resources (MDNR).

9-04 Commissions, River Authorities, Compacts, and Committees

The Upper Mississippi River Basin Association (UMRBA) is an interstate organization formed by the governors of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The primary responsibility of UMRBA is the coordination of Federal, State, Interstate, local, and non-Governmental plans for regional development of water and related land resources in the basin. The Mississippi Headwaters Board (MHB), formed in 1980, is a joint powers board of eight counties working to enhance and protect the natural, cultural, historic, scientific and recreational values of the headwaters region.

9-05 Non-Federal Hydropower

Big Sandy Lake does not have any non-federal hydropower facilities.

9-06 Reports

presents a listing of reports and other data sources related to the regulation of the reservoir.

Table 9-1 Reports on the Big Sandy Project		
Report Name	Date Required	Form Number
Compiled by Water Management		
Gage Records	As Needed	Computer Archived
Compiled by the Field Office for the Water Management Section		
Monthly Log Sheet	End of Month	NCS-64
Snow Reports and Frost Reports	November through March 30	NCS-430 NCS-58
Emergency Reports when Required or Requested	Daily at 0800 hours	By Phone/Email

10 Tables Longer than 1-Page

Table 10-1 Summary of Repair Measures				
No.	Project Feature		Corrected Deficiency	Date
1	Concrete Control Structure & Lock	Lock Modifications	Inability to maintain original timber crib walls led to demolition and replacement of the lock and dam with a gravity concrete structure. Construction was completed in 1912.	1907-1912
2	Perimeter Dike	Perimeter Dike No. 4	Dike No. 4 was constructed by raising the grade of Aitkin Lake Road, which was built by the township.	1909
3	Concrete Control Structure	Sluice Gates	The sluice gates were repaired.	1946-1947
4	Spillway Abutment	Embankment Sections	The spillway abutment/embankment sections were raised and widened during the flood event.	1950
5	Access Road	Access Road	The access road was raised to an elevation of 1,227.81 feet, with a top width of twenty feet, and 1V:3H side slopes.	1951
6	Perimeter Dikes	Perimeter Dikes Nos. 1, 2 and 3	A contract was let to protect Perimeter Dike No. 1 with twelve inches of riprap and a six inches of filter material. This same contract included work for Perimeter Dike No. 2, a 100 foot long reach adjacent to the right abutment of the structure, and Perimeter Dike No. 3, a 913 feet long dike beginning about 1,000 feet right of the structure. Borrow material under this contract was a silty fine sand. Perimeter Dikes No. 2 and 3 were also raised to elevation 1,225.31 feet, with ten foot top widths, and 1V:3H side slopes. On a 400 foot reach of the dike, twelve inches of riprap protection was placed, underlain by six inches of filter material.	1952
7	Concrete Control Structure & Lock	Lock Modifications & Downstream Timber Apron Replacement	In 1958, Five (5) Bays Were Installed In the Unused Lock. The Bays Were Fitted With Vertical Steel Beams And Removable Wooden Stoplogs For Additional Spillway Capacity. In Addition, the Wooden Aprons In Both The Downstream Area of The old Lock, And the	1958

**Table 10-1
Summary of Repair Measures**

No.	Project Feature		Corrected Deficiency	Date
			Downstream Area of The Six Operating Bays, Were Removed And Replaced With Concrete.	
8	Spillway Abutment	Embankment Sections	The spillway abutment/embankment sections were raised and widened during the flood event.	1969
9	Concrete Control Structure & Lock	New Sluice Gates	In 1971, The Lock's Wooden Stoplog Control Structure Was Replaced With a Concrete Curtain Wall To Elev. 1216.81 Feet, And Then Topped-Off With Wooden Stoplogs From There Up To Elevation 1219.31 Feet. This Allowed Partial Use of The Old Lock To Pass Large Flood Flows. In Addition, Mechanical Sluice Gates With Gate Operators Were Installed In The Six Operating Bays In 1971.	1971
10	Main Embankment	Widening & Raising	The Right And Left Main Embankment Sections Are 75 And 30 Feet Long, Respectively. The 2 Sections Were Raised, Widened, And Lengthened During the Flood of 1971.	1971
11	Perimeter Dike	Perimeter Dike No. 3 - Rebuilding	Dike No. 3 Previously Had Relatively Steep 1.5H To 1V Side Slopes Prior To 1994, When The Slopes Were Flattened To 4H To 1V. In Conjunction With The Re-Construction Work of 1994 And 1995, The Top of The Dike Was Widened To 30 Feet Across, And A New Bituminous Roadway Surface Was Installed. All of The Work Was Completed In The Late Fall of 1995.	Oct 1995
12	Concrete Control Structure	New Vehicle Bridge	A New Vehicle Bridge Was Installed Over The Period Of 1999 To 2001, With The Final Work Completed On 15 MAY 2001. The Old Bridge Was Severely Deteriorated And Was A Major Safety Concern.	May 2001

**Table 10-1
Summary of Repair Measures**

No.	Project Feature		Corrected Deficiency	Date
13	Downstream Apron	Floor Drains	Floor drains in the downstream apron were cleaned out by rodding approximately every other year.	1992-2006
14	Downstream Channel	Riprap Placement	Riprap was placed on the riverbed downstream of the dam and lockwall aprons on the existing channel bed.	2006

Table 0-1
Mississippi River Headwater Reservoirs, History of Operating Elevations and Stages in Feet

	Lake Winni.	Leech Lake	Lake Pokegama	Sandy Lake	Cross and Pine Lakes	Gull Lake
1. Original Operating Limits Informally Adopted	1288.94 - 1303.14 0.0 - 14.2	1292.20 - 1297.94 -0.5 - 5.24	1268.92 - 1276.42 4.5 - 12.0	1207.91 - 1218.31 0.6 - 11.0	1217.62 - 1234.82 1.3 - 18.5	1188.75 - 1194.75 1.0 - 7.0
2. February 11, 1931 Regulations First Official Operating Limits	1294.94 - 1303.14 6.0 - 14.2	1293.70 - 1297.94 1.0 - 5.24	1270.42 - 1276.42 6.0 - 12.0	1214.31 - 1218.31 7.0 - 11.0	1225.32 - 1231.32 9.0 - 15.0 (2)	1192.75 - 1194.75 5.0 - 7.0
3. April 1, 1931 Letter for Pine, Later Known as "Ord. Oper. Limits"					1227.32 - 1231.32 11.0 - 15.0 (3)	
4. May 14, 1935 Regulations, See Note No. 4.	1294.94 - 1303.14 6.0 - 14.2	1293.70 - 1297.94 1.0 - 5.24	1270.42 - 1276.42 6.0 - 12.0	1214.31 - 1218.31 7.0 - 11.0	1225.32 - 1231.32 9.0 - 15.0 (2)	1192.75 - 1194.75 5.0 - 7.0
5. February 4, 1936 Regulations, 1935 Upper Limits still apply.	1294.94 6.0	1293.70 1.0	1270.42 6.0	1214.31 7.0	1225.32 9.0	1192.75 5.0
6. 1944 request from Cong. Knutson Adj. Pine's Ordinary Oper. Limits.					1226.32 - 1230.32 10.0 - 14.0	
7. 1944 Ordinary Operating Limits Summary	1296.94 - 1300.94 8.0 - 12.0	1294.20 - 1296.20 1.5 - 3.5	1270.42 - 1274.42 6.0 - 10.0	1214.31 - 1218.31 7.0 - 11.0	1226.32 - 1230.32 10.0 - 14.0	1192.75 - 1194.75 5.0 - 7.0
8. Dec. 29, 1944 revision to the 1936 Regs lowering Leech's lower limit		1292.70 0.0				
9. Revisions to Leech's + Pine's Ordinary Oper. Limits (approx. 1945)		1293.20 - 1295.70 0.5 - 3.0			1227.32 - 1230.32 11.0 - 14.0	
10. Upper Limit Mods at Pokeg and Sandy for Aitkin Flood Control			1278.42, 14.0 1277.92, 13.5	1221.31 14.0		
11. Pine River Dam, Dam Safety Improvements, New Upper Limit					1235.30 18.98	
12. Operating Range (2002) Total storage available if needed	1294.94 - 1303.14 6.0 - 14.2	1292.70 - 1297.94 0.0 - 5.24	1270.42 - 1278.42 6.0 - 14.0	1214.31 - 1221.31 7.0 - 14.0	1225.32 - 1235.30 9.0 - 18.98	1192.75 - 1194.75 5.0 - 7.0
13. Present Ordinary Operating Limits (2002), Typical annual range	1296.94 - 1300.94 8.0 - 12.0	1293.20 - 1295.70 0.5 - 3.0	1270.42 - 1274.42 6.0 - 10.0	1214.31 - 1218.31 7.0 - 11.0	1227.32 - 1230.32 11.0 - 14.0	1192.75 - 1194.75 5.0 - 7.0
14. Public Law 100-676, Sec. 21 Cong. Notification Levels, WRDA 88	1296.94 - 1303.14 8.0 - 14.2	1293.20 - 1297.94 0.5 - 5.24	1270.42 - 1276.42 6.0 - 12.0	1214.31 - 1218.31 7.0 - 11.0	1227.32 - 1234.82 11.0 - 18.5	1192.75 - 1194.75 5.0 - 7.0
15. Public Law 110-114, Sec. 3175 WRDA 2007	1296.94 - 1303.14 8.0 - 14.2	1293.20 - 1297.94 0.5 - 5.24	1270.42 - 1278.42 6.0 - 14.0	1214.31 - 1221.31 7.0 - 14.0	1227.32 - 1235.30 11.0 - 18.98	1192.75 - 1194.75 5.0 - 7.0
Gage Zero Elev., 1929 NGVD	1288.94	1292.70	1264.42	1207.31	1216.32	1187.75

1. The lower limit was generally the sill elevation of the dam at that time. The upper limits were determined through engineering judgment and were set, with the exception of Gull, approx. 4 ft. below the flowage rights elevation.
2. In the case of Pine, correspondence indicates that the District, both before and after 1931, considered elevation 1234.82 feet (18.5 ft. stage) to be the useable upper limit (see Row No. 1). See **Chapter 3** in the Pine Water Control Manual for additional details.
3. Note No. 2 above still applies. This changed Pine's normal spring drawdown level to elev. 1227.32 (11 ft. stage). This adjustment was done by agreement rather than an official change in the regulations. A min. limit of 9 feet at Pine was still authorized in the regulations and available for use if necessary (e.g. large snowpack).
4. No change was made in the operating limits. The min. discharges were changed to ave. annual flows at Pokegama (flow also lowered), Sandy, Pine and Gull.
5. No upper limits are listed in the 1936 regs, however prior reference states that the previous upper limits (1935 regulations) still apply "should extremely wet year necessitate this action". The min. discharges were changed to average annual flows at Winnibigoshish and Leech (Leech's value was lowered).
6. Pine's upper ordinary operating limit was lowered to ease erosion. The lower limit was in turn lowered in order to retain the storage. See **Chapter 3** in the Pine Manual for details.
7. Sometime after the 1936 regulations were issued, in addition to Pine, Ordinary Operating Limits were adopted for all of the reservoirs. These limits represented a narrower "ordinary" or typical range, inside of the official limits, within which the reservoir might be operated in a typical year.
8. This resulted from a request by Congressman Knutson to lower Leech's upper ordinary limit from 3.5 to 3.0 ft. This was agreed upon as long as the lower limit in the 1936 regulations was reduced to 0.0 ft. In turn, a low ordinary operating limit of 0.5 ft. was adopted.
9. See Note No. 8 for Leech. Complaints were received when Pine's level was below 11 feet due to shallow water in the waterways connecting the various lakes in the chain. See **Chapter 3** in the Pine manual for details.
10. The 1956 Headwaters Operation Study for Aitkin flood control (see **Section 1-03**) determined that storage could be utilized in Pokegama and Sandy to elev. 1277.92 ft. and 1221.31 ft. respectively. The 1963 Master Manual permitted Pokegama to fill to 1278.42 ft., however; Pokegama dam must then be wide open until the elevation falls to 1277.92 ft.
11. Pine River Dam was rehabilitated and raised to allow it to safely pass the Inflow Design Flood (70% PMF). The peak pool elevation equals 1235.3 ft. Five feet of freeboard was provided above this level. See the March 1997 Pine Design Memorandum (see **Section 1-03** in the Pine Manual).
12. See Note Nos. 10 and 11 for information regarding Pokegama, Sandy and Pine's upper limits deviating from the regulations from Congress.
13. These are the Public Law 100-676, Section 21, Water Resources Development Act of 1988 (WRDA 1988) Congressional notification levels.
14. Public Law 110-114, Section 3175, Water Resources Development Act of 2007. Adjusting elevations, allowing Secretary to operate, effective date of water control manuals.

Table 10-1
Elevation-Storage Curve/Table and Area Capacity Curve
Big Sandy Lake Dam and Reservoir
Elevation in Feet (1929 NGVD) with Storage Capacity in Acre-Feet

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1213.0	34215	34290	34364	34438	34512	34586	34660	34734	34808	34882
1213.1	34956	35030	35103	35176	35249	35322	35395	35468	35541	35614
1213.2	35687	35760	35835	35910	35985	36060	36135	36210	36285	36360
1213.3	36435	36510	36586	36662	36738	36814	36890	36966	37042	37118
1213.4	37194	37270	37347	37424	37501	37578	37655	37732	37809	37886
1213.5	37963	38040	38118	38196	38274	38352	38430	38508	38586	38664
1213.6	38742	38820	38897	38974	39051	39128	39205	39282	39359	39436
1213.7	39513	39590	39667	39744	39821	39898	39975	40052	40129	40206
1213.8	40283	40360	40440	40520	40600	40680	40760	40840	40920	41000
1213.9	41080	41160	41239	41318	41397	41476	41555	41634	41713	41792
1214.0	41871	41950	42031	42112	42193	42274	42355	42436	42517	42598
1214.1	42679	42760	42840	42920	43000	43080	43160	43240	43320	43400
1214.2	43480	43560	43639	43718	43797	43876	43955	44034	44113	44192
1214.3	44271	44350	44433	44516	44599	44682	44765	44848	44931	45014
1214.4	45097	45180	45264	45348	45432	45516	45600	45684	45768	45852
1214.5	45936	46020	46103	46186	46269	46352	46435	46518	46601	46684
1214.6	46767	46850	46935	47020	47105	47190	47275	47360	47445	47530
1214.7	47615	47700	47781	47862	47943	48024	48105	48186	48267	48348
1214.8	48429	48510	48598	48686	48774	48862	48950	49038	49126	49214
1214.9	49302	49390	49475	49560	49645	49730	49815	49900	49985	50070
1215.0	50155	50240	50325	50410	50495	50580	50665	50750	50835	50920
1215.1	51005	51090	51178	51266	51354	51442	51530	51618	51706	51794
1215.2	51882	51970	52055	52140	52225	52310	52395	52480	52565	52650
1215.3	52735	52820	52909	52998	53087	53176	53265	53354	53443	53532
1215.4	53621	53710	53799	53888	53977	54066	54155	54244	54333	54422
1215.5	54511	54600	54690	54780	54870	54960	55050	55140	55230	55320
1215.6	55410	55500	55589	55678	55767	55856	55945	56034	56123	56212
1215.7	56301	56390	56479	56568	56657	56746	56835	56924	57013	57102
1215.8	57191	57280	57373	57466	57559	57652	57745	57838	57931	58024
1215.9	58117	58210	58302	58394	58486	58578	58670	58762	58854	58946
1216.0	59038	59130	59223	59316	59409	59502	59595	59688	59781	59874
1216.1	59967	60060	60151	60242	60333	60424	60515	60606	60697	60788
1216.2	60879	60970	61063	61156	61249	61342	61435	61528	61621	61714
1216.3	61807	61900	61996	62092	62188	62284	62380	62476	62572	62668
1216.4	62764	62860	62955	63050	63145	63240	63335	63430	63525	63620

Table 10-1
Elevation-Storage Curve/Table and Area Capacity Curve
Big Sandy Lake Dam and Reservoir
Elevation in Feet (1929 NGVD) with Storage Capacity in Acre-Feet

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1216.5	63715	63810	63905	64000	64095	64190	64285	64380	64475	64570
1216.6	64665	64760	64855	64950	65045	65140	65235	65330	65425	65520
1216.7	65615	65710	65805	65900	65995	66090	66185	66280	66375	66470
1216.8	66565	66660	66760	66860	66960	67060	67160	67260	67360	67460
1216.9	67560	67660	67757	67854	67951	68048	68145	68242	68339	68436
1217.0	68533	68630	68729	68828	68927	69026	69125	69224	69323	69422
1217.1	69521	69620	69719	69818	69917	70016	70115	70214	70313	70412
1217.2	70511	70610	70707	70804	70901	70998	71095	71192	71289	71386
1217.3	71483	71580	71681	71782	71883	71984	72085	72186	72287	72388
1217.4	72489	72590	72694	72798	72902	73006	73110	73214	73318	73422
1217.5	73526	73630	73731	73832	73933	74034	74135	74236	74337	74438
1217.6	74539	74640	74741	74842	74943	75044	75145	75246	75347	75448
1217.7	75549	75650	75751	75852	75953	76054	76155	76256	76357	76458
1217.8	76559	76660	76765	76870	76975	77080	77185	77290	77395	77500
1217.9	77605	77710	77815	77920	78025	78130	78235	78340	78445	78550
1218.0	78655	78760	78863	78966	79069	79172	79275	79378	79481	79584
1218.1	79687	79790	79896	80002	80108	80214	80320	80426	80532	80638
1218.2	80744	80850	80955	81060	81165	81270	81375	81480	81585	81690
1218.3	81795	81900	82009	82118	82227	82336	82445	82554	82663	82772
1218.4	82881	82990	83097	83204	83311	83418	83525	83632	83739	83846
1218.5	83953	84060	84169	84278	84387	84496	84605	84714	84823	84932
1218.6	85041	85150	85257	85364	85471	85578	85685	85792	85899	86006
1218.7	86116	86220	86331	86442	86553	86664	86775	86886	86997	87108
1218.8	87219	87330	87441	87552	87663	87774	87885	87996	88107	88218
1218.9	88329	88440	88551	88662	88773	88884	88995	89106	89217	89328
1219.0	89439	89550	89661	89772	89883	89994	90105	90216	90327	90438
1219.1	90549	90660	90773	90886	90999	91112	91225	91338	91451	91564
1219.2	91677	91790	91905	92020	92135	92250	92365	92480	92595	92710
1219.3	92825	92940	93053	93166	93279	93392	93505	93618	93731	93844
1219.4	93957	94070	94187	94304	94421	94538	94655	94772	94889	95006
1219.5	95123	95240	95356	95472	95588	95704	95820	95936	96052	96168
1219.6	96284	96400	96517	96634	96751	96868	96985	97102	97219	97336
1219.7	97453	97570	97687	97804	97921	98038	98155	98272	98389	98506
1219.8	98623	98740	98861	98982	99103	99224	99345	99466	99587	99708
1219.9	99829	99950	100069	100188	100307	100426	100545	100664	100783	100902

Table 10-1
Elevation-Storage Curve/Table and Area Capacity Curve
Big Sandy Lake Dam and Reservoir
Elevation in Feet (1929 NGVD) with Storage Capacity in Acre-Feet

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1220.0	101021	101140	101261	101382	101503	101624	101745	101866	101987	102108
1220.1	102229	102350	102471	102592	102713	102834	102955	103076	103197	103318
1220.2	103439	103560	103683	103806	103929	104052	104175	104298	104421	104544
1220.3	104667	104790	104915	105040	105165	105290	105415	105540	105665	105790
1220.4	105915	106040	106164	106288	106412	106536	106660	106784	106908	107032
1220.5	107156	107280	107405	107530	107655	107780	107905	108030	108155	108280
1220.6	108405	108530	108657	108784	108911	109038	109165	109292	109419	109546
1220.7	109673	109800	109929	110058	110187	110316	110445	110574	110703	110832
1220.8	110961	111090	111219	111348	111477	111606	111735	111864	111993	112122
1220.9	112251	112380	112511	112642	112773	112904	113035	113166	113297	113428
1221.0	113559	113690	113821	113952	114083	114214	114345	114476	114607	114738
1221.1	114869	115000	115133	115266	115399	115532	115665	115798	115931	116064
1221.2	116197	116330	116465	116600	116735	116870	117005	117140	117275	117410
1221.3	117545	117680	117817	117954	118091	118228	118365	118502	118639	118776
1221.4	118913	119050	119187	119324	119461	119598	119735	119872	120009	120146
1221.5	120283	120420	120558	120696	120834	120972	121110	121248	121386	121524
1221.6	121662	121800	121939	122078	122217	122356	122495	122634	122773	122912
1221.7	123051	123190	123333	123476	123619	123762	123905	124048	124191	124334
1221.8	124477	124620	124763	124906	125049	125192	125335	125478	125621	125764
1221.9	125907	126050	126195	126340	126485	126630	126775	126920	127065	127210
1222.0	127355	127500	127646	127792	127938	128084	128230	128376	128522	128668
1222.1	128814	128960	129111	129262	129413	129564	129715	129866	130017	130168
1222.2	130319	130470	130621	130772	130923	131074	131225	131376	131527	131678
1222.3	131829	131980	132135	132290	132445	132600	132758	132910	133065	133220
1222.4	133375	133530	133684	133838	133992	134146	134300	134454	134608	134762
1222.5	134916	135070	135229	135388	135547	135706	135865	136024	136183	136342
1222.6	136501	136660	136819	136978	137137	137296	137455	137614	137773	137932
1222.7	138091	138250	138412	138574	138736	138898	139060	139222	139384	139546
1222.8	139708	139870	140033	140196	140359	140522	140685	140848	141011	141174
1222.9	141337	141500	141667	141834	142001	142168	142335	142502	142669	142836
1223.0	143003	143170	143336	143502	143668	143834	144000	144166	144332	144498
1223.1	144664	144830	145001	145172	145343	145514	145685	145856	146027	146198
1223.2	146369	146540	146710	146880	147050	147220	147390	147560	147730	147900
1223.3	148070	148240	148415	148590	148765	148940	149115	149290	149465	149640
1223.4	149815	149990	150164	150338	150512	150686	150860	151034	151208	151382

Table 10-1
Elevation-Storage Curve/Table and Area Capacity Curve
Big Sandy Lake Dam and Reservoir
Elevation in Feet (1929 NGVD) with Storage Capacity in Acre-Feet

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1223.5	151556	151730	151909	152088	152267	152446	152625	152804	152983	153162
1223.6	153341	153520	153698	153876	154054	154232	154410	154588	154766	154944
1223.7	155122	155300	155483	155666	155849	156032	156215	156398	156581	156764
1223.8	156947	157130	157312	157494	157676	157858	158040	158222	158404	158586
1223.9	158768	158950	159137	159324	159511	159698	159885	160072	160259	160446
1224.0	160633	160820	161006	161192	161378	161564	161750	161936	162122	162308
1224.1	162494	162680	162871	163062	163253	163444	163635	163826	164017	164208
1224.2	164399	164590	164780	164970	165160	165350	165540	165730	165920	166110
1224.3	166300	166490	166685	166880	167075	167270	167465	167660	167855	168050
1224.4	168245	168440	168634	168828	169022	169216	169410	169604	169798	169992
1224.5	170186	170380	170578	170776	170974	171172	171370	171568	171766	171964
1224.6	172162	172360	172559	172758	172957	173156	173355	173554	173753	173952
1224.7	174151	174350	174546	174742	174938	175134	175330	175526	175722	175918
1224.8	176114	176310	176518	176726	176934	177142	177350	177558	177766	177974
1224.9	178182	178390	178597	178804	179011	179218	179425	179632	179839	180046
1225.0	180253	180460	180666	180872	181078	181284	181490	181696	181902	182108
1225.1	182314	182520	182730	182940	183150	183360	183570	183780	183990	184200
1225.2	184410	184620	184830	185040	185250	185460	185670	185880	186090	186300
1225.3	186510	186720	186944	187168	187392	187616	187840	188064	188288	188512
1225.4	188610									

Exhibit A Pertinent Data

A-01 General Information

Location	Big Sandy Lake Dam is on the Sandy River near Libby, Minnesota, 1.2 miles upstream of the confluence with the Mississippi River. The confluence is at river mile 1105.6 above the Ohio River. The dam is 14 miles north of McGregor, Minnesota in Aitkin County. It is at Lat. 46° 47' 20", Long. 93° 19' 10", in Section 25, T50 N, R24 W.
Type of Project	Dam and Reservoir
Project Owner	U.S. Government, Department of the Army
Operating Agency	U.S. Army Corps of Engineers, St. Paul District
Regulating Agency	U.S. Army Corps of Engineers, St. Paul District
Closure Date	The timber structure was complete and operational on October, 1895. This structure was replaced by the concrete structure in 1912. Dam discharge records began on 7 July 1893.
Datum/Conversion	All elevations use the 1929 National Geodetic Vertical Datum (1929 NGVD) unless otherwise stated. To convert to the 1988 North American Vertical Datum NAVD 88, use the following: 1929 NGVD + 0.69 feet = NAVD 88.

A-02 Reservoir Information

Table A-1 Operating Levels for Big Sandy Lake Dam			
Big Sandy Lake	Elevation (ft)	Area (acres)	Cumulative Storage (acre-ft)
Top of Control Structure	1221.31	12,900	118,000
Maximum Operating Limit	1218.31	10,700	82,000
Normal Summer Pool Level	1216.31	9,400	62,000
Minimum Operating Limit	1214.31	8,100	44,000
Sill	1207.31	--	0

Maximum Pool Elevation (Historic)	1224.82 ft on 19 May 1950 (See Section 4-06)
Real Estate Taking Line for Easement	4 ft above an 11.0 ft stage or Elevation 1222.31 ft (Approximate, See Chapter 2)
Reservoir Length at Top of Summer Pool	4.5 miles
Shoreline Length at Top of Summer Pool	56.5 miles

A-03 Hydrology

Drainage Area	421 square miles
One Inch of Rainfall Equals	22,453 acre-ft.
Storm Types	Thunderstorm, Frontal Rain, Snow
Flood Season	15 March – June
Low Flow Season	July – October
Note: All inflows are based on 24-hour averages from reverse routing.	
Minimum Daily Inflow	Flow is very low during dry periods
Minimum Mean Monthly Inflow	Flow is very low during dry periods
Minimum Mean Annual Inflow	76 cfs (1934)
Maximum 24-hr Average Inflow	6,910 cfs (8 May 1950)
Maximum Mean Monthly Inflow	2,870 cfs (May 1950)
Maximum Mean Annual Inflow	549 cfs (1953)
Average Annual Inflow	249 cfs (Period, 1899-1985)
Maximum Flood Volume	254,600 ac-ft (16 April – 8 June 1950) (overflow from Mississippi River included)
Name and Location of Key Streamflow Stations	Mississippi at Aitkin, MN and the Aitkin Diversion Channel
Type of Hydrometeorological Data Recorded at Site	Rainfall, Snowfall, Temperature, Cloud Cover, Wind (See Chapter 5)
Typical Maximum Snowpack	15-31 March
Number of Sediment Ranges	None
Probable Maximum Flood Data: See Section 8-02	

A-04 Embankments and Dikes

Embankment

Type	Earthfill with timber diaphragm
Slope Protection	Riprap and Grass; Bituminous Top (roadway)
Length	1,586 ft. (total left and right)
Height	20.5 ft.
Top Width	22 ft.
Minimum Top Elevation	1225.1 ft.

Perimeter Dikes (Also see Table 2-2)

Number	4
Purpose	Impoundment
Slope Protection	Riprap and Grass; Bituminous Top
Length	3,700 ft.
Height	Varies; Generally <20 ft.
Type	Compacted Earthfill
Minimum Compacted Earthfill	1225.1 ft.

A-05 Outlet Structure

Type	Gated multi-bay mass concrete sluiceways with concrete apron
Structure Length between Abutments	109 ft.
Number, Size, and Type of Gates	Six 5 ft. wide by 4 ft. high slide gates One 11 ft. wide stoplog bay (log sluice) Three 5 ft. 2 in. wide stoplog bays (in old lock chamber) Two 5 ft. 3.25 in. wide stoplog bays (in old lock chamber)
Entrance Invert Elevation	1207.31 ft. (slide gates and log sluice) 1216.81 ft. (stoplog bays in old lock chamber)
Energy Dissipater	Stilling Basin

A-06 Spillway

No Service or Emergency Spillways	Gated concrete sluiceway outlet facility only
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A-07 Spillway Apron

Type	Concrete on Timber Piles
Length	41.0 ft.
Width	109.0 ft.
Floor Elevation	1207.31 ft.

Table A-2
Mississippi River Headwaters Dams Summary of Control Structure Features

	Lake Winnibigoshish	Leech Lake	Lake Pokegama	Sandy Lake	Pine Lake	Gull Lake
Slide Gates						
Number of Gates	5	5	6	6	13	5
Gate Sill Elevation, ft.	1285.22	1288.49	1265.92	1207.31	1216.65	1188.75
Gate Width, ft.	3.5	4.0	8.0	5.0	6.0	5.0
Gate Height, ft.	5.0	4.0	12.5	4.0	17.0	4.0
Gate "C" Coefficient ⁴	0.63	0.74	0.64	0.78	0.73	0.49
Log Sluice Bays¹						
Number of Bays	1	1	1	1	None	1
Log Bay Sill Elev., ft.	1290.04	1287.74	1264.42	1207.31	-----	1188.75
Log Bay Width, ft.	12	12	12	11	-----	11
Log Bay "C" Coef. ⁴	3.33	3.33	3.33	2.85	-----	3.33
Stop Log Bays						
Number of Bays	15 ²	20	7	5 ³	None	None
Sill Elevation, ft.	5 @ 1290.64 10 @ 1285.22	1287.74	1264.42	All at 1216.81	-----	-----
Bay Width, ft.	5 @ 3.8 10 @ 4.25	6.0	8.0	2 @ 5' 3.25" 3 @ 5' 2"	-----	-----
Bay "C" Coef. ⁴	5 @ 3.17 10 @ 3.53	3.61	3.04	3.19 (all)	-----	-----
Fish Sluiceway	Sealed	None	None	None	None	Sealed

1. The log sluice bays are large stop log bays that were formerly used to pass logs downstream.
2. The dam has 5, 14-foot wide bays and one 12-foot wide log sluice bay. Each of the 5 bays has a 3.5 ft. wide by 5.0 ft. tall slide gate in the bottom center which is anchored in place by two vertical H-beams. The H-beams hold stop logs both above the gates and on either side.
3. There are 5 stop log bays on top of the old lock chamber. The two outer bays are wider than the 3 inner bays.
4. See Chapter 7 plates.

A-08 Control Points and River Reaches

Aitkin Diversion Channel

Location	Inlet at river mile 1064.0 above the Ohio River, 42.8 river miles downstream of Big Sandy Lake Dam near Aitkin, MN
Purpose	Flood control for the Aitkin area
Channel Description	Diversion Channel (6 miles long, 90 ft. bottom width, 1 on 3 side slopes)
Uncontrolled Drainage Area	2,454 sq. mi.
Treatment of Uncontrolled Runoff	Contributes to Flood Control
Target Flow Rate	See Guide Curves
Time of Water Travel	Approx. 1 day from Sand Lake Dam

Related Control Structures	Location
Weirs:	
Aitkin Diversion Inlet	River mile 1064.0
Aitkin Diversion Outlet	River mile 1040.4
Drop Structures:	
Little Willow River	Sta. 250+00 of Aitkin Diversion
Wakefield Creek	Sta. 160+80 of Aitkin Diversion
County Ditch #11	Sta. 21+56 of Aitkin Diversion
Channel Cutoffs:	
Pine Knoll	River mile 1040.9 – 1040.1
Tow Head Rapids	River mile 1031.4 – 1030.5

A-09 Control Structures Downstream

Purpose	Inlet and outlet weirs of the Aitkin Diversion Channel	
Type	Ungated overflow weirs	
Flow Passage Invert Elev.	Channel Bed	Crest
	Inlet: 1186.0 ft.	1190.0 ft.
	Outlet: 1181.3 ft.	1181.3 ft.
Pertinent Discharge Capacity:	6000 cfs	
Agency Responsible for Maintenance and Inspection	Aitkin County and the City of Aitkin	

Exhibit B Standing Instructions to the Project Manager for Water Control

Location: Sandy Lake Dam is on the Sandy River near Libby, Minnesota, 1.2 miles upstream of the confluence with the Mississippi River. The confluence is at river mile 1105.6 above the Ohio River. The dam is 14 miles north of McGregor, Minnesota in Aitkin County. It is at Lat. 46° 47' 20", Long. 93° 19' 10", in Section 25, T50 N, R24 W.

Drainage area above Big Sandy Dam is 421 square miles.

Data is in datum NGVD 1929. To convert to NAV 1988, NGVD 1929 + 0.69 ft = NAV 1988.

Big Sandy Dam

Dam Type:	Compacted Earth Filled
Dam Length:	1,586 feet
Dam Height:	20.5 feet
Dam Top Width:	22 feet
Control Structure Type:	Gated Multi-Bay Mass Concrete with Concrete Apron
Control Structure Length:	109 feet

Big Sandy Lake Reservoir	Elevation (ft)	Capacity (ac-ft)	Area (acres)
Gate Sills	1207.31		
Summer Conservation Pool (~15-May to 1-October)	1216.31	62,000	9,400
Winter Drawdown Pool (1-October to late February)	1214.31	44,000	8,100
Maximum Operating Limit	1218.31	82,000	10,700
Top of Control Structure	1221.31	118,000	12,900
Flowage Easement Level	1222.31		

B-1 Background and Responsibilities

1. General Information:

- a. **Authorization for Preparation of this Manual:** These “Standing Instructions to the Project Manager for Water Control” for the Big Sandy Dam and Reservoir were prepared in compliance with instructions contained within DIVR 1110-2-240, specifically paragraph 5 and page A-9-12. A copy of the Big Sandy Dam and Reservoir Water Control Manual, (of which these instructions are an exhibit), must be kept at the Big Sandy Corps office. Any deviation from the instructions will require the advance approval of the US Army Corps of Engineers (USACE or Corps) St. Paul District Commander. This manual was prepared in compliance with the guidelines presented in:
 - (1) Division Regulation, DIVR 1110-2-204, Water Control Management, Reporting Current Conditions, 5 August 1992.
 - (2) Engineering Regulation ER 1110-2-240, Water Control Management, 30 May 2016, amended 8 October 1982, 30 April 1987 and 1 March 1994.
 - (3) Engineering Manual EM 1110-2-3600, Management of Water Control System, 10 October 2017.

- b. **Project Location and Description:** Sandy Lake Dam and Reservoir are part of the Mississippi River Headwaters Basin. The dam is located in Aitkin County, Minnesota, on the Sandy River, 1.25 miles upstream of the junction of the Sandy and Mississippi Rivers, at Mississippi River mile 1106.85 above the Ohio River. It is 264.2 Mississippi River miles above St. Paul, 50.2 Mississippi River miles above Aitkin, Minnesota, and 77.7 Mississippi River miles below Pokegama Dam. Libby, Minnesota, is a nearby community. **See Plate 2-1.**

- c. **Project Owner and Operating Agency:** The U.S. Army Corps of Engineers, St. Paul District is responsible for the regulation of the Big Sandy Project. The United States government is the owner of the project. The U.S. Army Corps of Engineers, St. Paul District, Operations Division is responsible for the operation and maintenance of the Big Sandy Project. Regulation instructions for the project are provided by the Water Management Section, Engineering and Construction Division. The project is attended continuously during normal business hours by the Supervisory Park Manager and his/her staff. The Northern Headwaters Operations Project Manager is in the Pokegama Dam office in Grand Rapids, Minnesota.

- d. **Project Purposes:** The original authorized purpose of the Big Sandy Project, as authorized in the Rivers and Harbors Act of 1881, 21 Stat. 468, was to increase Mississippi River discharges during low-flow periods to aid navigation between St. Paul, Minnesota, and Lake Pepin, near Lake City, Minnesota. Other authorized purposes include flood risk management, recreation, hydropower, water supply, and enhanced fish and wildlife production.

- e. **Project Constraints:** Principal regulation problems include bank erosion and overtopping during extreme high water. Bank erosion due to higher than normal pool levels and wave action causes destruction to shoreline archaeological and cultural sites, damages recreation and commercial interests, and contributes to degraded water quality. Sandy Lake experiences considerable shoreline erosion due to its circular shoreline configuration and large range of lake level fluctuations. During the 1950 flood, Sandy Lake Dam was overtopped by 3.5 feet. Temporary dikes were constructed on the embankment to prevent erosion and loss of the structure. During the 2012 flood, a temporary dike was constructed on the left side of the structure.

2. Role of Project Manager:

- a. **Normal Hydrometeorological Conditions (including Floods and Droughts):** The Project Manager will be instructed by Water Management in the St. Paul District office on a day-to-day basis for water control actions under normal hydrometeorological conditions.
- b. **Emergency Conditions:** Conditions become emergency if needed to protect the safety of the structure, to avoid health hazards, or to avoid any other critical situation that may arise. The Project Manager will issue adequate warning or otherwise alert all affected interests to possible hazards caused by project regulation.

B-2 Hydrometeorological Data Collection and Reporting

- 1. **Normal Hydrometeorological Conditions (including Floods and Droughts):** The information needed to operate the dam and regulate the reservoir is provided to Water Management by the Project Resource Manager. Daily (8:00 a.m.) readings for the pool elevation, tailwater elevation, and outflow are given, as well as precipitation and wind readings. Once Corps Water Management System (CWMS) is fully implemented (expected in FY20) staff at the Big Sandy Project Office will continue to enter precipitation but instead of entering the 0800-hour pool, tailwater and outflow readings the staff will record gate changes as they occur to the nearest 15 minutes. The pool and tailwater elevations are also recorded by Data Collection Platforms (DCPs) and transmitted via satellite directly to Water Management's Local Readout Ground Station (LRGS). At each DCP gage, the correspondence between the gage and DCP readings is checked visually by project personnel at regular intervals. Daily inflow to the reservoir is calculated by Water Management from the change in reservoir elevation and the outflow. Copies of the official site log sheets are copied to Water Management's folder on the district server. In the winter, snow depth, water content, frost depth, and lake ice thickness are reported weekly to Water Management. The snow survey is used to estimate the amount of water available for spring runoff. Frost depth readings provide information on the amount of infiltration expected. The snow and frost information are also provided to the National Weather Service and the State of Minnesota Climatology Office.

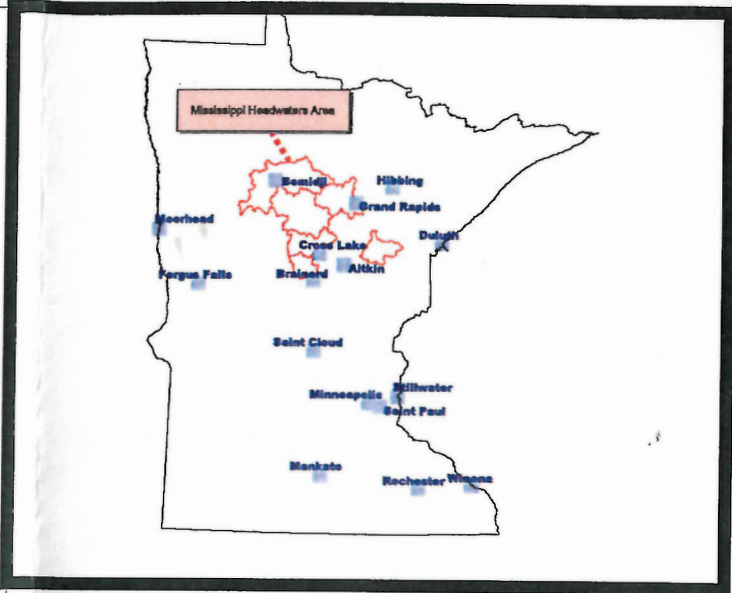
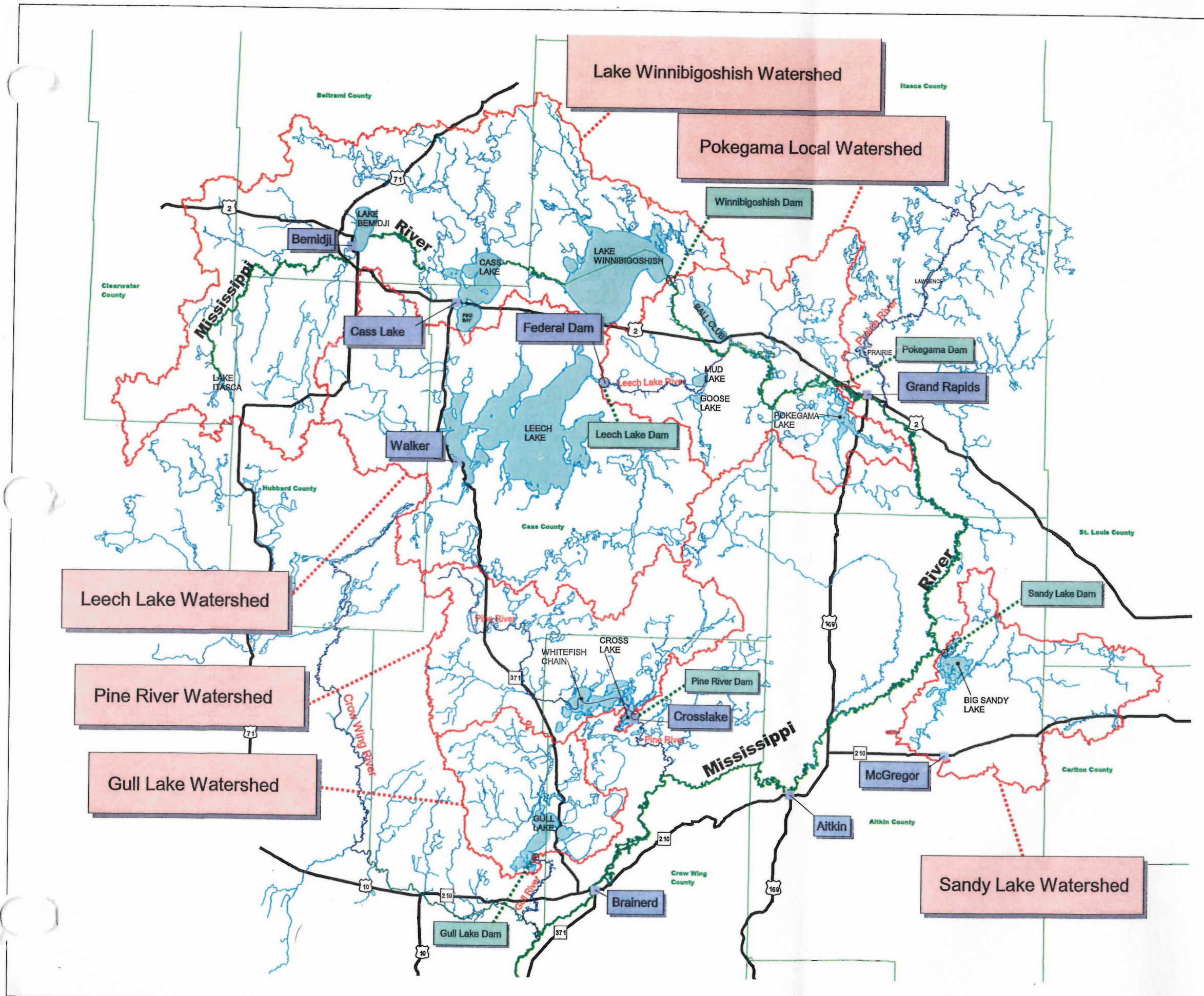
2. **Emergency Conditions:** The Project Manager will be informed by the District Office of regional hydrometeorological conditions that may impact the structure.

B-3 Water Management Action and Reporting

1. **Low Hydrometeorological Conditions (Droughts):** When the pool is above elevation 1214.31 ft, the minimum flow is 20 cfs. When the pool is below elevation 1214.31 ft, the minimum flow is 10 cfs.
2. **Normal Hydrometeorological Conditions:** Following the spring runoff event, the Big Sandy pool level is held at elevation 1216.31 +/- 0.25 feet. Big Sandy is regulated to maintain its spring/summer conservation elevation. A minimum flow of 20 cfs is maintained. On or around 1 October, the pool is gradually lowered for winter drawdown. The full winter drawdown is 2.0 feet. See **Plate 7-1** for a graphical depiction of drawdown elevations. Additional information is available in **Chapter 7**.
3. **High Hydrometeorological Conditions (Floods):**
 - a. **Spring Floods:** As the spring runoff progresses, which typically begins in March or April and concludes by late-May, the dam's gates will be opened to maintain the full drawdown and maintain as much flood control storage as possible. As the run-off starts, open gates so that outflow matches inflow in an attempt to hold the current pool elevation (drawdown of conservation) as long as possible. Once the Mississippi River rises and affects tailwater elevation at the dam, the gate openings typically go to full open. With the slide gates full open and inflow exceeding the outflow capacity of the gates, the gate in the log sluice bay may be opened. If further outflow is needed, the stop logs in the bays of the old lock chamber can be removed. As flows recede, the gates and stop logs are adjusted as necessary to hold the pool in the normal summer range.
 - b. **Summer/Fall Floods:** Generally during the period from mid-May until 1 October, the dam's gates will be opened to maintain the normal summer range. If the precipitation event is excessive and wide spread, the inflows will exceed outflow capacity and the pool will rise, especially if the Mississippi River rises. The log sluice gate and bays of the old lock chamber can be used to increase outflow.
4. **Emergency Conditions:** The Project Manager may temporarily deviate from these Standing Instructions in the event it is necessary for emergency reasons to protect the safety of the structure, to avoid health hazards, or to avoid any other critical situation that may arise. Such action will be reported immediately to Water Management personnel.
5. **Inquiries:** All significant inquiries received by the Project Manager from citizens, constituents or interest groups regarding water control procedures or actions must be referred to Water Management personnel.

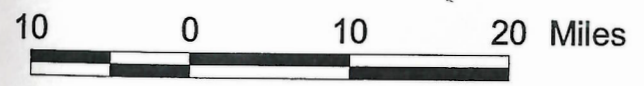
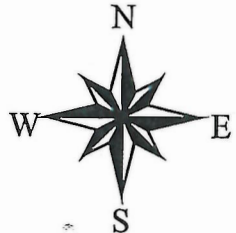
- 6. Water Management Problems:** Water Management must be contacted immediately by the most rapid means available in the event an operational malfunction, erosion, or other incident occurs that could impact project integrity, in general, or water control capability, in particular.

- 7. Communication Outage:** In the event of failure of the computer system, field staff will maintain contact with Water Management by telephone and will continue to follow the water control actions within the Standing Instructions along with **Chapter 7** of the Water Control Manual.



Key to Symbols

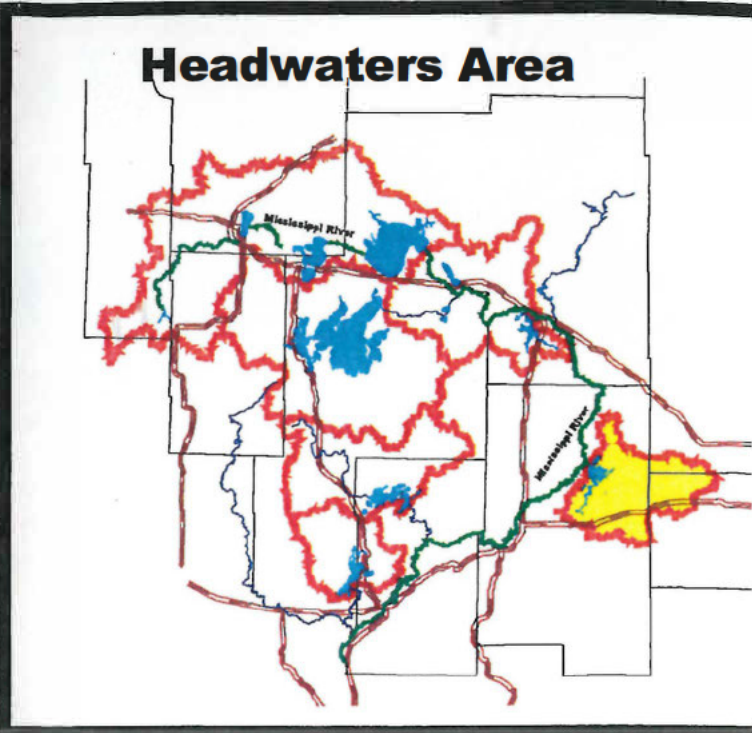
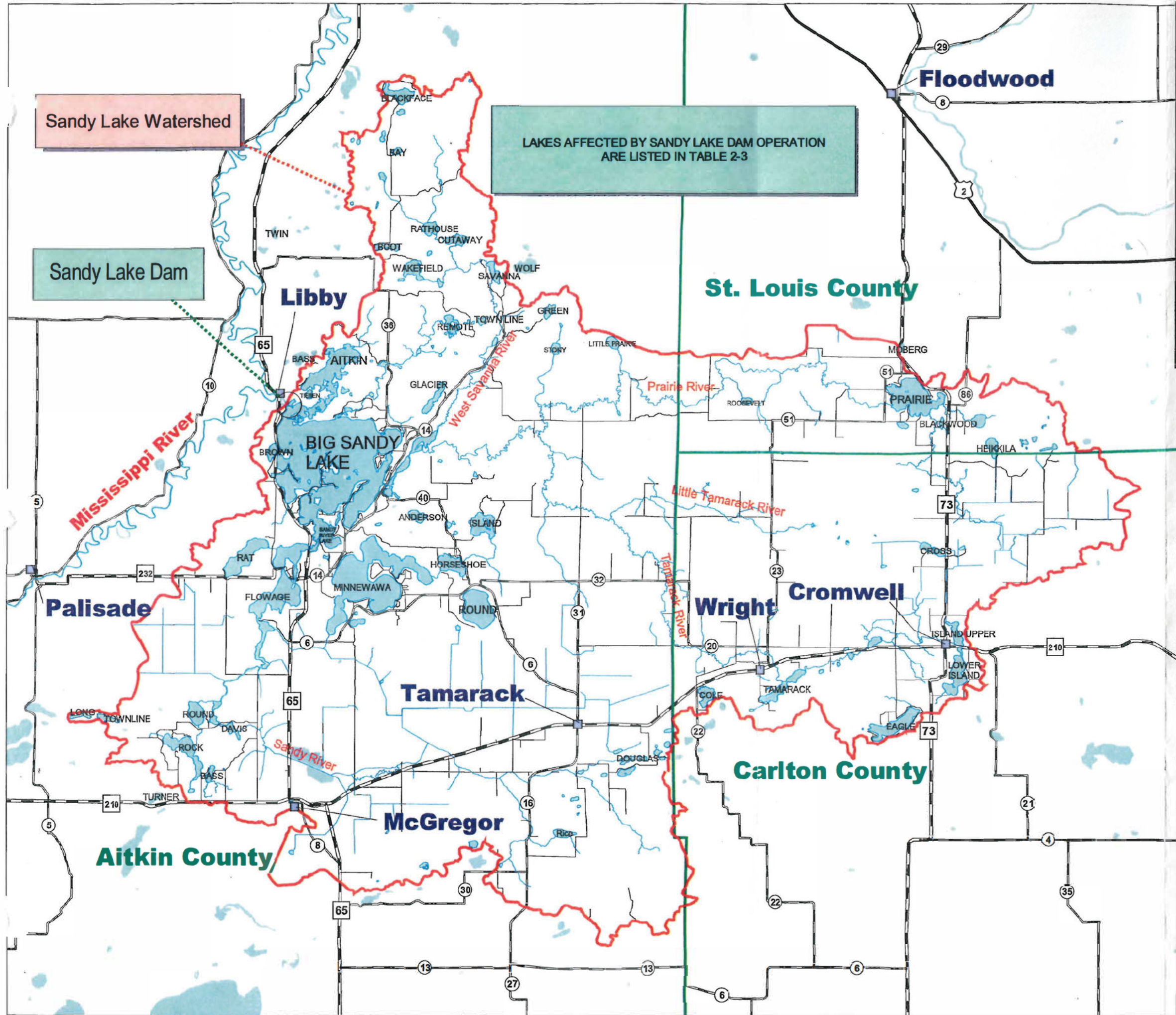
- City
- Watershed
- County
- Tributaries
- Mississippi
- Stream/Drainage
- lake
- U.S. Highway
- MN Highway



MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 WATER CONTROL MANUAL

MISSISSIPPI RIVER HEADWATERS WATERSHED

U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



Key to Symbols

- City
- ▭ Watershed
- Stream/Drainage
- ▭ County
- Lake
- US Highway
- MN Highway
- County Highway
- Secondary Road

3 0 3 6 Miles

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 WATER CONTROL MANUAL
 SANDY LAKE

BIG SANDY LAKE WATERSHED

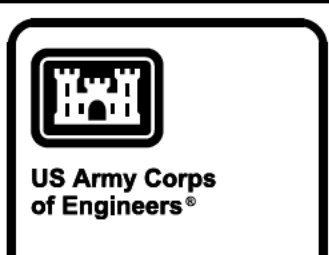
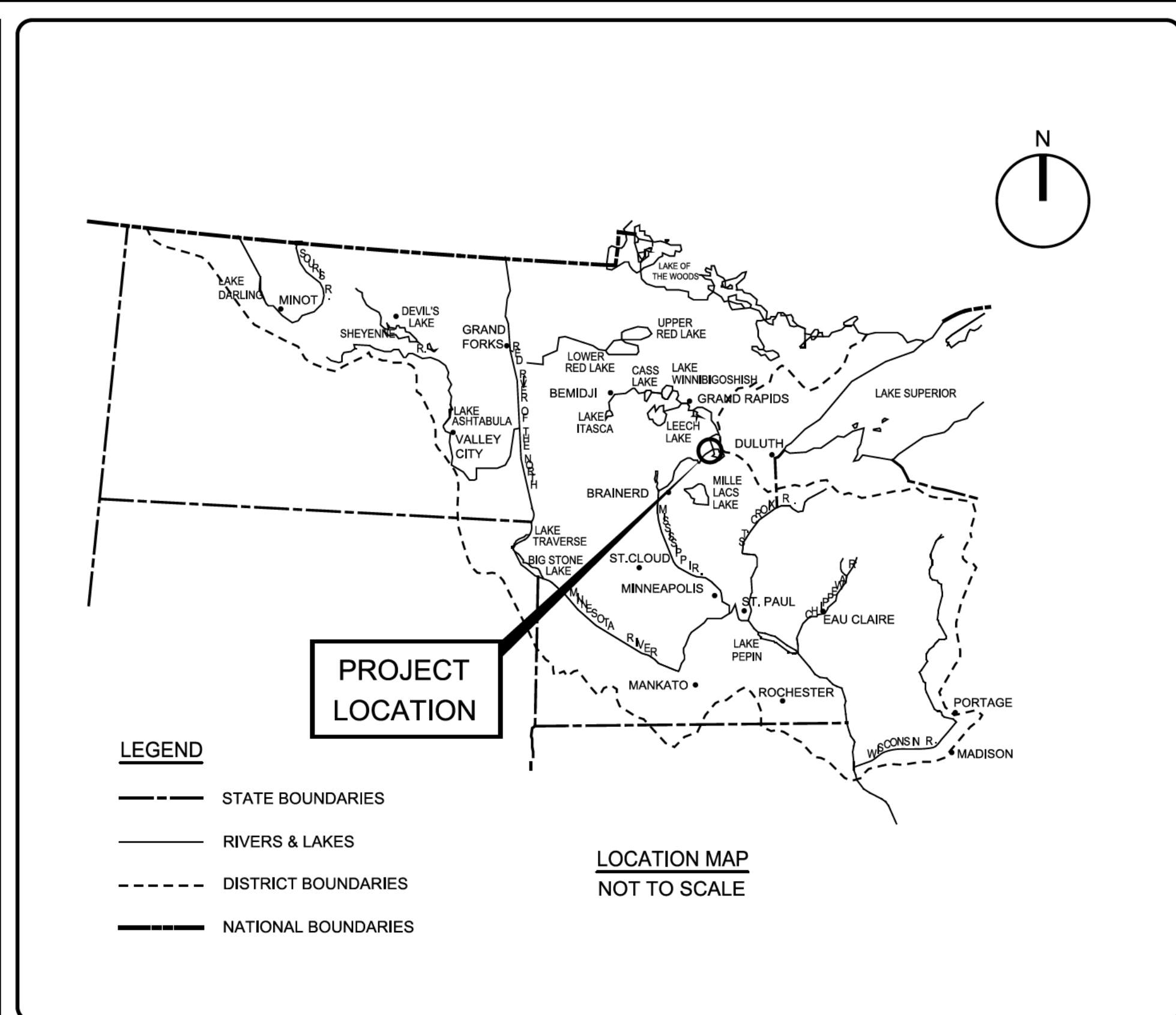
U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

Plate 2-1a



A2 VICINITY MAP
 SANDY LAKE DAM
 SCALE: 1" = 300'

0 300' 600'



MARK	DESCRIPTION	DATE	APPR. MARK	DATE	APPR.
	PRELIMINARY DRAWING				

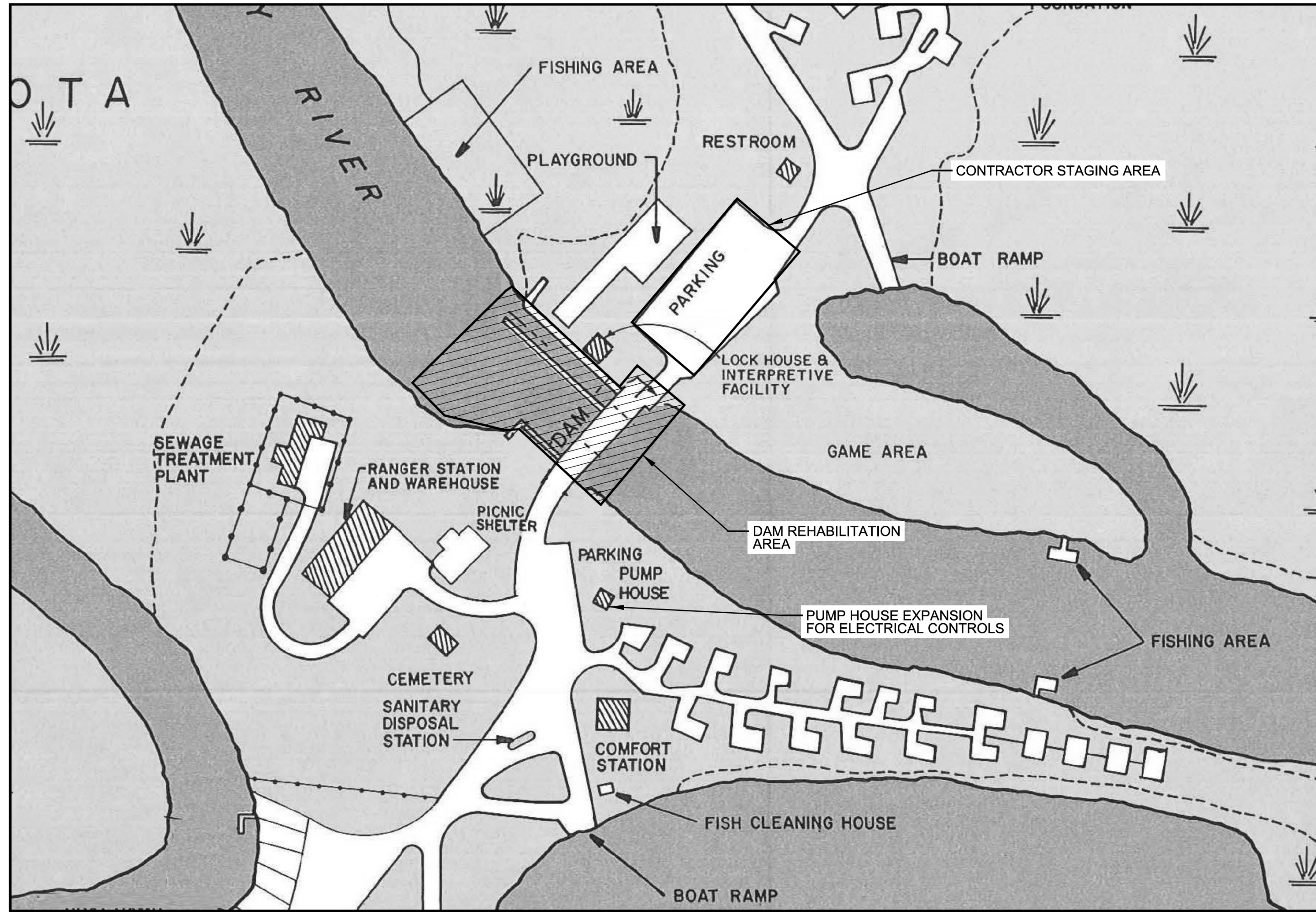
DESIGNED BY:	DATE:	SOLICITATION NO.:
DRAWN BY:	REV. BY:	CONTRACT NO.:
REVISIONS:	EDD	
U.S. ARMY CORPS OF ENGINEERS	ST. PAUL, MINNESOTA	
ST. PAUL DISTRICT		
ST. PAUL, MINNESOTA		
STANLEY CONSULTANTS, INC.		
5775 WANTZATA BLVD #500		
MINNEAPOLIS, MN		

SANDY LAKE DAM REHABILITATION
 SANDY RIVER
 SANDY LAKE DAM
 LIBBY, MN

LOCATION AND VICINITY MAPS

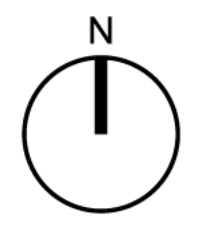
Sheet ID
G-002

ELEVATION DATUM (VERTICAL CONTROL): COORDINATE SYSTEM (HORIZONTAL CONTROL):
 NAVD 88 NAD 83 (2011)
 GEOD12B MN SPCS, CENTRAL ZONE-U.S. SURVEY FT.
 COMBINED FACTOR (CF):



USACE DRAWING - SEPTEMBER 1994

A2 **SITE MAP**
SANDY LAKE DAM
SCALE: NTS



ELEVATION DATUM (VERTICAL CONTROL): NAD 83 (2011)
NAVD 88
GEOID12B
COORDINATE SYSTEM (HORIZONTAL CONTROL): MN SPCS, CENTRAL ZONE-U.S. SURVEY FT.
COMBINED FACTOR (CF):

SANDY LAKE DAM REHABILITATION
SANDY RIVER DAM
SANDY LAKE DAM
LIBBY, MN
SITE MAP

Sheet ID
G-003

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA
DESIGNED BY: [REDACTED]
DRAWN BY: [REDACTED]
CHECKED BY: [REDACTED]
SUBMITTED BY: BIL HOLMAN
PLOT SCALE: AS NOTED
PLOT DATE: [REDACTED]
DATE: [REDACTED]
SOLICITATION NO.: [REDACTED]
CONTRACT NO.: [REDACTED]
FILE NUMBER: [REDACTED]
FILE NAME: SANDYLAKE_S003.dgn
ANSI D:

MARK	DESCRIPTION	DATE	APPR. MARK	DATE	APPR.
	PRELIMINARY DRAWING				

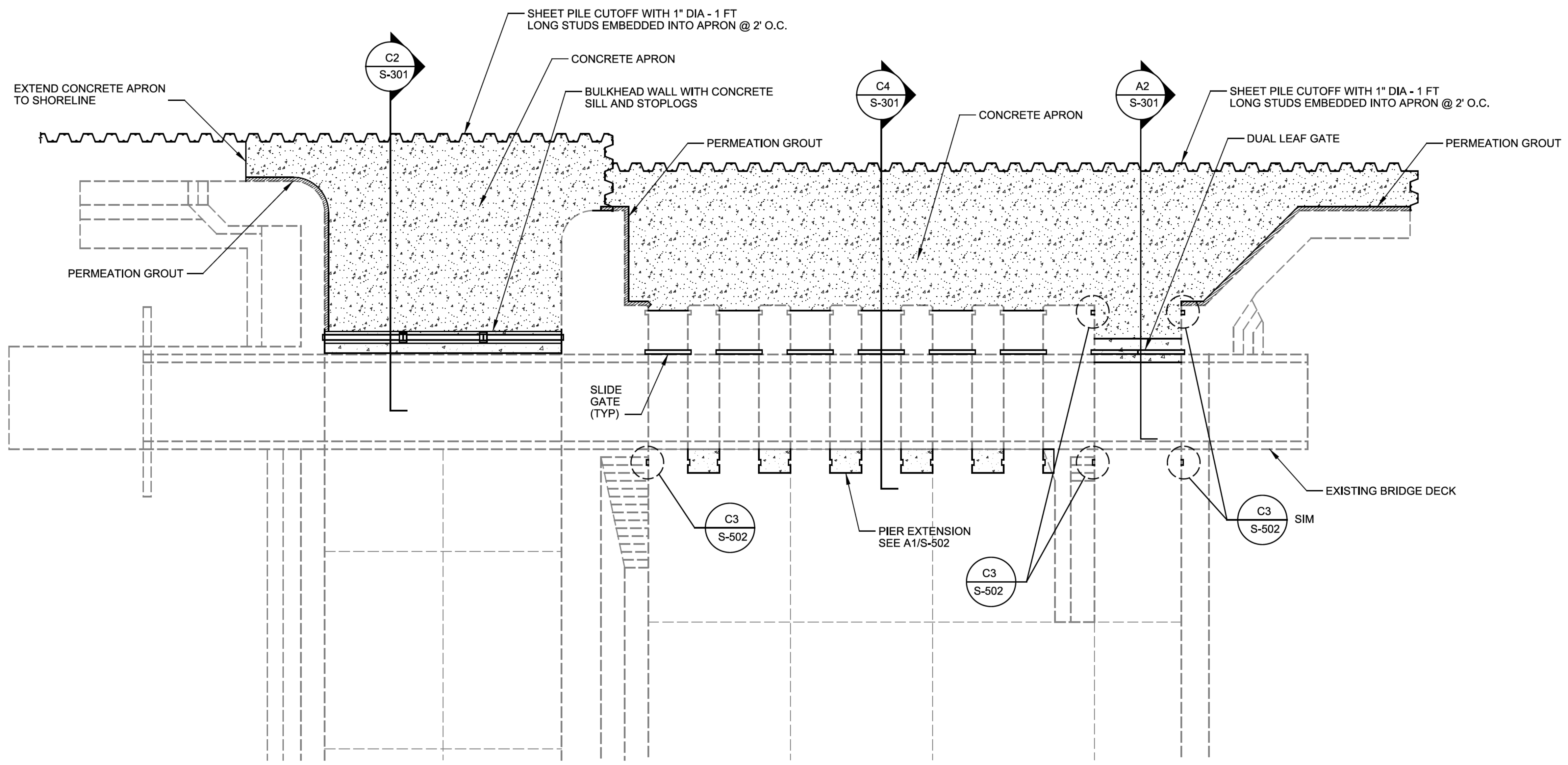


SHEET NOTES:

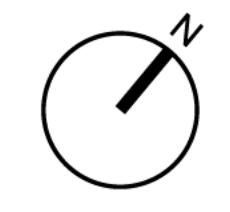
1. SEE SHEET S-501 FOR CONCRETE REPAIR PLAN.



US Army Corps of Engineers®



A3 PLAN
 PROPOSED
 SCALE: 1/8" = 1'-0"
 0 4' 8' 16'



MARK	DESCRIPTION	DATE	APPR. MARK
	PRELIMINARY DRAWING		

DESIGNED BY:	DATE:	SOLICITATION NO.:
DRAWN BY:	CHK BY:	CONTRACT NO.:
REV BY:	SUBMITTED BY:	FILE NUMBER:
PLOT SCALE:	PLOT DATE:	AS NOTED
SDATES	FILE NAME:	ANSI D
SIZE:	SANDYLAKE_S-101.dgn	

SANDY LAKE DAM REHABILITATION
 SANDY RIVER
 SANDY LAKE DAM
 LIBBY, MN
 PROPOSED PLAN

Sheet ID
S-101

SHEET NOTES:

1. COFFERDAM ELEVATIONS SHOWN FOR 5-YEAR EVENT PROTECTION.



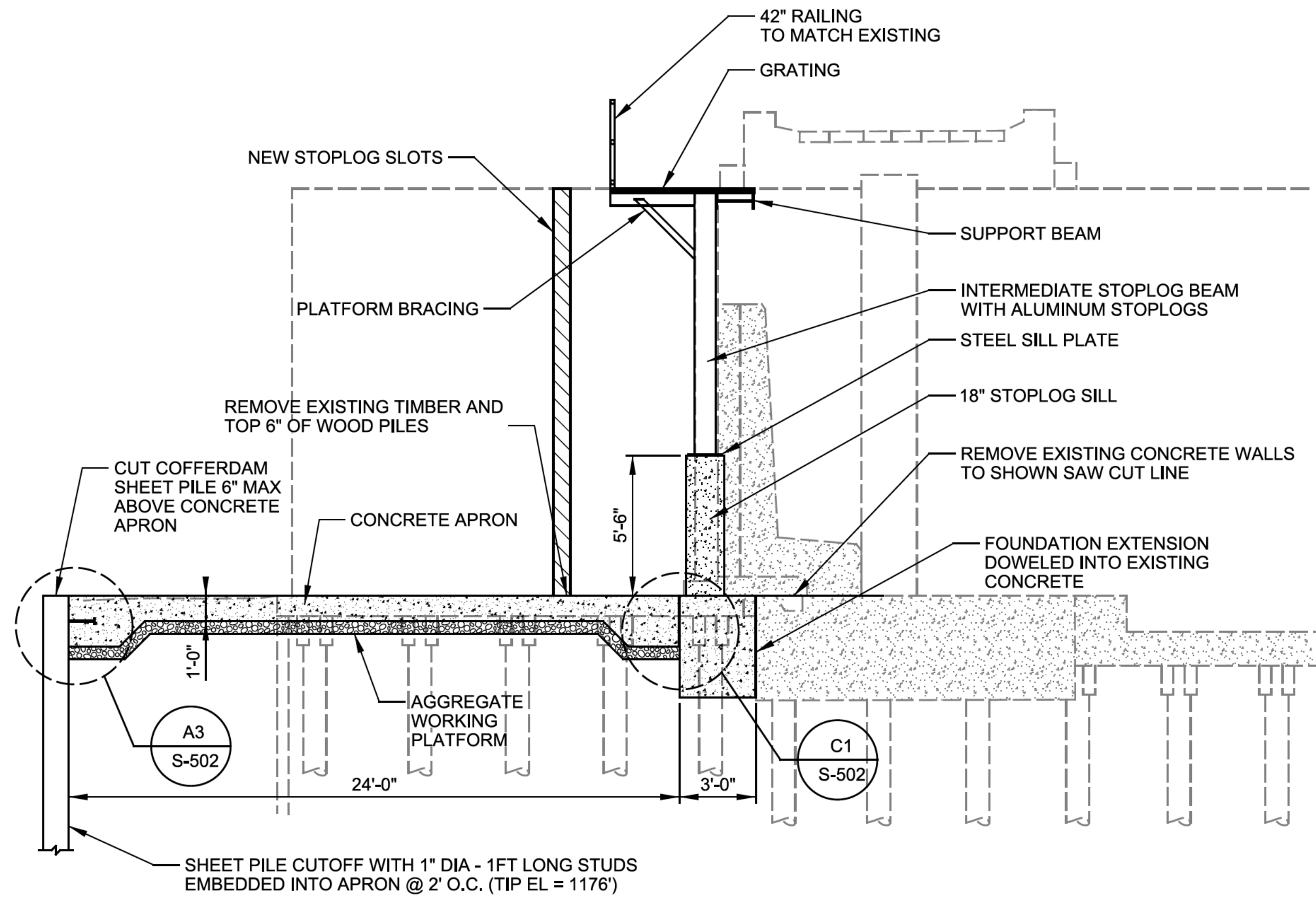
US Army Corps of Engineers

D

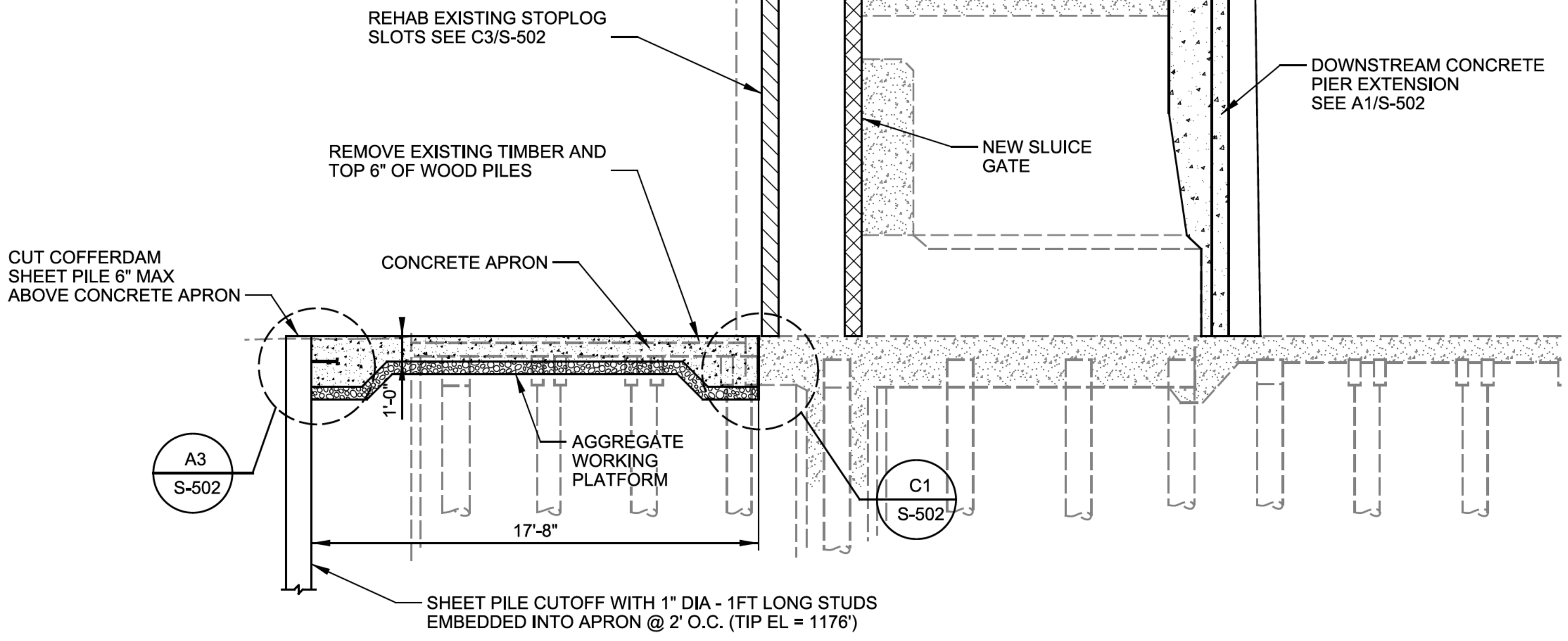
C

B

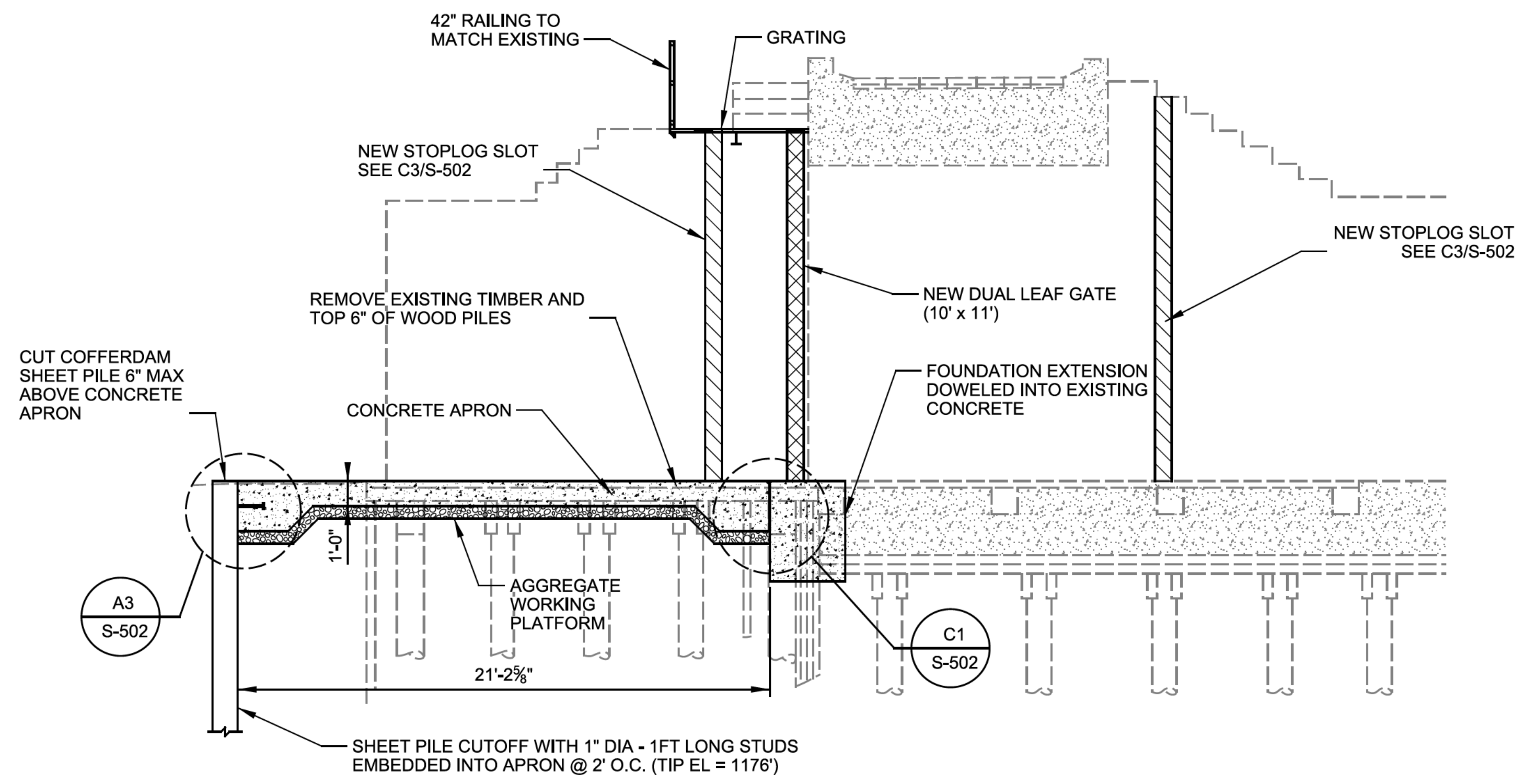
A



SECTION C2
LOCK BAY
SCALE: 1/4" = 1'-0"
0 2' 4' 8'



SECTION C4
SLUICE GATE
SCALE: 1/4" = 1'-0"
0 2' 4' 8'



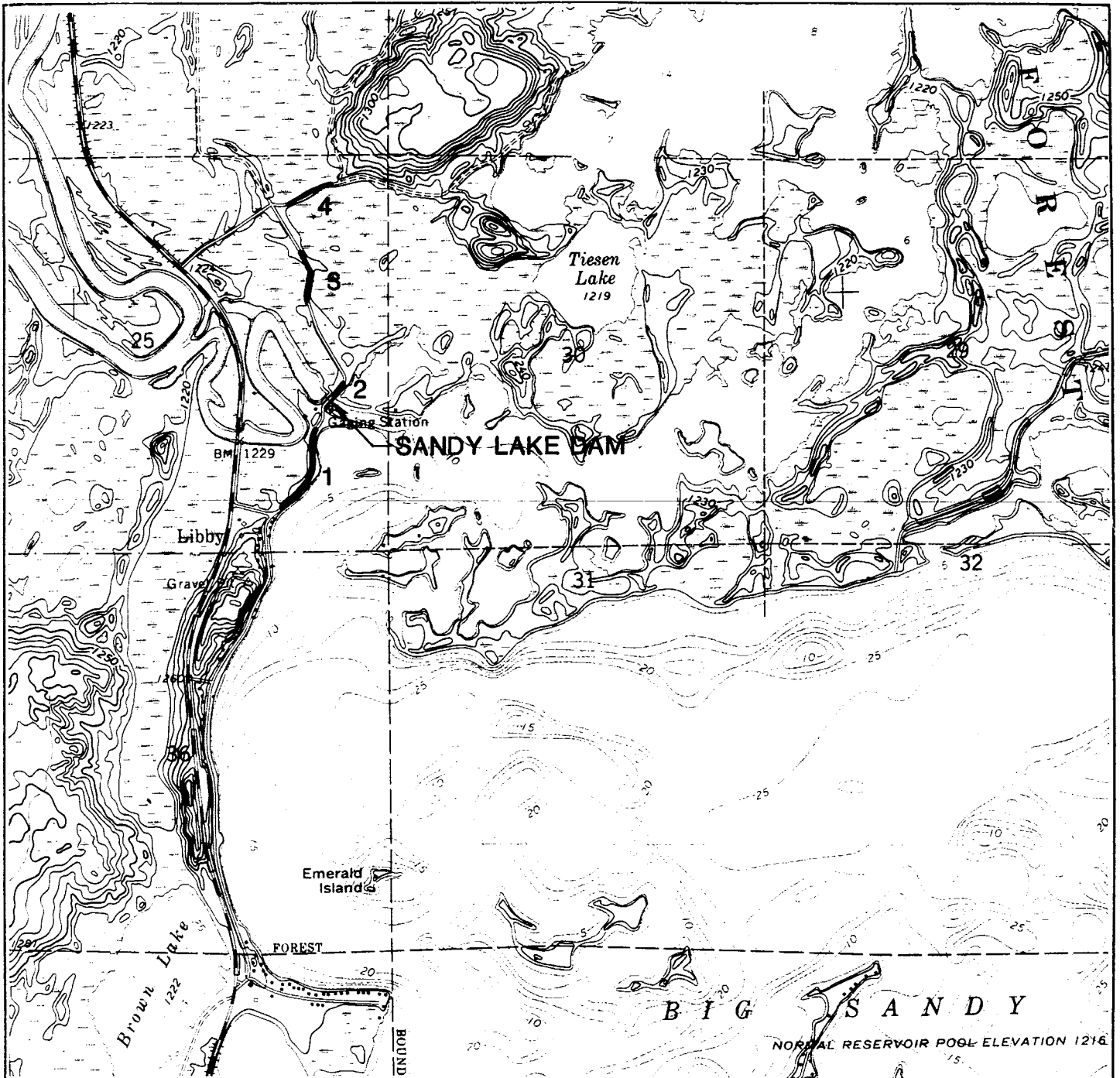
SECTION A2
LOG SLUICE
SCALE: 1/4" = 1'-0"
0 2' 4' 8'

MARK	DESCRIPTION	DATE	APPR. MARK
	PRELIMINARY DRAWING		

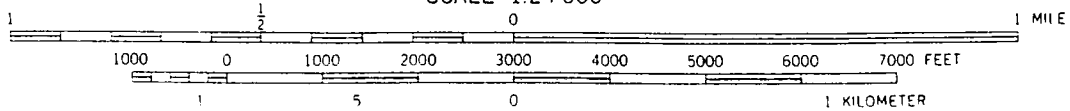
DESIGNED BY:	CHK BY:	SOLICITATION NO.:
DRAWN BY:	REV BY:	CONTRACT NO.:
U.S. ARMY CORPS OF ENGINEERS	ST. PAUL DISTRICT	ST. PAUL, MINNESOTA
STANLEY CONSULTANTS, INC.	5775 WAZATA BOULEVARD	SUITE 300
MINNEAPOLIS, MN 55416		

SANDY LAKE DAM REHABILITATION	SECTIONS
SANDY RIVER	
SANDY LAKE DAM	
LIBBY, MN	

Sheet ID
S-301



SCALE 1:24 000



3 PERIMETER DIKE NUMBER AND LOCATION

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 4, SANDY LAKE

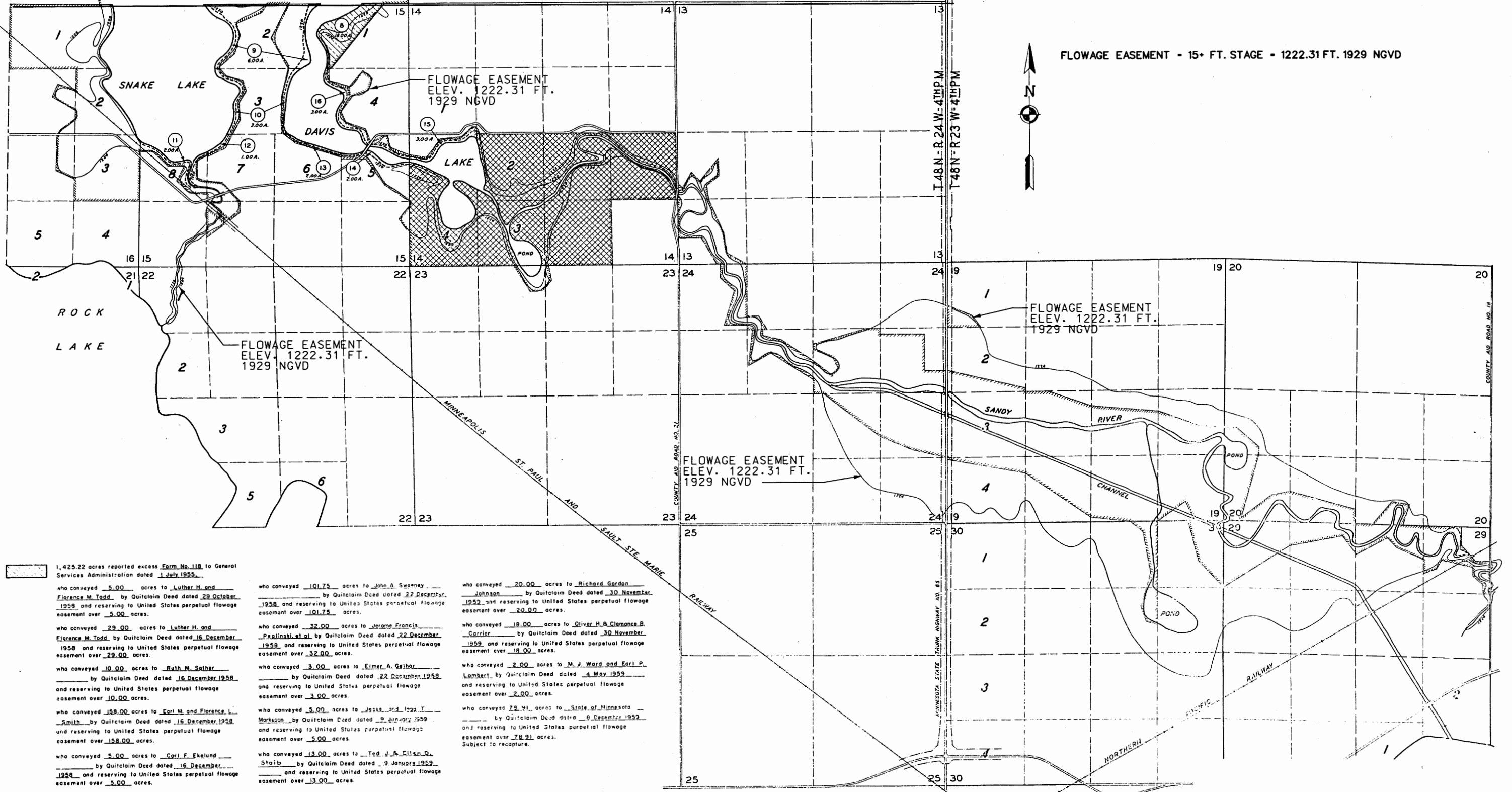
PERIMETER DIKE LOCATIONS

CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

MATCH LINE WITH PLATE 2-8

②

FLOWAGE EASEMENT - 15+ FT. STAGE - 1222.31 FT. 1929 NGVD



1,425.22 acres reported excess Form No. 118 to General Services Administration dated 1 July 1955.

who conveyed 5.00 acres to Luther H. and Florence M. Todd by Quitclaim Deed dated 29 October 1958 and reserving to United States perpetual flowage easement over 5.00 acres.

who conveyed 29.00 acres to Luther H. and Florence M. Todd by Quitclaim Deed dated 16 December 1958 and reserving to United States perpetual flowage easement over 29.00 acres.

who conveyed 10.00 acres to Ruth M. Sather by Quitclaim Deed dated 16 December 1958 and reserving to United States perpetual flowage easement over 10.00 acres.

who conveyed 158.00 acres to Earl M. and Florence L. Smith by Quitclaim Deed dated 16 December 1958 and reserving to United States perpetual flowage easement over 158.00 acres.

who conveyed 5.00 acres to Carl F. Ekelund by Quitclaim Deed dated 16 December 1958 and reserving to United States perpetual flowage easement over 5.00 acres.

who conveyed 358.55 acres to Janatius J. and Mattie Suchofsky by Quitclaim Deed dated 16 December 1958 and reserving to United States perpetual flowage easement over 358.55 acres.

who conveyed 28.00 acres to Paul R. and Margaret Knutson by Quitclaim Deed dated 16 December 1958 and reserving to United States perpetual flowage easement over 28.00 acres.

who conveyed 66.00 acres to John Peter and George Peter Boosalis by Quitclaim Deed dated 16 December 1958 and reserving to United States perpetual flowage easement over 66.00 acres.

who conveyed 9.00 acres to Clark O. and Matel M. Watring by Quitclaim Deed dated 22 December 1958 and reserving to United States perpetual flowage easement over 9.00 acres.

who conveyed 101.75 acres to John A. Sweeney by Quitclaim Deed dated 22 December 1958 and reserving to United States perpetual flowage easement over 101.75 acres.

who conveyed 32.00 acres to Jerome Francis Paplinski et al by Quitclaim Deed dated 22 December 1958 and reserving to United States perpetual flowage easement over 32.00 acres.

who conveyed 3.00 acres to Elmer A. Gelbar by Quitclaim Deed dated 22 December 1958 and reserving to United States perpetual flowage easement over 3.00 acres.

who conveyed 5.00 acres to Jessie and Inga T. Markson by Quitclaim Deed dated 9 January 1959 and reserving to United States perpetual flowage easement over 5.00 acres.

who conveyed 13.00 acres to Ted J. and Ellen D. Stalb by Quitclaim Deed dated 9 January 1959 and reserving to United States perpetual flowage easement over 13.00 acres.

who conveyed 55.00 acres to Chrissa H. Whitney by Quitclaim Deed dated 28 January 1959 and reserving to United States perpetual flowage easement over 55.00 acres.

who conveyed 399.76 acres to John P. Boosalis, et al. by Quitclaim Deed dated 12 February 1959 and reserving to United States perpetual flowage easement over 399.76 acres.

who conveyed 7.00 acres to Ted J. and Ellen D. Stalb by Quitclaim Deed dated 23 April 1959 and reserving to United States perpetual flowage easement over 7.00 acres.

who conveyed 21.25 acres to Ruth M. Sather by Quitclaim Deed dated 17 November 1958 and reserving to United States perpetual flowage easement over 21.25 acres.

who conveyed 20.00 acres to Richard Gordon Johnson by Quitclaim Deed dated 30 November 1952 and reserving to United States perpetual flowage easement over 20.00 acres.

who conveyed 18.00 acres to Oliver H. R. Clemence B. Carrier by Quitclaim Deed dated 30 November 1959 and reserving to United States perpetual flowage easement over 18.00 acres.

who conveyed 2.00 acres to M. J. Ward and Earl P. Lambert by Quitclaim Deed dated 4 May 1959 and reserving to United States perpetual flowage easement over 2.00 acres.

who conveyed 78.91 acres to State of Minnesota by Quitclaim Deed dated 8 December 1952 and reserving to United States perpetual flowage easement over 78.91 acres. Subject to recapture.

Indicates Public Domain lands over which flowage rights have been granted by executive orders dated 3 April, 1891, 1 April 1899, 19 December 1901, 22 March 1905, and Public Land Order No 1592, for 0.40 acre, dated 28 February 1958

Acreeage: Aitkin County, Minn. 3,043.73

NOTE: AREAS OF INDIVIDUAL TRACTS AS DENOTED ON THESE MAPS ARE BASED ON GOVERNMENT LAND OFFICE SURVEYS.

Acreeage: 1,116.30 Ac.-NET FEE AREA as of 8 December 1959.
6,741.31 Ac.-NET EASEMENT AREA as of 8 December 1959.

ACQUISITION AUTHORIZATION
River & Harbor Act dated 14 June 1880
4th Ind., OCE to NCO, 30 August 1957

NOTE: BASED ON U.S. ENGINEER OFFICE RECORDS AND FLOWAGE SURVEY OF RESERVOIRS AT HEADWATERS OF MISSISSIPPI RIVER MADE UNDER DIRECTION OF CORPS OF ENGINEERS, U.S. ARMY 1894-1904

ZERO OF GAUGE, SANDY LAKE RESERVOIR 1229.00.
ELEVATIONS ARE REFERRED TO U.S. ENGINEER OFFICE M.S.L. DATUM.

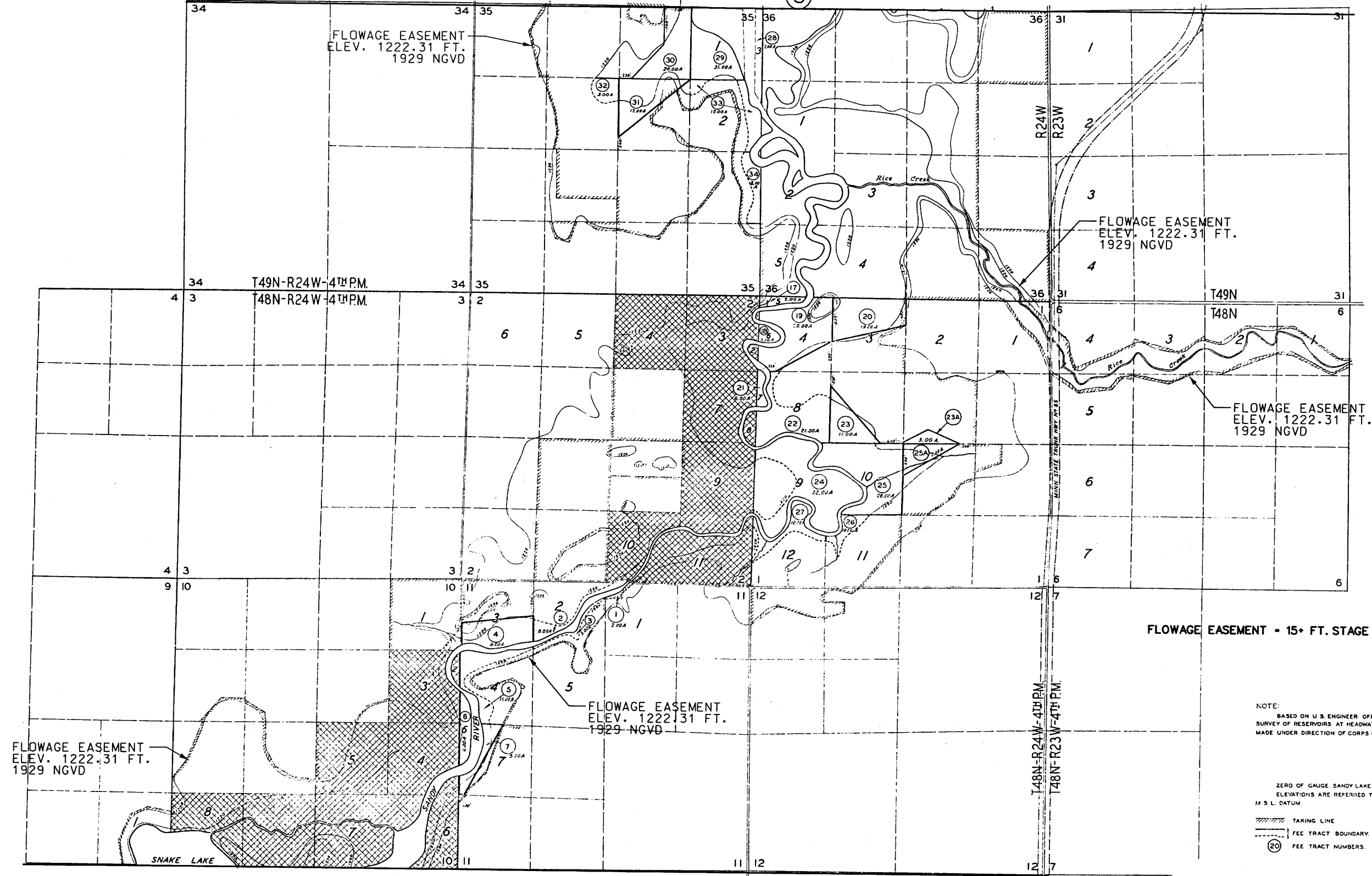
TAKING LINE
FEE TRACT BOUNDARY
FEE TRACT NUMBERS

M43-N-11/1

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
FLOWAGE EASEMENT
REAL ESTATE MAP
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

PLATE 2-7

MATCH LINE WITH PLATE 2-9 (3)



FLOWAGE EASEMENT - 15+ FT. STAGE - 1222.31 FT. 1929 NGVD

NOTE:
 BASED ON U.S. ENGINEER OFFICE RECORDS AND FLOWAGE
 SURVEY OF RESERVOIRS AT HEADWATERS OF MISSISSIPPI RIVER
 MADE UNDER DIRECTION OF CORPS OF ENGINEERS, U.S. ARMY, 1894-1904.

ZERO OF GAUGE SANDY LAKE RESERVOIR 1209.00.
 ELEVATIONS ARE REFERRED TO U.S. ENGINEER OFFICE
 M.S.L. DATUM.

////// TAKING LINE
 --- FEE TRACT BOUNDARY.
 (20) FEE TRACT NUMBERS.

MATCH LINE WITH PLATE 2-7 (1)

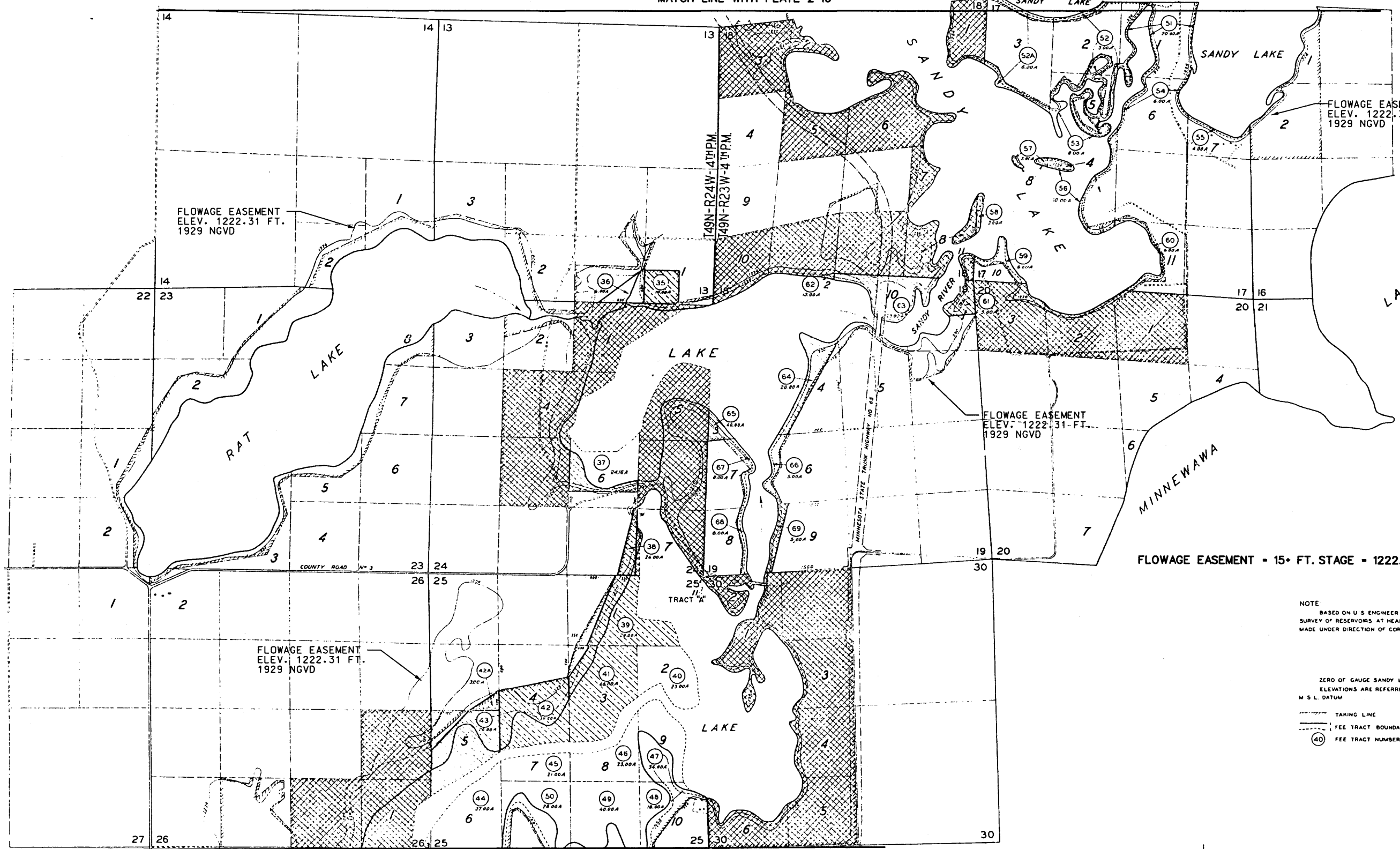
A I T K I N C O U N T Y M I N N .

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 4, SANDY LAKE
**FLOWAGE EASEMENT
 REAL ESTATE MAP**
 U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

ACQUISITION TRACT REGISTER				
TRACT NO.	LAND OWNER	ACREAGE		REMARKS
		FEE	PUBLIC DOMAIN	
A	DEPT. OF THE INTERIOR		0.40	P.L.O. NO. 1592 DATED: 28 FEBRUARY 1958

4

MATCH LINE WITH PLATE 2-10



FLOWAGE EASEMENT - 15+ FT. STAGE - 1222.31 FT. 1929 NGVD

NOTE
 BASED ON U.S. ENGINEER OFFICE RECORDS AND FLOWAGE SURVEY OF RESERVOIRS AT HEADWATERS OF MISSISSIPPI RIVER MADE UNDER DIRECTION OF CORPS OF ENGINEERS, U.S. ARMY 1894-1904.

ZERO OF GAUGE SANDY LAKE RESERVOIR 1209.00
 ELEVATIONS ARE REFERRED TO U.S. ENGINEER OFFICE M.S.L. DATUM

--- TAKING LINE
 --- FEE TRACT BOUNDARY
 (40) FEE TRACT NUMBERS

301.16 acres for the express purpose of the...
 Services, under authority of the... July 1955.

who conveyed 15.00 acres to Carl P. Egelund...
 by Quitclaim Deed dated 16 September 1958 and reserving to United States perpetual flowage easement over 15.00 acres.

who conveyed 15.00 acres to Jesse and Inga T. Johnson...
 by Quitclaim Deed dated 1 January 1958 and reserving to United States perpetual flowage easement over 15.00 acres.

who conveyed 5.00 acres to Carl P. Egelund...
 by Quitclaim Deed dated 16 September 1958 and reserving to United States perpetual flowage easement over 5.00 acres.

who conveyed 158.00 acres to Earl M. Smith and Florence L. Smith...
 by Quitclaim Deed dated 19 December 1958 and reserving to United States perpetual flowage easement over 158.00 acres.

who conveyed 3.00 acres to Elmer A. Geihar...
 by Quitclaim Deed dated 22 December 1958 and reserving to United States perpetual flowage easement over 3.00 acres.

who conveyed 21.25 acres to Ruth M. Geihar...
 by Quitclaim Deed dated 17 November 1958 and reserving to United States perpetual flowage easement over 21.25 acres.

who conveyed 20.00 acres to Richard Gordon Johnson...
 by Quitclaim Deed dated 30 November 1958 and reserving to United States perpetual flowage easement over 20.00 acres.

who conveyed 78.91 acres to State of Minnesota...
 by Quitclaim Deed dated 8 December 1958 and reserving to United States perpetual flowage easement over 78.91 acres. Subject to recapture.

A I T K I N C O U N T Y,
 M I N N.

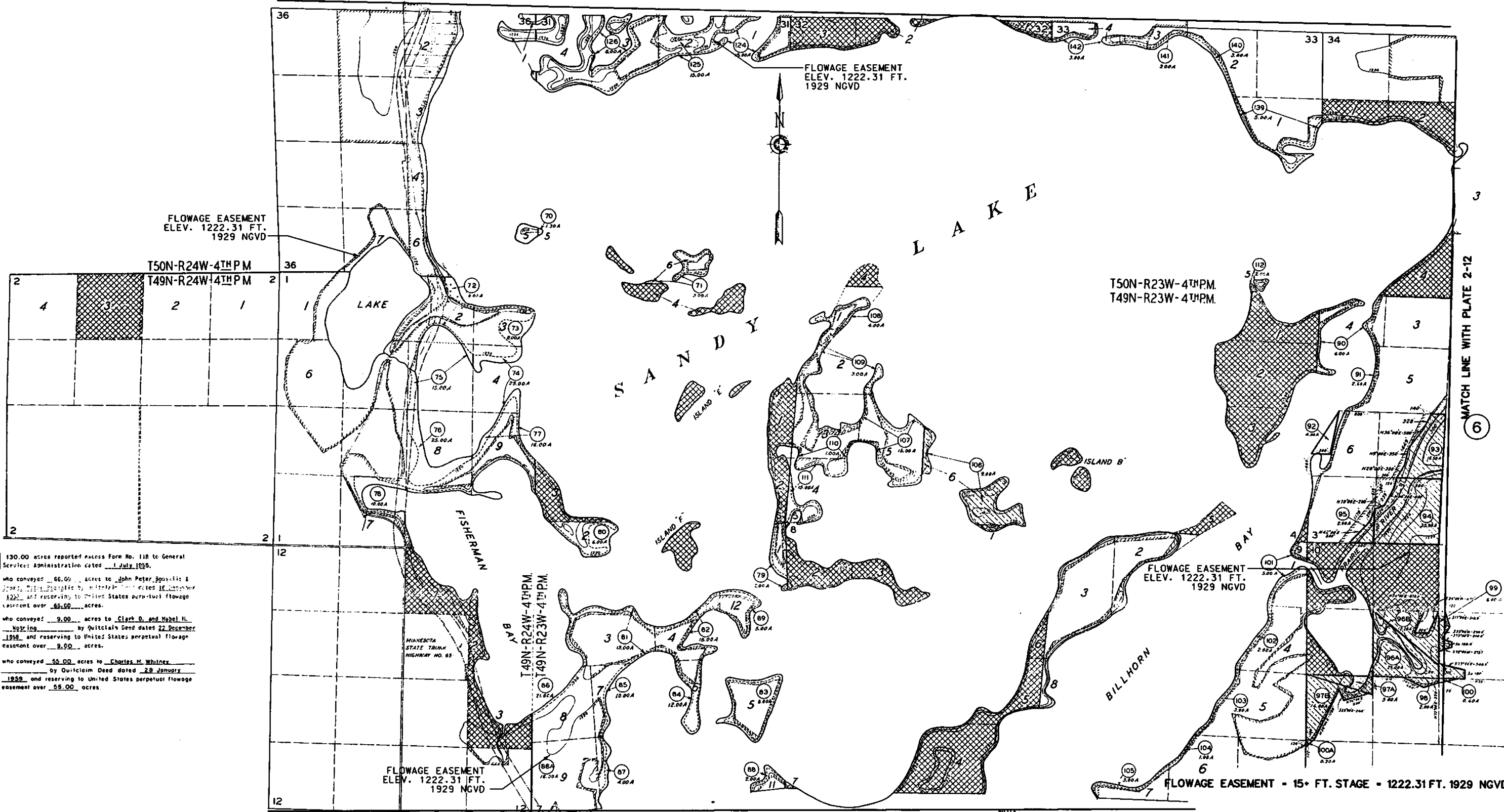
2

MATCH LINE WITH PLATE 2-8

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 4, SANDY LAKE
**FLOWAGE EASEMENT
 REAL ESTATE MAP**
 U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

5

MATCH LINE WITH PLATE 2-11



130.00 acres reported on Form No. 118 to General Services Administration dated 1 July 1955.

who conveyed 66.00 acres to John Peter Bossic & Sons, Inc. by Quitclaim Deed dated 16 December 1955 and reserving to United States perpetual flowage easement over 66.00 acres.

who conveyed 9.00 acres to Clark D. and Nabel H. by Quitclaim Deed dated 22 December 1958 and reserving to United States perpetual flowage easement over 9.00 acres.

who conveyed 55.00 acres to Charles W. Whitney by Quitclaim Deed dated 28 January 1959 and reserving to United States perpetual flowage easement over 55.00 acres.

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT - 15+ FT. STAGE - 1222.31 FT. 1929 NGVD

A I T K I N C O U N T Y M I N N

MATCH LINE WITH PLATE 2-9

3

NOTE:
BASED ON U.S. ENGINEER OFFICE RECORDS AND FLOWAGE SURVEY OF RESERVOIRS AT HEADWATERS OF MISSISSIPPI RIVER MADE UNDER DIRECTION OF CORPS OF ENGINEERS, U.S. ARMY, 1894-1904

ZERO OF GAUGE SANDY LAKE RESERVOIR, 1209.00 ELEVATIONS ARE REFERRED TO U.S. ENGINEER OFFICE M S L DATUM.

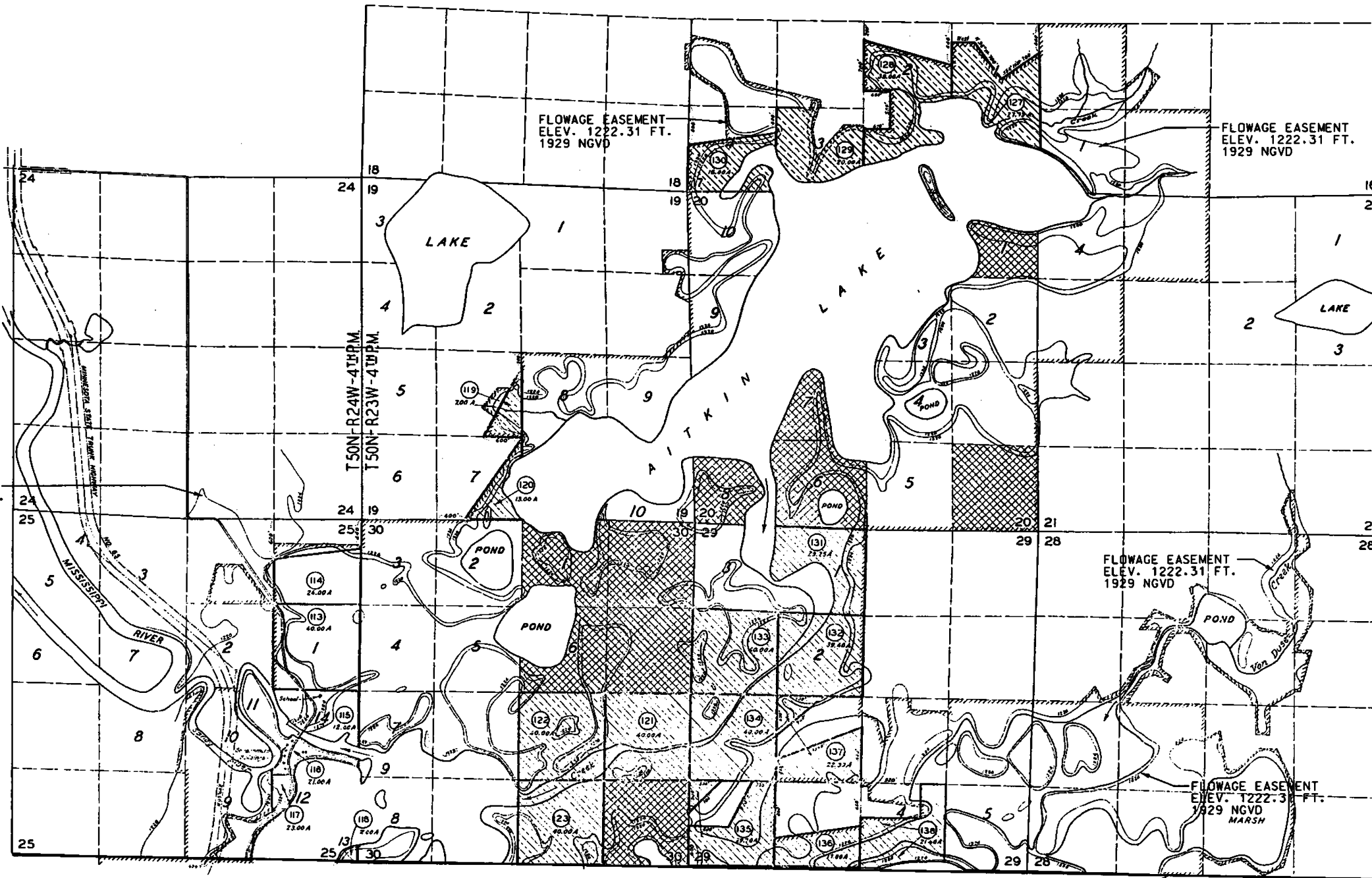
--- TAKING LINE
--- FEE TRACT BOUNDARY
--- FEE TRACT NUMBERS

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
FLOWAGE EASEMENT
REAL ESTATE MAP

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

M43-N-11/4

PLATE 2-10



FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD
MARSH

482.30 acres reported excess Form No. 118 to General Services Administration dated July 1953.

who conveyed 101.75 acres to John A. Sweeney by Quitclaim Deed dated 22 December 1953 and reserving to United States perpetual flowage easement over 101.75 acres.

who conveyed 358.55 acres to Ignatius J and Mattie Suchavsky by Quitclaim Deed dated 16 December 1958 and reserving to United States perpetual flowage easement over 358.55 acres.

who conveyed 13.00 acres to Ted J and Ellen D. Stalb by Quitclaim Deed dated 9 January 1959 and reserving to United States perpetual flowage easement over 13.00 acres.

who conveyed 7.00 acres to Ted J and Ellen D. Stalb by Quitclaim Deed dated 23 April 1959 and reserving to United States perpetual flowage easement over 7.00 acres.

who conveyed 2.00 acres to M. J. Ward and Earl P. Lambert by Quitclaim Deed dated 4 May 1959 and reserving to United States perpetual flowage easement over 2.00 acres.

NOTE:
BASED ON U.S. ENGINEER OFFICE RECORDS AND FLOWAGE SURVEY OF RESERVOIRS AT HEADWATERS OF MISSISSIPPI RIVER MADE UNDER DIRECTION OF CORPS OF ENGINEERS, U.S. ARMY 1894-1904.

ZERO OF GAUGE, SANDY LAKE RESERVOIR 1203.00.
ELEVATIONS ARE REFERRED TO U.S. ENGINEER OFFICE M. S. L. DATUM.

--- TAKING LINE.
--- FEE TRACT BOUNDARY.
○ FEE TRACT NUMBERS

MATCH LINE WITH PLATE 2-10

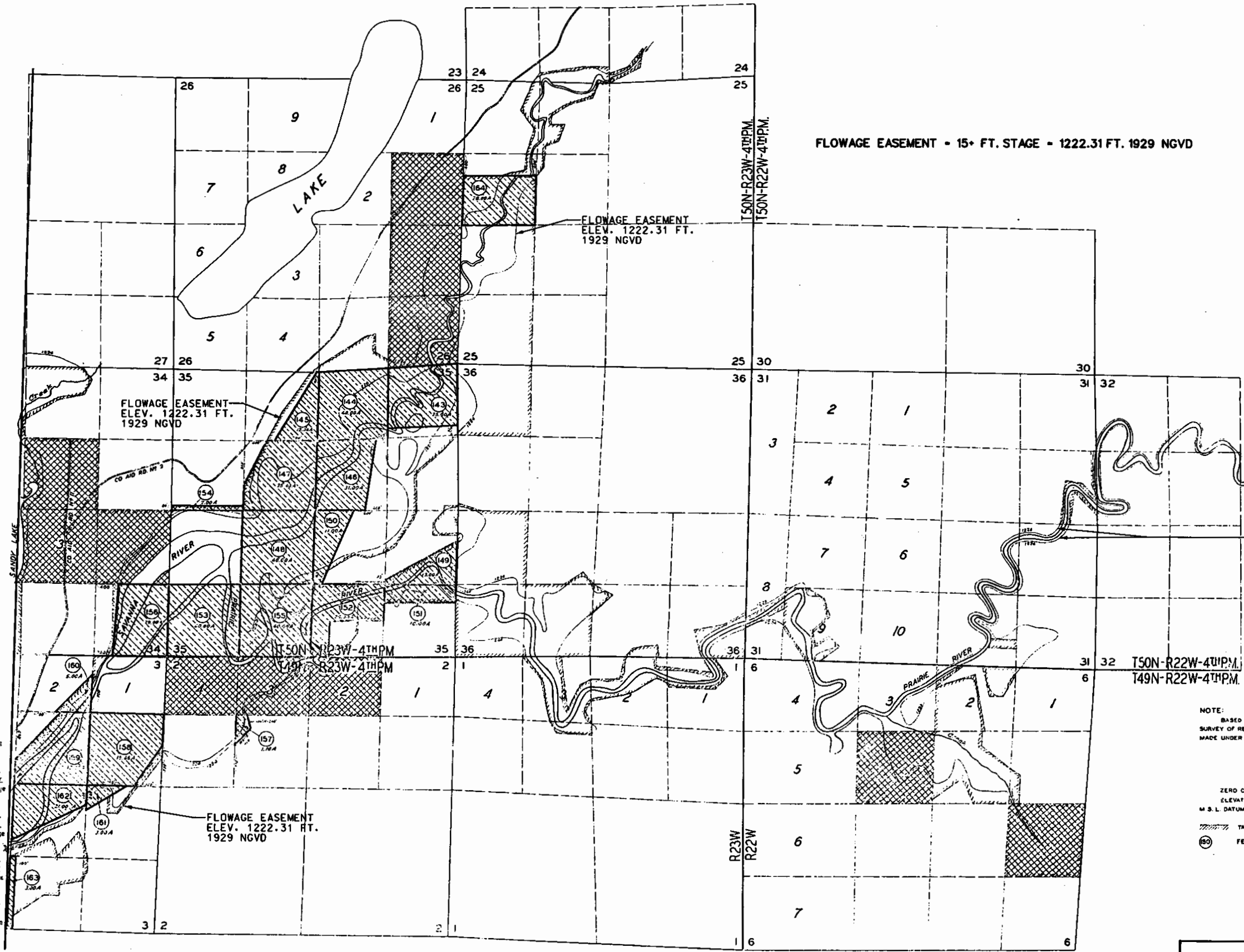
A I T K I N C O U N T Y M I N N

4

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
FLOWAGE EASEMENT
REAL ESTATE MAP
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

MATCH LINE WITH PLATE 2-10

4



FLOWAGE EASEMENT - 15+ FT. STAGE - 1222.31 FT. 1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

FLOWAGE EASEMENT
ELEV. 1222.31 FT.
1929 NGVD

493.76 acres reported excess Encl. No. 116 to General Services Administration dated July 1949.

who conveyed 70.79 acres to Luther H. and Florence M. Todd, by Quitclaim Deed dated 18 June 1958, and reserving to United States perpetual flowage easement over 39.00 acres.

who conveyed 5.00 acres to Luther H. and Florence M. Todd, by Quitclaim Deed dated 29 October 1958, and reserving to United States perpetual flowage easement over 2.00 acres.

who conveyed 28.90 acres to Paul B. Knutson and Margaret Knutson, by Quitclaim Deed dated 16 December 1958, and reserving to United States perpetual flowage easement over 28.00 acres.

who conveyed 189.76 acres to John P. Crossley et al., by Quitclaim Deed dated 12 February 1959, and reserving to United States perpetual flowage easement over 10.00 acres.

who conveyed 31.99 acres to Jerome Francis, Christine M. M. M., by Quitclaim Deed dated 22 December 1950, and reserving to United States perpetual flowage easement over 31.99 acres.

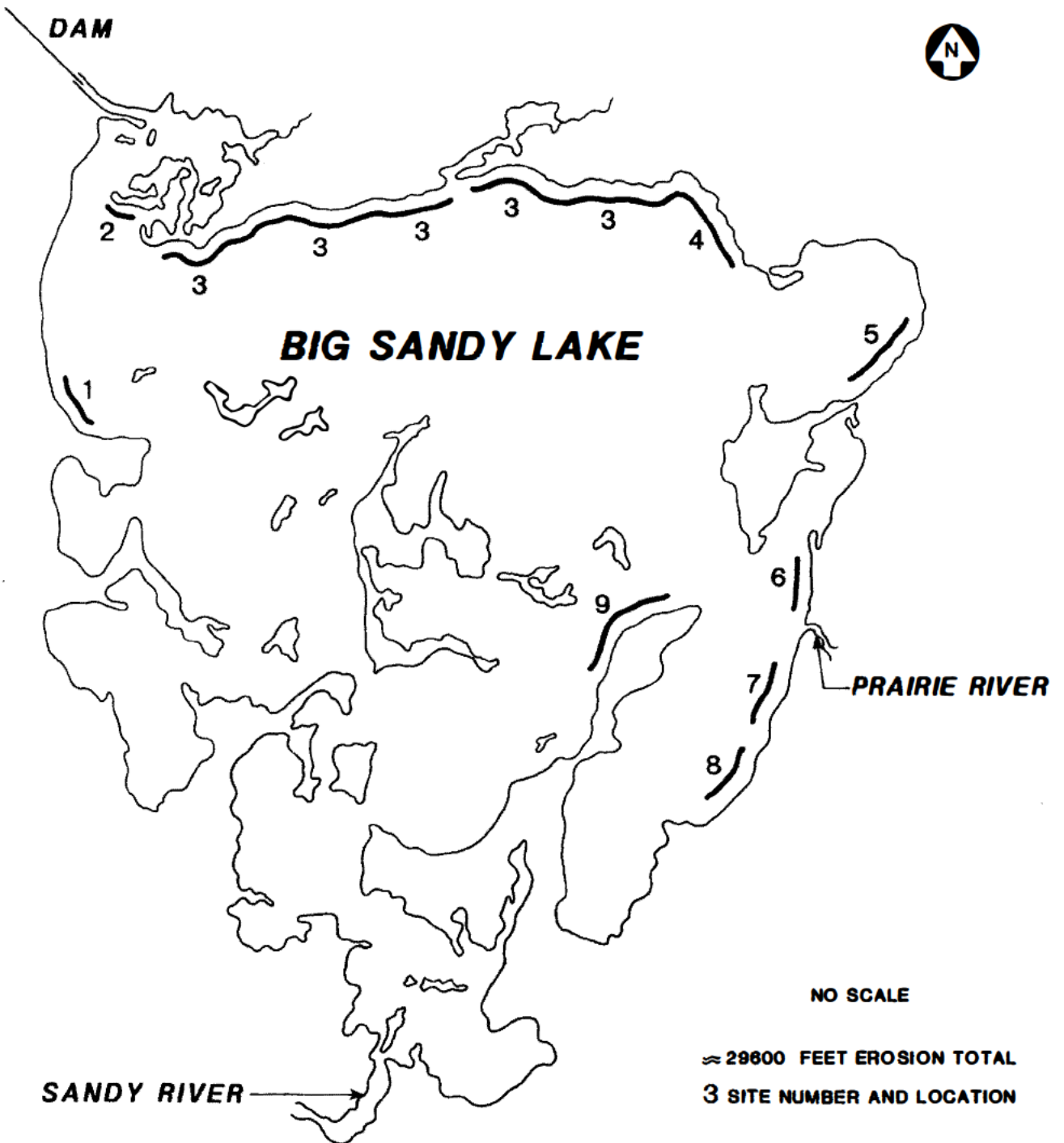
NOTE:
BASED ON U.S. ENGINEER OFFICE RECORDS AND FLOWAGE SURVEY OF RESERVOIRS AT HEADWATERS OF MISSISSIPPI RIVER MADE UNDER DIRECTION OF CORPS OF ENGINEERS, U.S. ARMY 1894-1904

ZERO OF GAUGE, SANDY LAKE RESERVOIR 1209.00.
ELEVATIONS ARE REFERRED TO U.S. ENGINEER OFFICE M.S.L. DATUM.

--- TAKING LINE.
①② FEE TRACT NUMBER

A I T K I N
C O U N T Y, M I N N.

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
FLOWAGE EASEMENT
REAL ESTATE MAP
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

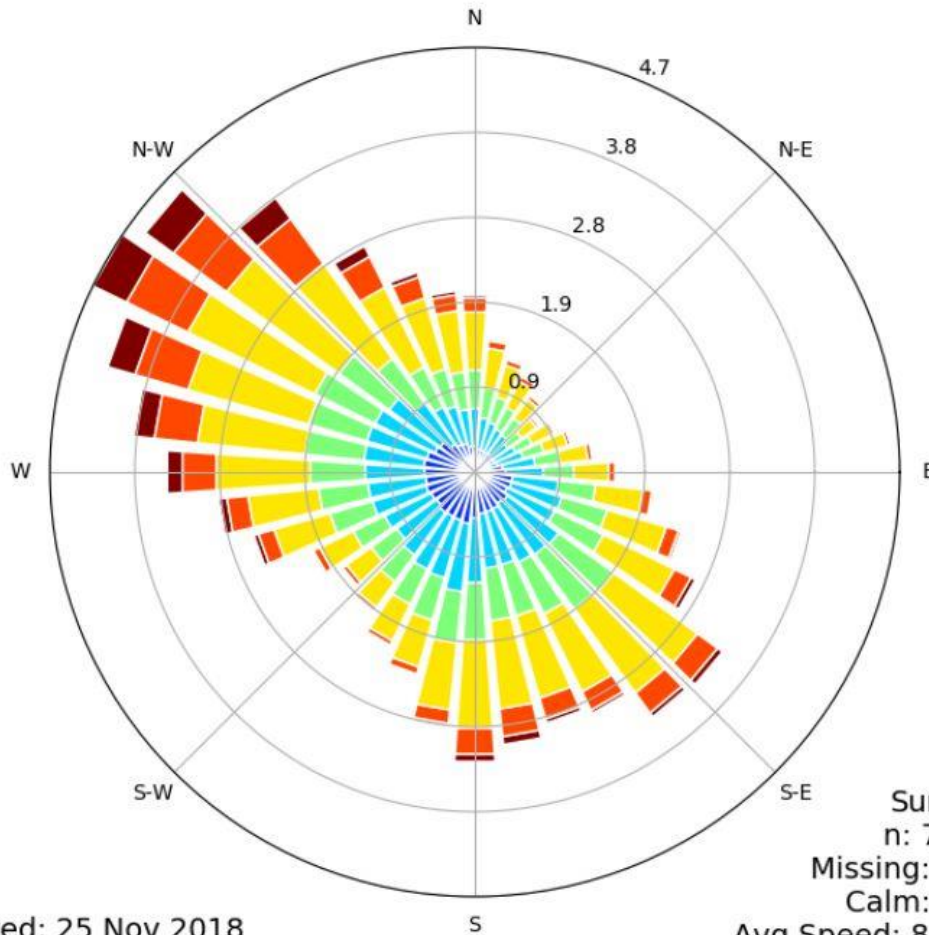


MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
BANK EROSION AREAS

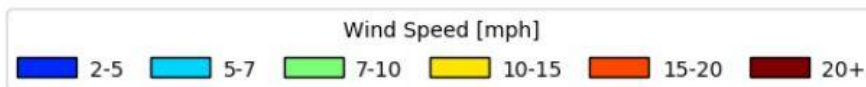
CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
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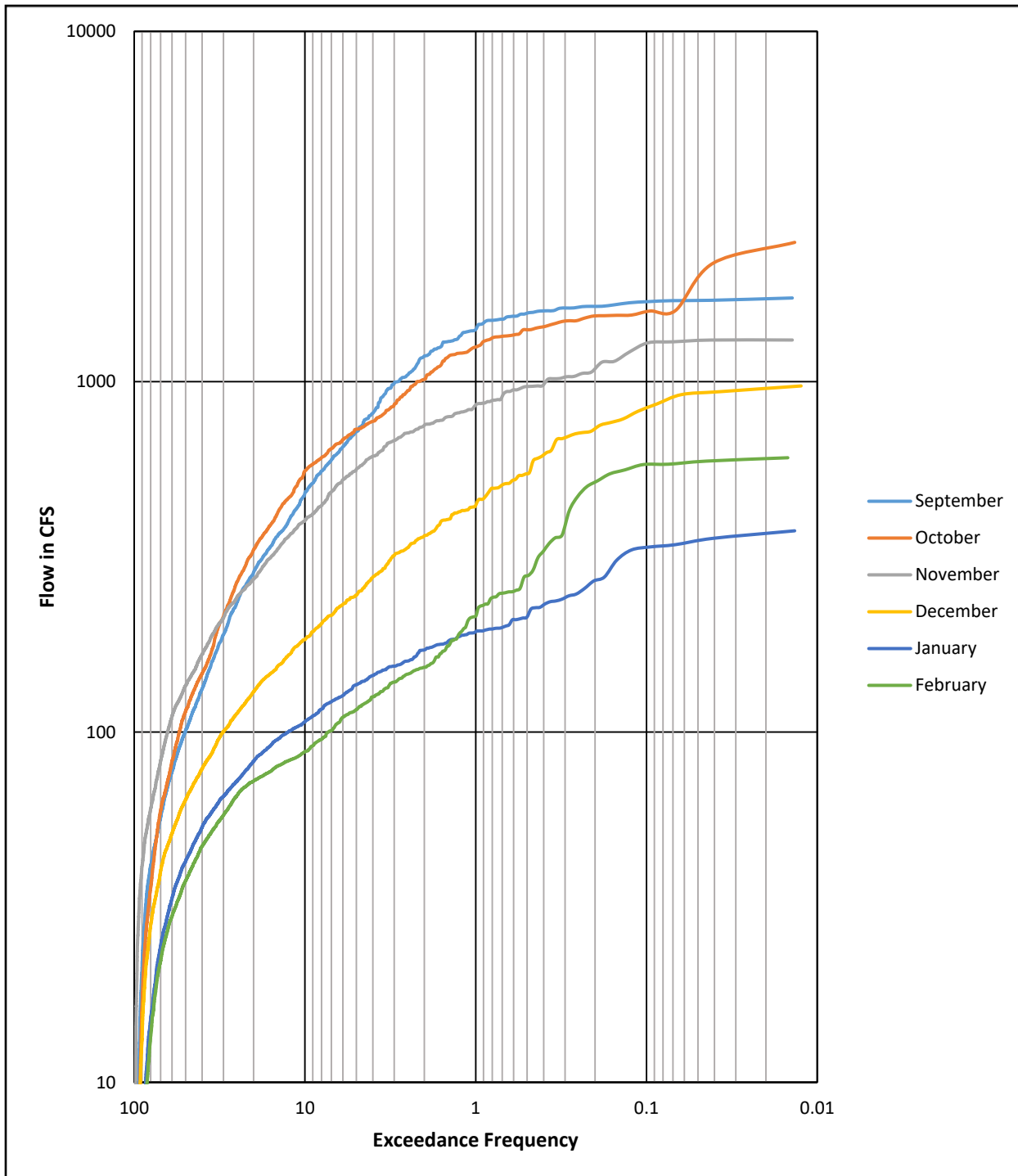
[BJI] BEMIDJI
Windrose Plot [All Year]
Period of Record: 31 Dec 1972 - 25 Nov 2018



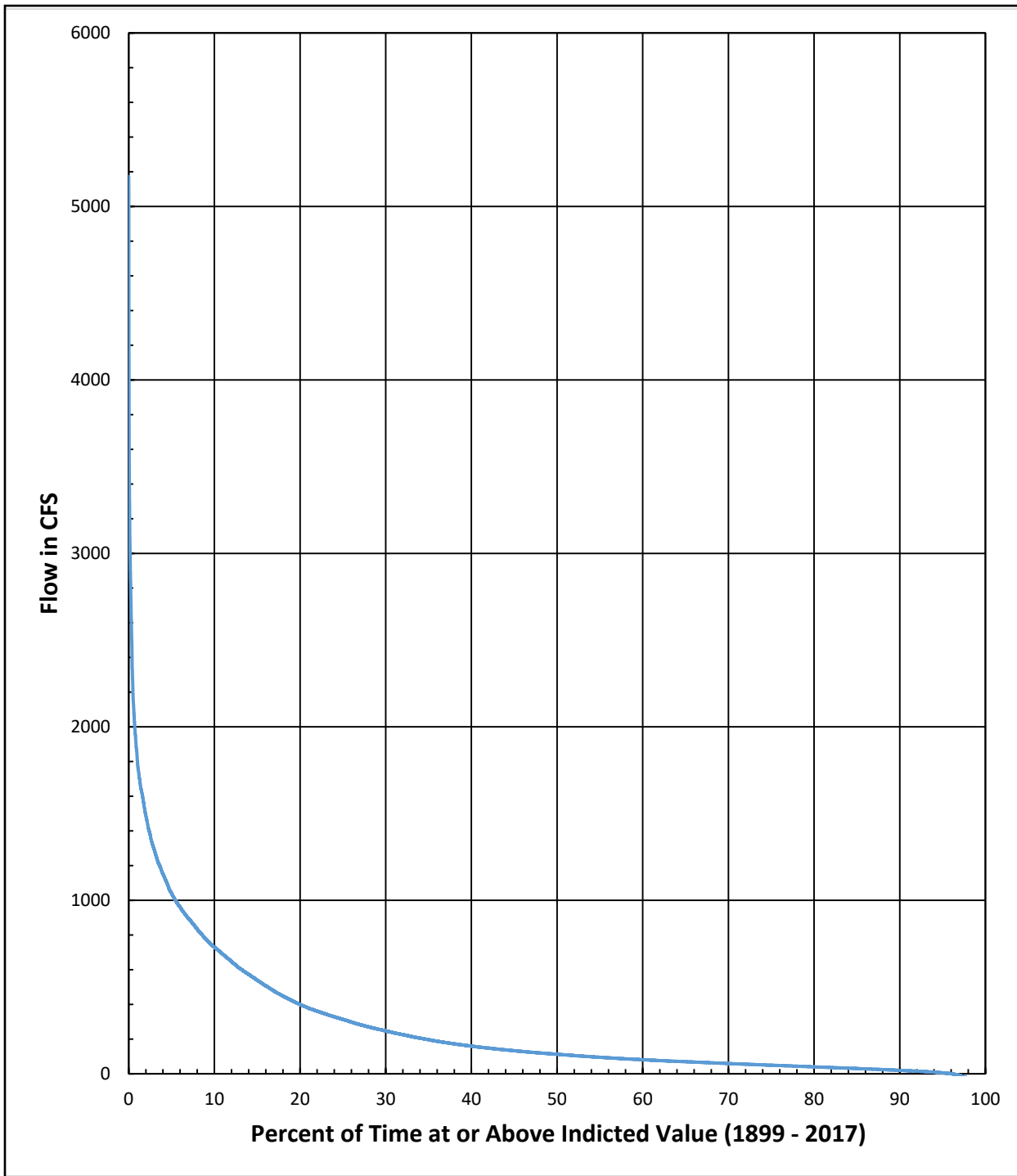
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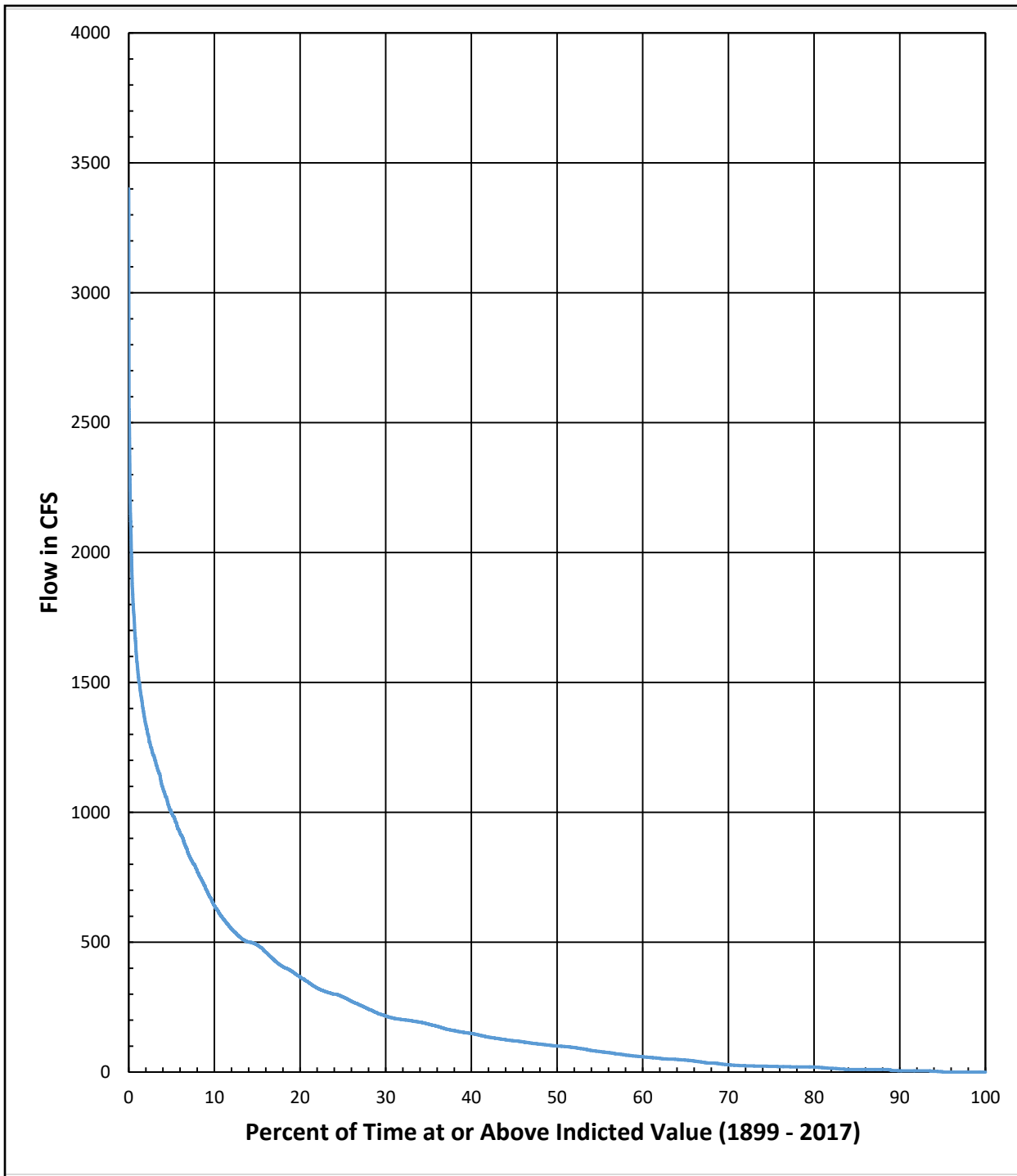
MISSISSIPPI RIVER HEADWATERS
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APPENDIX 4, SANDY LAKE
BEMIDJI, MN
(SANDY LAKE)
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MISSISSIPPI RIVER HEADWATERS
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APPENDIX 4, SANDY LAKE
Inflow Frequency Curves
September-February
(SANDY LAKE, 1899 - 2017)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

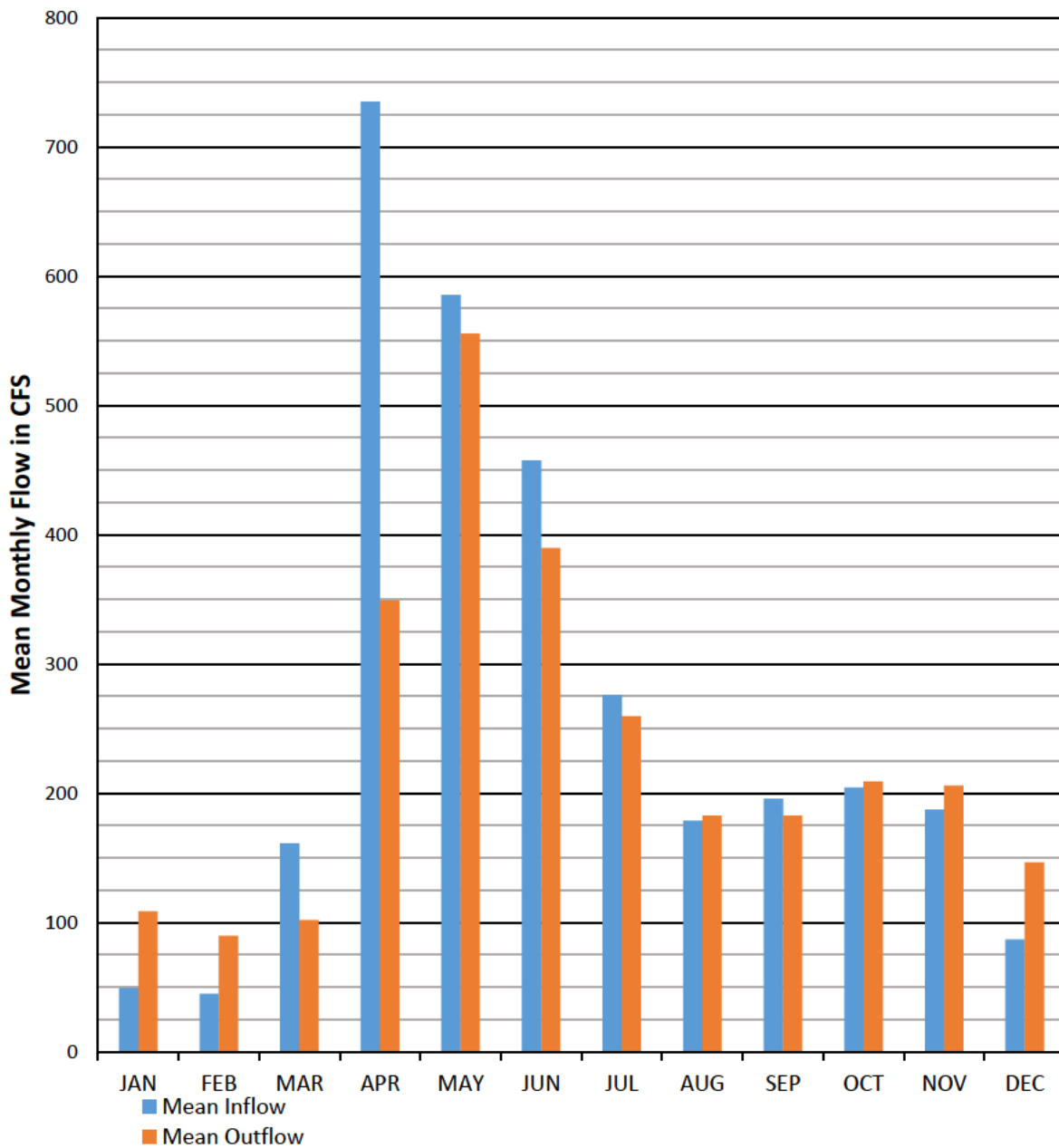


MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
Reservoir Inflow - Duration
(SANDY LAKE)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

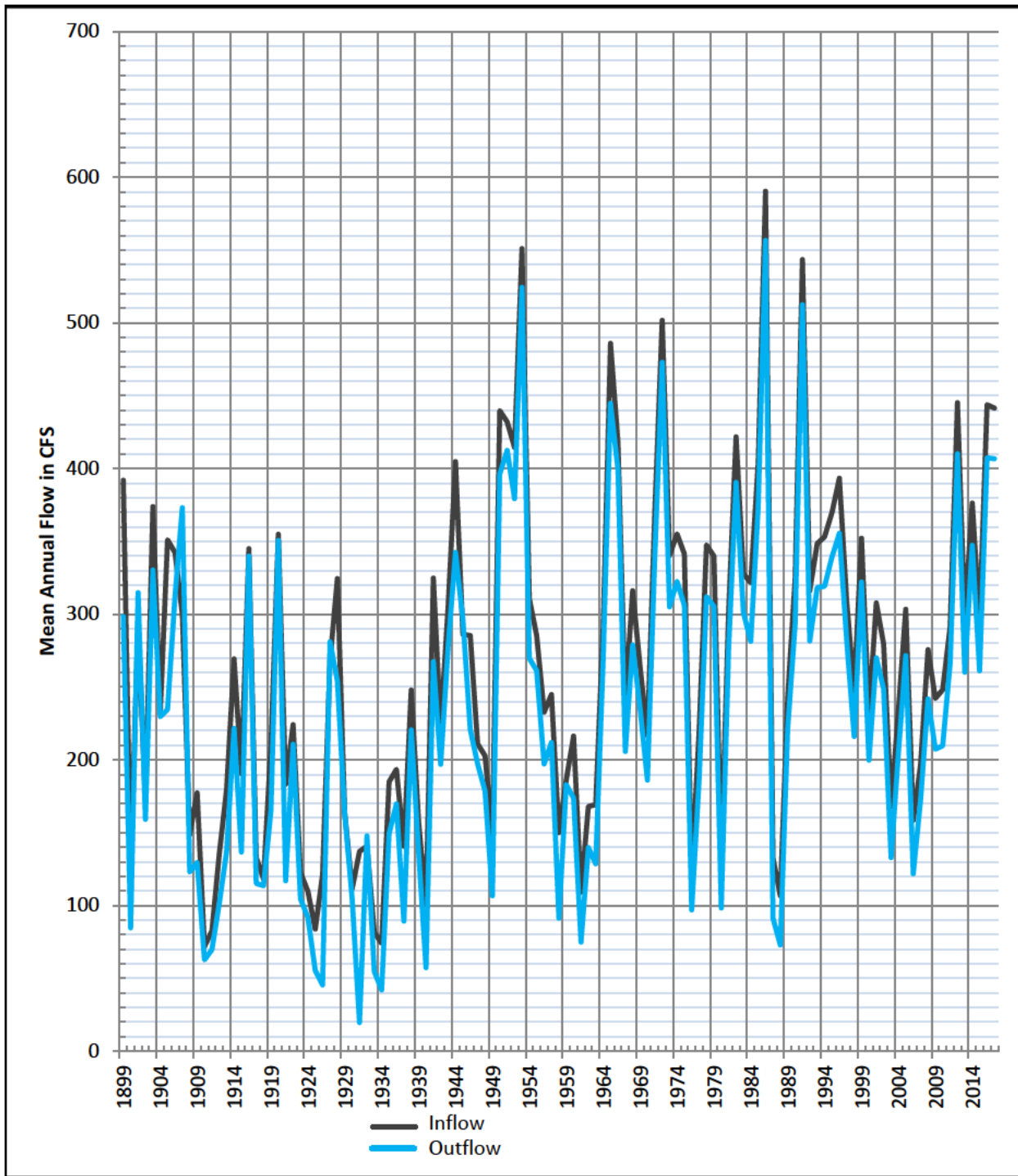


MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
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APPENDIX 4, SANDY LAKE
Reservoir Outflow - Duration
(SANDY LAKE)
 CORPS OF ENGINEERS, U.S. ARMY
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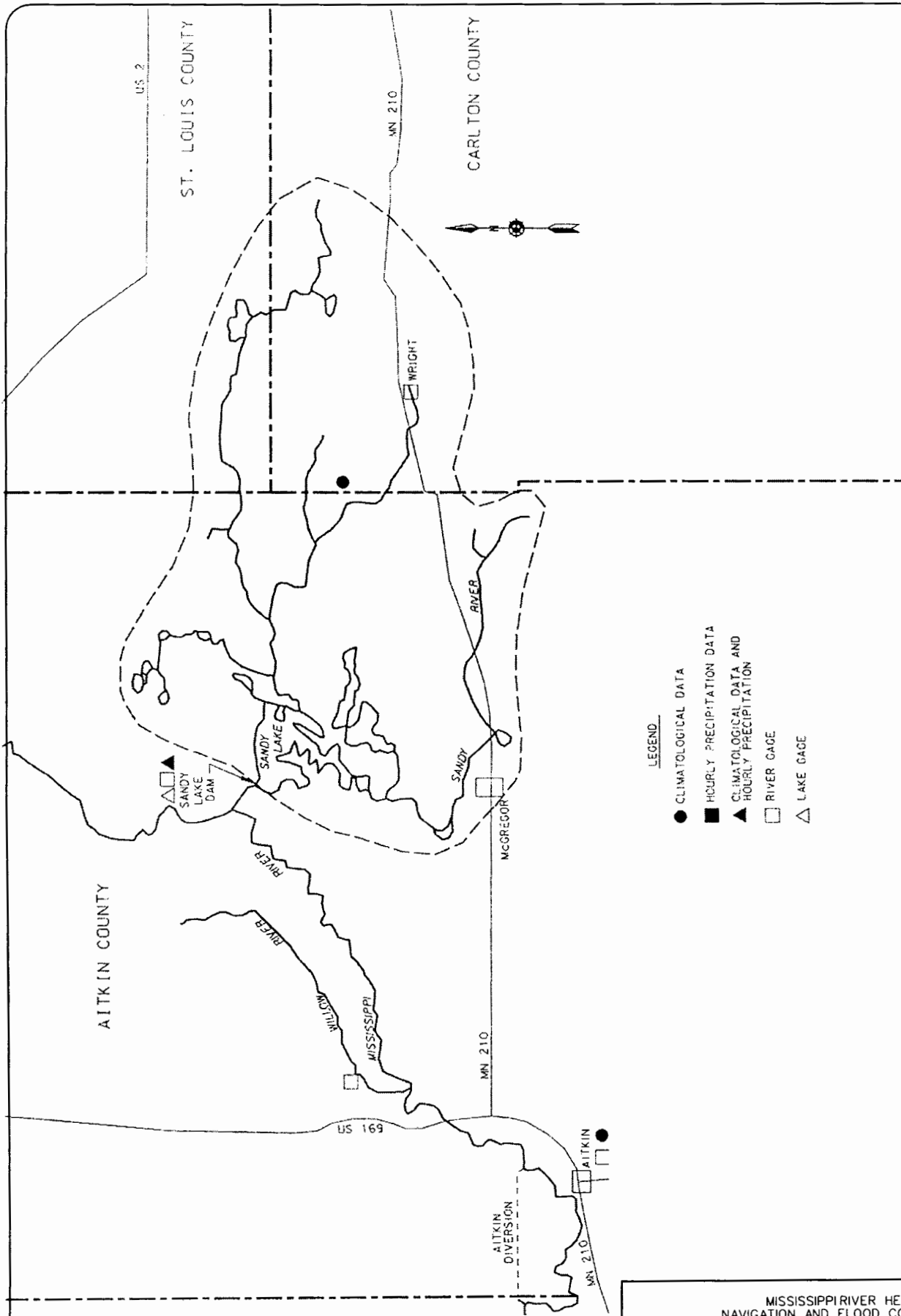
Big Sandy Lake Reservoir Monthly Inflow-Outflow (1899 - 2017)



MISSISSIPPI RIVER HEADWATERS
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 RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
Reservoir Monthly Inflow-Outflow
(SANDY LAKE)
 CORPS OF ENGINEERS, U.S. ARMY
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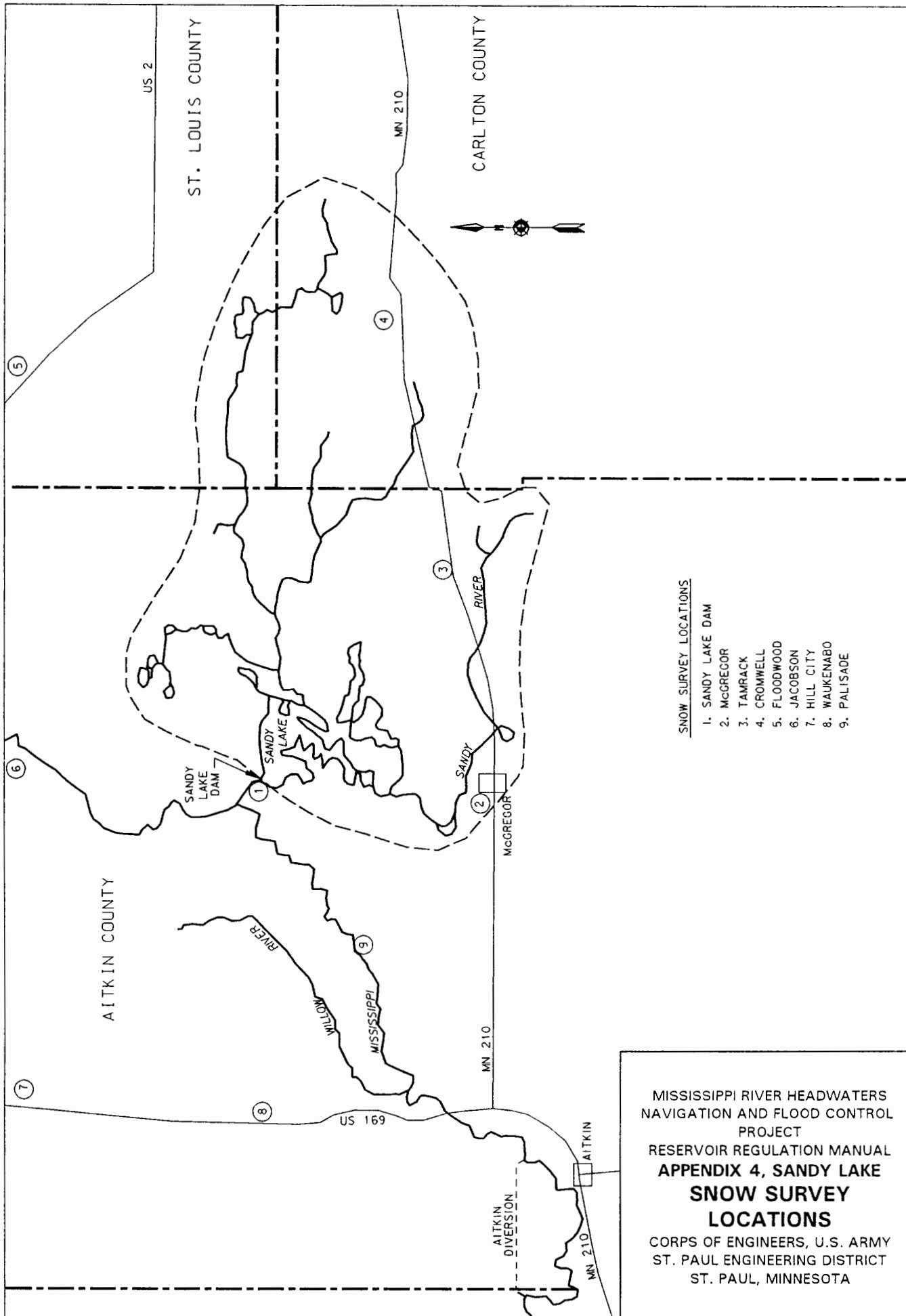


MISSISSIPPI RIVER HEADWATERS
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 APPENDIX 4, SANDY LAKE
 Reservoir Mean Annual Inflow and Outflow
 (SANDY LAKE, 1899 - 2017)
 CORPS OF ENGINEERS, U.S. ARMY
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- LEGEND**
- CLIMATOLOGICAL DATA
 - HOURLY PRECIPITATION DATA
 - ▲ CLIMATOLOGICAL DATA AND HOURLY PRECIPITATION
 - RIVER GAGE
 - △ LAKE GAGE

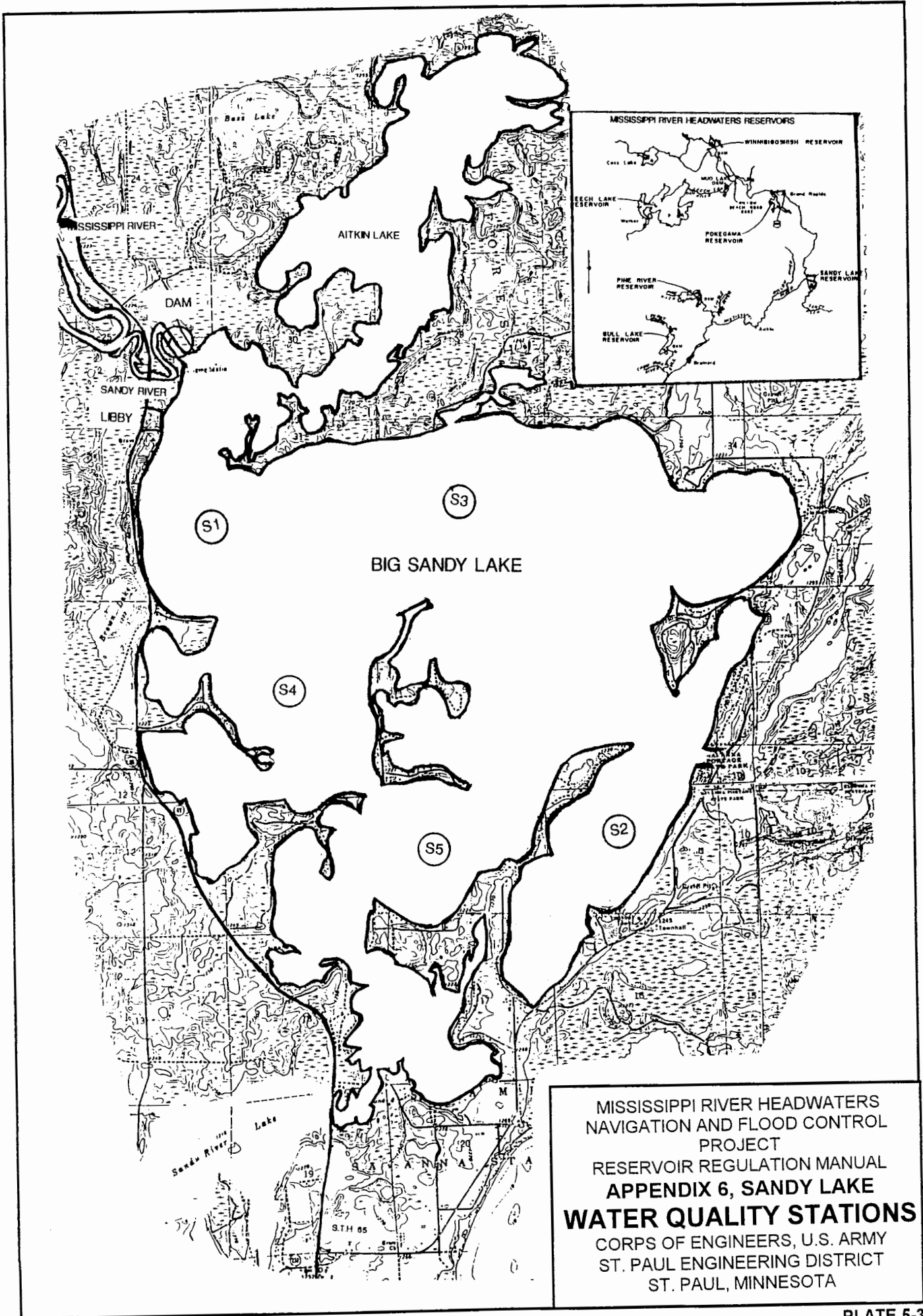
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 4, SANDY LAKE
**HYDROMETEOROLOGICAL, RIVER
 AND LAKE STATIONS**
 U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



SNOW SURVEY LOCATIONS

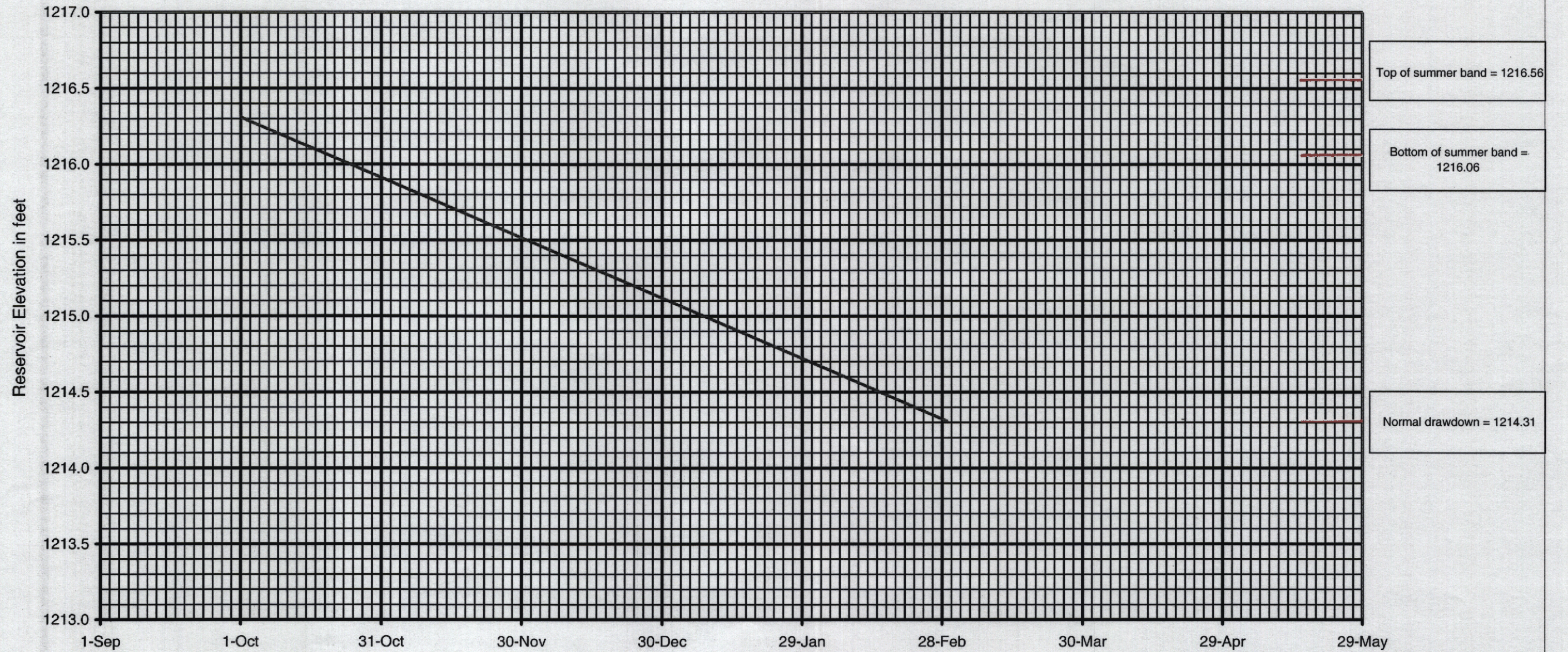
- 1. SANDY LAKE DAM
- 2. MCGREGOR
- 3. TAMRACK
- 4. CROMWELL
- 5. FLOODWOOD
- 6. JACOBSON
- 7. HILL CITY
- 8. WAUKENABO
- 9. PALISADE

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL
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SNOW SURVEY
LOCATIONS
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



MISSISSIPPI RIVER HEADWATERS
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APPENDIX 6, SANDY LAKE
WATER QUALITY STATIONS
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

Big Sandy Lake

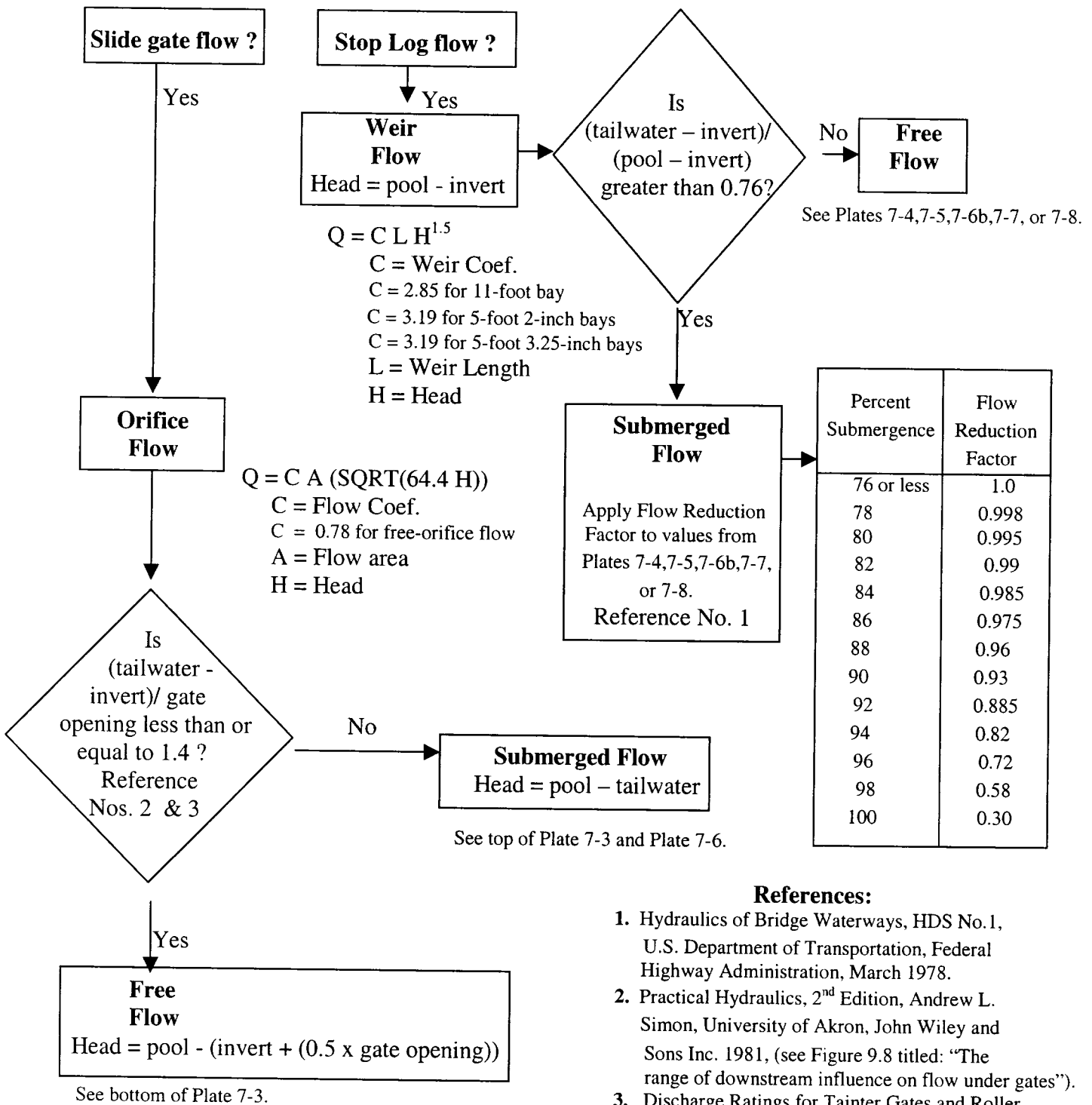


1. See Paragraph 7-05.
2. The drawdown curve should be followed until January.
Snow water content should then be monitored to determine the final drawdown target elevation.
3. The discharge for a "Normal" drawdown to 1214.31 Ft. is approximately 60 cfs above inflow.
4. All Elevations are 1929 NGVD.

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT WATER
CONTROL MANUAL

BIG SANDY LAKE DRAWDOWN CURVE

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA



References:

1. Hydraulics of Bridge Waterways, HDS No.1, U.S. Department of Transportation, Federal Highway Administration, March 1978.
2. Practical Hydraulics, 2nd Edition, Andrew L. Simon, University of Akron, John Wiley and Sons Inc. 1981, (see Figure 9.8 titled: "The range of downstream influence on flow under gates").
3. Discharge Ratings for Tainter Gates and Roller Gates at Lock and Dam No. 7 on the Mississippi River, La Cresent, MN, U.S. Geological Survey Water Resources Investigations Report 95-4089, Madison, WI, 1995.

Submerged-Orifice Flow
Discharge Table for Big Sandy Lake Lake Dam Slide Gates
 (Discharge for one foot of opening through one gate only)
 (See Plate 7-2 to determine Free Flow versus Submerged Flow conditions)

Head in feet	Discharge in cfs	Head in feet	Discharge in cfs	Head in feet	Discharge in cfs	Head in feet	Discharge in cfs
0.00	0	1.75	44	3.50	65	5.25	82
0.25	11	2.00	48	3.75	68	5.50	84
0.50	20	2.25	51	4.00	70	5.75	87
0.75	26	2.50	54	4.25	73	6.00	89
1.00	32	2.75	57	4.50	75	6.25	91
1.25	36	3.00	60	4.75	77	6.50	93
1.50	40	3.25	62	5.00	80	6.75	96
						7.00	98

note : A curve found in Water Control files dated 17 July 1974 were used to create this table.

note : 6 Slide gates, each 5.0 ft. wide x 4.0 ft. tall, Invert elevation = 1207.31 ft.

note : This table is valid if ((Tailwater El. -1207.31)/ gate opening) is greater than or equal to approximately 1.4. See below and Plate 7-2.

note : Head = Pool Elevation - Tailwater Elevation (for submerged flow).

note : The sill elevation at Big Sandy Lake Dam is 1207.31 ft. The tailwater below the dam is above 1211.0 about half of the time and often times exceeds elevation 1209.0 ft. This results in submerged-orifice flow for most of the flow conditions.

note : See Plate 7-6 for Slide Gate Rating Curve.

**Discharge Through Slide Gates For
Free Flow**

1. See Plate 7-2 for Free Flow versus Submerged Flow.
2. Use $C = 0.78$ (See Plate 7-6).
3. Use Head = Pool -(Invert + (0.5 x gate opening)).
4. $Q = C A (\text{SQRT}(64.4 H))$.

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 WATER CONTROL MANUAL

BIG SANDY LAKE DAM
 SLIDE GATE RATING TABLE

U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

Plate 7-3

**Discharge Table for Big Sandy Lake Dam 5-foot 2-inch Stop Log Bay
Free Flow Only**

(See Plate 7-2 to determine Free Flow versus Submerged Flow conditions)

Head in feet	Discharge in cfs	Head in feet	Discharge in cfs	Head in feet	Discharge in cfs	Head in feet	Discharge in cfs
0.5	5	2.5	60	4.5	160	7.0	330
1.0	14	3.0	81	5.0	190	7.5	370
1.5	25	3.5	105	5.5	224	8.0	410
2.0	41	4.0	132	6.0	258	8.5	452
				6.5	293	9.0	498

note : Free weir flow, $Q = C * L * (H^{1.5})$, C = 3.19, L = 5 ft. 2 in., H = Difference in feet between water surface and top of stop logs.

**Discharge Table for Big Sandy Lake Dam 5-foot 3 1/4-inch Stop Log Bay
Free Flow Only**

(See Plate 7-2 to determine Free Flow versus Submerged Flow conditions)

Head in feet	Discharge in cfs	Head in feet	Discharge in cfs	Head in feet	Discharge in cfs	Head in feet	Discharge in cfs
0.5	5	2.5	61	4.5	163	7.0	337
1.0	15	3.0	83	5.0	194	7.5	377
1.5	26	3.5	107	5.5	228	8.0	418
2.0	42	4.0	135	6.0	263	8.5	461
				6.5	299	9.0	508

note : Free weir flow, $Q = C * L * (H^{1.5})$, C = 3.19, L = 5 ft. 3 1/4 in., H = Difference in feet between water surface and top of stop logs.

note : These tables are based on Table G-7 in the 1963 (revised 17 Feb 1968) Master Reservoir Regulation Manual.

An average "C" value of 3.19 was determined from Table G-7.

note : See Plate 7-7 for Stop Log (In Old Lock Chamber) Rating Curves.

note : Invert elevation = 1216.81.

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
WATER CONTROL MANUAL

BIG SANDY LAKE DAM
STOP LOG BAYS (IN OLD LOCK CHAMBER)
RATING TABLES

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

Discharge Table for Big Sandy Lake Dam 11-foot Stop Log Bay Free Flow Only

(See Plate 7-2 to determine Free Flow versus Submerged Flow conditions)

Head in feet	Discharge in cfs	Head in feet	Discharge in cfs	Head in feet	Discharge in cfs	Head in feet	Discharge in cfs
0.5	10	5.0	380	9.5	952	14.0	1596
1.0	30	5.5	438	10.0	1022	14.5	1670
1.5	55	6.0	498	10.5	1093	15.0	1745
2.0	85	6.5	560	11.0	1163	15.5	1820
2.5	120	7.0	620	11.5	1233	16.0	1895
3.0	166	7.5	682	12.0	1305	16.5	1968
3.5	208	8.0	750	12.5	1375	17.0	2040
4.0	260	8.5	815	13.0	1450	17.5	2115
4.5	320	9.0	883	13.5	1522	18.0	2190

note : Free weir flow, $Q = C * L * (H^{1.5})$, $C = 2.85$, $L = 11$ ft., $H =$ Difference in feet between water surface and top of stop logs.

note : This table was plotted based on data from a curve obtained from a bound file in the Water Control Section

labeled "Headwaters Reservoirs, Rating Tables and Discharge Curves". The curve used an average "C" value of 2.85.

note : See Plate 7-8 for 11-Foot Stop Log Bay Rating Curve.

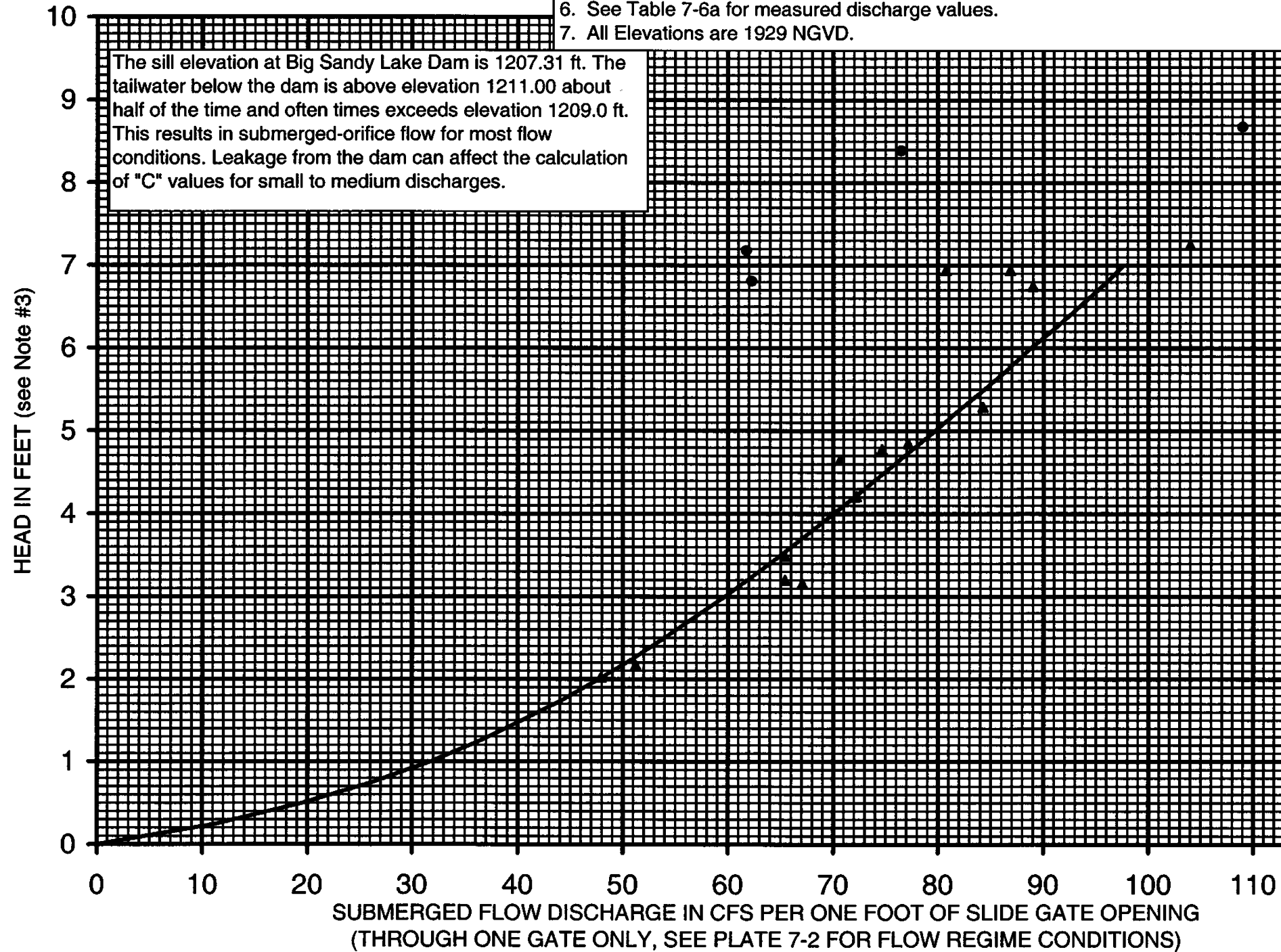
MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
WATER CONTROL MANUAL

BIG SANDY LAKE DAM
11-FOOT STOP LOG BAY RATING TABLE

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

Big Sandy Lake Dam

1. 6 Slide gates, each 5.0 ft. wide x 4.0 ft. tall, sill elevation = 1207.31 ft.
2. Head for free-orifice flow = Pool El. - (1207.31 + (0.5 x Gate opening)), head for submerged-orifice flow = Pool El. - Tailwater El.
3. Submerged-orifice curve is valid if the gate is in the water and ((Tailwater El. - 1207.03)/ gate opening) is greater than or equal to approximately 1.4. See References on Plate 7-2.
4. Free-orifice flow calculations = $C A (\text{SQRT}(64.4 H))$, using an average "C" value = 0.78.
5. A curve found in Water Control files dated 17 July 1974 were used to create this plate.
6. See Table 7-6a for measured discharge values.
7. All Elevations are 1929 NGVD.



The sill elevation at Big Sandy Lake Dam is 1207.31 ft. The tailwater below the dam is above elevation 1211.00 about half of the time and often times exceeds elevation 1209.0 ft. This results in submerged-orifice flow for most flow conditions. Leakage from the dam can affect the calculation of "C" values for small to medium discharges.

Measured Discharge

- free-orifice flow
average "C" value = 0.78
- ▲ submerged-orifice flow
(see notes)

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT WATER
 CONTROL MANUAL

BIG SANDY LAKE DAM
 SUBMERGED FLOW SLIDE GATE RATING CURVE

U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

See Plate 7-3 for Rating Table

Slide Gate Discharge Measurements for Big Sandy Lake Dam

Date	Average Gate Opening	Head in feet	Discharge per foot of gate opening (CFS)	"C" Value	Flow Regime
21-Sep-89	1.30	6.94	81	0.76	submerged-orifice
16-Aug-87	0.2	7.25	104	0.96	submerged-orifice
25-Apr-86	4.0	2.17	51	0.87	submerged-orifice
28-Aug-85	3.00	4.65	71	0.82	submerged-orifice
2-Oct-72	1.0	5.29	84	0.91	submerged-orifice
28-Aug-72	4.0	3.16	67	0.94	submerged-orifice
18-Aug-72	1.0	6.75	89	0.85	submerged-orifice
10-Aug-72	2.0	4.85	77	0.87	submerged-orifice
10-Aug-72	3.0	4.21	72	0.88	submerged-orifice
28-Jul-72	4.0	3.20	65	0.91	submerged-orifice
27-Jul-72	4.00	3.49	65	0.87	submerged-orifice
24-Jul-72	3.0	4.78	75	0.85	submerged-orifice
19-Jun-72	0.7	6.94	87	0.82	submerged-orifice
22-May-72	4.0	2.02	48	0.84	submerged-orifice
20-Apr-90	1.00	8.39	77	0.66	free-orifice
23-May-89	4.00	7.18	62	0.57	free-orifice
08-Jul-88	0.20	8.68	109	0.92	free-orifice
22-Sep-82	4.00	6.81	62	0.59	free-orifice
01-Jun-76	0.20	8.69	135	1.14	free-orifice

note : This table is based on a series of discharge measurements that were made from 1972 through 1990.

An average "C" value of 0.78 for free-orifice flow was determined from these measurements.

note : See Plate 7-6 for Slide Gate Rating Curve.

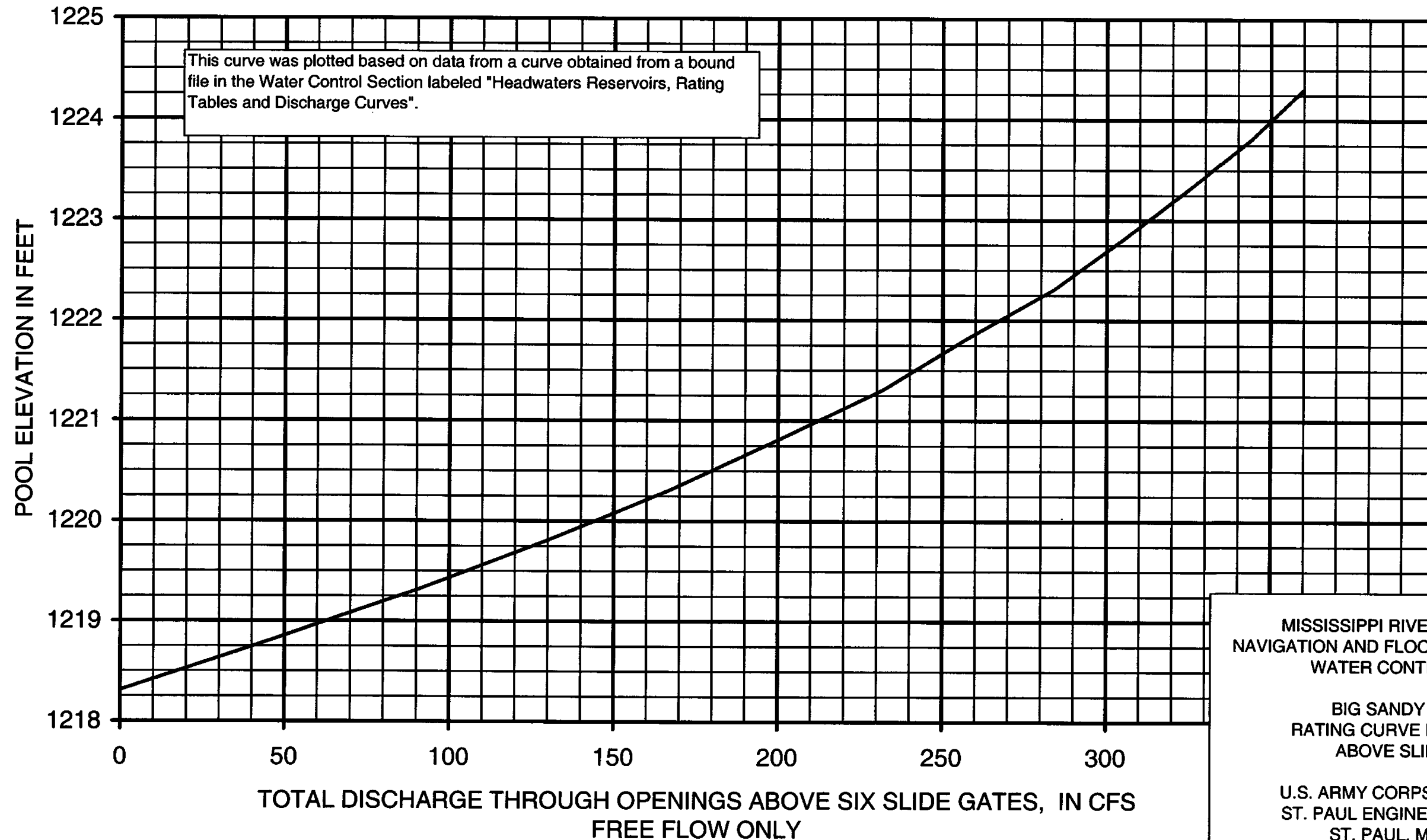
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 NAVIGATION AND FLOOD CONTROL PROJECT
 WATER CONTROL MANUAL

BIG SANDY LAKE DAM
 DISCHARGE MEASUREMENTS FOR VARIOUS SLIDE GATE OPENINGS

U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

Big Sandy Lake Dam

1. There are six arched openings above the slide gates in the Control Structure.
2. A curve found in the water control files dated 1 MAY 1972 was used to create this plate.
3. Invert elevation of arched opening above slide gates = 1218.31.
4. All Elevations are 1929 NGVD.



TOTAL DISCHARGE THROUGH OPENINGS ABOVE SIX SLIDE GATES, IN CFS
FREE FLOW ONLY

(See Plate 7-2 to determine Free Flow versus Submerged Flow conditions)

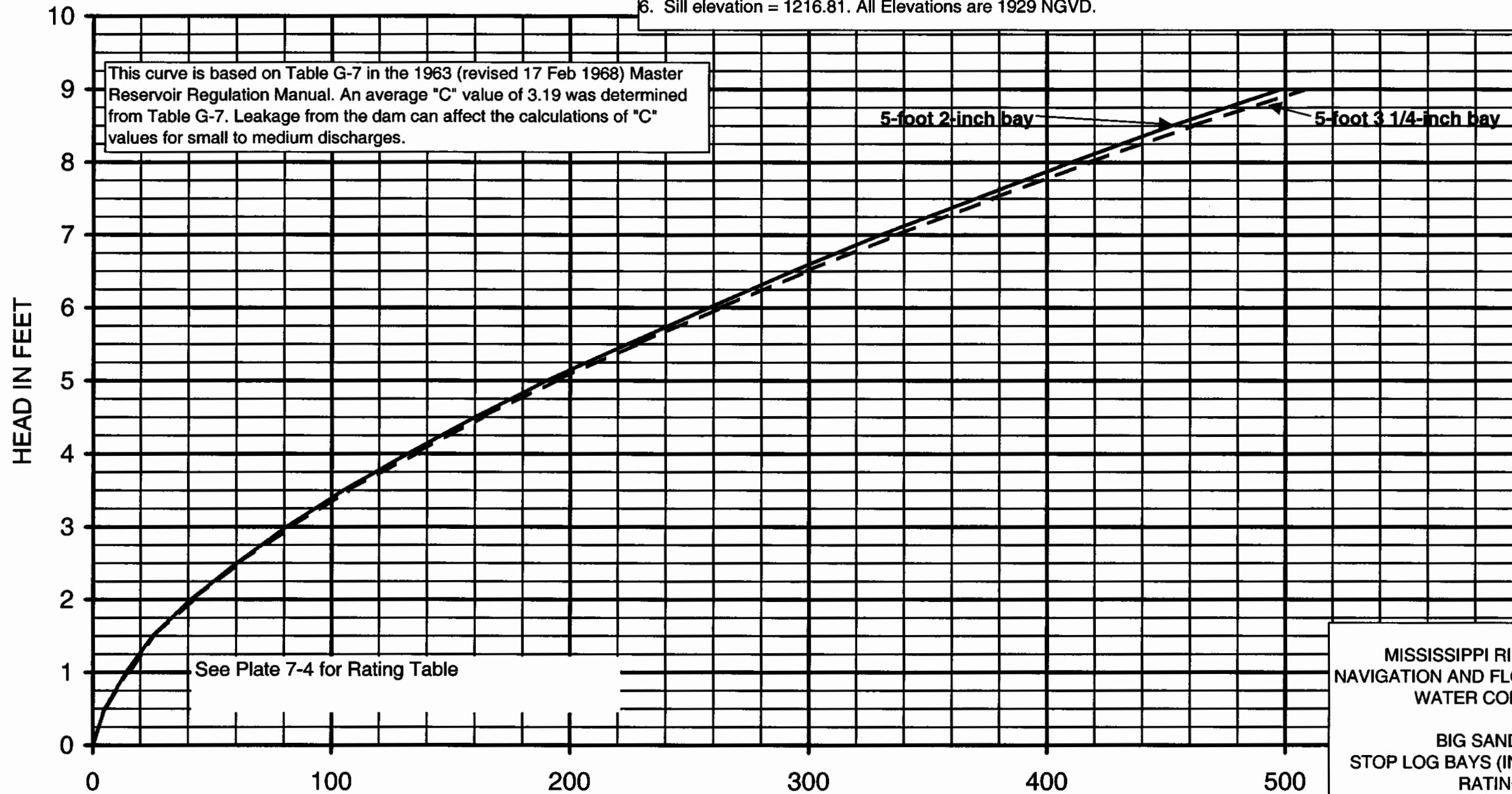
MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
WATER CONTROL MANUAL

BIG SANDY LAKE DAM
RATING CURVE FOR OPENINGS
ABOVE SLIDE GATES

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

Big Sandy Lake Dam

1. The three center stop log bays in the old lock chamber are 5-foot 2-inches wide.
2. The two end stop log bays in the old lock chamber are 5-foot 3.25- inches wide.
3. Head = Difference between the water surface and top of stop logs.
4. Weir flow, $Q=C*L*(H^{1.5})$, $C = 3.19$, $L = 5.17$ ft. if 5-foot 2-inch opening or 5.27 ft. if 5-foot 3.25-inch opening, $H =$ Head.
5. See Plate 7-2 if submerged flow conditions exists and the reduction factor applies.
6. Sill elevation = 1216.81. All Elevations are 1929 NGVD.



See Plate 7-4 for Rating Table

DISCHARGE THROUGH ONE STOP LOG BAY IN OLD LOCK CHAMBER, IN CFS
 FREE FLOW ONLY
 (See Plate 7-2 to determine Free Flow versus Submerged Flow conditions)
 See Plate 7-4 for Rating Table

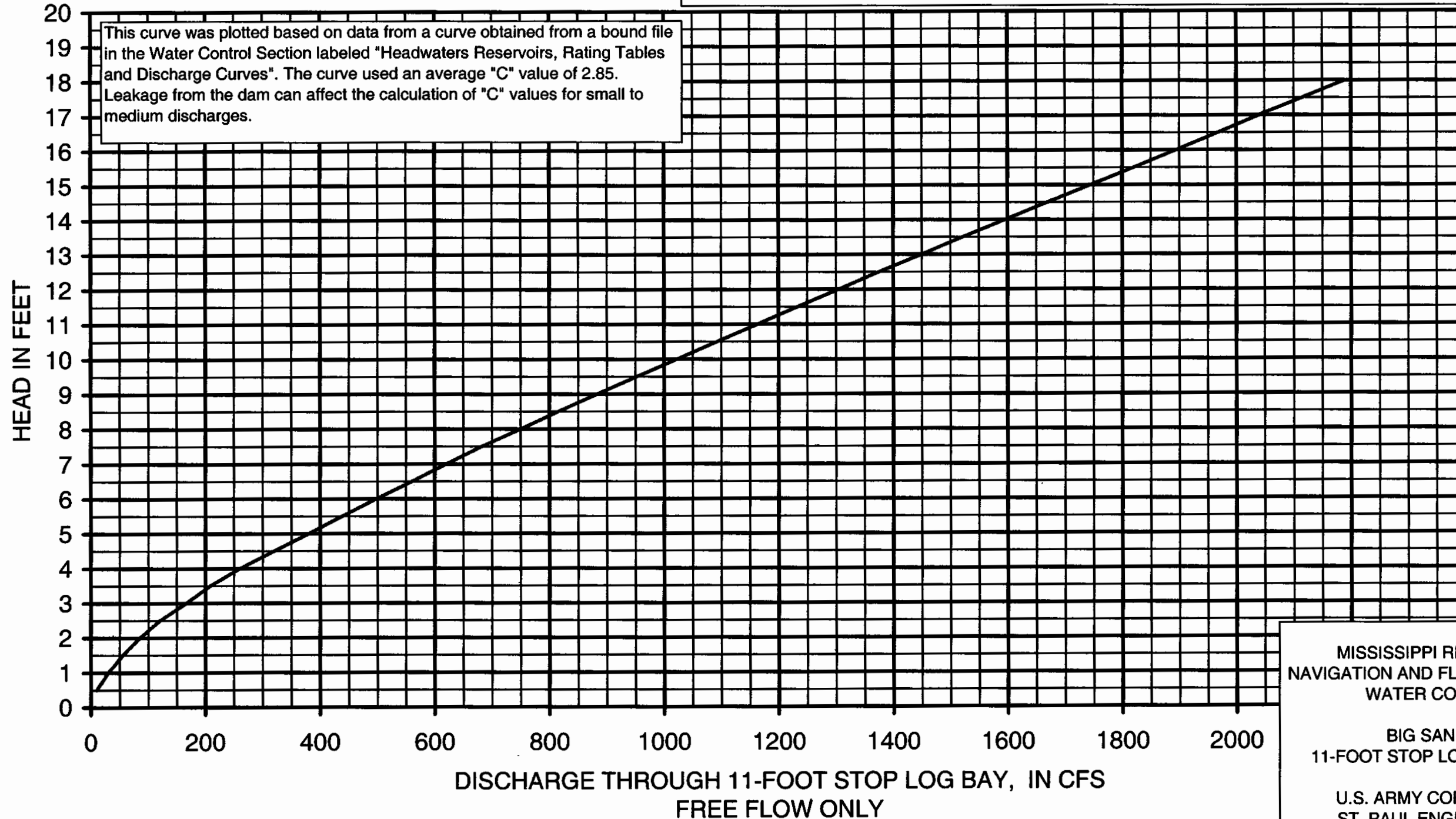
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 WATER CONTROL MANUAL

BIG SANDY LAKE DAM
 STOP LOG BAYS (IN OLD LOCK CHAMBER)
 RATING CURVES

U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

Big Sandy Lake Dam

1. There is one 11-foot wide stop log bay in the Control Structure.
2. Head = Difference between the water surface and top of stop logs.
3. Free weir flow, $Q=C*L*(H^{1.5})$, $C = 2.85$, $L = 11\text{ft.}$, $H = \text{Head}$. See Plate 7-2 if submerged flow reduction factor applies.
4. A curve found in the water control files dated 27 AUGUST 1958 was used to create this plate.
5. Sill elevation = 1207.31. All Elevations are 1929 NGVD.



DISCHARGE THROUGH 11-FOOT STOP LOG BAY, IN CFS
FREE FLOW ONLY

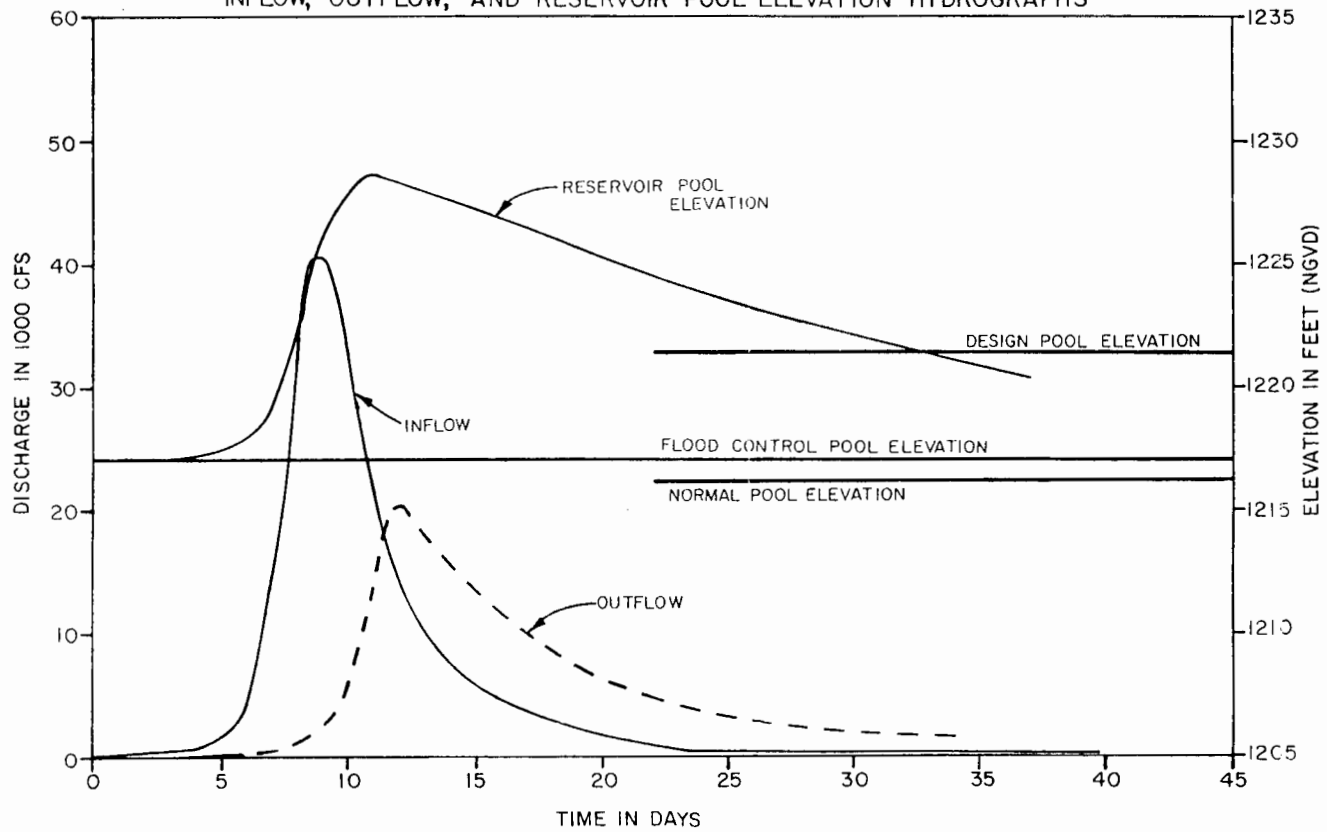
(See Plate 7-2 to determine Free Flow versus Submerged Flow conditions)
See Plate 7-5 for Rating Table

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
WATER CONTROL MANUAL

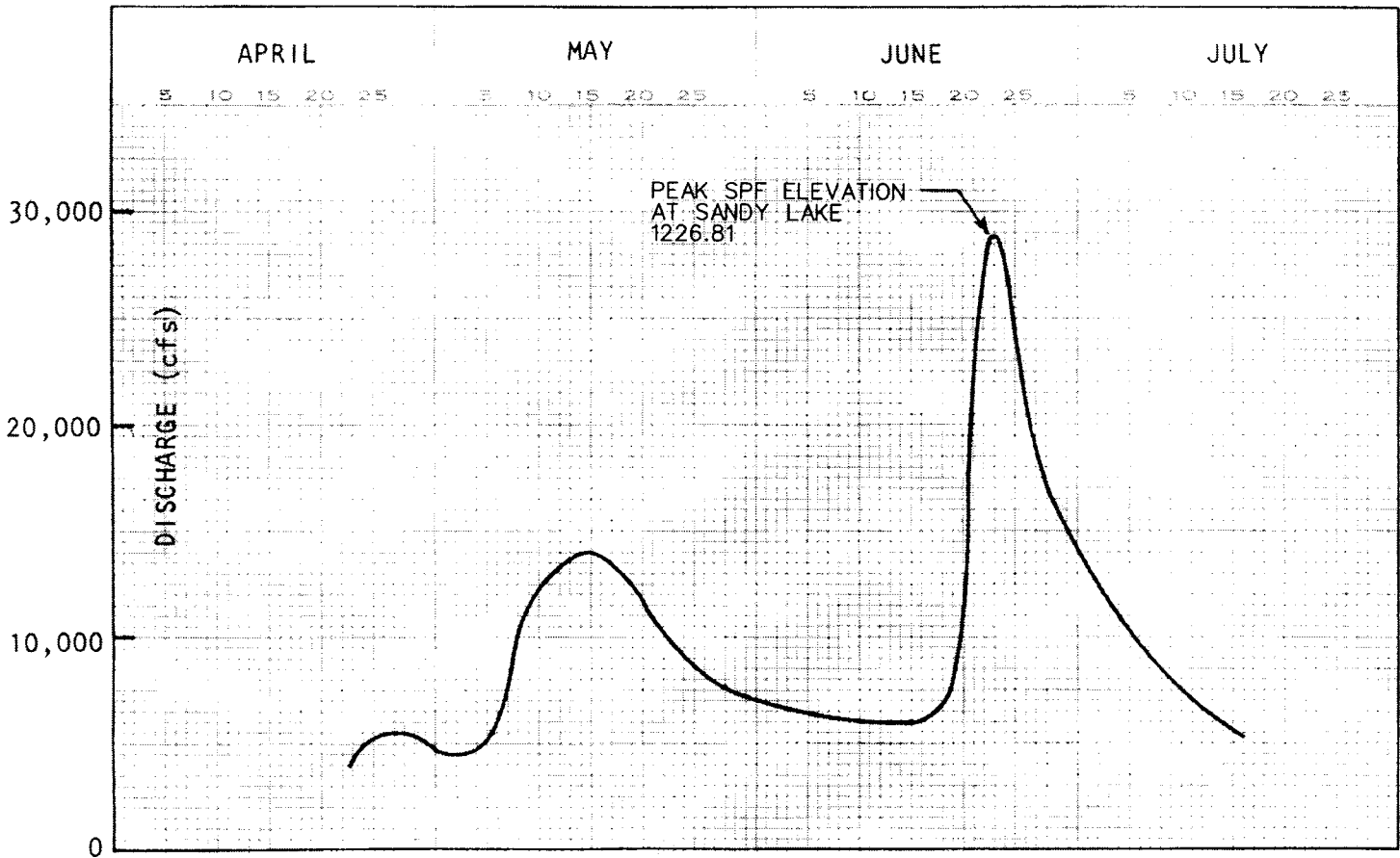
BIG SANDY LAKE DAM
11-FOOT STOP LOG BAY RATING CURVE

U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

PROBABLE MAXIMUM FLOOD - "PROJECT WITHOUT FAILURE"
 INFLOW, OUTFLOW, AND RESERVOIR POOL ELEVATION HYDROGRAPHS



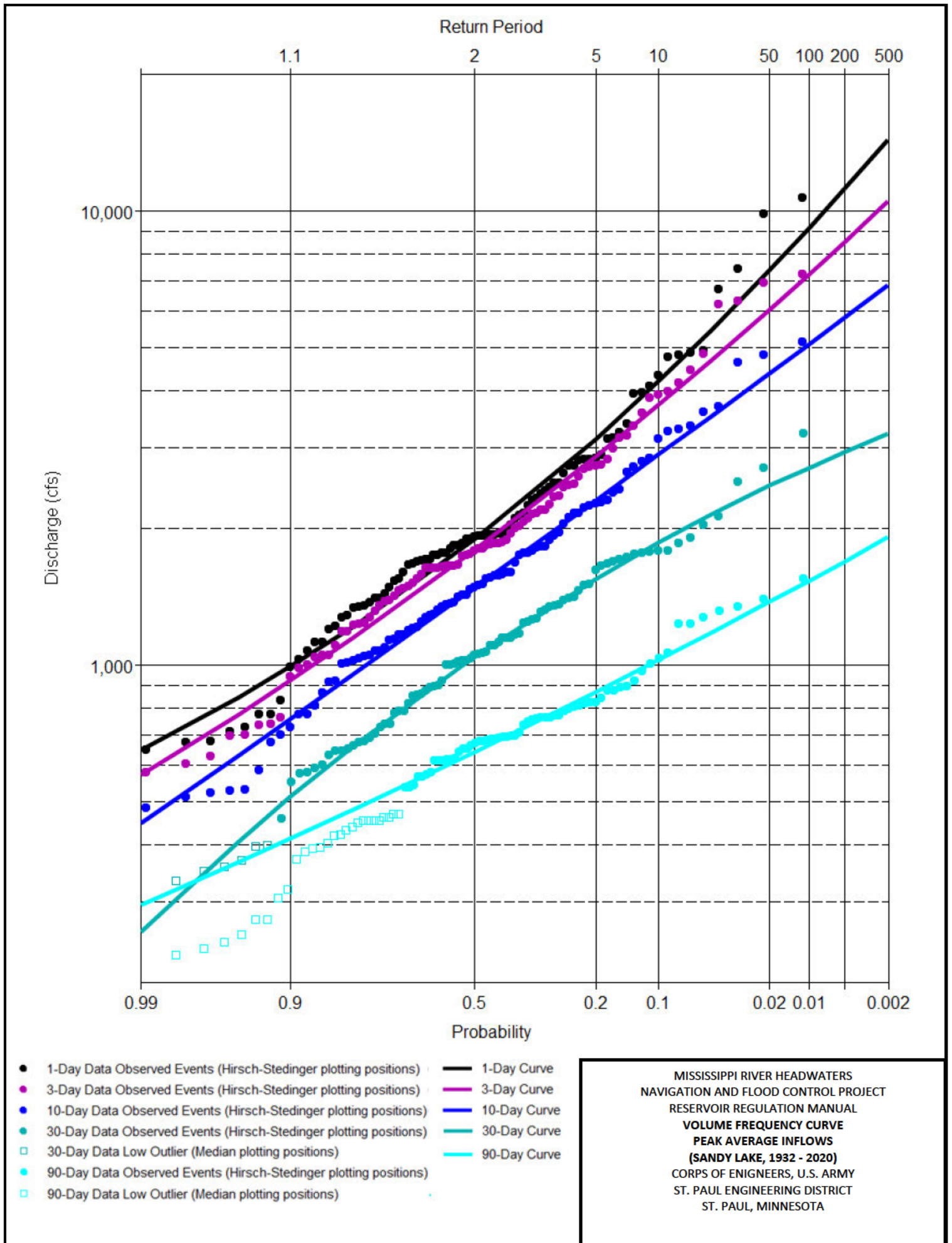
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APPENDIX 4, SANDY LAKE
PMF HYDROGRAPHS
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

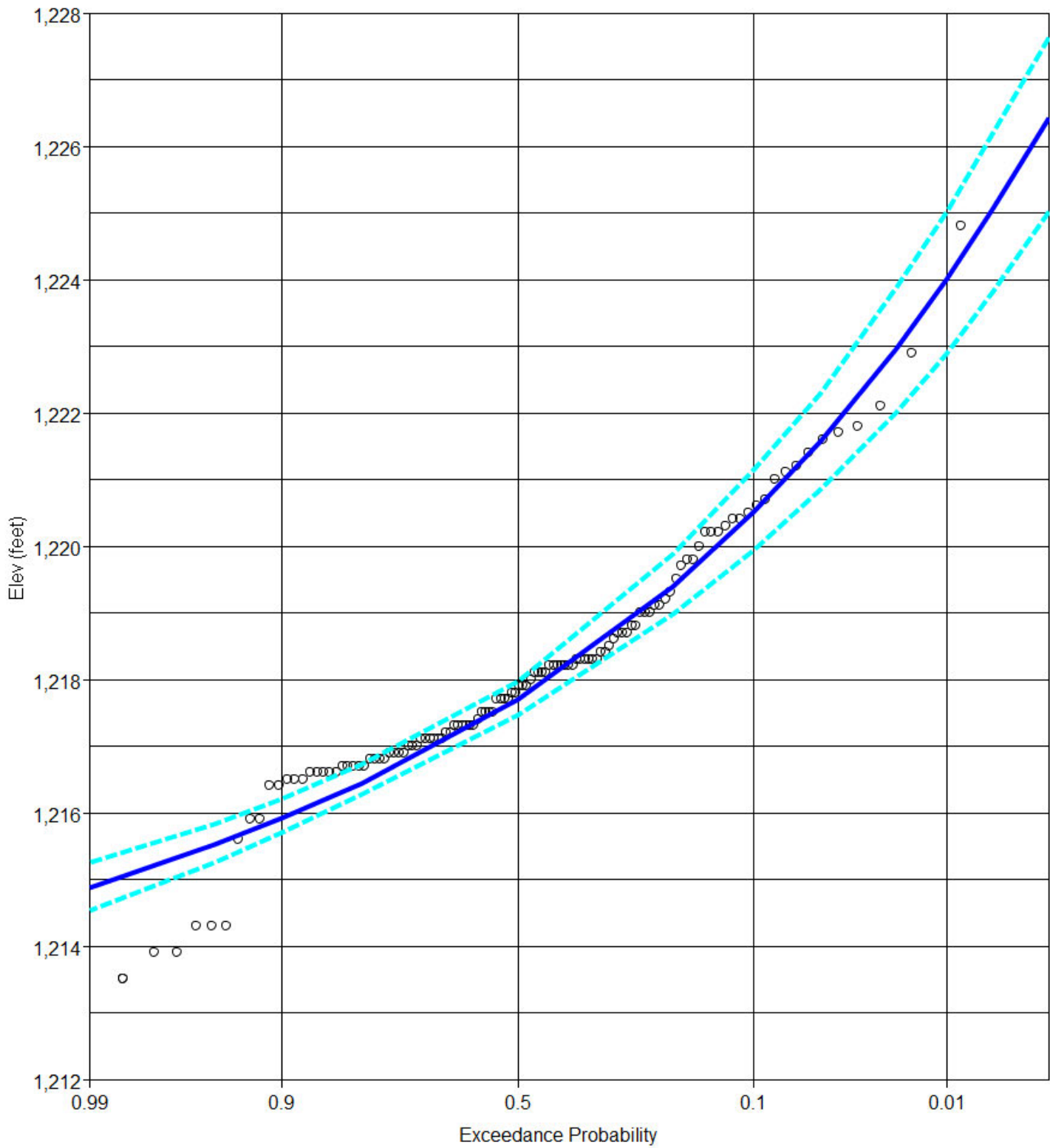


MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 4, SANDY LAKE

**STANDARD PROJECT FLOOD
 (MISSISSIPPI RIVER AT LIBBY)**

U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

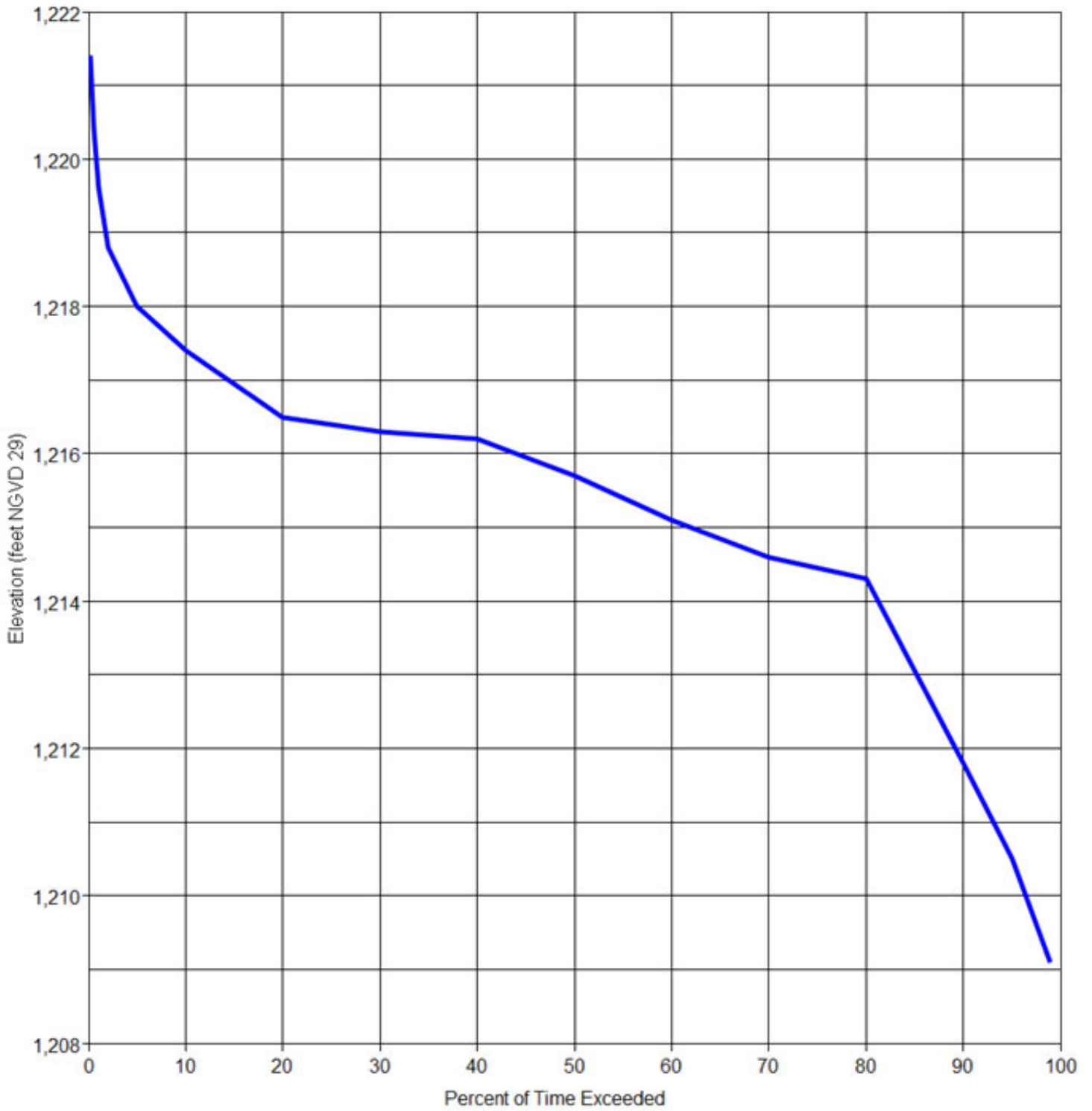




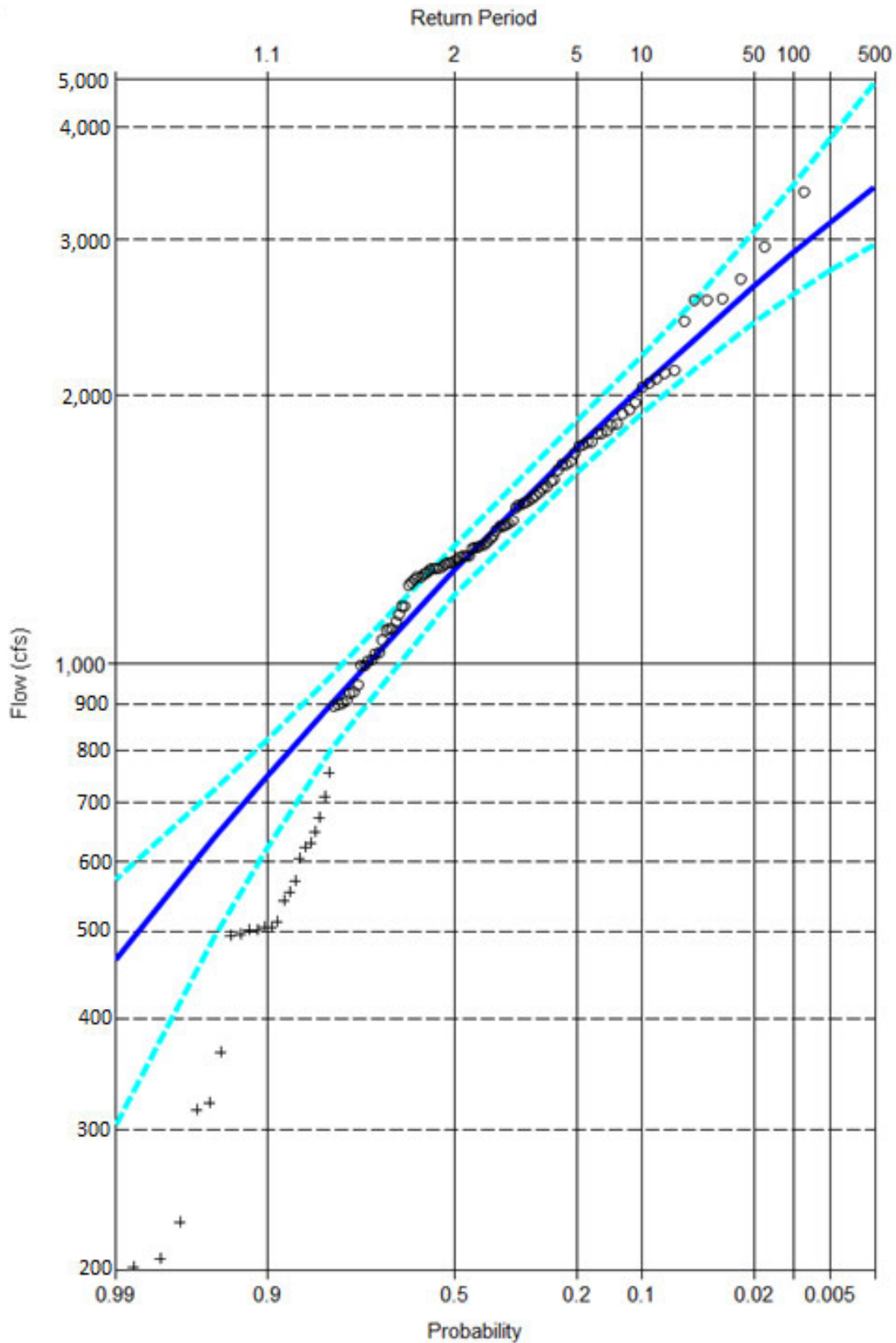
- Data (WEIBULL plotting positions)
- Gumbel Distribution
- - - Gumbel 5.0 Percent Confidence Limits
- - - Gumbel 95.0 Percent Confidence Limits

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
ELEVATION FREQUENCY CURVE
(SANDY LAKE POOL, 1899 - 2020)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

Duration Analysis Plot for Sandy Lake Pool Elev Duation

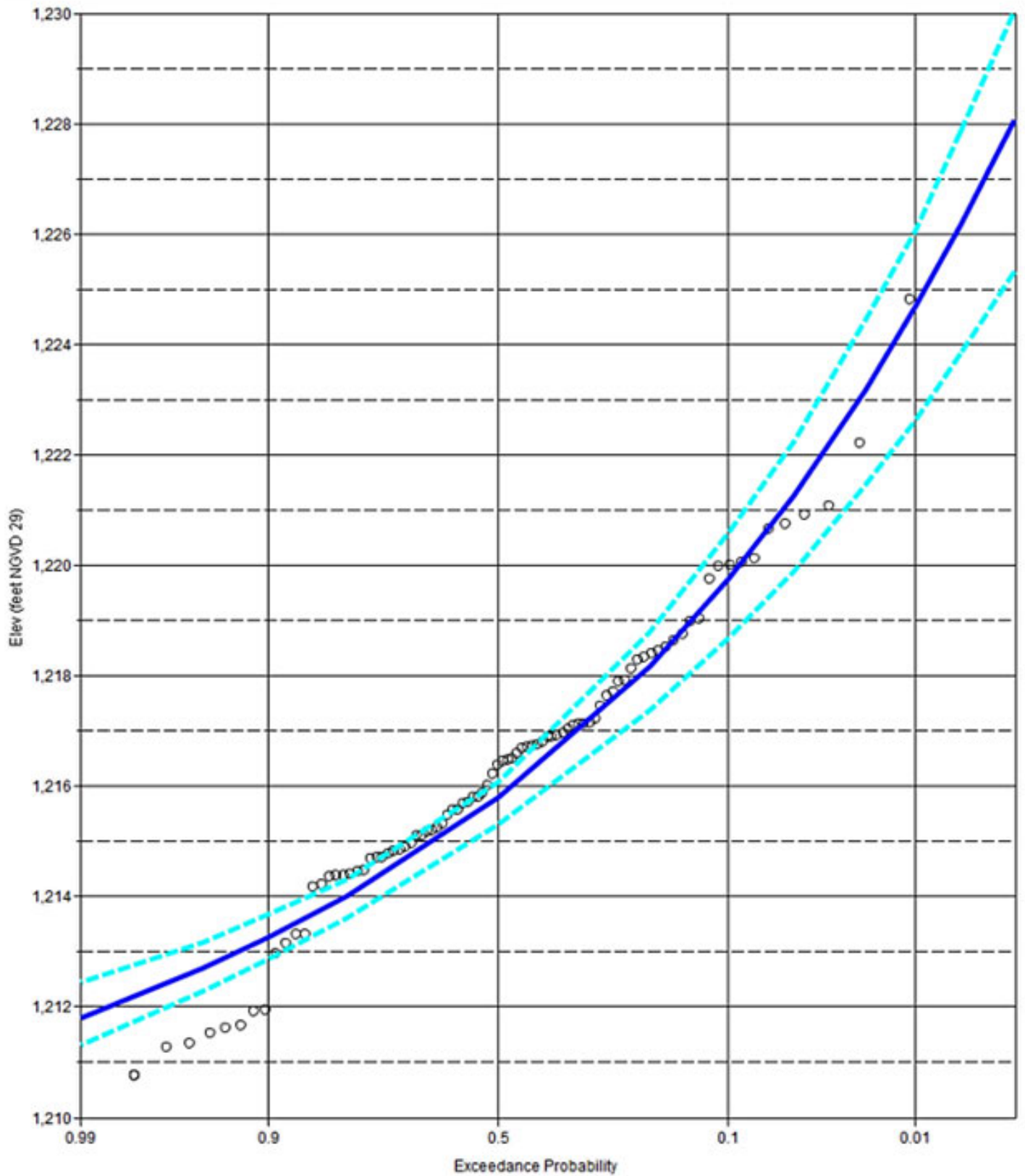


MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
ELEVATION DURATION CURVE
(SANDY LAKE POOL, 1899 - 2020)
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA



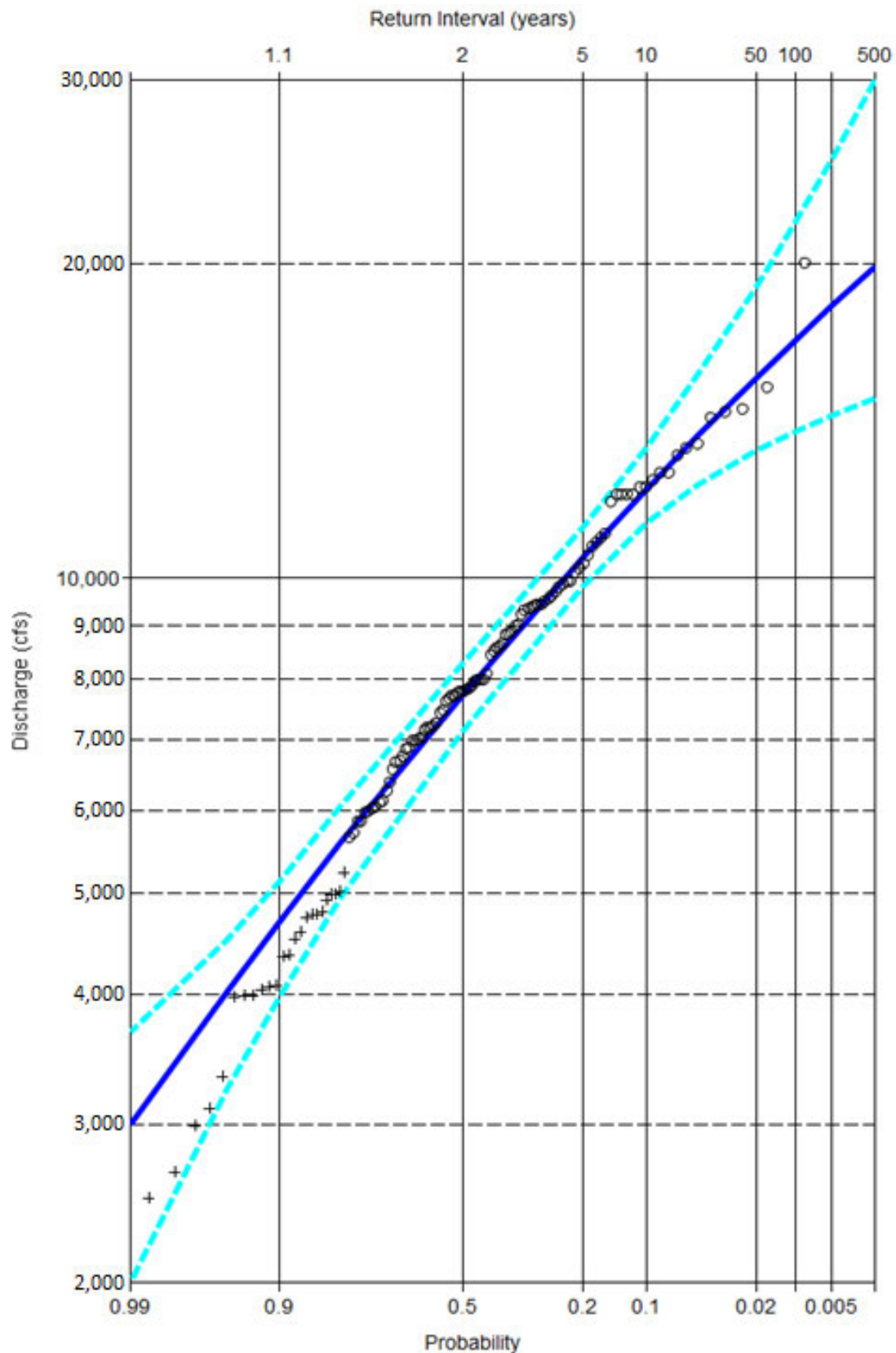
- Computed Curve
- - - 5 Percent Confidence Limit
- - - 95 Percent Confidence Limit
- Observed Events (Hirsch-Stedinger plotting positions)
- + Low Outlier (Median plotting positions)

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
DISCHARGE FREQUENCY CURVE
(SANDY LAKE, 1932 - 2020)
 CORPS OF ENGINEERS, U.S. ARMY
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- Data (WEIBULL plotting positions)
- Gumbel Distribution
- - - Gumbel 5.0 Percent Confidence Limits
- - - Gumbel 95.0 Percent Confidence Limits

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 4, SANDY LAKE
ELEVATION FREQUENCY CURVE
 (SANDY LAKE TAILWATER, 1930 - 2020)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



- Computed Curve
- - - 5 Percent Confidence Limit
- - - 95 Percent Confidence Limit
- Observed Events (Hirsch-Stedinger plotting positions)
- +

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 4, SANDY LAKE
 PEAK DISCHARGE FREQUENCY CURVE
 USGS GAGE 05227500
 MISSISSIPPI RIVER AT AITKIN, MN
 120 RECORDS (1888, 1899, 1902 - 2020)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA