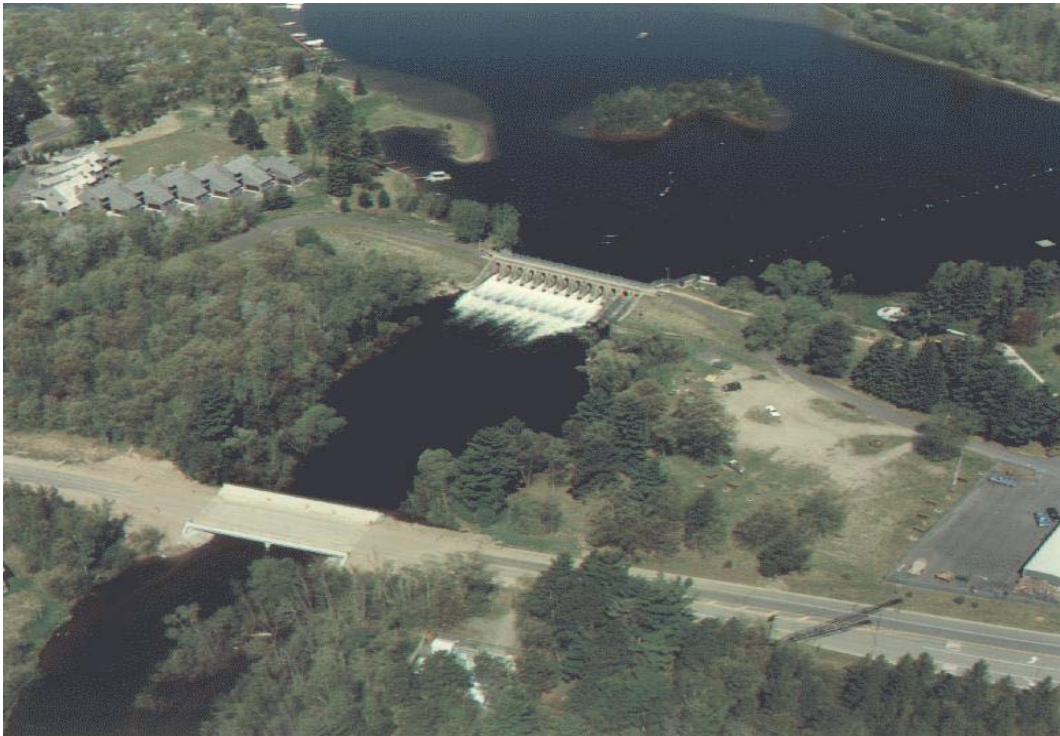




US Army Corps
of Engineers®
St. Paul District

WATER CONTROL MANUAL

MISSISSIPPI RIVER HEADWATERS PROJECT



PINE RIVER DAM AND CROSS LAKE RESERVOIR

PINE RIVER, WHITE FISH CHAIN OF LAKES

MINNESOTA

JANUARY 2003

WATER CONTROL MANUAL

MISSISSIPPI RIVER HEADWATERS PROJECT

**Pine River Dam, Cross Lake Reservoir
Pine River, Whitefish Chain of Lakes**



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

January 2003

PINE RIVER DAM, CROSS LAKE RESERVOIR

Water Control Manual, Cross Lake Reservoir, Pine River Dam
January 2003

NOTICE TO USERS OF THIS MANUAL

This manual has been reviewed and approved by the Mississippi Valley Division Office. If the pending legislation of the Water Resource Development Act changes operating levels or notification procedures, these manuals will have to be revised to reflect those changes.

Corps of Engineers regulations specify that this Water Control Manual be published in loose-leaf form to facilitate modifications. In the future, only those sections, or parts thereof, requiring changes will be revised and replaced.

Two documents used in anticipated low and high pool levels are presented in Exhibit D as Reference No. 12 and contain the latest regulations from Congress.

Exhibit D, Reference No. 12a. A copy of Public Law 100-676, Section 21, November 17, 1988, Water Resources Development Act of 1988 (WRDA 1988) regarding the headwaters of the Mississippi.

The goal of this law is to require the Secretary of the Army to notify Congress when the specified operating limits (both high and low) where going to be exceeded. The references “contingency plan” is included below as Reference 12.b.

Exhibit D, Reference No. 12b. A copy of the Reservoir Regulation Contingency Plan for the Mississippi River headwaters Reservoirs prepared to comply with the Water Resources Development Act of 1988 (WRDA 1988), Public Law 100-676, Section 21 of November 17, 1988 (see Reference 12.a.).

Note. The information used to write this document was extracted from draft copies of the Water Control Manual (dated approx. 1986). The draft manuals contained errors which also appear in the Contingency Plan. Pokegama’s upper notification limit should be elev. 1278.42 ft. (not 1276.42) and the dam should be wide open at 1278.42 ft. (not 1277.92). Sandy’s upper notification limit should be elev. 1221.31 ft. (not 1218.31). Pine’s upper notification limit should be elev. 1235.30 ft. (not 1234.82) due to the dam safety rehabilitation.

These errors are highlighted throughout the manual. When the pending WRDA is approved, these errors will be corrected and revisions will be made to this manual.

**HYDRAULICS AND HYDROLOGY BRANCH
EMERGENCY REGULATION ASSISTANCE PROCEDURES**

In the event that unusual conditions arise during normal business (duty) hours, contact can be made by telephone to Water Control (651.290.5617) or the District Communication Center's VHF-FM radio (call signal WUG6, Hastings, MN). Water Control's radio call signal is WUG613 (St. Paul, MN). During non-duty hours assistance can be achieved by contacting, in the order listed, one of the following persons. Their duty hour (work) phone numbers are also listed. See also **Tables 1-1 and 5-4**.



Name		Number
Jodi Kormanik,	Headwaters Project Regulator	Work 651.290.5646 [REDACTED]
Farley Haase,	Headwaters Project Regulator	Work 651.290.5633 [REDACTED]
Vacant,	Chief, Water Control Section	Work 651.290.5610
Ferris Chamberlin,	Hydraulic Engineer	Work 651.290.5619 [REDACTED]
Michael Knoff,	Chief, Hydraulics and Hydrology Branch	Work 651.290.5600 [REDACTED]
Michael Bart,	Chief, Engineering Division (Dam Safety Officer)	Work 651.290.5303 [REDACTED]

**Mississippi River Headwaters Project
Pine River Dam, Cross Lake Reservoir
Pine River, Whitefish Chain of Lakes**

**U.S. Army Corps of Engineers
St. Paul District
January 2003**

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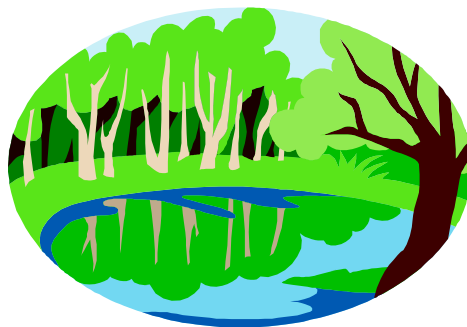


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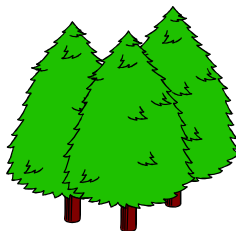
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National Geodetic Vertical Datum Reference

All elevations in this manual use the 1929 National Geodetic Vertical Datum (1929 NGVD) unless otherwise stated.

Metric Equivalents and Conversions

Length:

1 Centimeter = 0.394 inches

1 meter = 3.2808 feet

1 kilometer = 0.621 miles

Area:

1 square mile = 640 acres = 2.59 kilometer²

1 meter² = 10.764 feet²

1 kilometer² = 0.386 miles²

1 hectare = 2.471 acres

Volume/Flow:

1 cfs = 448.831 gallons per minute

1 cfs x 1 day = 1 SFD = 86,400 ft³

1 SFD = 1.9835 acre-feet

1 sq. mi. inch = 26.9 SFD

1 acre-foot = 43,560 ft³ = 325,900 gallons

1 meter³ = 35.31 feet³

1 meter³ = 1.308 yards³

1 meter³ = 0.81 x 10⁻³ acre-feet

1 meter³/second = 35.31 feet³/second

Temperature:

(Degrees Fahrenheit - 32)/1.8 = Degrees Celsius



World Wide Web Internet Address

<http://www.mvp-wc.usace.army.mil>



I - INTRODUCTION

1-01. Authorization. This manual was prepared in compliance with the following guidance: 1) Engineering Regulation 1110-2-240, titled "Water Control Management", dated 30 April 1987; 2) Engineering Manual 1110-2-3600, titled "Management of Water Control Systems", dated 30 November 1987; 3) DIVR 1110-2-240, 5 August 1992; 4) Engineering Regulation 1110-2-8156 titled, "Preparation of Water Control Manuals", dated 31 August 1995.

The previous manual (1963 Master Regulation Manual) for the Mississippi River Headwaters Reservoirs was authorized by multiple letter from the Office, Chief of Engineers, dated 8 May 1951, to the Division and District Engineers, subject: Operation of Flood Control Reservoirs, Re-submission of Reservoir Regulation Manuals, as required by Engineering Manual 1110-2-3600, **Chapter 6**, dated 25 May 1959.

1-02. Purpose and Scope. The purpose of this manual is to provide guidance and instruction for project personnel and as a reference source for others who may be involved with, or affected by, project regulation. The manual is for daily use in Water Control Section activities for essentially all foreseeable conditions. 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. The 1963 Master Regulation Manual, referred to in **Paragraph 1-01**, contained the Water Control Plan for all six reservoirs. It is now superseded by individual Water Control Manuals for each of the six Mississippi Headwaters reservoirs. The basic Water Control Plan in the 1963 manual remains unchanged in the individual manuals with the following notable exceptions: Lake Winnibigoshish's summer operating band was lowered

one foot in 1975, and Pine River/Cross Lake's upper operating limit was raised 0.48 feet as a result of dam safety work, which was completed in 2002. Prior reports pertinent to this manual are as follows:

- a. 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.
- b. The Upper Mississippi River Reservoirs, Gopher Historian, Lucile M. Kane, Manuscripts Curator, Minnesota Historical Society, Spring 1962.
- c. Master Reservoir Regulation Manual, Headwaters Dams and Reservoirs, U.S. Army Engineer District, St. Paul, Corps of Engineers, St. Paul, Minnesota, April 1963.
- d. 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).
- e. 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).
- f. Environmental Review of the Headwaters of the Mississippi River Reservoir Projects, Bemidji College, 1973.

- g. Review of Design Features of Existing Dams at Mississippi River Headwaters Reservoirs, RCA ENGCW-(OT)761, St. Paul District, Corps of Engineers, March 1974.
- h. 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.
- i. Mississippi River Headwaters - Master Plan for Public Use Development, St. Paul District, Corps of Engineers, August 1977.
- j. 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.
- k. 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.
- l. 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.

- m. Mississippi River Headwaters Lakes Feasibility Study, Main Report and Appendices, Two Volumes, St. Paul District, Army Corps of Engineers, 1982.
- n. 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.
- o. Area-capacity Table Reevaluation for the Mississippi River Headwaters Study, St. Paul District, Corps of Engineers, August 1983.
- p. 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.
- q. Emergency Plan, Dam Safety Program, Flood Control Project, Pine River Dam and Reservoir, St. Paul District, Corps of Engineers, September 1990.
- r. Mississippi River Headwaters Lakes in Minnesota - Low Flow Review, St. Paul District, Corps of Engineers, October 1990.
- s. Drought Contingency Plan, Appendix DCP to the Pine River Dam and Reservoir Regulation Manual, Mississippi River Headwaters, Corps of Engineers, St. Paul District, September 1992 (Draft). (This draft was never officially incorporated as an appendix. The final will be a stand-alone document.)

- 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, Pine River Dam and Reservoir, Corps of Engineers, St. Paul District, October 1992.
- 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. Reconnaissance Report, Dam Safety Assurance Program, Pine River Dam, Cross Lake, Minnesota, St. Paul District, Corps of Engineers, 13 September 1993, revised 21 December 1994.
- y. System-Wide Low-Flow Management Plan, Mississippi River above St. Paul, Minnesota, Interagency Agreement, September 1996.
- z. Pine River Dam, Cross Lake, Minnesota, Dam Safety Assurance Program, Design Memorandum and Environmental Assessment, St. Paul District, Corps of Engineers, March 1997.

1-04. Project Owner. The United States Government is the owner of the project.

1-05. Operating Agency. The U.S. Army Corps of Engineers, St. Paul District, Construction-Operations Division is responsible for the operation and maintenance of the Pine River Dam, Cross Lake Reservoir Project. Regulation instructions for the project are provided by the District's Engineering Division Water Control Section.

The Manager is stationed at Pine River Dam. The Operational Project Manager, Headwaters Project Office is located at Pokegama Lake Dam. Information on contacting the Manager and the Operational Manager is listed in **Table 1-1**.

Table 1-1

Project Office Points of Contact

Name	Number
Ray Nelson, Manager 35507 County Road Nos. 3 and 66 P.O. Box 36 Cross Lake, Minnesota 56422-0036	Work 218.692.2025 After Hours 218.546.6219 Cell Phone 651.261.3567 Fax 218.692.4911 VHF Radio WUG 640 FM Radio 6400
Robert Gossett, Assistant	Work 218.692.2025 After Hours 218.963.3718
John O'Leary, Operations Project Manager Headwaters Projects Office Pokegama Lake Dam 34385 Highway No. 2 West Grand Rapids, Minnesota 55744-9663	Office 218.327.4027 Cell Phone 651.261.6030 Fax 218.327.3162 VHF Radio WUG 639 Mobile Radio 6390

1-06. Regulating Agency. The regulation of the project is under the supervision of the Water Control Section within the St. Paul District, U.S. Army Corps of Engineers. Information on contacting Water Control is listed in the introduction to this manual.



II - DESCRIPTION OF PROJECT

2-01. Location. The Pine River Dam, Cross Lake Reservoir Project, is part of the Mississippi River Headwaters basin and is located in Crow Wing County, 22 miles north of Brainerd, Minnesota. The dam is on the Pine River at the outlet of Cross Lake, 14.5 river miles above the junction of the Pine and Mississippi Rivers, 199.0 Mississippi river miles above St. Paul, Minnesota, at Mississippi river mile 1038.3 above the Ohio River. The dam is at the village of Cross Lake, Minnesota, and is sometimes referred to as the Cross Lake Dam. The General Location Map and General Plan are presented on **Plates 2-1 and 2-2**, respectively.

2-02. Purpose.

a. Flow Augmentation for Navigation. The original authorized purpose of the six Headwaters Reservoirs, as authorized in the Rivers and Harbors Act of 1880, Public Law # RHA 1880, was to increase Mississippi River discharges during low-flow periods to aid navigation between St. Paul, Minnesota, and Lake Pepin, near Lake City, Minnesota (see **Paragraph 3-02**). However, the need for flow augmentation from the reservoirs was greatly reduced after completion in the 1930's of the Mississippi River 9-foot channel project, the system of 29 locks and dams from Minneapolis, Minnesota to St. Louis, Missouri with the primary purpose of maintaining a depth of nine feet for navigation. The project has rarely been operated for flow augmentation since the 1930's. Releases for navigation occurred during World War II due to low water problems in the St. Louis, Missouri area (Chain of Rocks, see **Paragraph 3-05**). Releases from Pine River Dam for downstream navigation cannot be made without the approval of the Chief of Engineers (see **Exhibit D, Reference 3**).

b. Other Purposes. Other authorized purposes of the reservoirs include flood control, recreation, hydropower, 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**.

Table 2-1 Pine River Dam, Cross Lake Reservoir Project Authorized Purposes Assigned by Congress		
Authorized Purpose	Public Law No.	Description
Flood Control	74-738	Flood Control Act of 1936
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	92-500	Federal Water Pollution Control Act Amendments of 1972
Fish and Wildlife	93-205	Conservation, Protection, and Propagation of Endangered Species Law of 1973

2-03. Physical Components.

a. Control Structure. The control structure consists of reinforced concrete abutments and piers supported on timber pilings. The total length of the structure between abutments is 150 feet. As the result of a dam safety study, larger gates were installed in 2001 in order to increase the discharge capacity of the structure (see the March 1997 report in **Paragraph 1-03**). The design for the dam safety project was done in metric units so data in both metric and English units are listed in this discussion to facilitate references to drawings.

The aforementioned larger gates (there are a total of 13 gates) were first put into operation on 10 July 2001 at 1600 hours. They are dual-leaf slide gates. The lower leaf section is 7.6 feet tall while the upper leaf section is 7.5 feet tall. When the lower leaf raises to its top elevation (raised approx. 7.6 ft.), it engages the bottom half of the upper leaf such that both gate leafs rise in tandem from that point.

Each gate bay has an archway on the top as opposed to the bay being a rectangular opening (see **Plate 2-3**). The gate sill is at approximately elevation 1216.65 feet (approx. 370.83 meters) while the top of the gate bay (top of the archway) is at elevation 1234.32 feet (376.22 meters). The top of a dual-leaf gate in the closed position is at elevation 1231.73 feet (375.43 meters), which also corresponds to the location, near the top of the gate bay, where the curve of the archway begins. As a result, all thirteen of the gates must be raised to some degree to prevent water from spilling over the top of the gates when the pool is above elevation 1231.73 feet (i.e. surcharge). When the gates are raised as high as they can go, the elevation of the gate bottom is at approximately elevation 1233.60 feet (376.00 meters), which is approximately 0.72 feet below the top of the archway. The dual-leaf slide gates have a total height of 15.1 feet when closed. Each one is 6.0 feet wide, which results in a spillway width of 78 feet. For the Inflow Design Flood (70 percent of the PMF) the pool level will reach elevation 1235.3 feet (376.52 meters) and the outflow (with the gates wide open) will be equal to 16,300 cfs (462 cms) (see **Chapter 8, Paragraph 8-02**).

The elevation of the concrete spillway apron below the dam corresponds to the gate sill elevation of approximately 1216.65 feet (approx. 370.83 meters). A walkway with a top elevation of 1237.20 feet (377.10 meters) is supported by the structure. The top of the control structure corresponds to the top of the concrete parapet wall at elevation 1240.3 feet (378.05 meters). Details can be found on **Plates 2-3 and 2-4**. See **Paragraph 3-05** for information on the control structure that existed prior to the aforementioned dam safety rehabilitation work. See also **Exhibit A**.

b. Emergency Spillway. There is no emergency spillway at Pine River Dam. All flow is through the main control structure (slide gates), which has the capacity to pass 70 percent of the Probable Maximum Flood. See **Chapter 8** for information on the Spillway Design Flood.

c. Embankments and Perimeter Dikes. Cross Lake Reservoir is contained by one main embankment and 17 perimeter dikes. The main embankment extends out from the right side of the control structure about 158 feet, and out to the left side about 1,611 feet. The original perimeter dikes were constructed in the late 1800's to early 1900's at various locations around the rim of the reservoir.

Prior to the dam safety rehabilitation, the main embankments at Pine River Dam partly consisted of earth fill with a timber diaphragm and a core filled with puddled clay. During the rehabilitation the embankment was strengthened with sheetpiling. A majority of the main embankment was raised with a concrete parapet I-wall cantilevered on steel sheetpile driven through the embankment. The total length of the main embankments, excluding the control structure, is 1,769 feet with a top elevation of 1240.3 feet (378.05 meters). Elevation 1240.3 feet provides 5 foot of freeboard above the Inflow Design Flood (70% of the Probable Maximum Flood) maximum pool elevation of 1235.3 feet (376.52 meters). The perimeter dikes have a combined total length of 9,805 feet and are designed to prevent uncontrolled overflow of stored

water during extreme flood events. The locations of these dikes are shown on **Plate 2-5** and are discussed further in **Paragraph 3-06**. The Pine River reservoir perimeter dikes are described in **Table 2-2**.

Only sixteen perimeter dikes existed prior to the Pine River Dam rehabilitation. A low swale near Dike No. 10 necessitated construction of an additional dike (Dike No. 10b) and the original Dike No. 10 was renumbered to Dike No. 10a (for a total now of 17 dikes). A low area was also identified crossing West Shore Drive to the north of Dike No. 11. Dike No. 11 was renumbered to Dike No. 11a and an additional perimeter dike, designated 11b, was planned for construction across the low area on Government property. This plan changed when verbal agreements with Ideal Township were reached such that Ideal Township would raise West Shore Drive to elevation 1240.3 feet when future road upgrades are made in this area. Currently this area would need to be sandbagged to provide flood protection to elevation 1240.3 feet. The approximate future location of Dike No. 11b is shown on **Plate 2-5** for completeness.

Generally, the perimeter dikes were constructed originally with horse drawn scrapers and placed with little compaction. They were, however, constructed with wide top widths and gentle sideslopes. Eleven of the seventeen Cross Lake reservoir perimeter dikes are part of a road system in the area. The remaining dike Nos. 2, 3, 10b, 12, 15 and 16 (all without road surfacing) are clear of all trees and brush on at least the top of dikes so they can easily be accessed for inspection or emergency measures. Some of the dikes have been cleared of trees and brush along the downstream toe area for inspection purposes while others remain fully vegetated. For the dikes that were not cleared, computed seepage gradients were so low that the potential for seepage erosion was highly unlikely. Signs identify the dikes and most of the property boundaries are denoted by property boundary markers and line posts. Some property boundaries were changed in the early 1990's after a comparison was made of the boundaries to the actual dike locations. By May 1993, lands and easements were acquired at perimeter dike locations so that access to the dikes (except dike No. 2) would be available at all times and so that the dikes and dike abutment areas could be maintained. Generally dike easements were obtained except at

dikes No. 13 and 14 where seepage concerns justified acquiring additional property in fee title. Although boundaries were changed, the boundary signage has not been updated to represent current conditions or dike easement locations.

**Table 2-2
Cross Lake Reservoir, Pine River Dam Perimeter Dikes**

Dike No.	Top Width (feet)	Length (feet)	Maximum Height (feet)	Lake Side Slope Protection	Controlling Dike Elev. In Feet ¹ 1929 NGVD	Existing Dike Side Slope (V:H)	
						Lake	Land
1	40	600	8.5	Vegetated	1243.5	1:4	1:12
2	40	450	9.0	Vegetated	1242.0	1:4	1:5
3	45	540	10.0	Vegetated	1242.0 ^{2,9}	1:4	1:5
4	25	390	7.0	Vegetated	1240.6 ^{2,9}	1:4	1:8
5	40	900	7.7	Vegetated	1240.7 ⁹	1:3	1:5
6	45	1,200	6.0	Vegetated	1241.1	1:3	1:4
7	40	300	7.0	Vegetated	1242.6 ³	1:4	1:4
8	35	750	10.5	Vegetated	1242.9 ⁴	1:3	1:3.5
9	40	400	9.0	Vegetated	1242.3	1:3	1:4
10a	40	400	11.5	Riprap	1242.5 ⁵	1:4	1:4
10b	40	175	9.0	Vegetated	1240.3 ⁶	1:3	1:5
11a	35	1,000	13.5	Riprap	1242.4 ⁷	1:3	1:5
11b	10	240	3.3	Vegetated	1238.5 ^{8,9}	1:3	1:5
12	20	180	8.0	Vegetated	1243.2	1:4	1:4
13	40	1,060	22.0	Riprap	1242.9	1:4	1:4
14	40	450	23.0	Riprap	1240.7	1:4	1:5
15	50	550	12.0	Vegetated	1242.9	1:5	1:4
16	20	220	13.0	Riprap	1240.6	1:3	1:5

1. Main embankment minimum elevation = 70% PMF + 5 ft. of freeboard = 1240.3 ft. Normal pool elev. = 1229.32 ft.
2. Dike Nos. 3 and 4 are connected by CSAH No. 3. CSAH No. 3 at dike No. 3 is at elevation 1238.85 ft (see Note 9.).
3. Elevation 1241.2 ft. adjacent to Dike No. 7 controls.
4. Elevation 1241.2 ft. adjacent to Dike No. 8 controls.
5. Original dike No. 10 was renumbered to 10a when an additional dike (10b) was constructed across a nearby low swale.
6. Dike No. 10b was constructed across a low swale east of dike No. 10a in an area formerly at elevation 1235.1 ft.
7. Dike No. 11 was renumbered to 11a. See Note No. 8.
8. Dike No. 11b was not constructed as part of the dam safety rehabilitation project. At some point in the future it will be relocated from its original planned location to beneath West Shore Drive when this road is raised by Ideal Township.
9. Sandbag closures are required between Dike Nos. 3 and 4 along CSAH No. 3 (elev. 1238.85), at the east end of Dike No. 5 on top of Highway 103 (elev. 1239.9 ft.) and at future dike No. 11b on top of West Shore Drive (see Note No. 8) to bring the elevation at these locations up to 1240.3 ft.

Date obtained from the St. Paul District Geotechnical Section in May of 2002. Also see the March 1997 Design Memorandum (see Paragraph 1-03).

See Table 4-3 in this manual for a list of historical lake elevations.

d. Reservoir. The Pine River Dam controls runoff from 562 square miles of the Pine River drainage basin. The backwater effect from the dam affects 15 lakes, which are connected to the reservoir (see **Table 2-3**). Information on reservoir storage can be found in **Exhibit F**.

Table 2-3	
Lakes Affected by Pine River Dam Operation in the Whitefish Chain of Lakes	
1. Cross	9. Big Trout
2. Daggett	10. Arrowhead
3. Little Pine	11. Pig
4. Rush	12. Clamshell
5. Island	13. Bertha
6. Ox	14. Upper Hay
7. Upper Whitefish	15. Lower Hay
8. Lower Whitefish	

2-04. Related Control Facilities. The Cross Lake Reservoir, Pine River Dam Project does not contain any additional integrated components (see also **Paragraph 3-04**).

2-05. Real Estate Acquisition.

a. Dam Site and Recreation Area. The Federal Government holds fee title to 475.58 acres of land associated with the project. The Corps of Engineers has jurisdiction over a number of scattered parcels besides the Ronald Louis Cloutier Recreation Area at the dam. These include lands on South Cross Lake Bay, Clamshell Lake, Upper Whitefish, Arrowhead Lakes and a site at Rush Lake (see **Plate 2-8**).

b. Flowage Rights. In addition to the above, the Corps has flowage rights to 21,708 acres of land around Pine River/Cross Lake reservoir. See **Plates 2-8 through 2-11** for the location of lands on which the Corps of Engineers holds fee title or flowage rights. **Table 2-4** contains a summary of the flowage rights elevations for the Headwaters reservoirs. See **Exhibit D, Reference 8** for critical information about the assumptions behind the flowage elevations listed in **Table 2-4**.

Table 2-4
Mississippi River Headwater Reservoir System
Operating Levels and Flowage Rights Elevations and Stages in Feet
(see also Paragraphs 7-16, Tables 3-1, 7-1 and 7-2 and Exhibit D Reference 8)

	Winni- bigoshish	Leech	Poke- gama	Sandy	Cross L. Pine R.	Gull
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. Normal Summer Range/Band Stage in Feet Middle of the Summer Band Elev.	1297.94-1298.44 9.0 - 9.5 1298.19	1294.50-1294.90 1.8 - 2.2 1294.70	1273.17-1273.67 8.75 - 9.25 1273.42	1216.06-1216.56 8.75 - 9.25 1216.31	1229.07-1229.57 12.75 - 13.25 1229.32	1193.75-1194.00 6.0 - 6.25 1193.87
3. Total Operating Range 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. Flowage Rights Acquired To Approx. this Stage (see Note 5)	14.2 + 3.72 = 17.92 +	5.24 + 4.0 = 9.24 +	12.0 + 4.0 = 16 +	11.0 + 4.0 = 15 +	18.5 + 4.0 = 22.5 +	7 ft. See Exh. D, Ref. 8
Gage Zero Elev., 1929 NGVD Datum	1288.94	1292.70	1264.42	1207.31	1216.32	1187.75
5. Flowage Rights To Approx. This Elev., Ft, 1929 NGVD (see Note 5)	1306.86 1929 NGVD	1301.94 1929 NGVD	1280.42 1929 NGVD	1222.31 1929 NGVD	1238.82 1929 NGVD	1194.75 1929 NGVD
6. Gage Zero Elev., USE Datum	1290.08	1293.76	1265.27	1209.00	1218.20	1190.00
7. Flowage Rights Acquired To Approx. Elev. in Ft., U.S.E. Datum	1308.0 USE Datum	1303.0 USE Datum	1281.27 USE Datum	1224.0 USE Datum	1240.70 USE Datum	1197.0 USE Datum
8. Gage Zero Elev., 1912 M.S.L. adj.	1289.47	1293.23	1264.89	1207.70	(8.)	1188.14

1. The lower limit was generally the sill elev. of the dam at that time. The upper limits were determined through engineering judgement and were set, with the exception of Gull, approx. 4 ft. below the flowage rights elevation. Leech's lower limit is sometimes listed as a positive 0.5 instead of the correct negative 0.5 value.
2. The most desirable levels for the summer season. Lake Winnibigoshish's band was lowered one foot in 1975 and Pokegama's was lowered 0.25 feet in 1952.
3. The Total Operating Range is in accordance with the latest regulations and designs. See **Tables 3-1, 7-2** and **Para 7-16**.
4. Flowage rights on the Cass L. Chain obtained to approx. a 18.92 ft stage which is elev. 1307.86 ft. in the 1929 NGVD.
5. See **Exhibit D, Ref. No. 8.c.** for details and clarification of flowage rights. The Corps began using the 1929 NGVD for the Headwaters reservoirs in July of 1973 and began to report water levels in elevation as opposed to stage.
6. The U.S. Engineer (USE) Datum was in use prior to July 1973 and water levels were reported in stage.
7. Provided here for historical reference. Elevs. on the original flowage survey maps are generally listed in the USE datum.
8. Provided for additional reference. 1912 M.S.L. adj. information for the Pine River Dam gage zero is not available.

2-06. Public Facilities. The Corps owns two recreation areas and one boat-launch area on the Cross Lake Reservoir (Whitefish Chain of lakes). See also **Paragraphs 7-06 and 8-03.**

The Ronald Louis Cloutier Recreation Area, located at Pine River Dam, consists of 42 acres of land (see **Plate 2-12**). The topography is gently rolling with slopes well below five percent. The average elevation of the site is approximately 1235 feet. Oak, birch, and pine trees shade the area, which has been completely developed with campground and day use recreation facilities. There are 119 campsites, two of which are handicap-use designed and 69 have electrical hookups. An inventory of the facilities available at this recreation area is included in **Table 2-5**.

The Clamshell Recreation Area is located 12 miles west of Cross Lake on County Road 16. It consists of five acres of land on the north shore of Clamshell Lake. Facilities include a launching ramp, two vault toilets and parking for 23 automobiles and boat trailers. No overnight camping facilities are provided.

The boat-launch area is on the east side of Trout Lake about three miles from Pine River Dam. It consists of approximately two to three acres of land. The area is accessible from Highway 66 and has parking for 15 cars and trailers. No overnight camping facilities are provided.

Table 2-5
Ronald Louis Cloutier Recreation Area Facilities
Pine River Dam, Cross Lake Reservoir

Description	Facility	Description	Facility
Mixed Camping	119	Maintenance Facility	X
Camping w/ Electric Hookup	69	Residence	0
Tent Camping	X	Access to the Recreation Areas	X
Picnic Units	119	Internal Vehicular Circulation	X
Swimming Beach	2	Walkways	X
Boat Launch	2	Bulletin Boards	X
Boat Dock	2	Camp Cleaning Tools	X
Canoe Launch	X	Picnic Tables	140
Day Use Area	X	Picnic Shelters	0
Playground	X	Fireplace	X
Parking	60	Firewood	X
Ranger Station	X	Barbecue Units	X
Interpretive Facilities	0	Trash Receptacles	X
Interpretive Trails	0	Movie Screen	X
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	X	Telephones	X
Sewage Treatment Plant	X		

119 = No. Of Units

X = Available

0 = Not Available



III - HISTORY OF PROJECT

3-01. Authorization. The River and Harbor Acts of 14 June 1880 and 2 August 1882 authorized the construction of dams at each of the six Mississippi River Headwaters lakes for the purpose of forming reservoirs. The lakes affected by these acts include Winnibigoshish, Leech, Pokegama, Sandy, Cross (Pine River) and Gull. Following authorization of the reservoirs, Congress directed the Secretary of War to establish regulations governing their operation through the River and Harbor Act of 11 August 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 would 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 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 (see **Paragraph 3-05**).

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 **Paragraph 1-03**). For information on the effects that the reservoir project had on Indian Tribes see Carroll: 1990 and Treuer: 1992 (see **Paragraph 1-03**).

3-03. Construction. The construction of the dam on Pine River at Cross Lake commenced early in 1884 and it was in operation by March 1886. 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. The replacement of Pine River Dam began in 1905 and was complete by 1908. 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 perimeter dikes have been modified at various times (see **Chapter 2 and Paragraph 3-06**).

The downstream timber apron was replaced by concrete in 1971. The timber slide gates were replaced with metal slide gates in 1972. These slide gates were replaced with dual-leaf slide gates in 2001. The dual-leaf gates are 6.0 feet wide and extend almost the entire height of each bay (see **Paragraph 2-03**). In addition, all the bays now have slide gates whereas the previous configuration had stop logs in two bays. The larger gates were put into operation on 10 July 2001 at 1600 hours. See **Paragraph 3-05.q**.

3-04. Related Projects. Cross Lake reservoir (Pine River Dam) is one of six Mississippi River Headwaters reservoirs. It is the fifth proceeding downstream, following Sandy Lake and preceding Gull Lake. The regulation of Cross Lake reservoir is independent from the other Mississippi River Headwaters reservoirs. The other Headwaters reservoirs include Lake Winnibigoshish, Leech Lake and Pokegama Lake.

3-05. Modifications and Deviations to Regulation. 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 with the last addition from Congress occurring in 1988. A copy of the regulation, which incorporates all the changes made through the 1944 order, can be found in the Code of Federal Regulations, Title 33, Section 207.340 while the 1988 addition can be found in Public Law 100-676, Section 21 of the Water Resources Development Act of 1988 (see **Exhibit D**). A description of the various regulation orders, as well as various other rules, guidelines and deviations that have occurred, are listed below. Also see **Table 3-1 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 (see **Exhibit D, Reference 1**). 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, 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 **Table 3-1 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. Pine’s (Cross Lake reservoir) “Original Operating Limits” are 1217.62 feet to 1234.82 feet (1.3 ft. to 18.5 ft. stage).

b. 1896 Overflow Problem. In June 1896, a crevasse was formed in the area that is now Perimeter Dike No. 14, due to overflow in that location. This problem was remedied within a year, but records indicate that, due to the problem of overflow at higher pool elevations, the regulation of the reservoir was restrained to elevations below the set maximum operating level (1234.82 ft., 18.5 ft. stage) until the completion of an adequate diking system around 1913 to 1915.

c. 11 February 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 **Table 3-1**). A minimum discharge of 10 cfs was prescribed for Cross Lake (Pine River Dam) and, at the request of the Minnesota Lake Levels Association, the lower operating limit was raised 7.7 feet to 1225.32 feet (9.0 ft. stage). Their request to change this to elevation 1227.32 feet (11.0 ft. stage) was denied (a compromise was adopted later, see **Paragraph 3-05.d.**). It was felt that a minimum elevation of 1225.32 feet was needed to maintain adequate storage capacity in the reservoir. An upper operating limit was also specified as 1231.32 feet (15.0 ft. stage). However, the District considered an elevation of 1234.82 feet (18.5 ft. stage) to be the safe upper limit at Pine even though the 1931 and later regulations from Congress list an upper limit of 1231.32 feet (15 ft. stage) (see **Exhibit D, Reference 13**). Rules regarding the release of water for navigation and the sluicing of logs were clarified in 1931 in addition to other details. See **Exhibit D, References 2.a. and 2.b.** Note that Paragraphs 3.c. and 3.d. in **Reference 2.b.** specify minimum flow values at St. Paul, MN that the reservoirs were to maintain.

d. 1 April 1931 Letter Related to the 11 February 1931 Regulation Order. On 26 February 1931, Congressman Harold Knutson requested that the lower operating limit for Cross

Lake reservoir be raised from 9.0 feet (elev. 1225.32 ft.) to 11.0 feet (1227.32 ft.). A subsequent letter dated 1 April 1931 from Major General Lytle Brown, Chief of Engineers to Congressman Knutson permitted a lower operating limit of 1227.32 feet (11.0 ft. stage) (see **Exhibit D, Reference 3**). This was done by agreement rather than an official change in the regulations. The 9-foot minimum, set forth in the earlier 1931 regulations, was still available for emergency situations (e.g., drawdown for a very wet snow pack). The letter prohibits the release of water from Pine River Dam for navigation without the approval of the Chief of Engineers.

e. 1935 Regulation Order. In the years 1930 through 1934 many protests were received in the District office in regards to low water levels (see **Exhibit D, Reference 6.a., Paragraph 4**). 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 in Paragraph 3.i. was added to minimize “The range of fluctuations in levels in any reservoir in a single year.....”. Note that Paragraphs 3.c. and 3.d. in **Exhibit D, Reference 4** specify minimum flow values at St. Paul, MN that the reservoirs were to maintain. See also **Table 3-1**.

f. 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 for Cross Lake (Pine River Dam) (stated in the 1935 order) was changed to 90 cfs (see **Exhibit D, References 5.a. and 5.b.**). 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 **Exhibit D, Reference 6.a. Paragraph 8.**). See also **Table 3-1.**

g. 1944 Regulation Order. This order for the Headwaters reservoirs did not affect Cross Lake (Pine River Dam). 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 **Table 3-1 and Exhibit D, References 6.a., 6.b. and 6.c.**

h. Title 33, Section 207.340, Code of Federal Regulations. This document provides a codification of all the regulations affecting the Headwater reservoirs through the 1944 Regulation Order (see **Exhibit D, Reference 7**). These regulations, combined with **Public Law 100-676, Section 21, of the Water Resources Development Act of 1988, and the referenced Reservoir Regulation Contingency Plan (see Exhibit D, Reference 12), contain the latest regulations from Congress for the Headwaters reservoirs.**

i. 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.

j. September 1953. The discharge from the Headwaters reservoirs was adjusted to facilitate emergency repairs of the locks and dams in the Twin Cities area.

k. 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.

l. August 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.

m. August 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.

n. August 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.

o. 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 (see **Exhibit D, References 9, 10 and 11**). 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 (see Section I, Paragraphs 12 and 13 of the 1963 Findings of Fact). 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 H-8** of the Headwaters Master Reservoir Regulation Manual, dated April 1963. However, Appendix D, **Table H-8** 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 as well as the rate-of-change 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**.

i. Maximum discharges from the reservoir were recommended for elevations ranging from 1217.32 feet to 1230.32 feet (1.0 ft. to 14.0 ft. stage). See **Tables B, C and E** in the 19 April 1963 Findings of Fact in **Exhibit D** or consult **Chapter 7** for details.

ii. A minimum discharge from the reservoir was recommended for periods when the reservoir was at, or below, critical elevations. See **Table D** in the 19 April 1963 Findings of Fact in **Exhibit D** or consult **Chapter 7** for details.

iii. Limits on the rate of change in discharge were recommended in the 15 August 1963 Plan. Although these are not listed in the revised Headwaters Master Reservoir Regulation Manual, dated April 1963 (revised 19 February 1968) correspondence indicates that rate-of-change guidelines were considered and thus were adopted for this manual. See **Exhibit D, Reference 11** or consult **Chapter 7** for details.

p. 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 (see **Exhibit D, Reference 12.a.**). 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 **Paragraph 1-03 and Exhibit D, Reference 12.b.**). The Congressional notification elevations for Cross Lake reservoir (Pine River Dam) are elevations 1227.32 feet and 1234.82 feet (see **Table 3-1 and Chapter 7**). Since the law was enacted, a situation requiring Congressional notification has not occurred.

q. 2001, Larger Gates. In order to increase the discharge capacity of the structure for dam safety reasons, larger gates were installed in 2001 (see the March 1997 report in **Paragraph 1-03**). The slide gate bays were restored to their original width of 6 feet and dual-leaf gates were installed to allow almost the entire height of each the bay to be utilized (see **Paragraph 2-03**).

In addition, all the bays now have slide gates whereas the previous structure had stop logs in two bays. The larger gates were first put into operation on 10 July 2001 at 1600 hours. The previous slide gates were 4.5 feet high and 5.0 feet wide, while the stop log bays were 6.0 feet wide.

Some of the perimeter dikes were also raised and a parapet wall was added to the main embankment in order to provide 5 feet of freeboard. The top of the dam is now at elevation 1240.3 feet. See **Chapter 2**.

Table 3-1
Mississippi River Headwater Reservoirs, History of Operating Elevations and Stages in Feet
 (see also Paragraphs 7-05, 7-16 and Table 7-1)

	Winni	Leech	Pokegama	Sandy	Cross/Pine	Gull
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, The 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
Gage Zero Elev., 1929 NGVD	1288.94	1292.70	1264.42	1207.31	1216.32	1187.75

- The lower limit was generally the sill elevation of the dam at that time. The upper limits were determined through engineering judgement and were set, with the exception of Gull, approx. 4 ft. below the flowage rights elevation.
- See **Exh. D, Ref. 2a and 2b**. 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 **Reference 13** for additional details.
- See **Exh. D, Ref. 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).
- See **Exh. D, Ref. 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.
- See **Exh. D, Ref. 5a and 5b**. No upper limits are listed in the 1936 regs, however **Ref. No. 6.a., Para. 8** 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).
- 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 **Reference 13** for details.
- 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. See **Exh. D, Reference 6.b**.
- 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. See **Exh. D, Reference 6.a., 6.b. and 6.c**.
- 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 **Reference 13** for details.
- The 1956 Headwaters Operation Study for Aitkin flood control (see **Paragraph 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.
- Pine River Dam was rehabilitated and raised to allow it to safely pass the Inflow Design Flood (70% PMF). The peak pool elev. equals 1235.3 ft. Five feet of freeboard was provided above this level. See the March 1997 Pine Design Memorandum (see **Paragraph 1-03**).
- See Note Nos. 10 and 11 for information regarding Pokegama, Sandy and Pine's upper limits deviating from the regulations from Congress.
- These are the Public Law 100-676, Sect. 21, Water Resources Development Act of 1988 (WRDA 1988) Congressional notification levels. See **Exhibit D, Reference 12**.

3-06. Principal Regulation Problems.

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. Cross Lake reservoir experiences a relatively small amount of shoreline erosion in comparison to the other Headwaters reservoirs. The peak inflows are not as variable and the lake level can normally be maintained within desirable regulation limits year-round and from year to year.

A boat survey in 1977 identified 13 locations of existing bank erosion areas, shown on **Plate 3-1**. At that time it was estimated that 3,610 feet out of 559,680 feet of total shoreline was affected.

b. Perimeter Dikes. The construction of the original 16 perimeter dikes around Cross Lake reservoir (Pine River Dam) began around the turn of the century (1900) to prevent impounded water from seeking alternative overflow outlets. The need for the dikes apparently was established based on maximum flowage limits and on original topography that may not have been accurate in some areas. During the early years of regulation some overflow occurred at high pool elevations. In June 1896, a crevasse was formed in the area that is now Dike No. 14, due to the overflow in that location. This problem was remedied within a year, but records indicate that due to the problem of overflow at higher pool elevations, the regulation of the reservoir was restrained to elevations below the set maximum regulating level (1234.82 feet, 18.5 ft. stage), until the completion of an adequate diking system around 1913 to 1915.

Cross Lake reservoir is now contained by 17 perimeter dikes. Dike 10b was added as part of a dam safety project (see **Paragraph 2-03** and the March 1997 report in **Paragraph 1-03**). The location of the 17 perimeter dikes is illustrated on **Plate 2-5**.



IV - WATERSHED CHARACTERISTICS

4-01. General Characteristics. Cross Lake reservoir, Pine River Dam, controls the runoff from a 562-square mile basin. The basin is located 90 miles west of Duluth, Minnesota, and 120 miles north-northwest of Minneapolis, Minnesota. The watershed shares a common boundary with the Leech Lake reservoir basin to the north, and the Gull Lake reservoir basin to the south. Its extent is about 20 miles north to south and 30 miles east to west.

Cross Lake reservoir is actually a chain of lakes. The water in the reservoir includes 15 natural lakes and originates from three main rivers. Pine River begins at about elevation 1,395 feet in a small lake in the northwest portion of the basin and joins with the South Fork of the Pine River from the west. The Pine River then flows into the western end of the reservoir. The average river slope is 4.7 feet per mile. Daggett Creek drains the northeastern portion of the watershed and flows into the east end of the reservoir. Along the shoreline, the ground generally rises dramatically from the water and is densely covered with pine and hardwoods, such as oak and birch. More than 50 percent of the shoreline is comprised of Norway, white and jack pine.

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 in the Cross Lake reservoir, Pine River Dam basin ranges from 1570 feet on some of the rises in the northern corners of the watershed to the reservoir shoreline at about elevation 1229 feet. The topography is typical of glacial effects, mostly level with gentle rolling hills. The slopes around the shoreline are predominantly 6 to 19 percent.

4-03. Geology and Soils. Crow Wing County, in which Cross Lake reservoir, Pine River Dam is located, consists primarily of glacial outwash with a dominant moraine in the eastern portion and areas of till plain to the south. The reservoir is located on outwash soils predominated by sand and clay with fair to poor fertility. A red drift region approximately 200 to 300 feet thick covers the reservoir area. The forest soils in the area are coarse to medium texture, formed from the glacial outwash, and are comprised mostly of gravel or sandy gravel near the surface. Often these sands and gravels are overlain with fine sandy loams which become peat in depressions. These soils may be excessively drained and are subject to drought and wind erosion.

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 **Paragraph 3-06**.

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. 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. Winds in the area blow predominantly from the northwest (see **Plates 4-1 and 4-2**).

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.

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. It is interesting to note that Pine River Dam recorded the record snowfall for the State of Minnesota for the month of April with 37.0 inches in 1950 based

on records from 1887 through 2001. 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 Cross Lake reservoir, Pine River Dam area can be drawn from **Tables 4-1 and 4-2**.

The seasonal (May-October) average evaporation of 24.4 inches in **Table 4-2** corresponds very well with Free Water Surface (FWS) seasonal evaporation of 24 to 26 inches found in the National Weather Service Technical Report 33. Monthly values will deviate somewhat since the model data in **Table 4-2** accounts for the heat storage effects of the reservoir water.

Table 4-1				
Extreme Climatological Data				
Extremes	Temperature ¹ Degrees, F	Annual ² Precipitation Inches	Lake Evaporation ³ Inches	
			Annual	July
Minimum	- 53 (Jan. 12, 1912)	14.81 (1936)	24.8 (1928)	3.7 (1950)
Maximum	104 (July 28, 1917)	45.86 (1902)	36.2 (1974)	8.1 (1936)

1. Pine River Dam, National Oceanic and Atmospheric Administration, Climatological Data, 1896-2000. (NOAA Station No. 216547)
2. Pine River Dam, National Oceanic and Atmospheric Administration, Climatological Data, 1887-2000. (NOAA Station No. 216547)
3. Watershed Study in Northeastern Minnesota, 1916-1980 (Meyer Model, Barr Engineering Co.)

4-06. 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. Large areas of poorly-drained marsh and timberlands throughout the basin have been frequently flooded.

Table 4-2
Cross Lake Reservoir, Pine River Dam Average Climatological Data

Month	Normal Temp ¹ Degrees F	Normal Precip ¹ Inches	Normal Snowfall ² Inches	Lake Evap ³ Inches	Wind	
					Speed MPH	Prevailing Direction
January	5.9	1.04	12.3	0.3	8	WNW
February	14.0	0.69	7.1	0.5	8	NNW
March	26.4	1.66	8.0	0.9	9	WNW
April	41.0	2.06	2.4	1.3	10	NW
May	54.7	3.29	0.3	3.2	9	NW
June	63.7	4.23	--	5.0	8	WNW
July	68.5	4.28	--	5.4	7	NW
August	66.1	3.57	--	4.7	6	S
September	56.2	2.83	--	3.6	7	NW
October	44.3	2.66	0.4	2.5	8	NNW
November	27.9	1.79	6.0	2.2	8	NNW
December	12.3	0.77	7.5	0.4	8	WNW
Annual	40.1	28.87	44.0	30.0	8	NW

1. Pine River Dam, National Oceanic and Atmospheric Administration, Climatological Data, 1971-2000, (NOAA Station No. 216547)
2. Pine River Dam, National Oceanic and Atmospheric Administration, Climatological Data, 1971-2000, (NOAA Station No. 2165471)
3. Based on 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

Selected floods at Cross Lake/Pine River Dam are tabulated in **Table 4-3**. A brief description of these floods follows. Refer to **Chapter 5 and Paragraph 8-02** for further information.

Table 4-3		
Peak Elevations and Discharges for Selected Events at Cross Lake Reservoir, Pine River Dam ¹		
Date ²	Pool Elevation ³ in Feet	Discharge in cfs
7 July 1916 ⁴	1234.73	570 (Peak WY=589 on 15 July) ⁵
20 May 1938	1231.32	180 (Peak WY=1,026 on 2 June)
17 June 1943	1231.50	1,357 (Peak WY=1,394 on 6 June) ⁵
17 June 1944	1231.98	643 (Peak WY=1,490 on 19 June) ⁵
25 May 1950	1231.41	1,039 (Peak WY=1,610 on 15 May) ⁵
12 June 1965	1230.57	1,370 (Peak WY=2,890 on 13 April) ⁵
17 May 1999	1230.17	1,232 (Peak WY=1,500 on 18 May)

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 **Paragraph 3-05**. Due to regulation effects, Water Years may not provide hydrologically independent events.
3. Gage zero elevation = 1216.32 feet (1929 NGVD). The log sheets and USGS records should be consulted for additional information to include the time when the values were recorded and other details.
4. High lake levels occurred on 17 July 1914 (1234.40 ft.), July 29, 1920 (1233.29 ft.), August 1st - 5th, 1915 (1232.59 ft.) and June 11th and 22nd, 1927 (1232.30 ft.). However, these levels were probably induced in order to provide sufficient water for downstream navigation and other purposes as opposed to being the result of large flood events.
5. From records supplied to the United States Geologic Survey. See USGS Water Supply Paper (WSP) No. 435 (for 1916), WSP No. 975 (for 1943), WSP No. 1005 (for 1944), WSP No. 1175 (for 1950) and Water Resource Data for MN, 1965. Also see Corps log sheets and **Chapter 5**.
From records supplied to the United States Geologic Survey. See **Chapter 5**, USGS 1916 Water Supply Paper (WSP) No. 435 and Corps log sheets.

a. July 1916 Flood. This flood, unlike the others described below, occurred before the regulation modifications in 1931 (see **Paragraph 3-05**). The data for this period illustrates that, reservoir prior to the regulation modifications, it was common to store the majority of the spring runoff. High lake elevations did relatively little damage due to fewer cabins and residents near the reservoir at that time.

Most of the 1916 spring runoff from Pine River basin was stored in the reservoir. The maximum elevation of record, 1234.73 feet on 7 July, was due to a reservoir already full from spring runoff, which received the runoff from 3.08 inches of late June rain. Most of this runoff was also stored in the lake, thus causing the high stage. The maximum outflow of 589 cfs occurred eight days after the peak reservoir elevation.

Under current regulation procedures, this flood would have resulted in a substantially lower peak reservoir elevation. The maximum 10-day inflow for the 1916 event ranks 32nd in an 87-year record.

b. May 1938 Flood. The reservoir elevation on the first of April was about normal for early spring at 1227.89 feet. Total precipitation in April was 2.03 inches above average (see **Table 4-2**). This, added to the heavy rains in the first week of May, totaling 5.52 inches, and 1.02 inches more between 13 and 18 May resulted in the fifth highest reservoir elevation of record. An elevation of 1231.32 feet was recorded on 20 May 1938. Increased discharges lowered the lake elevation to near normal by mid-July with the maximum reservoir outflow of 1,026 cfs occurring on 2 June.

c. June 1943 Flood. The peak reservoir elevation of 1231.50 feet on 17 June was caused by far above normal rainfall in May and June. In May, 5.67 inches, out of a monthly total of 7.58 inches, fell in the last week. Approximately 3.0 inches of additional rainfall in the second week of June further raised the level of the reservoir. The reservoir was brought back down to normal by the end of July. The maximum reservoir outflow of 1,394 cfs occurred on 6 June.

d. June 1944 Flood. The highest lake elevation, since modifications were made to the regulation procedures in the 1930's, occurred 17 June 1944. This flood was primarily due to heavy rains in early summer. Five inches of rain fell in the first week of June and a storm on the 13th resulted in an additional 2.04 inches of precipitation. This extensive moisture input

combined with the wet spring conditions caused a peak lake elevation of 1231.98 feet. The maximum outflow of 1,490 cfs occurred 19 June 1944. The discharge of the reservoir averaged approximately 1,200 cfs until the lake elevation was returned to near normal in mid-July.

This was not the only high stage in 1944. July rainfall was average, but 7.55 inches fell in August, which is 3.54 inches above normal. The peak lake elevation in August was 1230.70 feet on 12 August with a maximum reservoir outflow of 1,476 cfs on 15 August.

e. May 1950 Flood. Precipitation during the winter of 1949-50 was considerably above normal. The snow cover remained on the ground until the 5th of May 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 4.6 inches above normal rainfall of April and May, produced the flood of record throughout much of the headwaters area. The peak lake elevation of 1231.41 feet occurred on the 25th of May with the peak reservoir outflow of 1,610 cfs occurring on 15 May. The outflow of the reservoir remained above 1,000 cfs for a month before the lake elevation returned to the normal summer range.

f. June 1965. Over 5 inches of rain fell at Pine River Dam between 1 June and 12 June on soil that was very saturated from a snow pack that contained 4 to 6 inches of water content. Cross Lake reservoir peaked at elevation 1230.57 feet on 12 June 1965.

g. May 1999. Approximately 6.3 inches of rain fell between 1 May and 17 May. Cross Lake reservoir peaked at elevation 1230.17 feet on 17 May 1999.

4-07. Runoff Characteristics. The runoff from Cross Lake reservoir (Pine River Dam) watershed is slow and significantly attenuated as a result of the relatively flat topography and the presence of many lakes and wetlands. Pine River Dam controls the runoff from a 562 square mile area, of which 42 percent is dry land, 24 percent is water, and 34 percent is wetlands. In general, the land not covered by wetlands is forested. The average overland slope is 48.05 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 1898 to 1985, as well as average lake evaporation from **Table 4-2**, 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 **Plates 4-3 and 4-4**. 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, **Plates 4-5 and 4-6**. See also **Paragraph 8-11**.

The monthly streamflow distribution determined from the period of record is presented on **Plate 4-7**. Minimum monthly discharges occur in mid or late summer. The maximum monthly inflow occurs in April from snowmelt and spring rain runoff. Some of this inflow is retained in the reservoir for flood protection purposes. 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. The inverse is true during the fall and winter as the reservoir level is drawn down for use in spring flood protection, or during periods when large evaporation losses occur.

The annual streamflow distribution is shown in **Plate 4-8**. The maximum peak annual inflow and outflow occurred in 1905. A steady decline in annual discharges is noted from this period to the minimum annual outflow in 1931 and inflow in 1934. A cyclic pattern is evident in the 87 years of record (1898-1985).

4-08. Water Quality. Cross Lake reservoir (Pine River Dam) is a natural chain of lakes in the Northern Lakes and Forests (NLF) ecoregion in north central Minnesota, whose water surface elevation is artificially controlled by a Corps' dam at its outlet. Cross Lake reservoir is mesotrophic based on the Carlson's Trophic State Index using 1990 thru 1995 data. Dissolved oxygen and water temperature profiles exhibit the characteristics of a classically stratified dimictic lake. Stratification usually occurs prior to the end of May and continues throughout the summer until late September or October. Mean summer (June thru September) total phosphorus, chlorophyll a, and secchi transparency are 23 ug/l, 3.4 ug/l, and 13.8 feet (4.22 meters) respectively. These values are comparable to "typical" NLF ecoregion lakes as shown in **Table 4-4**.

Cross Lake reservoir currently fully supports swimming and aesthetics-use criteria developed by the Minnesota Pollution Control Agency. The lakes however, are extremely vulnerable to cultural-induced eutrophication from both point and non-point source pollution. Small increases in the reservoir's phosphorus content could result in a perceptible loss in secchi transparency and increased frequency of nuisance algal blooms. Specific pollution concerns in the watershed result from both point and non-point source pollution such as extensive land development, urban and agricultural runoff, and malfunctioning or outdated septic systems, and a publicly owned

treatment works facility, which discharges directly above the reservoir into the Pine River. The Corps of Engineers and Whitefish Area Property Owners are cooperating in an effort to track, control, and limit the cultural-induced eutrophication of Cross Lake reservoir.

A limnological survey of the headwaters reservoirs was conducted in 1980 (see **Paragraph 1-03**). Also see also **Paragraphs 5-02, 7-07, and 8-04**.

Table 4-4 Comparison of Cross Lake Reservoir (Pine River Dam) to Ecoregion Data Set Lakes		
	Cross Lake Reservoir	Typical Northern Lakes and Forest Ecoregion Lake
Mean Total Phosphorus (ppb)	23	14-27
Mean Chlorophyll a (ppb)	3.4	<10
Maximum Chlorophyll a (ppb)	18.6	<15
Mean Secchi Transparency (meters)	4.22	2.5-4.5
Trophic State	Mesotrophic	Mesotrophic to mildly eutrophic

4-09. Channel and Floodway Characteristics. Pine River Dam is located on the Pine River 14.5 miles upstream of its confluence with the Mississippi River (at river mile 1023.8 above the Ohio River). Pelican Brook and Mud Brook join Pine River in this reach. The confluence of the

Pine and Mississippi Rivers is at 5.9 river miles above Black Bear and Miller Lakes and 22.3 river miles above Brainerd, Minnesota. Mississippi River backwater has caused flooding problems in the Black Bear and Miller Lakes area. A closure structure was built at this site in the late 1980's.

4-10. Upstream Structures. There are no reservoir structures above Pine River Dam on the Pine River.

4-11. Downstream Structures.

a. Rock Weir, Big Pine Lake. There is a small rock weir/dam at the outlet of Big Pine Lake downstream of Pine River Dam. High discharges from Pine River Dam will occasionally washout this structure. The rock weir/dam has a minimal effect on the tailwater stages at Pine River Dam. At the present time the average crest elevation of the dam is 1195.8 feet (max. height of 1197.04 ft.) while the invert elevation at Pine River dam is at elevation 1216.65 feet.

4-12. Economic Data.

a. Population. The lakes which form Cross Lake reservoir (Pine River Dam) are completely within the Crow Wing County boundaries. The outermost portions of the Pine River Watershed are located in Cass County. Population figures for the area are given in **Table 4-5**. Crow Wing County includes the City of Brainerd (1990 population 12,353) which accounts partially for the large difference between the two counties. The northern half of Cass County consists of the sparsely populated Chippewa National Forest and part of the Leech Lake Indian Reservation.

Table 4-5		
Census Information for Crow Wing and Cass Counties		
	Crow Wing	Cass
Population, 1970	34,826	17,323
1980	41,722	21,050
1990	44,249	21,791
2000	55,099	27,150
Area, Square Miles	997	2,018
Density, Persons/Square Mile, 2000	55.3	13.5
Percent Rural Population, 1990	64.0	100
Percent Rural Farm Population, 1990	1.7	5.0
Percent Rural Non-Farm Population, 1990	62.3	95.0
Median Household Income, 1997	\$32,616	\$27,704
Note: Average density state-wide, 2000 = 61.8 persons/sq. mi		

b. Agriculture. Agriculture in Crow Wing and Cass Counties is economically unattractive due to the generally poor soil conditions and the relatively short growing season. **Table 4-6** presents a profile of the agriculture in the area. Dairying is the primary agricultural pursuit, but the milk production is well below the state average and that of more southerly located farms. A few mixed crops such as soybeans, corn, rye and oats are produced. Livestock production, beef cattle, and the farrowing of pigs supplement the county's agricultural income.

Table 4-6		
1997 Agricultural Profile of Crow Wing and Cass County		
Item	Crow Wing	Cass
Number of Farms	593	598
Average Size (Acres)	228	321
No. Of Beef Cows	7,235	13,769
No. Of Milk Cows	2,210	2,409
No. Of Hogs & Pigs	5,330	11,402
No. Sheep & Lambs	1,112	912
No. Of Chickens, Broilers, Layers, & Pullets	NA	672
Hay in Acres	30,332	49,068
Wheat, Barley, & Oats for Grain in Acres	2,298	1,961
Corn for Grain or Seed in Acres	7,819	4,350
Soybeans in Acres	592	80

c. Industry. Industry in the Crow Wing and Cass County areas around Cross Lake reservoir includes tourism, lumber, and some mining. Cross Lake reservoir contributes substantially to the tourism base of the area. The activities associated with the natural amenities are very important factors in the overall economic picture. In 1975, 190,103 visits were made to the Ronald Louis Cloutier Recreation Area, the largest number of visits to any of the Corps of Engineers recreational areas in the Mississippi River Headwaters.

Not only are the lakes important economically in attracting recreational visitors, but they are also an important resource in attracting permanent residents, both retired and non-retired. About 60 percent of the population in the area is classified as rural, non-farm, compared with the state average of 20 percent. The industries of agriculture, forestry, fishing and mining have shown a very significant decline in employment. Their past prominence economically is now shifting to the tourism related industries. The lumber and wood industry is more significant in Cass County than Crow Wing County. The total value of timber cut on public lands in these counties in 1970 represented 4.1 percent of the state total.

d. Flood Damages. High water damages consist of flood fight or preparedness measures, damage and loss of personal property, clean-up and repair for both residential and commercial units, and damage of public facilities including roads. 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.

The low water damages for Cross Lake reservoir 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 (see **Paragraph 3-06**). Private landowners also experience increased expenses and equipment damage from low water. Low water damages are especially severe at locations in Cross Lake reservoir with very gradually sloping bottoms.

The elevation-damage curve derived for Cross Lake reservoir is shown on **Plate 4-9**. The curve shows both the low and high water damage relationships.

The high water damage-frequency curve for Cross Lake reservoir shown on **Plate 4-10** was developed using data from 1936 to 1976. Average annual high water damages are based on this curve and were estimated to be \$4,150,000 based on October 1977 prices.

The downstream damage-discharge relation for the Pine River Dam area is shown on **Plate 4-11**. Damage will occur mainly to downstream residences and to the commercial areas of the community of Cross Lake. **Plate 4-11** is based on the dam safety study for Pine River Dam.



V - DATA COLLECTION & COMMUNICATION NETWORKS

5-01. Hydrometeorological Stations. Several hydrometeorological stations are utilized to collect the various hydraulic and hydrologic parameters used in the regulation of the project.

a. Facilities. **Table 5-1** lists the data collection facilities at the dam. **Plate 5-1** shows the locations of the facilities in the area. **Table 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**.

b. Reporting. The information needed to operate the dam and regulate the reservoir is reported to the Water Control 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. Daily inflow to the reservoir is calculated by Water Control from the change in reservoir elevation and the outflow.

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.

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 Control Section. A report of this survey is forwarded to Water Control 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 a survey has been completed, another survey may be required. See **Plate 5-2** and **Table 5-3**.

c. 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.

Table 5-1			
Pine River Dam Streamflow and Hydrometeorological Stations			
Location	Data Type	Equipment	Ownership
Pine River Dam	Pool Elevation ¹	DCP ²	Corps of Engineers
Pine River Dam	Tailwater Elevation ³	DCP ²	Corps of Engineers
Pine River Dam	Precipitation	Standard Rain Gage	National Weather Service
Pine River Dam	Temperature	Thermometer	Corps of Engineers
Pine River Dam	Wind Direction	Manual Estimate	Corps of Engineers
Pine River Dam	Snow Depth and Water Equivalent	Snow Tube	Corps of Engineers
Pine River Dam	Frost Depth	Frost Tube in Ground	Corps of Engineers
Cross Lake	Ice Thickness	Manual Estimate	Corps of Engineers
<p>1. Some elevation data was published by the U.S. Geological Survey (Gage No. 0530500) October 1941 thru 1997 based on records provided by the Corps of Engineers. See Paragraph 4-06. Data is available on Corps log sheets dating back to March 1886.</p> <p>2. There is one Data Collection Platform (DCP) servicing both the pool and tailwater gages.</p> <p>3. Discharge data was published by the U.S. Geological Survey (Gage No. 0531000) January 1895 to September 1916 and October 1941 thru 1994. See Paragraph 4-06.</p>			

Table 5-2			
Stations in the Vicinity of Pine River Dam and Reservoir			
Owner/Gage No.	Drainage Area Sq. Mi.	Location	Notes
U.S.G.S. Gage No. 05242300	7,320	Mississippi River at Brainerd, MN	On the left bank in the Potlach hydropower plant in Brainerd, MN
U.S.G.S. Gage No. 05261000	11,010	Mississippi River near Fort Ripley, MN	On the left bank 600 ft. upstream from Nokasippi River, 1.0 mile north of Fort Ripley

Table 5-3	
Snow Survey Sites for Pine River Dam/Cross Lake Reservoir (see Plate 5-2)	
Number and Name	Location
1. Pine River Dam	Pine River Dam Site
2. Fifty Lakes	On Crow Wing County 1 West of Fifty Lakes
3. Outing	At Forestry Station North of Outing on MN Hwy. 6
4. Longville	At Longville Airport
5. Hackensack	In Hackensack at School Ball Field
6. Backus	In Backus at City Park
7. Pine River	In Pine River on Golf Course
8. Pequot Lakes	Near electrical power station on county road 112

5-02. Water Quality. See also Paragraphs 4-08, 7-07 and 8-04.

a. Facilities. The Corps regularly maintains four (4) water quality data collection stations in Pine River Reservoir. 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.

When part of a water quality program at Cross Lake, data collection activities are concentrated during the open water period from May through October. Vertical profiles of water temperature, dissolved oxygen, pH, and specific conductance are electronically monitored on a regular basis at each station. In addition, two meter integrated surface water samples are collected analyzed for total phosphorus, total kjeldahl nitrogen, nitrate-nitrite nitrogen, ammonia nitrogen, and chlorophylla. 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

b. Reporting. In situ water quality data is recorded on data sheets and mailed to the Water Quality Unit in the District office. 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 EPA or equivalent procedures. Laboratory results are forwarded to the Water Quality Unit in the District office. Both in situ and nutrient data are reviewed and entered into DBASE by the staff. The Corps produces periodic data reports describing data collection activities and laboratory results for the project. All water quality data is available in hard copy or on magnetic media upon request.

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

A National Weather Service precipitation gage is used at the dam to record the daily precipitation. The 24-hour precipitation and weather observations are recorded daily. The recorder chart and Form B-91 are mailed monthly to the National Weather Service. Precipitation for weekends and holidays is recorded on the next workday. The data are archived by the National Climatic Data Center in Asheville, North Carolina. The data from some of the U.S.G.S.-maintained stations are archived in the U.S.G.S. WATSTORE data base in Reston, Virginia. The U. S. Geological Survey and various contractors conduct streamflow measurements as requested by the District office.

During the annual snow survey, three to four 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 telephone, modem, facsimile and via the United States mail. The Headwaters sites have access to VHF radios. However, present radio facilities do not allow for a reliable audible signal between St. Paul and the Headwaters region. Data Collection Platform data is transmitted hourly to a GOES satellite and then back down to a Direct Readout Ground Station (DRGS) in Wallops Island, Virginia. The DRGS transmits the data to a Domestic Communication Satellite (DOMSAT) which then transmits the data to a Domestic Receive Station (DRS) in the Water Control Section. All of the project related data is available on the World Wide Web. The project data is also provided to the National Weather Service via a dedicated communication line.

5-06. Emergency Communication with Project.

a. Regulating Office with Project Office. 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.

b. Between Project Office and Others. Local residents have access to project-related information from the project staff either by telephone, in person, on the World Wide Web 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 Potlatch Corporation (Potlach Dam, Brainerd), 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 Control will call the project staff. **Paragraph 1-05** contains phone numbers for project personnel. The introduction to this manual contains phone numbers for Water Control and various District personnel. In the event of emergencies affecting project regulation and concerns downstream, the officials listed in **Table 5-4** will be contacted (also see **Paragraphs 7-13 and 8-10**).

Table 5-4

Points of Contact for Emergency Notification

Point of Contact	Telephone Numbers	
	Work	After Hours
Cass Co., MN, Civil Defense Director, 24 Hr	218.547.3300	218.335.6191
County Sheriff, 24 Hr	Extension 222 218.547.3345	-----
Crow Wing County, MN Civil Defense Director, 24 Hr County Sheriff	218.829.1711 218.829.4749	218.829.9329
Mississippi Valley Division U.S. Army Corps of Engineers	601.634.5946	-----
National Weather Service, Chanhassen, MN National Weather Service, Duluth, MN	952.361.6708 218.729.0653	-----
Minnesota Div. Emergency Man. Minnesota Statewide Emergency	651.649.5451 1.800.422.0798	24 Hours 24 Hours

Note: Phone Nos. for Water Control, District, and project personnel are listed in the introduction to this manual and in **Paragraph 1-05**.



VI - HYDROLOGIC FORECASTS

6-01. General. All stream-stage forecasting in the public interest is performed by the National Weather Service Forecast Office in Chanhassen, Minnesota. The St. Paul District, Corps of Engineers, will provide advisory forecasts as needed for its projects. These Corps forecasts may arise from either wet or dry conditions, and they may be used to guide Water Control Section regulators and the Managers in their tasks. In the public interest, the Water Quality Division of the State of Minnesota, Pollution Control Agency, will forecast water quality conditions when warranted. The St. Paul District may provide test data through its Water Quality Unit in the Engineering Division.

6-02. Flood Condition Forecasts.

a. Introduction. During the development of this Water Control Manual, the runoff characteristics of the Pine River Dam watershed were simulated using the HEC-1 computer model and selected historical runoff events. The elevation and outflow records from 1898 to 1985, and average lake evaporation values, were utilized in a reverse routing procedure to compute estimated daily inflows to the reservoir. The computed inflows were used to calibrate the model to historic events and create data for statistical analyses (see also **Paragraph 4-07**). The HEC-1 model was used to develop **Plates 6-2 thru 6-4**. The following paragraphs discuss the development of the model and subsequent tools that were developed for forecasting purposes.

b. Watershed Subbasins. In order to generate unit hydrographs by computer modeling, the watershed above the Pine River Dam was divided into sub-areas based on the drainage pattern. The boundaries of the watershed sub-areas and a schematic of the HEC-1 model are presented on **Plate 6-1**. The watershed above the dam was divided into six sub-areas for use in the model. All sub-areas were assumed to discharge directly into the reservoir (sub-areas C, D and E) with the exception of sub-areas A and B. The sixth sub-area is the surface of the reservoir. Rain falling directly into the lake is treated as an instantaneous addition to the reservoir volume with no infiltration losses. The curves on **Plate 6-2** include as surface runoff, the rain which falls directly into the reservoir. The reservoir lakes include the Whitefish Chain of Lakes and Cross Lake Reservoir.

c. Forecast Tools. Reservoir inflow and downstream flow forecasts are made by the Water Control Section as conditions warrant. **Plates 6-2, 6-2a, 6-3 and 6-4** are the result of HEC-1 computer model simulations or calculations, and can be used to develop runoff forecasts. The total surface runoff from a precipitation event for the entire watershed above Pine River Dam can be estimated based on the rainfall-runoff curves on **Plate 6-2**. To define the rainfall-runoff curves, various basin-mean areal precipitations were input to the calibrated HEC-1 model of the watershed for each of the three antecedent soil moisture conditions. The resulting curves compare favorably with National Resource Conservation Service standards.

The hydrologic response of the watershed, or the rate of runoff following a precipitation event, is demonstrated by the watershed unit hydrograph. The HEC-1 watershed model produced reservoir inflow hydrographs based on a three-hour time increment. The unit hydrographs derived for the reservoir for this manual are illustrated on **Plate 6-2a**. The three-hour unit hydrographs represent one-inch of runoff from a three-hour rainfall over each watershed sub-area.

The time of concentration of the overall unit hydrograph is relatively long at 2.5 days. This is the time from the end of the rainfall period to the inflection point of the recession limb of the runoff hydrograph, or approximately the time to the peak discharge. The shallow slope of the recession limb is an indication of the large amount of storage caused by the lakes and marshes within the watershed. These unit hydrographs do not include the amount of precipitation which falls directly into the reservoir.

The total inflow hydrograph for the reservoir following a precipitation event can be forecast by multiplying ordinates of the unit hydrograph (**Plate 6-2a**) by the predicted runoff volume from the corresponding rainfall-runoff curve (**Plate 6-2**). The volume of rain that falls directly into the reservoir is included in **Plate 6-2**.

Another useful forecasting tool for reservoir regulation is the family of inflow recession volume curves on **Plate 6-3**. If the peak inflow from the watershed into the lake after a given rainfall event is known, the remaining inflow volume at any given time past the peak may be estimated from this plate. The curves are intended to provide additional guidance for reservoir regulation during flood conditions. The curves do not account for evaporation losses from the lake.

d. Discussion. **Plate 6-4** illustrates a comparison between Cross Lake inflows computed by the calibrated HEC-1 model, and those calculated by a reverse routing procedure using the observed lake elevations and outflows. Rainfall floods were simulated in the HEC-1 model using a three-hour computation intervals. The observed data used for the reverse routing is from daily discharge records and elevation records, which were recorded at frequencies varying from daily to every ten days. Consequently, the reverse-routed inflows are 24-hour average values, which are not as sensitive as the HEC-1 model (based on a three-hour interval) to large, rapid variations in inflow, particularly with regard to instantaneous additions to lake volume from precipitation directly into the lake.

In general, the accuracy of the HEC-1 model was verified by comparing modeled inflows with reverse-routed flows. However, both methods of estimating inflows involve some margin of error. A small error in lake-elevation measurement due to human error or wind effects, for example, will result in a large error in the calculated lake volume for that day. This will then cause a large error in calculated reverse-routed daily inflow.

The user of the aforementioned forecast tools must consider the underlying assumptions inherent in the HEC-1 model. The HEC-1 computer model is a "single event" model. Precipitation events separated by a period of dry weather can not be included in the same runoff simulation because HEC-1 has no provision to increase soil infiltration rates during dry periods. The HEC-1 model has no provision to account for lake evaporation losses, which at some point following a storm, will exceed the rate of inflow. Use of the aforementioned graphical relationships should be limited to computing reservoir inflow volumes during the periods of high runoff following storms.

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 Control Section routine. Short-term projections of water level, flows, temperature and local hydrologic conditions may be obtained from Water Control upon request.

6-04. Forecasts During Drought Conditions. Hydrologic and meteorologic forecasts are issued by the National Weather Service (see **Paragraph 6-01**). The Minnesota Department of Natural Resources has provided minimum discharge guidelines for the reservoirs that are based on reservoir levels (see **Chapter 7**).

6-05. 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.



VII - WATER CONTROL PLAN

7-01. General Objectives. The reservoir is regulated primarily for recreation, flood control and fish and wildlife. The Water Control Plan supports recreation by maintaining, when possible, stable reservoir levels within a specified elevation band during the summer. Flood control 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 concerns. The low-flow plan manages water resources both upstream and downstream of the dam during critical periods. See **Paragraph 2-02** for information on these and other authorized purposes.

7-02. Constraints and Issues Related to the Water Control Plan.

a. Connecting Channel Obstructions. Cross Lake reservoir (Pine River Dam) is a part of the Whitefish Chain of Lakes (see **Plate 2-1**). Tree stumps and sand bars in connecting channels between several lakes of the Whitefish Chain pose a hazard to boats. This issue is particularly apparent during low water periods such as occurred in 1976. In some cases, the connecting channels are very narrow and tend to silt in fairly rapidly due to littoral drift. The connecting lake inlets provide serious problems to boats moving from one lake to another. Approximately twenty problem areas have been identified by local property owners. Six of the 20 sites are particularly troublesome. The six locations are the channels from Whitefish Lake to: Bertha, Lower Hay, Big Trout, Pig, and Island Lakes, and the channel from Island Lake to Loon Lake.

b. Big Pine Lake. Big Pine Lake/flowage is attached to the Pine River downstream of Pine River Dam. The Pine River flows into and out of the northern end of the lake. There is a small rock weir/dam at the outlet of Big Pine Lake on the Pine River. High water levels on the Pine River can cause abnormally high water levels on Big Pine Lake. This can become an issue for property owners on the lake in the form of inundated docks, boat lifts and water in basements. At the present time the average crest elevation of the dam is 1195.8 feet (max. height of 1197.04 ft.). For comparison purposes, the invert elevation at Pine River dam is at elevation 1216.65 feet. High discharges from Pine River Dam will occasionally washout this structure (which is maintained by the county).

c. Sandbag Closures, Perimeter Dikes. Pending a future road raise, Perimeter Dike No. 11.b. must be sandbagged to provide flood protection to the top of the main embankment (elev. 1240.3 ft.). See **Paragraph 2-03.c.**

7-03. Overall Plan for Water Control. Cross Lake reservoir (Pine River Dam) is regulated between a minimum elevation of 1225.32 feet and a maximum elevation of 1235.30 feet. If possible, the reservoir level should be within its summer range/band of 1229.07 feet to 1229.57 feet by the first day of the fishing season (approx. mid-May). The winter drawdown of the reservoir for spring flood control begins in the fall. The ordinary (normal) spring drawdown elevation is 1227.32 feet, however the reservoir can be drawn down to 1225.32 feet if warranted by potential spring runoff conditions. Details of the water control plan are given in the following paragraphs. Significant shoreline erosion begins to occur at approximately elevation 1230.32 feet but storage to elevation 1235.30 feet can be used if needed to prevent flooding downstream. To promote whitefish spawning, the drawdown of the reservoir is coordinated with the Minnesota Department of Natural Resources. Details of the water control plan are given in the following paragraphs.

Until Public Law 100-767, WRDA 1988 and its Contingency Plan at Pine River Dam are modified to change the Congressional Notification Limit from elevation 1234.82 to 1235.30, the project will be operated to level 1235.30 subject to the following actions:

- **recognize that the present upper storage limit for notification of Congress remains at elevation 1234.82 as shown in Table 7-1 for wet conditions and footnote (7), and Table 7-2 for item 4 Congressional Notification Levels and footnote (4). The Congressional Notification will contain the District Water Control best estimate of maximum elevation possible and cite the dam safety elevation 1235.30 and our actions, which will include coordination with Mississippi Valley Division using existing operating deviation authority to operation to elevation 1235.30 in accordance with the dam safety report. This will entail an early notification to Congress, but would have likely occurred regardless for an event this large.**
- **recognize that although the Contingency Plan says that the gates must be wide open at elevation 1231.32, this value should be 1235.30, and that paragraph 7-05 Water Management and Flood Control sub-paragraph i.1. for Flood Control, Regulation and Operation will be used where it states that outflow will be ramped upwards until the dam is completely open by the time the reservoir reaches elevation 1235.30 feet to insure the safety of the dam.**

7-04. Standing Instructions to the Project Staff. The project is to be regulated in accordance with **Paragraph 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 **Paragraph 7-15**. 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, in **Chapter 1** and in **Chapter 5**.

7-05. Water Management and Flood Control. The regulation of the reservoir and the operation of the dam is done in accordance with the instructions given 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**. Examples of reservoir regulation during selected floods are shown on **Plates 8-3 through 8-9**. See **Chapter 9** for information related to the coordination of Water Control 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 1963) in order to provide consistency with the earlier manual and are defined in **Paragraph 7-16**. **Table 7-1** provides a summary of the regulation for Cross Lake only. **Table Nos. 7-2, 7-3, 7-4 and 7-5** provide a summary of the regulation parameters for the entire Mississippi River Headwaters system for comparison and easy reference. Both stages and elevations are included in **Table 7-2**, and elsewhere in this chapter, to facilitate references to historical documents that refer to stages only (e.g. in **Exhibit D**). **Table 7-6** lists recommended maximum discharge rates and **Table 7-7** and **Plate 7-1** contains drawdown information.

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.

Location	Description
Plate 7-1	Drawdown Curve
Plate 7-2	Free/Submerged Flow Decision Matrix
Plate 7-3	Slide Gate Rating Table (Gate Openings Less Than One Foot)
Plate 7-4	Slide Gate Rating Table (All 13 Gates Open an Equal Amount)
Plate 7-5	Slide Gate Rating Curves (Gate Openings Less Than One Foot)
Plate 7-6	Slide Gate Rating Curves (All 13 Gates Open an Equal Amount)
Plate 7-7	Tailwater Rating Curve
Exhibit E	Stage-Discharge Tables for Aitkin and Brainerd, MN
Exhibit F	Elevation-Storage Curve / Table and Area-Capacity Curve

b. Emergency Regulation. See Paragraph 7-13.

c. Minnesota Department of Natural Resources Guidelines. The Minnesota Department of Natural Resources has provided the Corps with guidelines for the regulation of the Headwaters reservoirs. These guidelines are discussed below where applicable with key provisions covered in **Tables 7-1, 7-2, 7-5 and 7-6**. The guidelines are effective only when the reservoir is not functioning for the primary purposes of navigation and flood control. See **Paragraph 3-05.o.** and **Exhibit D (Reference Nos. 9, 10 and 11)**.

d. Rate-of-Release Change. The District has an informal agreement (see **Exhibit D, Reference No. 11**) with the Minnesota Department of Natural Resources regarding rate-of-release changes. The guideline states that, for increases and decreases in discharge from the dam, changes should be limited to approximately 60 cfs per day or a change in the tailwater elevation of not more than 0.25 feet. The guideline is not applicable when the reservoir is being operated for flood control and/or to prevent property damage. At all times, reasonable judgement must be exercised. For example, a large percent increase or decrease in the total magnitude of the flow is not advisable (e.g. going from 100 to 500, 500 to 100 cfs or 1,000 to 500 cfs in one

gate move). The District's Environmental Section should be consulted when changes are being made during critical flow periods particularly during low-flow conditions. Two or three gate changes per day may be necessary during critical flow periods to alleviate stress to fish and wildlife resources. See **Table 7-5**.

e. Regulation For Dry Conditions. The Federal low-flow regulations and State low-flow guidelines are included in the **Low Water Contingency Plan, which was provided to Congress as a requirement of Public Law 100-676, Water Resources Development Act of 1988 (see Exhibit D, Reference 12)**. The information is outlined below. Area-capacity curves and a storage table for Cross Lake/Pine River Dam are in **Exhibit F**. See **Paragraph 7-12** for information on the draft Drought Contingency Plan and other applicable reference documents. See **Tables 7-1 and 7-2** for a summary of the Federal and State low-flow regulations and guidelines.

1. Federal Regulations, Title 33, Sect. 207.340 and P.L. 100-676. Federal regulations (Title 33, Sect. 207.340) require that the average annual discharge from the reservoir must equal or exceed 90 cfs (32,850 SFD or 65,158 ac-ft) (see **Exh. D, Ref. 7, Para. d.2**). The exception being if inspections, repairs, or the prevention of damages, is necessary (see **Exh. D, Ref. 7, Par. d.1**). The average is assumed to be over the course of a water year. In addition, whenever the reservoir is at or below the minimum elevation of 1225.32 feet (9.0 ft. stage), no discharge other than the specified minimum of 90 cfs shall be permitted "except such increases of discharge as may specifically be directed by the Chief of Engineers" (see **Exh. D, Ref. 7, Para. d.5**). If the reservoir falls below elevation 1225.32 feet, the minimum level "will be restored at the first practicable opportunity". The average annual requirement is satisfied in most years by the spring runoff. During prolonged dry periods, however, a careful consideration of the attendant hydrometeorological variables is necessary in order to insure, if practicable, that the average annual requirement is satisfied.

Note that, other than during drawdown periods in anticipation of flood control operations, the Secretary of the Army must notify Congress (P.L. 100-676, see **Exh. D, Ref. 12**) 14 days prior to the reservoir level falling below elevation 1227.32 feet (2 ft. above the min. of 1225.32 ft.).

2. Minnesota Department of Natural Resources (MDNR) Guidelines. After taking measures to insure that the average annual federal discharge/volume/minimum flow requirement can be satisfied (see above), Minnesota Department of Natural Resources (MDNR) guidelines are followed. The MDNR guideline states that, if the reservoir is at or above elevation 1225.32 feet (9.0 ft. stage), the minimum discharge is 30 cfs. Furthermore, if the reservoir is below elevation of 1225.32 feet, the minimum discharge is reduced to 15 cfs. See **Tables 7-1 and 7-2 and Exhibit D, Reference 10**. In most cases, anytime the reservoir is above elevation 1225.32 feet, 30 cfs is the minimum discharge. However, during an extreme dry period, over the span of many months or years, while it may appear that the MDNR guidelines could conflict with the Federal average annual discharge requirement (e.g. 15 or 30 cfs vs. 90 cfs), the Federal regulations will be taken as primary.

f. Regulation for Fish Spawning (Fall/Winter). Beginning in approximately the 1970's or 1980's, the start of the winter drawdown was delayed in some years to as late as 15 December. This was due to a Minnesota Department of Natural Resources recommendation related to water temperature and insuring adequate water depth over whitefish spawning beds. A warm fall, and thus warmer water temperatures, would result in a later start of the drawdown. This issue was revisited in conjunction with the development of this manual. Pending further research and data collection, the drawdown will start each year on 1 October. See **Exhibit D, Reference 13.e.** for details.

g. Recreation Season Regulation. 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.) (see **Tables 7-1 and 7-2**). When runoff conditions permit, the reservoir level should be within the Normal Summer Band of 1229.07 to 1229.57 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 (see **Tables 7-1 and 7-2**). As the recreation industry has grown, the number of people using the resource in the late fall (at least thru Sept.) has also increased. A gradual drawdown, beginning on approximately 1 October, keeps the pool within the summer band in the fall to accommodate late season recreation (see drawdown discussion for details).

h. Fall/Winter Drawdown. The fall/winter drawdown of the reservoir normally begins on 1 October, however, if necessary, it can begin anytime after Labor Day (approx. 10 Sept.). The 1 October start of the drawdown allows for an extended recreation season in the fall (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.

1. Drawdown Discharge. In the fall, the total discharge and the length of time required to lower the pool to the normal drawdown level (elev. 1227.32 ft.) by 1 March, are determined. An average discharge from 1 October to 1 March of approximately 100 cfs above inflow is required for a drawdown from elevation 1229.32 (mid-summer band) to 1227.32 feet. However, the required drawdown discharge may change as the winter/snowpack progresses. The area-capacity curves and storage tables in **Exhibit F** 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. If the drawdown is completed before the spring snowmelt begins, discharge inflow to maintain the drawdown level.

2. Drawdown Target Elevations. The final drawdown target level, which may be higher or lower than 1227.32 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. The snow water content guidelines in **Table 7-7** can be used to assist in this decision making process. 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. A drawdown to elevation 1227.32 feet results in a minimum amount of disturbance to resources in the reservoir. However, the reservoir can be lowered to elevation 1225.32 feet if needed for extreme conditions. See **Tables 7-1, 7-2, 7-7** and **Plate 7-1** for a summary. It is recommended that the drawdown be reviewed after the January snow survey results have been published.

Some caution must be exercised when drawing down the reservoir. There is always the danger (although in the case of Cross it is slight) of not being able to fill the reservoir back up to the Normal Summer Band in the spring if a reasonable balance between the drawdown target elevation, snowmelt, spring rains and other factors are not weighed properly. **Tables 7-3 and 7-4** can be used to assess the storage capacity of the system relative to the snowpack and the respective drainage area of the reservoir.

A considerable amount of hydrologic judgement is required during the drawdown process. Considering the myriad number of variables, there will be years when, even with the best of intentions, the ideal drawdown situation will not be achieved.

i. Flood Control, General. Pine River Dam is operated, if necessary, for flood control to prevent damages on the Mississippi River from Fort Ripley to the Twin Cities and other areas downstream. However, the majority of the benefits occur in the areas immediately adjacent to

the river downstream of the dam. The dam does not have a specific downstream control point or trigger stage that governs the flood control operation. For additional details see **Tables 7-1 and 7-2**.

The spring melt can occur as early as March or as late as May with runoff extending into early June. As such, the March 1 drawdown target date allows for an early spring runoff. 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 downstream areas require flood control operation, the discharge from Pine River Dam is adjusted as necessary and the applicable procedures below will be followed.

The High Water Contingency Plan, delivered to Congress as a requirement of the Water Resources Development Act of 1988 (Public Law 100-676) is, with additional details, outlined below (see **Exhibit D, Reference 12**). [Note for later.....the WRDA 88 Plan contains errors..also will have to fix Exh D, Chap 3 etc.]

1. Flood Control, Regulation and Operation. Storage is available between the elevations of 1225.32 feet (max. drawdown level) and 1235.30 feet (Upper Operating Limit, if sandbags are placed on Dike 11.b, see **Para. 7-02.c.**) with a drawdown target elevation determined each year based on conditions (see **Tables 7-1, 7-2, 7-7 and Paragraph 7-05.g.**). After the reservoir fills from the drawdown elevation to the summer band (1229.07 to 1229.57 ft.), discharge inflow if downstream conditions permit. However, if conditions warrant, inflow can be stored for downstream protection up to the Upper Operating Limit (1235.30 ft.). During floods, daily estimates of the remaining inflow volume will be made (see **Chapter 6**). After the reservoir reaches the upper Ordinary Operating Limit (elev. 1230.32 ft.) the outflow will be adjusted, based on the daily inflow forecast and the remaining storage in the reservoir, to utilize the storage, if necessary, up to elevation 1235.30 feet while not exceeding that elevation. As the

storage in the reservoir below elevation 1235.30 feet is filled, the discharge from the control structure will, out of necessity, be ramped upwards until the dam is completely open by the time the reservoir reaches elevation 1235.30 feet.

Open river conditions will then exist until the reservoir falls to elevation 1235.30 feet and regulation is again possible. The control structure must be opened completely when the pool is above elevation 1235.30 feet to insure the safety of the dam. After it is no longer necessary to operate for flood control, the pool 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 problems within the reservoir or downstream. If possible, the pool level should be kept below the upper ordinary operating limit elevation (1230.32 ft., above which shoreline erosion intensifies). The Secretary of the Army must notify Congress 14 days prior to the reservoir level going above elevation 1234.82 feet (0.48 ft. below the upper limit, see **Exhibit D, Reference 12**).

Table 7-6 should be consulted if the flood control operation requires large discharges from the dam. Based upon an informal agreement between the Minnesota Department of Natural Resources and the St. Paul District Corps of Engineers, maximum reservoir releases will follow, as closely as possible, the recommended values (see, **Exhibit D, Reference 10**). Whenever possible, the discharge from the reservoir will follow the guidelines, however; reasonable judgment must be exercised to provide balanced benefits for flood control, in stream resources and considerations for dam safety.

See **Paragraph 7-05.d and Table 7-5** for information on rate-of-release change guidelines.

2. Travel Times. The travel time from Pine River Dam down to Brainerd, Minnesota is approximately 1 day. The travel time down to Fort Ripley is approximately 2 days.

3. Flood Forecasts. The National Weather Service (NWS) river forecasts extend 7 days into the future, which allows time to reduce the discharge at Pine River Dam for the benefit of points downstream (e.g. approx. 2-day travel time to Fort Ripley). 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**.

Table 7-1
Cross Lake Regulation Parameters, (see Paragraphs 3-05, 7-05 and Table 7-2)

Date or Period	Reservoir Elevation, Ft.	Discharge, cfs	Comments
Recreation Season , Start of Fishing Season into Sept. Approx. 15 May to 10 Sept.	1229.07-1229.32-1229.57 Normal Summer Band Middle = 1229.32	As needed to maintain the band but not less than 30 cfs. (1)	See Note No. 1 on min. flows. The summer band is usually held until October.
Fall/Winter Drawdown Approx. 1 Oct. to 1 Mar. (Varies)	1229.32 down to 1227.32 Can go down to 1225.32 Varies, see Table 7-7 and Plate 7-1 (2)	Approx. 100 cfs <u>above</u> inflow.	If necessary, the winter drawdown can begin any time after Labor Day.
Flood Control Operation Approx 1 Mar. to 15 May → Approx 15 May to Fall →	Can go up to 1235.30 (3) 1227.32 up to 1235.30 (2) 1229.32 up to 1235.30	If necessary, reduce flow for flood control at Fort Ripley, MN or other areas. (1) (4)	See Paragraph 7-05.h .
Wet Conditions/High Inflow 1 Jan. to 31 Dec.	At or Above 1235.30 (3) 14 Days Prior to 1234.82 notify Sec. Army (7)	Dam wide open to insure the safety of the structure.	See Paragraph 7-05.h .
Federal Average Annual Outflow Requirement 1 Jan. to 31 December	All Conditions and Levels	Average annual outflow/volume must equal or exceed 90 cfs. (5) (7)	The spring runoff assists in fulfilling this requirement. See Paragraph 7-05.e .
MDNR Guideline, Dry Conditions/Low Inflow 1 Jan. to 31 December	≥ 1225.32, 14 Days Prior to 1225.32 Notify Sec. Army (7) (Exclusive of Drawdown)	30 cfs (6), But, see average annual outflow requirement above. (5)	The minimum flow is 30 cfs. when the pool is ≥1225.32 ft. See Paragraph 7-05.e .
MDNR Guideline, Very Dry Cond./Low Inflow 1 Jan. to 31 December	Less than 1225.32	15 cfs (6), But, see average annual outflow requirement above. (5)	<1225.32 MDNR guideline is 15 cfs. Reservoir is below minimum operating limit.

1. At or above 1225.32 ft., the MDNR minimum flow guideline is 30 cfs. However, the average annual outflow must equal or exceed 90 cfs over a water year (see **Para. 7-05.e.**). For max. discharge ranges see **Table 7-6**. See **Table 7-2**.
2. Elev. 1227.32 ft. is the normal drawdown target elevation. The drawdown elevation can be higher or lower than this depending on runoff/snowpack conditions (see **Table 7-7**). Elevation 1225.32 ft. is the lower operating limit.
3. Shoreline erosion intensifies above elev. 1230.32 ft. If necessary, storage can be used to elev. 1235.30 ft. for flood control (if sandbags are placed on Dike 11.b, see **Para. 7-02.c.**). The Total Operating Limits extend from 1225.32 to 1235.30 feet (see **Table 7-2** and **Paragraph 7-16**).
4. The travel time to Ft. Ripley is approx. 2 days. See **Paragraph 7-05**.
5. See Title 33, Code of Fed. Regulations, Sect. 207.340(d) which prescribes the minimum operating limits and min. ave. annual flows (see **Exh. D, Ref. No. 7**). At or below 1225.32 ft., no flow, greater than the specified min. of 90 cfs is permitted unless directed by the Chief of Engineers. Fed. ave. annual flows are primary over MDNR guidelines. See **Para. 7-05.e**.
6. Minnesota Department of Natural Resources Guideline. See **Exhibit D, Reference No. 10**. See **Note No. 5**.
7. **P. L. 100-676, Sec. 21, WRDA, 1988** contains min. and max. notification elevations. The Secretary of the Army must notify Congress 14 days prior to the reservoir being below the min. or above the max. elevation (see **Exhibit D, Reference No. 12**). The District will notify the Secretary well in advance of the 14-day period.

Table 7-2
Mississippi River Headwater Reservoir System
Operating Elev. And Stages in Feet, (see also Paragraphs 3-05, 7-05, 7-16 and Table 7-1)

	Winni- bigoshish	Leech	Poke- gama	Sandy	Cross L. Pine R.	Gull
1. Normal Summer Range/Band Stage in Feet Middle of the Summer Band Elev.	1297.94-1298.44 9.0 - 9.5 1298.19	1294.50-1294.90 1.8 - 2.2 1294.70	1273.17-1273.67 8.75 - 9.25 1273.42	1216.06-1216.56 8.75 - 9.25 1216.31	1229.07-1229.57 12.75 - 13.25 1229.32	1193.75-1194.00 6.0 - 6.25 1193.87
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 (2002)	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 100-676, Sect. 21, 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
5. Fed. Min. Ave. Annual Flow and Min. Level, Code Fed. Reg., Title 33, See No. 6	1294.94 / 6.0 150 cfs	1292.70 / 0.0 70 cfs	1270.42 / 6.0 200 cfs	1214.31 / 7.0 80 cfs	1225.32 / 9.0 90 cfs	1192.75 / 5.0 30 cfs
6. MDNR Minimum Flow Guidelines The Federal Minimum Average Annual Flow Regulations are Primary See No. 5 and Paragraph 7-05.e.	≥ 1294.94 / 6.0 100 cfs, < 1294.94 50 cfs	≥ 1292.70 / 0.0 100 cfs, < 1292.70 50 cfs	(See Note No. 6.)	≥ 1214.31 / 7.0 20 cfs, < 1214.31 10 cfs	≥ 1225.32 / 9.0 30 cfs, < 1225.32 15 cfs	≥ 1192.75 / 5.0 20 cfs, < 1192.75 10 cfs
7. Flowage Rights Acquired To Elev.: 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
8. Est. Downstream Chan. Cap., cfs	2,000	1,500	6,000	(8.)	2,000-2,500	950
Gage Zero Elev., 1912 M.S.L. adj.	1289.47	1293.23	1264.89	1207.70	(9.)	1188.14
Gage Zero Elev., U.S.E. Datum	1290.08	1293.76	1265.27	1209.00	1218.20	1190.00
Gage Zero Elev., 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 spring drawdown level (see **Table 7-7**). See **Table 7-1** and **Paragraph 7-16**.
3. Pine's Present/Total Operating Limits are in accordance with the latest Water Control Plan. The upper and lower limits provide maximum storage for flood control and other purposes. See **Para. 3-05, Table 7-1** and **Para. 7-16**.
4. **Public Law 100-676, Section 21, of the Water Resources Development Act of 1988** requires the Secretary of the Army to notify Congress 14 days prior to a reservoir being below the minimum or above the maximum listed here. The District will notify the Secretary well in advance of the 14-day period (see **Exhibit D Reference 12**).
5. Title 33, Code of Federal Regulations, Sect. 207.340(d) prescribes the min. operating limits and min. ave. annual discharges as set forth in the 1936 and (for Leech) 1944 regulations (see **Para. 3-05, 7-05.e., 7-16 and Exh. D Ref. 7**).
6. The MDNR elev. and flows are based on an informal agreement between the Corps and the MN Dept. of Natural Resources and are followed after taking measures to insure the federal ave. annual flow requirement is met (see **Para. 7.05.e.**). When Pokegama is below elev. 1273.17 ft., releases are limited to the sum of the Winni. and Leech discharges. In addition, 200 cfs has been adopted as the minimum discharge when Pokegama is at or above elev. 1273.17 ft.
7. See **Para. 2-05** for information. Flowage rights on the Cass L. Chain obtained to elev. 1307.86 (18.92 ft stage).
8. The channel below 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 (see **Exhibit D Reference 14**). 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.

Table 7-3
Drainage and Reservoir Surface Areas of Mississippi River Headwaters Reservoirs

Dam/Reservoir	Drainage Area in Sq. Mi.	Surface Area at Max. Oper. Limit in Sq. Mi. (see Exh F.)	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 Winnibigoshish/Leech and Pokegama = 660 sq. mi. Total D.A. = 3,265 sq. mi (see Note No. 2).
2. Of the 6,240 sq. mi. of drainage area above Aitkin, MN, 3,265 sq. mi. are controlled by Winnibigoshish, Leech and Pokegama (see Note No. 1), 421 sq. mi. are controlled by Sandy and 2,554 sq. mi. are uncontrolled.

Table 7-4
Mississippi River Headwaters Reservoirs
Comparative Storage per Change in One Unit of Reservoir Level

General Ratios of One Unit of Reservoir Volume						
Enter Table From the Top Row						
Reservoir	1 Unit at Winni =	1 Unit at Leech =	1 Unit at Pokeg =	1 Unit at Sandy =	1 Unit at Pine/Cross =	1 Unit at Gull =
Winni	1.00	1.93	0.26	0.15	0.21	0.20
Leech	0.52	1.00	0.13	0.08	0.11	0.10
Pokegama	3.88	7.49	1.00	0.56	0.81	0.78
Sandy	6.88	13.27	1.77	1.00	1.44	1.38
Pine/Cross	4.78	9.23	1.23	0.70	1.00	0.96
Gull	5.00	9.65	1.29	0.72	1.05	1.00

Examples: A change in storage of 1.0 ft. in Winni = 0.52 ft. in Leech (or 0.1 ft = 0.052 ft.)
 A change in storage of 1.0 ft. in Leech = 1.93 at Winni and 7.49 at Pokegama
 (Leech has almost twice as much storage as Winnibigoshish)

Table 7-5
Mississippi River Headwaters Dams
Minnesota Department of Natural Resources Guidelines for Rate of Release Changes

Dam	Rate of Release Guideline
Winni-bigoshish	For increases and decreases limit changes to approx. 200 cfs/day or a change in the tailwater elev. of not more than 0.5 feet. No more that a 10% change in outflow in any 2 hr. period when the USGS gage at Grand Rapids reports an ave. daily flow of 400 cfs or less. No restriction when oper. for walleye spawning.
Leech	For increases and decreases limit changes to approximately 100 cfs per day or a change in the tailwater elevation of not more than 0.25 feet.
Pokegama	Reasonable judgment must be exercised. In general changes are limited to 20-30% of the total flow except when operating for flood ctrl. and/or to prevent property damage. No more that a 10 % change in outflow in any 2 hour period when the USGS gage at Grand Rapids reports an average daily flow of 400 cfs or less.
Sandy	No guideline was provided. Reasonable judgment must be exercised. In general changes are limited to 20-30% of the total flow except when operating for flood control and/or to prevent property damage.
Pine/Cross Lake	For increases and decreases limit changes to approximately 60 cfs per day or a change in the tailwater elev. of not more than 0.25 feet except when operating for flood control and/or to prevent property damage.
Gull	No guideline was provided. Reasonable judgment must be exercised. In general changes are limited to 20-30% of the total flow except when operating for flood control and/or to prevent property damage.

Note on Source: Plan of Operation, Miss. R. Headwaters, Minnesota Department of Conservation, Division of Fish and Game, 15 August 1963 (see **Exh. D, Ref. 11**). Not applicable when operating for flood control and/or to prevent property damage. During other times, reasonable judgment must be exercised. For example, a large percent increase or decrease in the magnitude of the flow is not advisable (e.g. going from 300 cfs to 100 cfs in one move). The District's Environmental Section should be consulted when changes are being made during critical flow periods particularly during low-flow conditions. Two or three gate changes per day may be necessary during critical flow periods to alleviate stress to fish and wildlife resources. For the 10 percent guideline at Winni and Pokeg see **Exh. D, Ref. 13**.

Table 7-6
Informal Agreement With the Minnesota Department of Natural Resources
Maximum Releases From Pine River Dam (see Exhibit D, Reference No. 10)

Reservoir Pool Elevation, Feet	Max Discharge Recommended by MDNR
1217.32	15
1218.32	30
1219.32	40
1220.32	50
1221.32	60
1222.32	70
1223.32	80
1224.32	90
1225.32	100
1226.32	200
1227.32	300
1228.32	400
1229.32 (1)	500
1230.32 and above	2,500

1. Middle of the summer range/band (see **Tables 7-1 and 7-2**).

Table 7-7
Cross Lake, Pine River Dam, Suggested Drawdown Target Elevations

Average Basin Snow Water Equivalent	Suggested Drawdown Target Elev. In Feet
Less Than or Equal to Approximately 2 Inches	1228.00 or Higher
Approximately 2 to 4 inches	1228.00 to 1227.32 Normal Drawdown
Approximately 4 to 5 inches	1227.32 to 1227.00
Approximately 5 to 6.0 inches	1227.00 to 1226.50
Greater than Approximately 6.0 inches	1226.50 to 1225.32 Maximum Drawdown

Note: The above guidelines were developed after consultation with experienced operators and regulators of the dam and reservoir combined with the assumption of 20 to 30 percent runoff of the snowpack over the drainage area of 562 square miles.

The drawdown can begin any time after Labor Day (approx. 10 Sept.) if conditions warrant (e.g. high inflows, wet conditions etc.). However, the drawdown is often times delayed (depending on conditions) until approximately 1 Oct. due to the use of the reservoir in the fall for recreation purposes (see **Paragraph 7-05** for details). The relatively small size of the reservoir compared to, for example, Winnibigoshish and Leech, permits the start of the drawdown to occur later in the fall. The drawdown should be targeted for completion by approximately 1 March to be prepared for the possibility of an early spring melt. See **Plate 7-1**.

7-06. Recreation. Recreation is an important feature of Cross Lake reservoir. There are numerous lakeshore homes and resorts around the lakes and a public recreation area (see **Paragraph 2-06**). 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. See also **Paragraphs 7-05 and 8-03**.

7-07. Water Quality. All Corps of Engineers reservoirs must comply with Public Law 92-500 that requires all Federal facilities be managed, operated, and maintained to protect and enhance the quality of water through conformance 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. See **Paragraphs 2-02, 4-08, 5-02, and 8-04.**

7-08. Fish and Wildlife. All Corps of Engineers reservoirs must comply with Public Law 85-624 and 93-205 that requires all Federal facilities be managed, operated, and maintained to protect and enhance issues related to fish and wildlife (see **Paragraph 2-02**). See **Paragraphs 7-05 and 8-05.**

7-09. 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 (see **Paragraph 1-03**).

7-10. Hydroelectric Power. In the Cross Lake basin area, there is no existing or planned Federal hydropower development.

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 **Paragraphs 2-02 and 3-05.**

7-12. Drought Contingency Plans. The Drought Contingency Plan is a stand-alone document (see **Paragraph 1-03**). The plan is currently a draft pending approval. It contains procedures

for interagency basin-wide planning procedures. A copy of the draft plan is kept in the Water Control Section. **Paragraph 7-05** contains information on the Federal and Minnesota Department of Natural Resources requirements, guidelines and interagency agreements for regulation during dry conditions that are designed to balance resources in the reservoir with in-stream flow requirements.

The October 1990 “Mississippi River Low-Flow Review” report and the September 1994 “Water Available from Upstream Locations” Section 22 Report (see **Paragraph 1-03**) should be consulted for further guidance during low-flow conditions.

7-13. Flood Emergency Action Plans. The Emergency Action Plan is a stand-alone document (see **Paragraphs 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 Control 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 **Paragraphs 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 **Paragraph 7-05**.

7-14. Deviation from Normal Regulation. The District’s Water Control Section chief will determine if a desired deviation is minor, significant or major. Minor deviations can be handled between the Section chief and the Division Office. The Division can give an oral (sometimes conveyed by email) approval to the Section chief for minor deviations. A formal recommendation from the District’s Chief, Engineering Division is required for all significant and major deviations. 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.

7-15. 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 Control if special operation is required. If Water Control 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 control or emergency operation, the appropriate procedure in this chapter will be followed until contact with the District Office is re-established.

7-16. Definitions, Operation Levels. The following terms are used in **Paragraph 7-05** (e.g. see **Tables 7-1 and 7-2**) and elsewhere in this manual. This information is provided here to assist in interpreting the regulations (see **Exhibit D**) and other historical references (see **Paragraph 3-05**).

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 7-1 and 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 **Paragraph 3-05 and Tables 7-1 and 7-2**). 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 **Tables 3-1 and 7-2**). This is due to the fact that Pokegama, Sandy and Pine, due to subsequent flood control 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 **Paragraph 3-05** in the respective manuals). 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). In any case, these limits represent the absolute upper and lower reservoir levels that the Corps can operate within (see **Tables 7-1 and 7-2**). 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 **Paragraph 1-03**) and Cross Lake/Pine’s upper limit was modified in the 1997 Design Memorandum (see also **Paragraph 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 **Exhibit D, Reference 12**). See **Paragraphs 3-05, 7-05 and Exhibit D** of this manual for more information.



VIII - EFFECT OF WATER CONTROL PLAN

8-01. General. The Water Control Plan primarily affects flood control, recreation and fish and wildlife. The flood control benefits of the reservoir are very small. The plan strives to maintain stable water levels during the summer months, which provides many benefits related to recreation and fish and wildlife (see also **Chapter 2**).

8-02. Flood Control. The unit hydrographs used in the following studies were developed separately from the information discussed in **Chapter 6**.

a. Probable Maximum Flood. The original dam was constructed prior to the development of current spillway design flood standards. However, the 1993 Dam Safety Assurance Program Reconnaissance Report (revised 21 December 1994, see **Paragraph 1-03**) concluded that additional spillway capacity was needed to insure the safety of the structure and areas downstream. The Probable Maximum Flood (PMF) was calculated using a March 15 snowmelt-rainfall event. A uniform loss rate of 0.02 inches per hour and an initial loss of 4.0 inches was adopted. The resulting PMF has a peak inflow of 36,800 cfs. However, 70 percent of the PMF was adopted as the Spillway Design Flood (see below). See **Plate 8-1**.

b. Spillway Design Flood. The aforementioned Reconnaissance Report determined the appropriate Inflow/Spillway Design Flood (SDF). Alternatives designed to pass both the 70 percent and the 100 percent PMF event were examined. The difference in estimated costs for these two alternatives was over \$4 million. Design capacities below the 70 percent PMF inflow were not considered due to the risk of loss of life. There exists a relatively small decrease (1 person) in the loss of life risk between the 70 percent PMF and full PMF designs; and, an

unquantifiable small reduction in the average annual damages due to dam failure. Because of the small decrease in loss of life and damages, and the large difference in cost (\$4 million) between the 70 percent PMF and 100 percent PMF designs, the selected inflow design flood for Cross Lake/Pine River reservoir was determined to be 70 percent of the PMF. This resulted in a peak inflow of 25,700 cfs with a maximum pool value elevation of 1235.3 feet (5 feet of freeboard) and a peak outflow of 16,300 cfs (see **Plate 8-1**). In order to obtain the required 5 feet of freeboard, the gate capacity of the dam was increased along with raising the embankment and other modifications. For more information consult the March 1997 Design Memorandum (see **Paragraph 1-03**).

c. Standard Project Flood. A Standard Project Flood (SPF) for Pine River Dam was developed and presented in the Corps of Engineers report titled, "Review of Design Features of Existing Dams (RCS ENGCW-(OT) 761; Supplement No. 1), Mississippi River Headwaters Reservoirs", in March 1974 (see **Paragraph 1-03**). 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. The SPF series was developed by assuming that the Standard Project Storm occurred immediately following the 1950 spring flood. The computed peak inflow from the SPF is 12,250 cfs. Since the reservoir routings were done for this report the gate capacity of the dam has been increased (see SDF discussion) so computed elevations and outflows will not be listed here.

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 5.49 inches. The SPF was not updated when the aforementioned PMF was developed.

d. Other Floods. Selected floods are described in **Paragraph 4-06** and are listed in **Table 4-3**. Inflow-frequency is shown on **Plate 8-2** and reservoir routings for some of these floods are shown on **Plates 8-3 through 8-7**. The plates present reservoir stage and storage data in addition to the reverse-routed inflow hydrograph and the outflow hydrograph for each year to show the overall effects of the Water Control Plan. The corresponding data for one normal year and one dry year are presented on **Plates 8-8 and 8-9**. High lake levels also occurred on July 17, 1914 (1234.40 ft.), July 29, 1920 (1233.29 ft.), August 1st - 5th, 1915 (1232.59 ft.) and June 11th and 22nd, 1927 (1232.30 ft.). However, these levels were probably induced in order to provide sufficient water for downstream navigation as opposed to being the result of large flood events.

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 landowners to use for cabins and docks. See **Paragraphs 2-06 and 7-06**.

8-04. Water Quality. Cross Lake's water quality is not significantly impacted by the current Water Control Plan. Current water quality is good, however there is concern that accelerated eutrophication will occur if non-point source pollution from extensive lakeshore development, urban and agricultural runoff, and other sources is not controlled using best management practices. The Corps conducts a water quality monitoring program in conjunction with the Minnesota Pollution Control Agency to evaluate the water quality impacts of reservoir operation and identify water quality trends and problems. Additional efforts by local organizations focus on controlling eutrophication by reducing reservoir phosphorus loading through implementation of best management practices in the watershed. See **Paragraphs 4-08, 5-02, and 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 Pine River Reservoir, 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 **Paragraph 7-08.**

8-06. Water Supply. The headwaters reservoirs are not used for water supply. The Drought Contingency Plan should be referenced for information on water supply issues in the region. The Drought Contingency Plan is in draft form (dated September 1992) and is a stand-alone document. See **Paragraphs 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 **Paragraph 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 **Paragraph 2-02.**

8-09. Drought Contingency Plans. The Water Control Plan is complimentary to the Drought Contingency Plan. The water stored in the reservoir provides a source to augment in-stream flow needs during dry periods while providing maximum benefits to the reservoir.

The Drought Contingency Plan should be referenced for additional information. The Drought Contingency Plan is in draft form (dated September 1992) and is a stand-alone document (see **Paragraph 1-03**). Also see **Paragraph 7-12**.

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 **Paragraph 1-03**).

8-11. Frequencies. The frequency and duration curves in this manual use various periods of record. The beginning of the modern homogenous period of record is listed alternatively as 1931 or 1936. The first draft version of this manual was published in the mid-1980's and it used 1936 as the beginning of the homogenous record. This is the last year in which the official regulations from Congress, related to water levels and flows, were changed (see **Paragraph 3-05**). **Plates 4-6, 4-7, 8-12 and 8-13**, which resulted from the 1980's effort, utilize a period of record from 1936 through 1985. **Plate 8-11** (elev.-freq., 1931-1995) uses 1931 as the beginning of the homogenous record. This plate was developed for the March 1997 Pine River Dam Design Memorandum (see **Paragraph 1-03**). The start date (1931) was chosen as it is the first year that regulations from Congress restricted the pool elevations (see **Paragraph 3-05**). It was determined that the subsequent changes in the regulations through 1936 would not have significantly affected elevation-frequency. The 1997 work uses a period of record through 1995. **Plate 8-2** (1898-1995) was also adopted from the 1997 report. However, curves that involve inflow use 1898 as the beginning of the record regardless of which study the work originated from as shown on **Plates 4-3, 4-4, 4-5, 4-8, 8-10** (all 5 use 1898-1985), and **8-2**(which use 1898-1995) (see **Paragraph 4-07**). Updated plates from the 1997 report were inserted into this manual as appropriate.

a. Inflow Volume-Frequency. **Plate 8-10** illustrates the probability of given inflow volumes into Cross Lake Reservoir 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 1898 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".

b. Pool Elevation-Duration and Frequency. The annual probability of a given peak pool elevation is given on **Plate 8-11** (period of record 1931-1995). A frequency-damage curve for the pool is shown on **Plate 4-10** which is based on a frequency curve from an earlier study. The percent of the time the pool is at, or above, a given elevation is presented on **Plate 8-12**.

c. Discharge-Frequency Curve. Seasonal and annual inflow-frequency curves are shown on **Plates 4-3, 4-4 and 8-2**. The seasonal inflow-frequency curves on **Plates 4-3 and 4-4** were not updated for this version of the manual. The annual curve on **Plate 8-2**, however, was adopted from the March 1997 Pine River Dam Design Memorandum (see **Paragraph 1-03**). The discharge-frequency curve for the Pine River Dam outflow is shown on **Plate 8-13**. Inflow- and outflow-duration curves are shown on **Plates 4-5 and 4-6**.

8-12. Other Studies.

a. 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 ENGCW-(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. The Spillway Design Flood for Pine River Dam has since been updated (see **Paragraph 8-02**). Study (5) describes and evaluates resource management at the six Corps of Engineers' administered recreation areas.

b. Channel and Floodway Modification. Floodplain studies have been performed for several communities on the Mississippi River below Pine River Reservoir. 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 **Table 8-1**.

Table 8-1			
Floodplain Studies Downstream of Pine River Reservoir			
Community	Study Number	County	Comments
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
Fort Ripley	270097	Crow Wing	Mississippi River Below Brainerd
Little Falls	270299#	Morrison	Mississippi River above St. Cloud
# - This community has a map with a 10-digit ID number. Each map with such a number will be published as one or more Z-fold panels (like road maps.)			



IX - WATER CONTROL MANAGEMENT

9-01. Responsibilities and Organization.

a. Corps of Engineers. The Corps of Engineers is the owner, operator, and regulator of the Cross Lake Reservoir, Pine River Dam Project. The Water Control Section has direct day-to-day responsibility for the regulation and the Construction-Operations Division has responsibility for the operation and maintenance of the project.

b. Other Federal Agencies. The National Weather Service has the responsibility for all 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**). The U.S. Fish and Wildlife Service, National Resource Conservation Service, U.S. Geological Survey, U.S. Forest Service, and the Environmental Protection Agency, all have an ongoing interest in the regulation of the Pine River Reservoir.

c. State and Local Agencies. State agencies having an interest in Pine River Reservoir regulation are the Minnesota Pollution Control Agency and the Minnesota Department of Natural Resources. Other local interests include area resorts, homeowners, and recreational users.

9-02. Interagency Coordination.

a. Local Press. Information concerning the regulation of the reservoir is provided by the St. Paul District's Public Affairs Office (PAO) 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.

b. 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.

c. U.S. Geological Survey. This agency receives data from its own and co-operative observer gages, as well as from the Water Control Section on a regular schedule and other times on request.

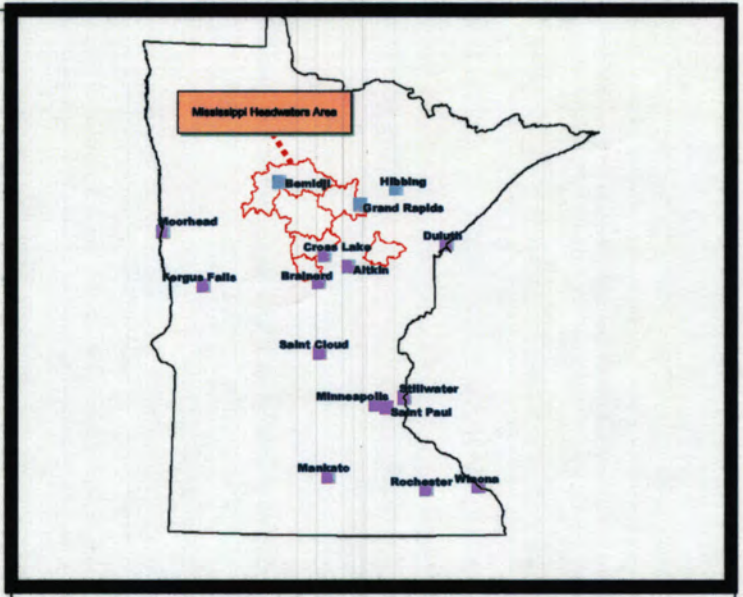
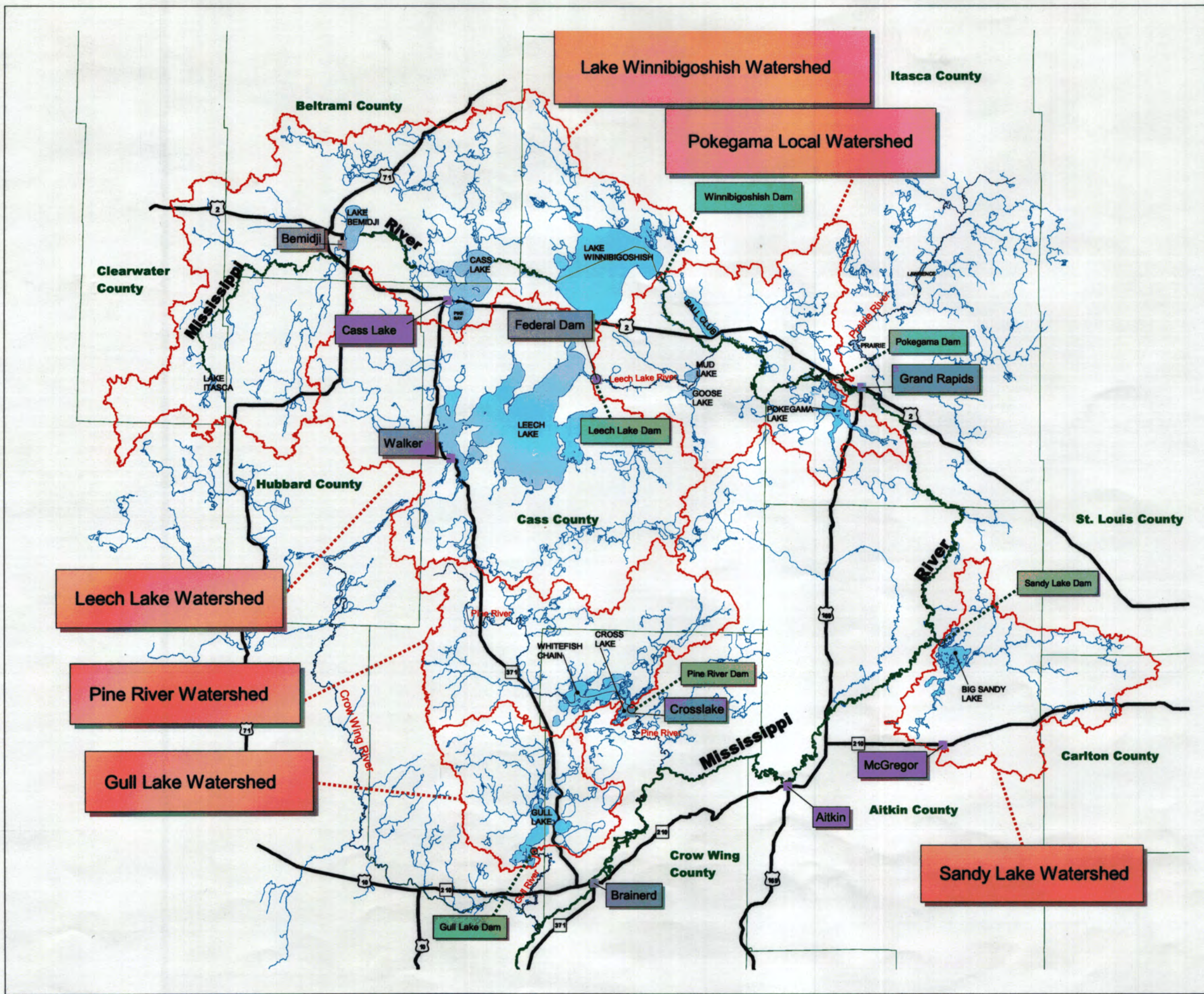
9-03. Interagency Agreements. There is an informal agreement between the St. Paul District, the Indian Tribes and the State of Minnesota, Department of Natural Resources (MDNR), that in all regulatory matters affecting Tribal or state interests, issues will be resolved through consultation. The Corps follows informal guidelines from the MDNR. These are described in **Paragraph 3-05** and **Chapter 7**.

9-04. Commissions, River Authorities, Compacts, or Committees. The Upper Mississippi River Basin Commission (UMRBC), superseded by the Upper Mississippi River Basin Association (UMRBA), is a multi-state organization formed by the Federal Government. It's primary responsibility is the coordination of Federal, State, Interstate, local and non-Governmental plans for regional development of water and related land resources in the basin.

9-05. Non-Federal Hydropower. The Mississippi River Headwaters dams do not contain any hydropower facilities.

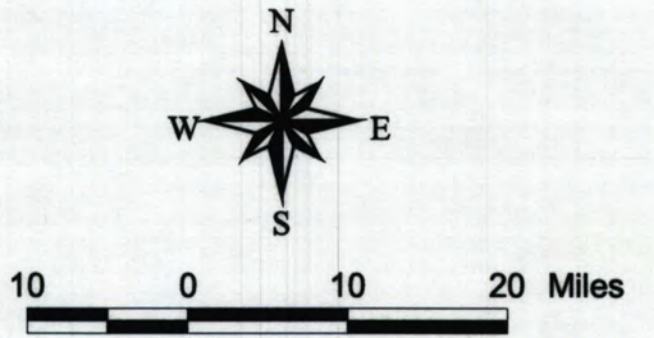
9-06. Reports. Table 9-1 presents a listing of reports and other data sources related to the regulation of the reservoir.

Table 9-1	
Reports	
Report Name	Form Number
Monthly Log Sheet	CEMVP 64E
Climatological Report	WS-E15
Emergency Reports when Requested	By Phone



Key to Symbols

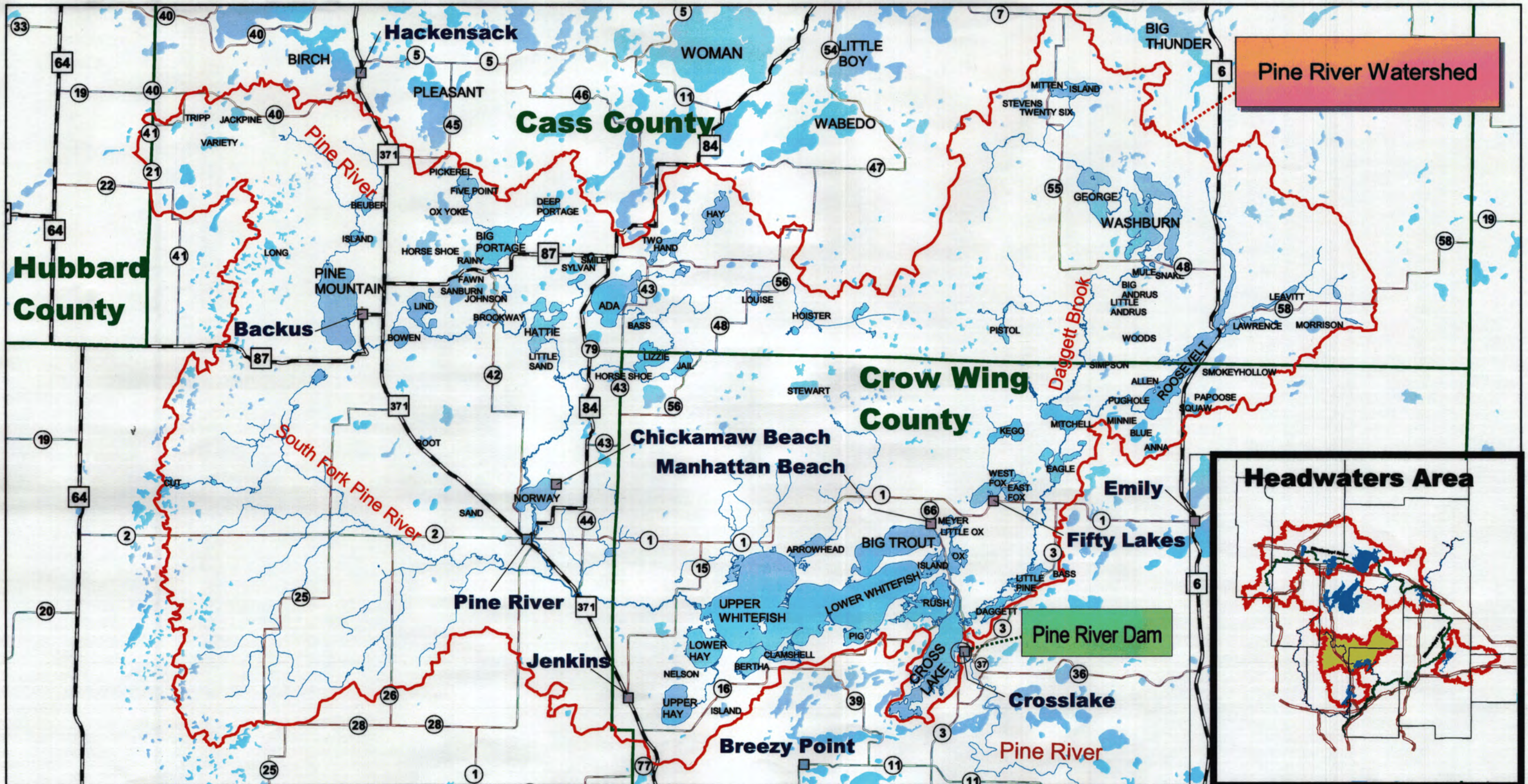
- City
- ▭ Watershed
- ▭ County
- Tributaries
- Mississippi
- Stream/Drainage
- lake
- U.S. Highway
- MN Highway



MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 WATER CONTROL MANUAL

MISSISSIPPI RIVER HEADWATERS WATERSHED

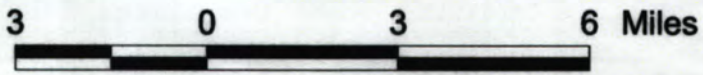
U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



Pine River Watershed



LAKES AFFECTED BY PINE RIVER DAM OPERATION
IN THE WHITEFISH CHAIN OF LAKES
ARE LISTED IN TABLE 2-3

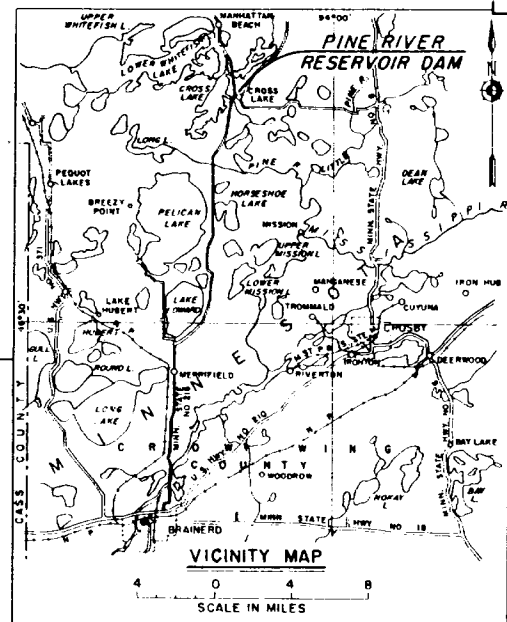
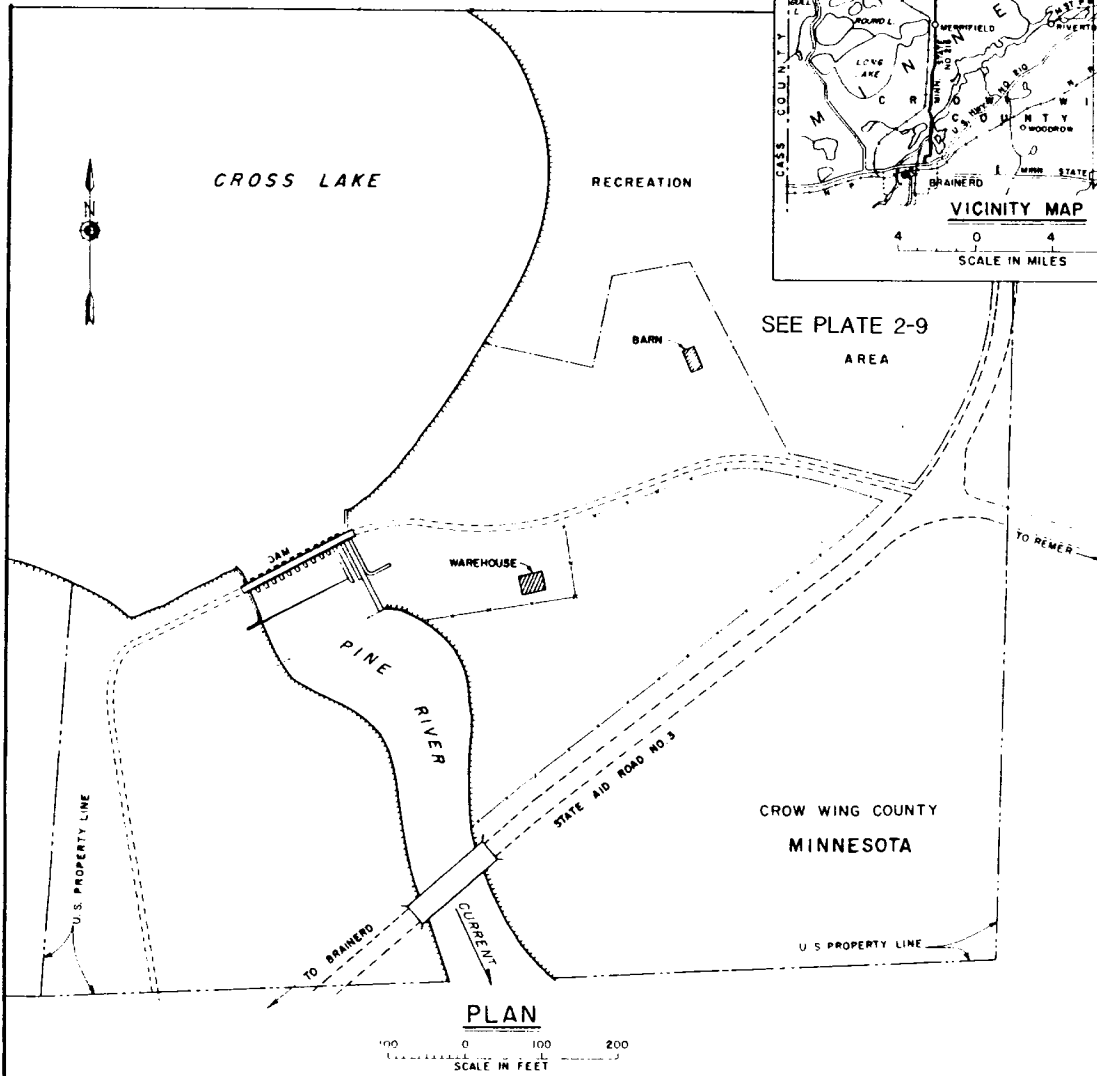


- City
- ▭ Watershed
- Stream/Drainage
- ▭ County
- Lake
- US Highway
- MN Highway
- County Highway

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
WATER CONTROL MANUAL
PINE RIVER

PINE RIVER WATERSHED

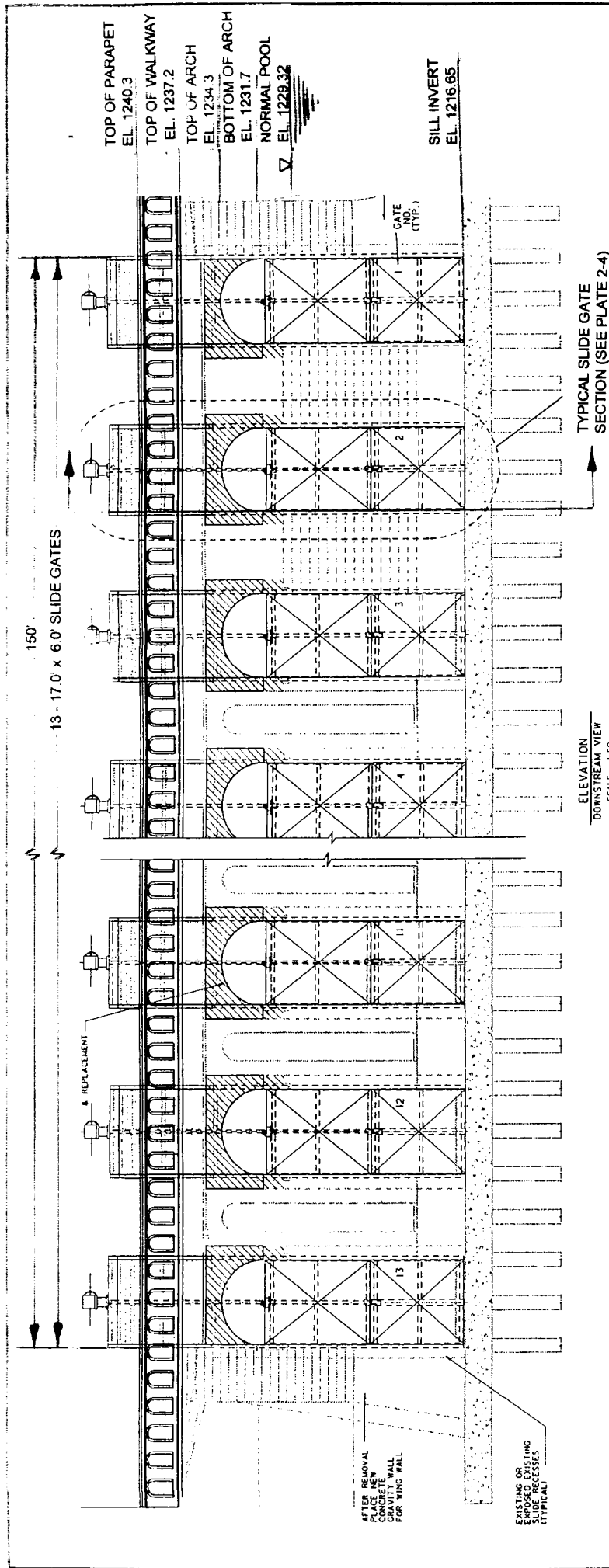
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA



MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER

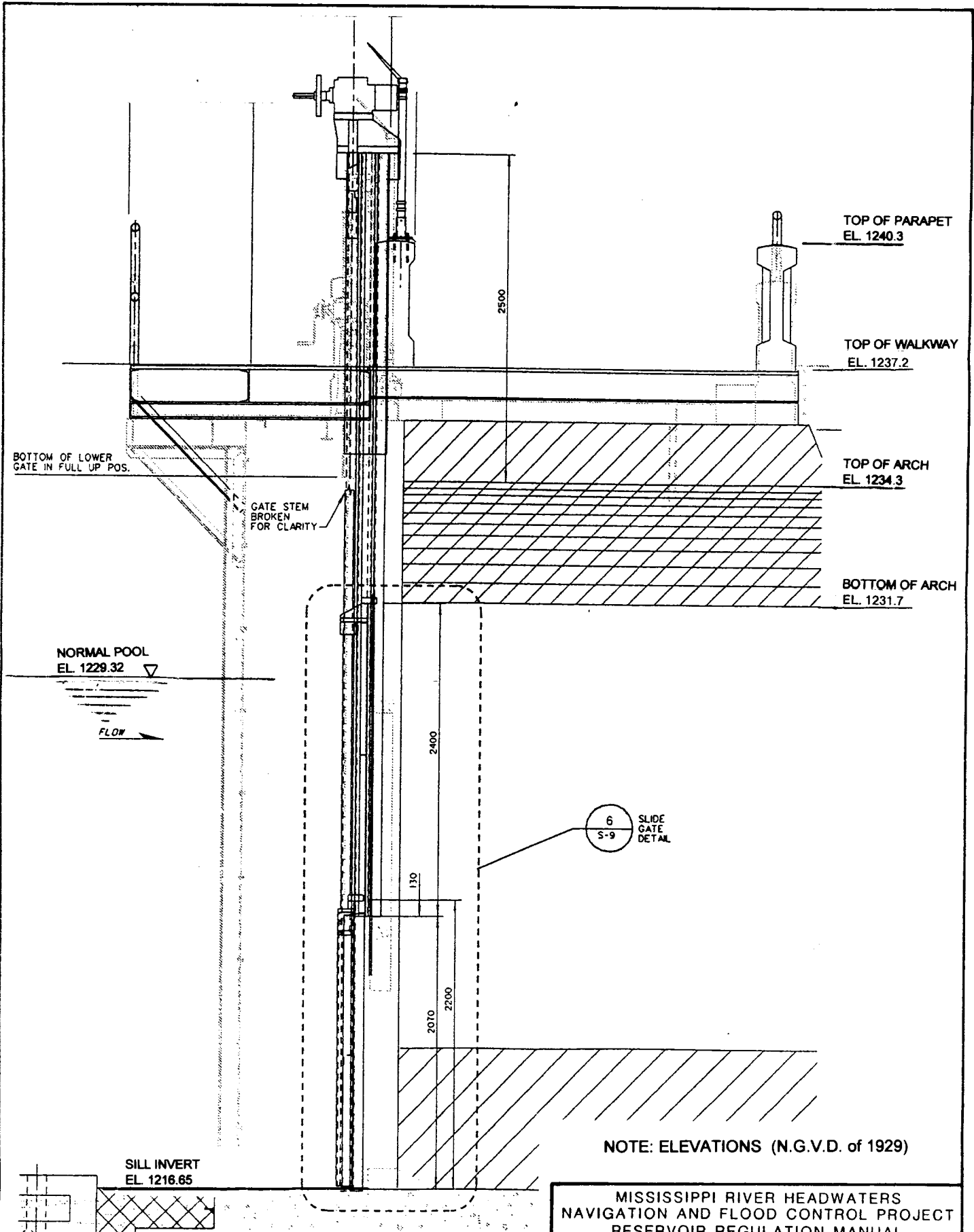
GENERAL PLAN

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



NOTE: ELEVATIONS (N.G.V.D. of 1929)

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
CONTROL STRUCTURE
ELEVATION
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

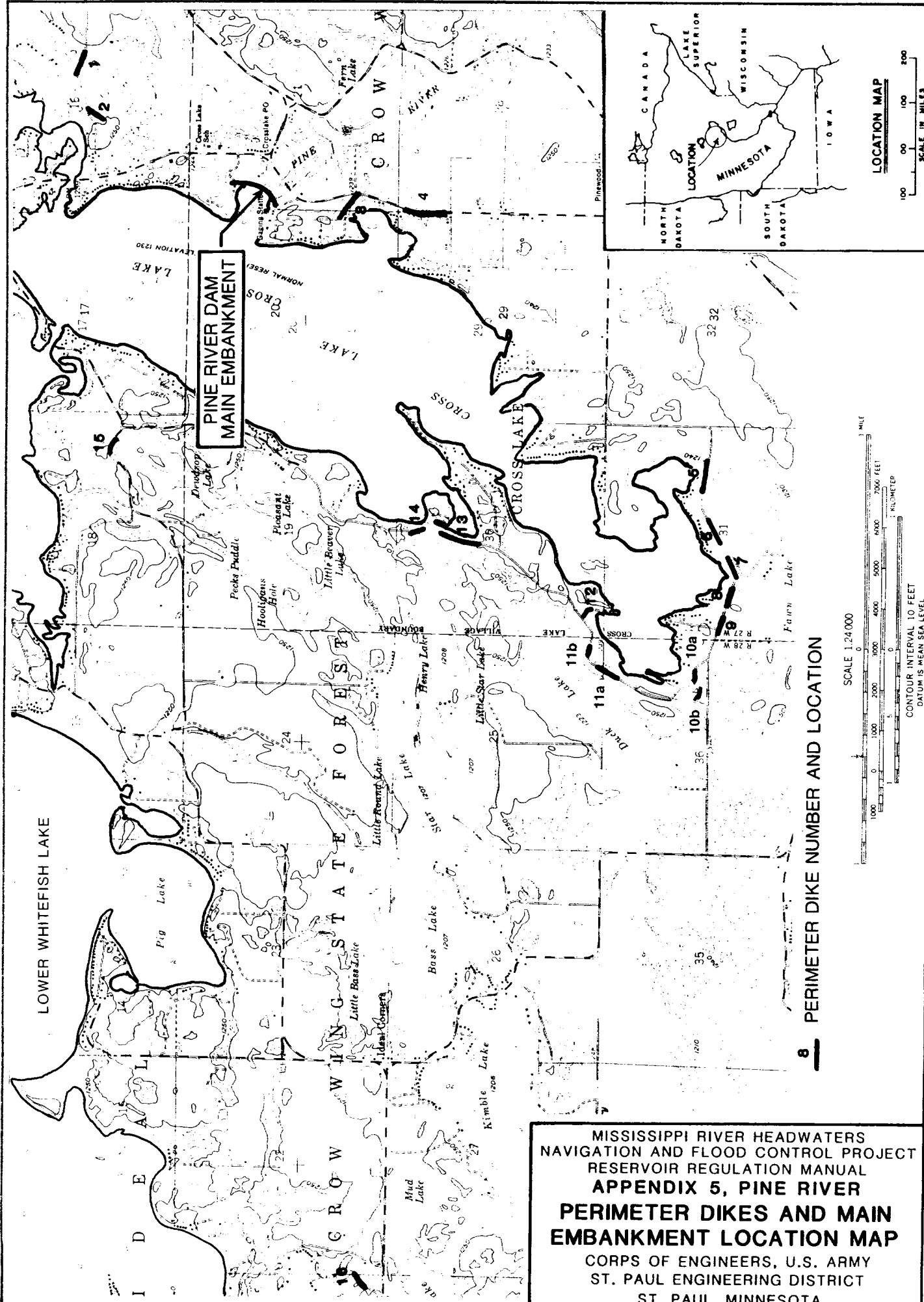


NOTE: ELEVATIONS (N.G.V.D. of 1929)

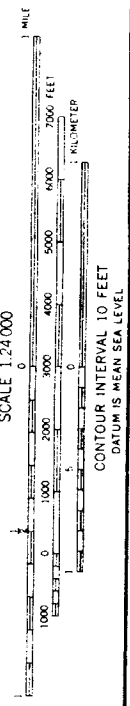
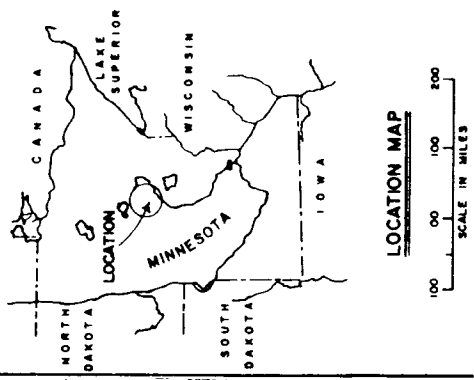
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER

SLIDE GATE SECTION

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

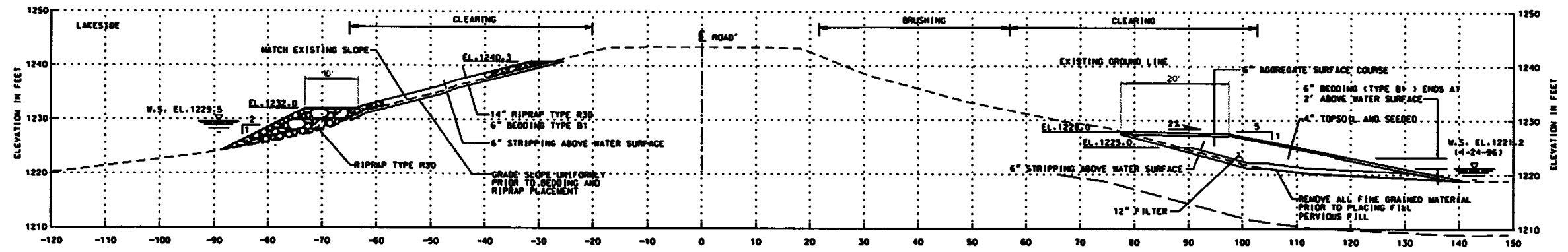


**PINE RIVER DAM
MAIN EMBANKMENT**

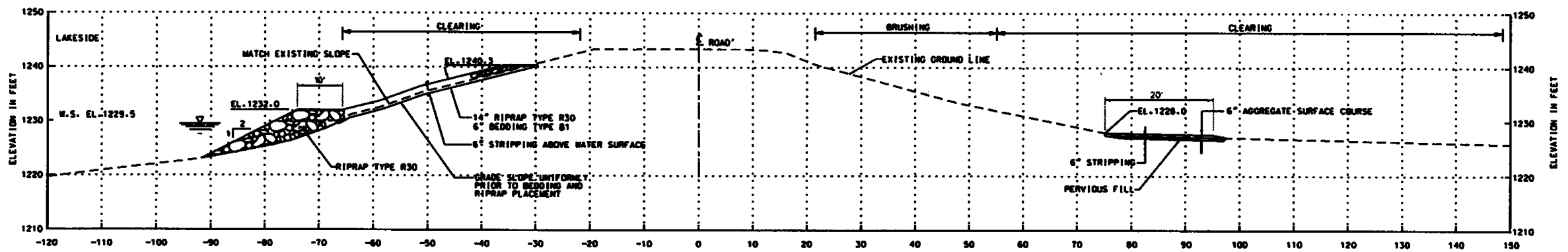


8 PERIMETER DIKE NUMBER AND LOCATION

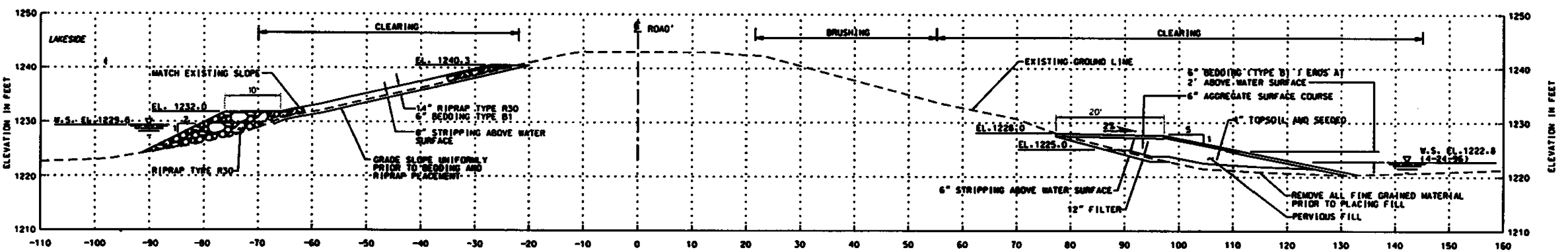
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
**PERIMETER DIKES AND MAIN
 EMBANKMENT LOCATION MAP**
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



SECTION
DIKE 13
SCALE: 10V:10H

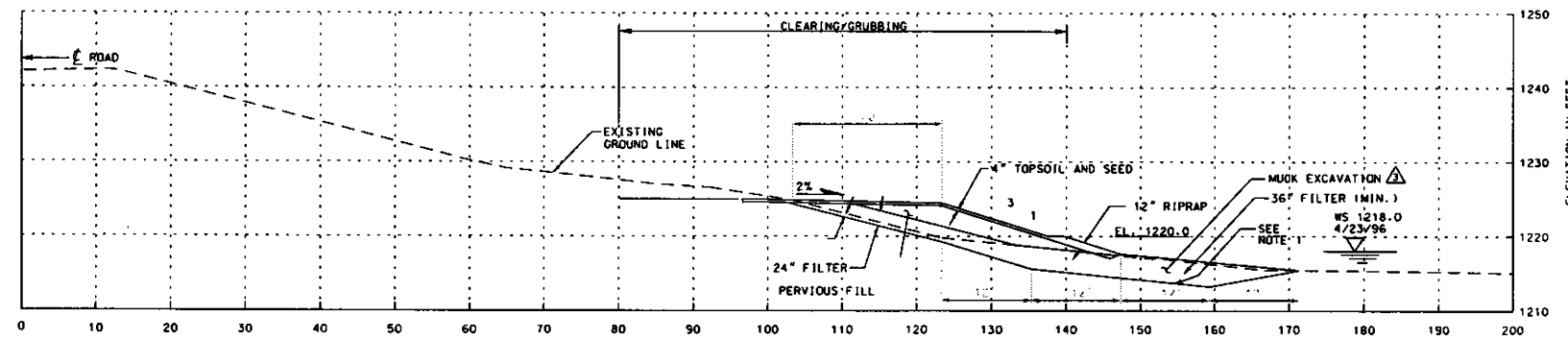
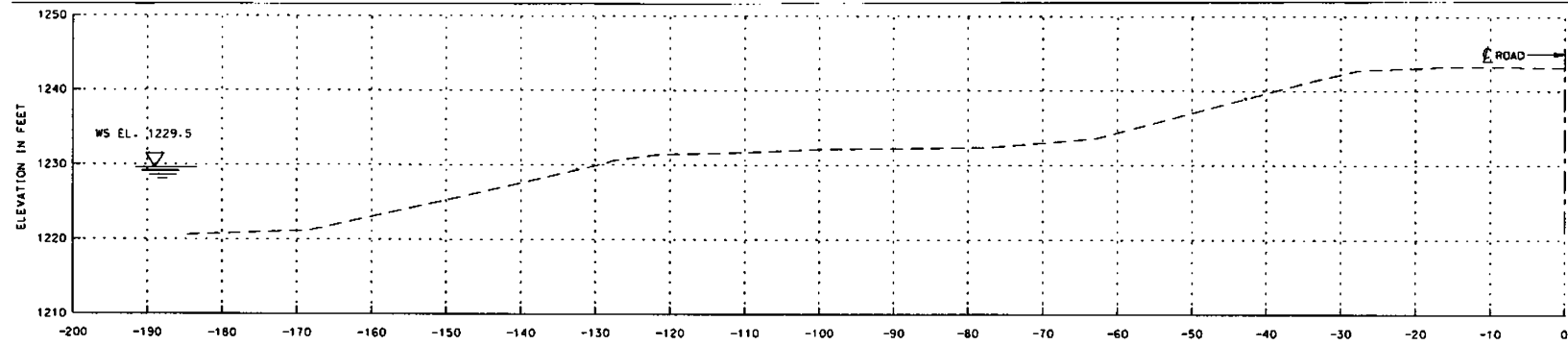


SECTION
DIKE 13
SCALE: 10V:10H

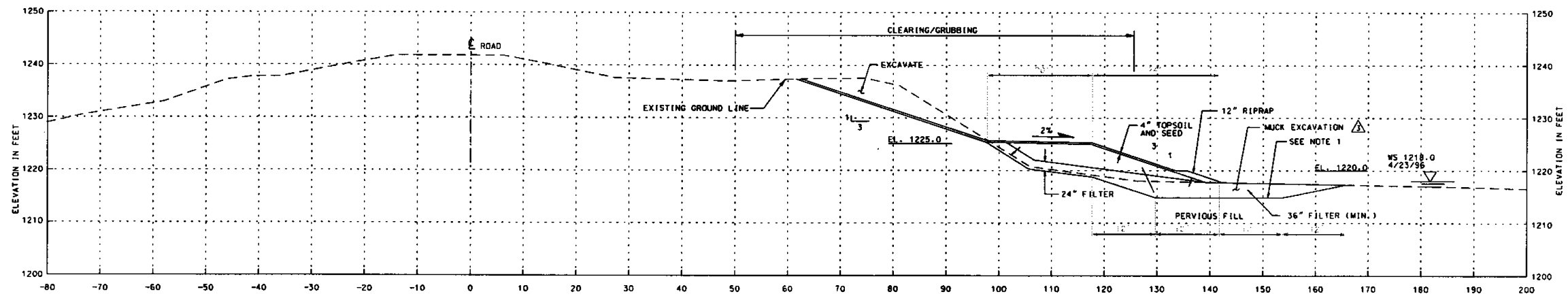


SECTION
DIKE 13
SCALE: 10V:10H

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
DIKE #13
SECTIONS
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA



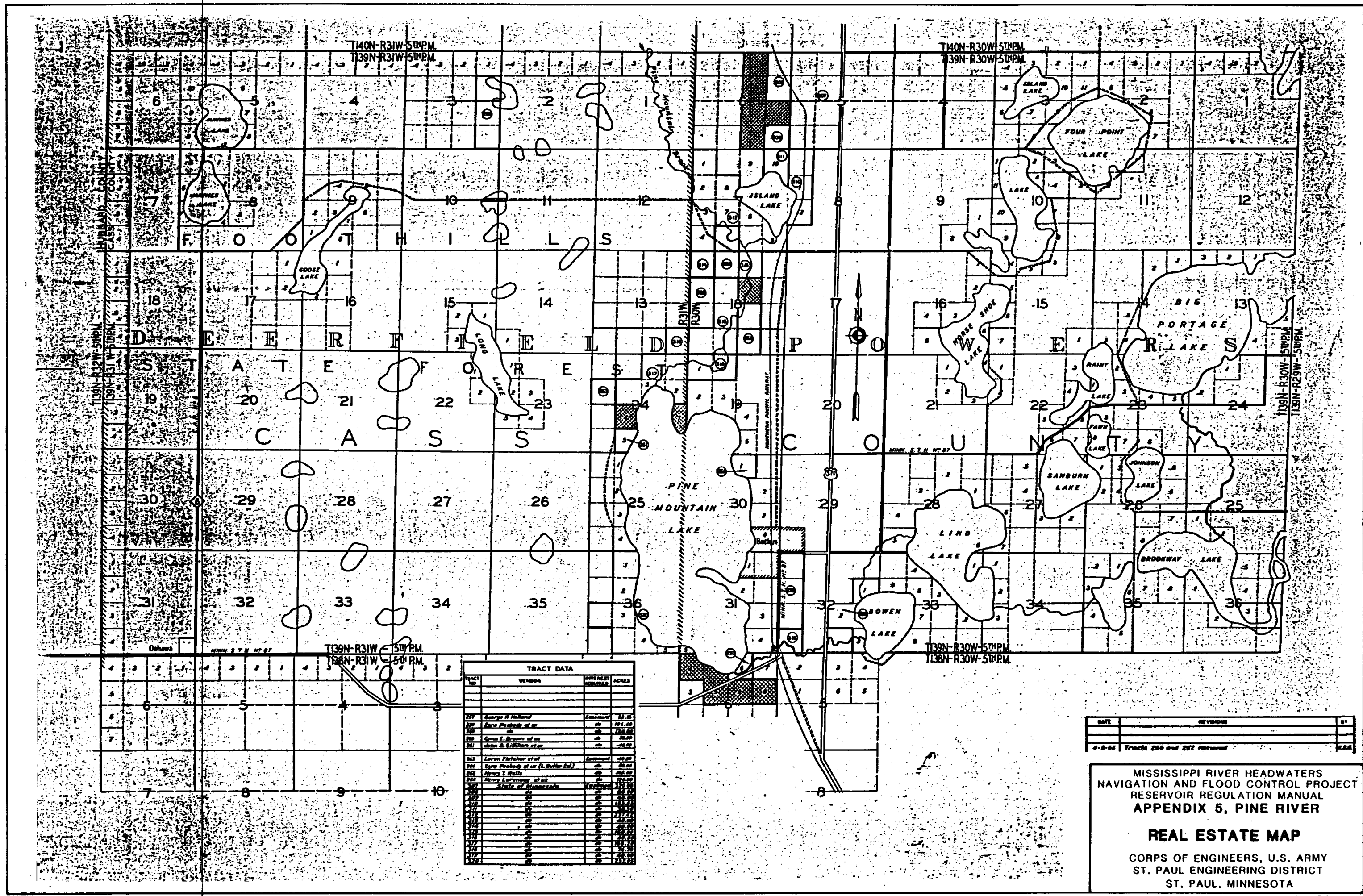
TYPICAL SECTION
DIKE 14
SCALE: 10V:10H



TYPICAL SECTION
DIKE 14
SCALE: 10V:10H

NOTE:
1. EXCAVATE TO TOP OF GRAVELLY LAYER AS DIRECTED BY THE CONTRACTING OFFICER (5' MAX. DEPTH OF EXCAVATION).

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
DIKE #14
SECTIONS
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA



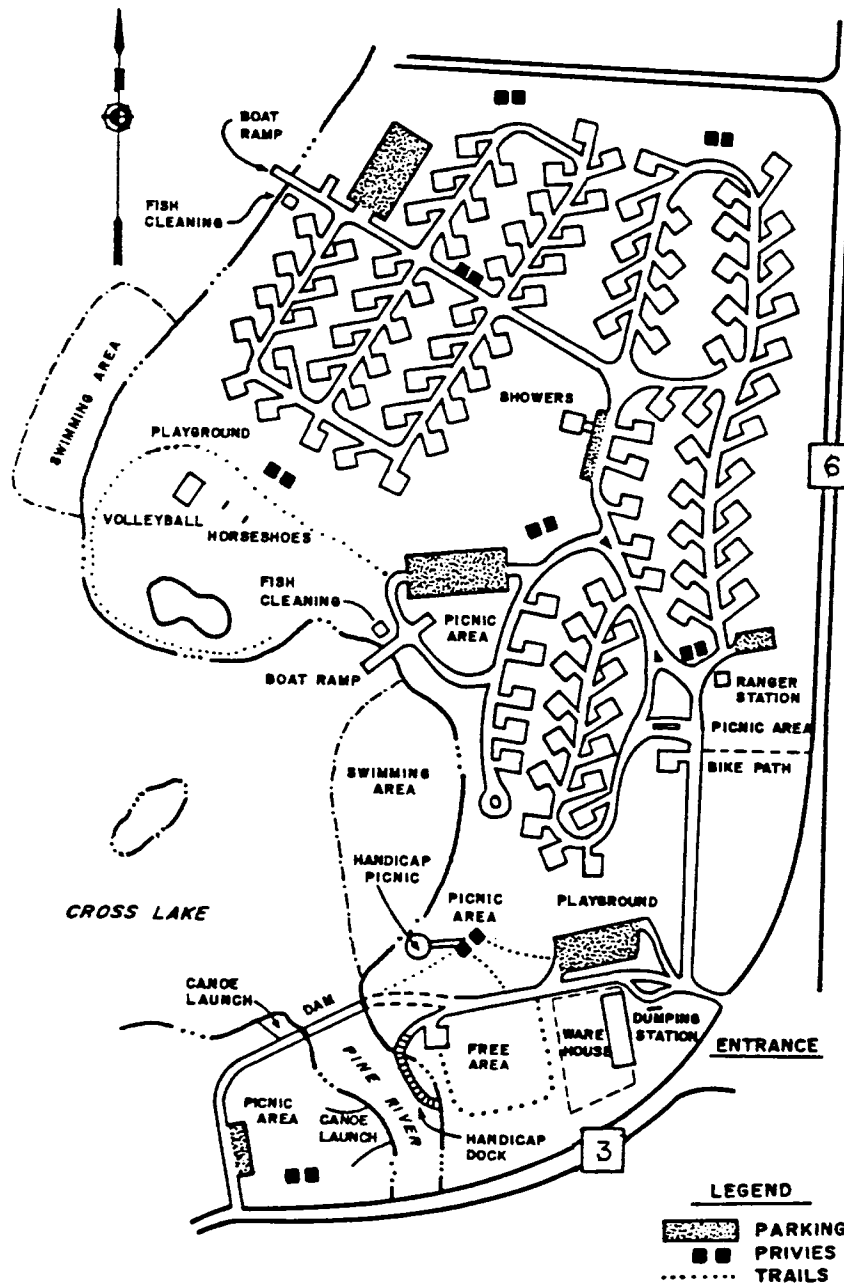
TRACT DATA			
TRACT NO.	OWNER	HYDRETT NUMBER	ACRES
257	George H. Holland	Landmark	52.15
258	Eva Probst et al	db	104.00
259	db	db	128.00
260	Carl E. Brown et al	db	38.00
261	John B. Giffers et al	db	48.00
262	Loren Fletcher et al	Landmark	44.00
263	Eva Probst et al (L. Butler Ed.)	db	88.00
264	Henry T. Wells	db	288.00
265	Mary Larom et al	db	128.00
267	State of Minnesota	Landmark	128.00
268	db	db	128.00
269	db	db	128.00
270	db	db	128.00
271	db	db	128.00
272	db	db	128.00
273	db	db	128.00
274	db	db	128.00
275	db	db	128.00
276	db	db	128.00
277	db	db	128.00
278	db	db	128.00
279	db	db	128.00
280	db	db	128.00

DATE	REVISION	BY
4-8-66	Tracts 266 and 267 removed	R.S.A.

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 5, PINE RIVER

REAL ESTATE MAP

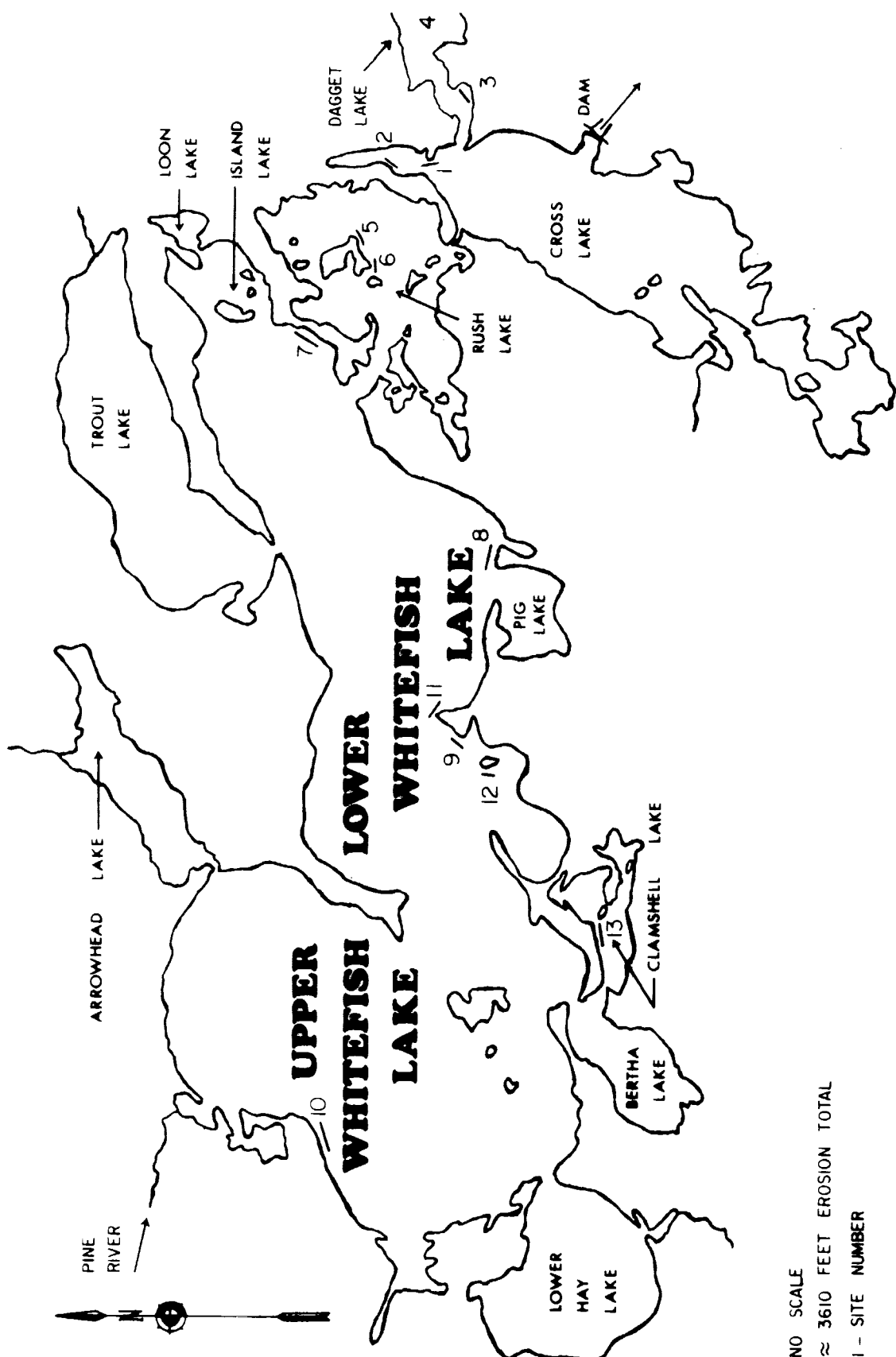
CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER

PUBLIC USE SITE

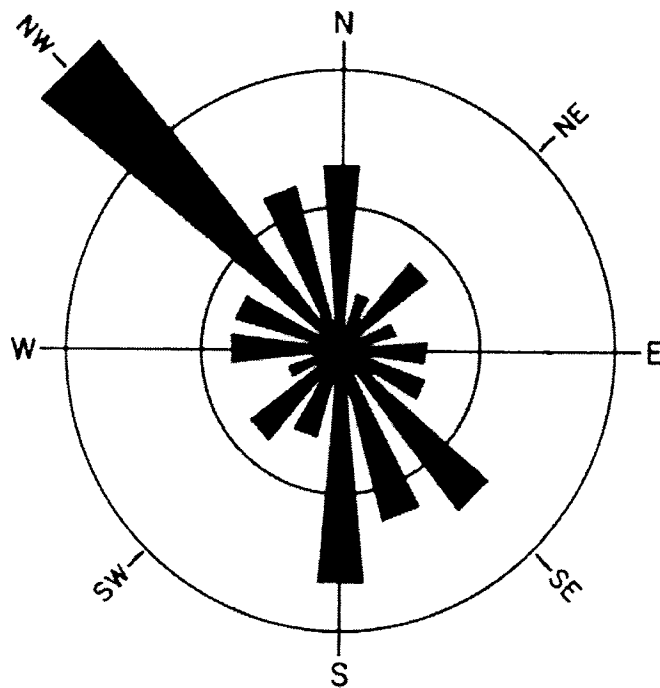
CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



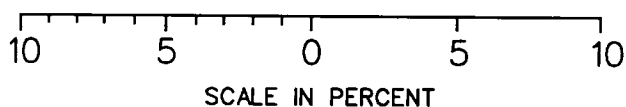
NO SCALE
 ≈ 3610 FEET EROSION TOTAL
 1 - SITE NUMBER

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
BANK EROSION AREAS
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

PERCENT OF TIME WIND BLOWS FROM EACH OF
16 MAJOR DIRECTIONS



BRAINERD
(1958 - 1962)



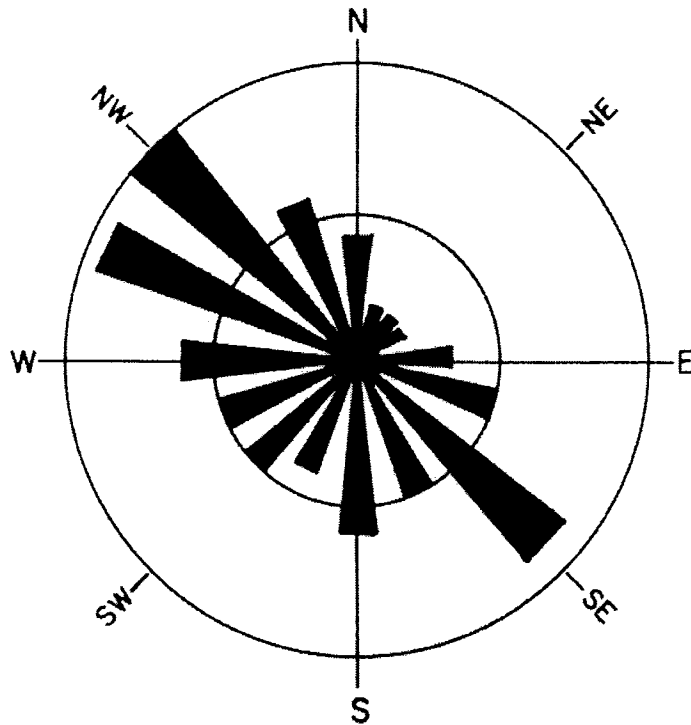
SOURCE: U.S. DEPT. OF COMMERCE
ASHVILLE, NORTH CAROLINA

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL

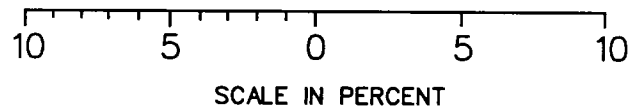
APPENDIX 5, PINE RIVER
BRAINERD, MN
WIND ROSES

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

PERCENT OF TIME WIND BLOWS FROM EACH OF
16 MAJOR DIRECTIONS



BEMIDJI
(1956 - 1961)



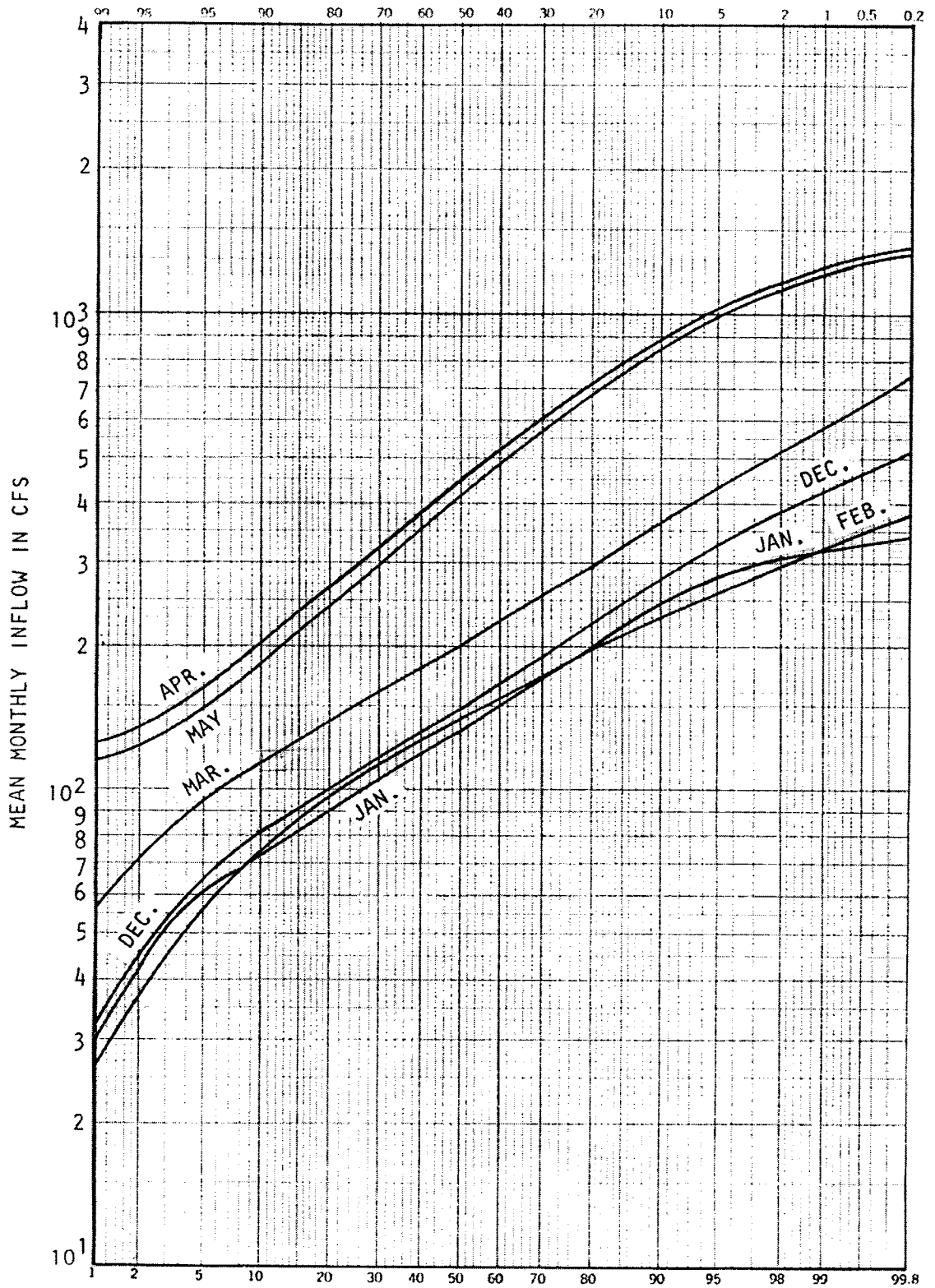
SOURCE: U.S. DEPT. OF COMMERCE
ASHVILLE, NORTH CAROLINA

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL

APPENDIX 5, PINE RIVER
BEMIDJI, MN
WIND ROSES

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

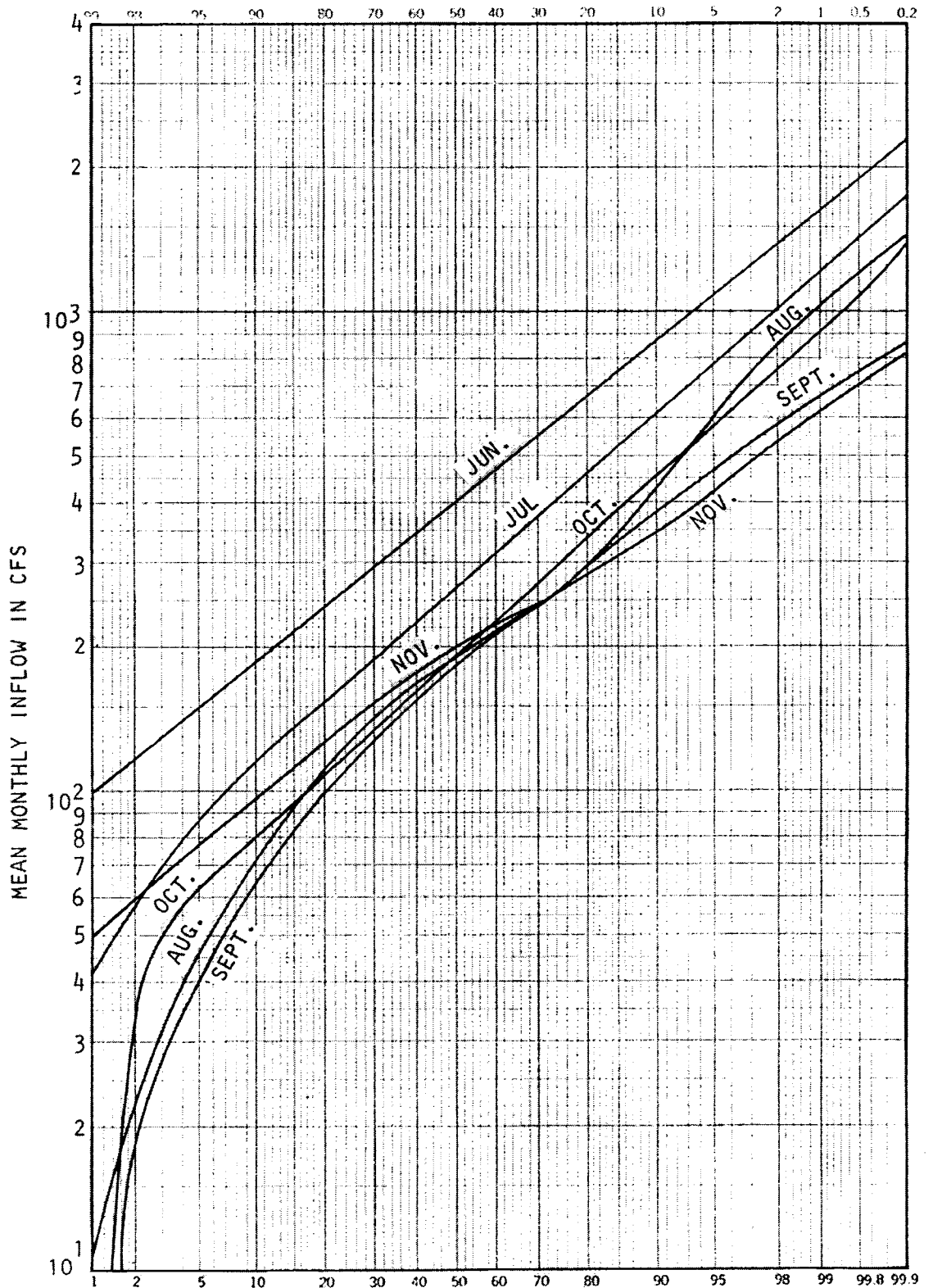
EXCEEDANCE FREQUENCY IN PERCENT



Period of Record Used
1898 -- 1985

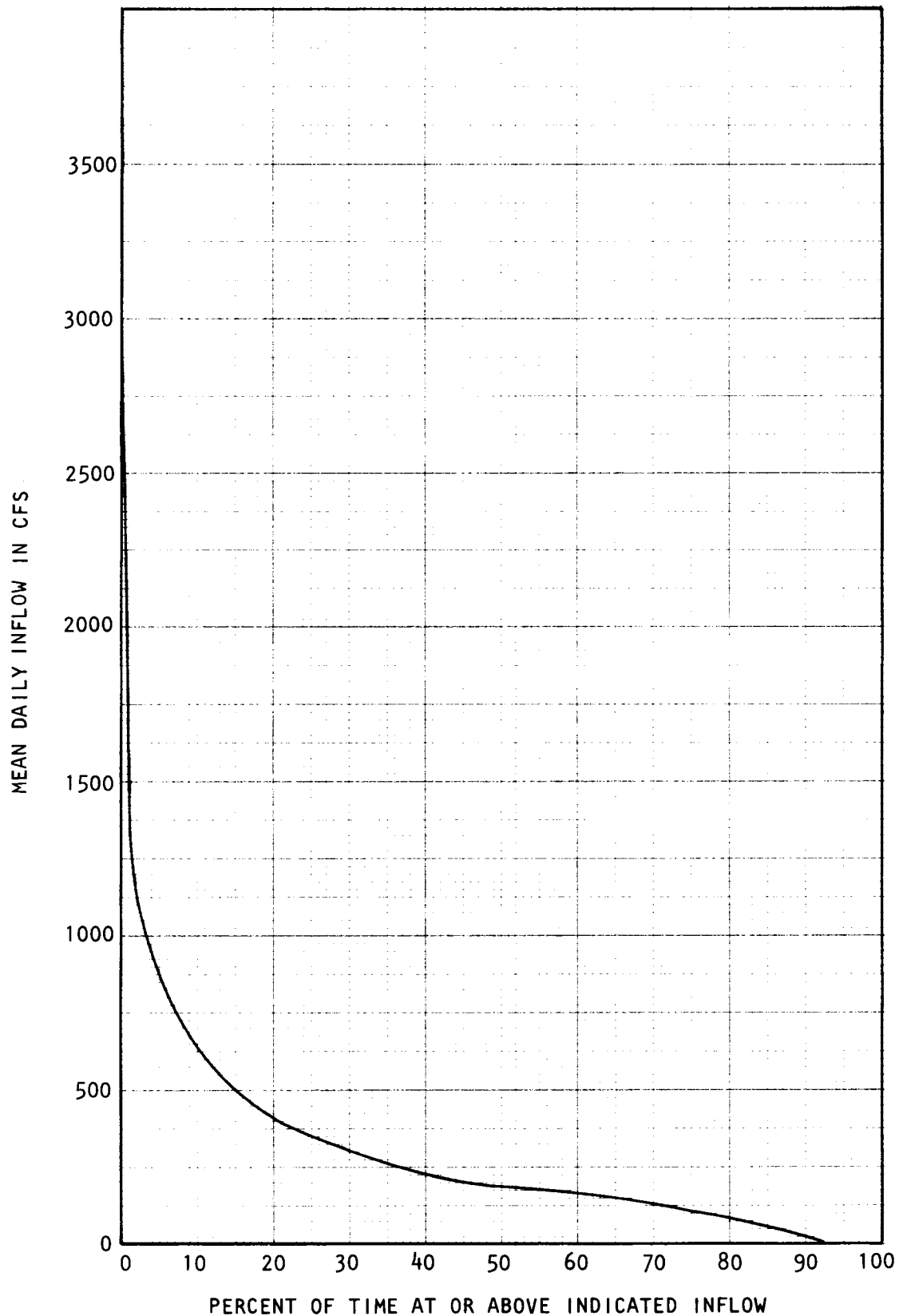
MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
INFLOW FREQUENCY CURVES
MEAN MONTHLY FLOW
(DECEMBER - MAY)
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

EXCEEDANCE FREQUENCY IN PERCENT

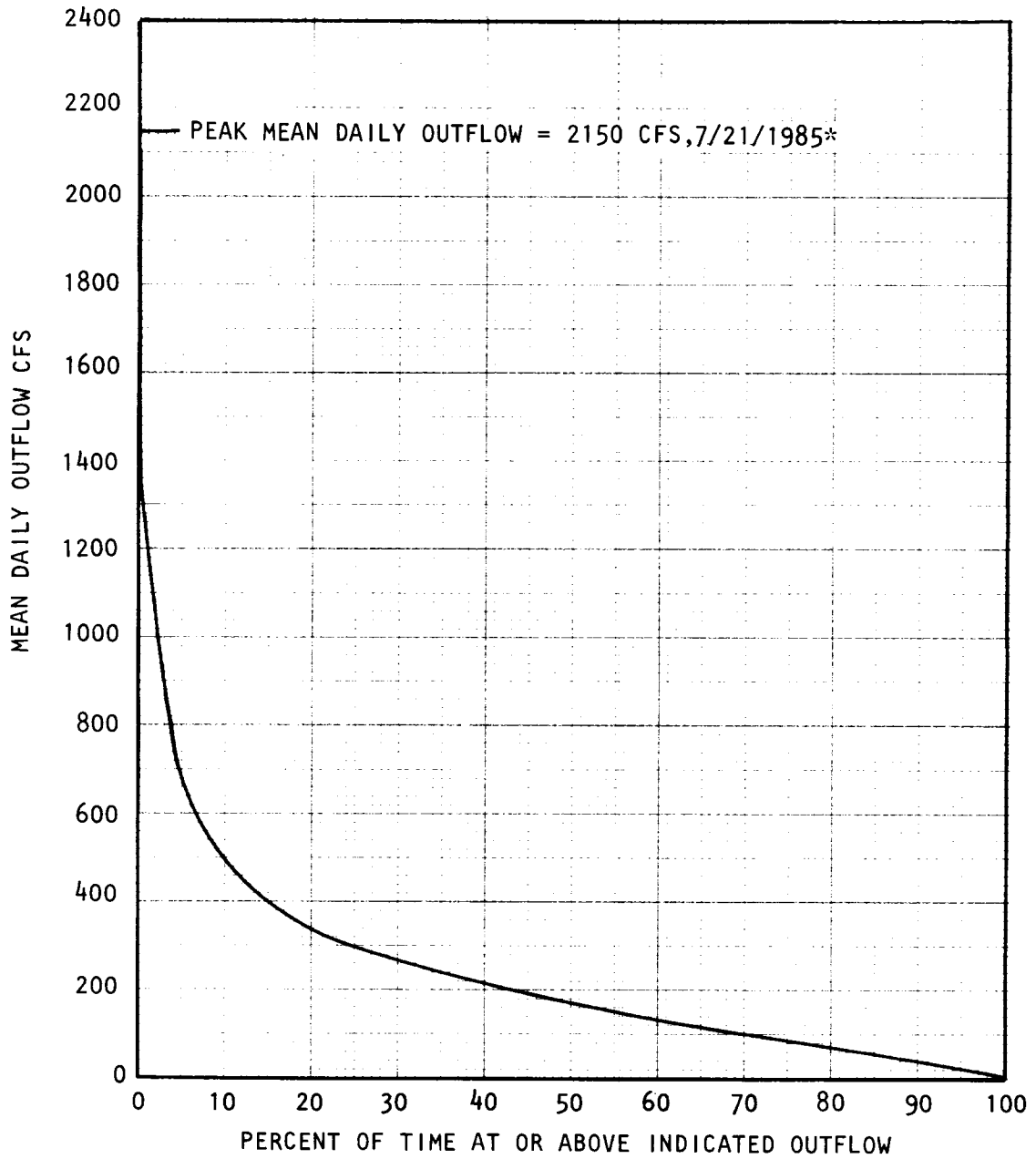


Period of Record Used
1898 -- 1985

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
INFLOW FREQUENCY CURVES
MEAN MONTHLY FLOW
(JUNE - NOVEMBER)
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

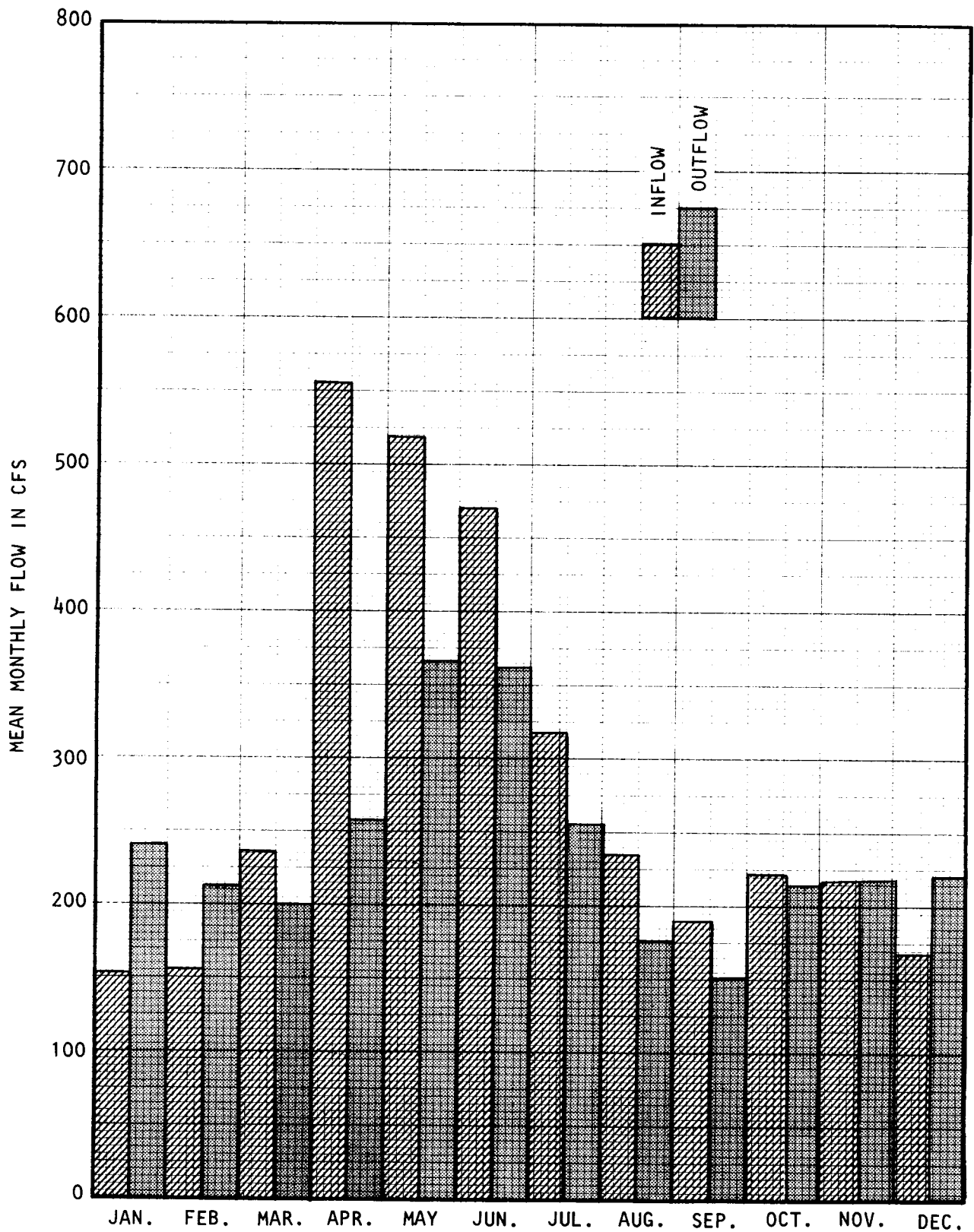


MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
INFLOW DURATION CURVE
(1898-1985)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



* PEAK MEAN DAILY DISCHARGE SINCE CURRENT REGULATION PLAN WENT INTO EFFECT IN 1936. PEAK MEAN DAILY DISCHARGE OF RECORD=2,250 CFS 27 JUNE 1896.

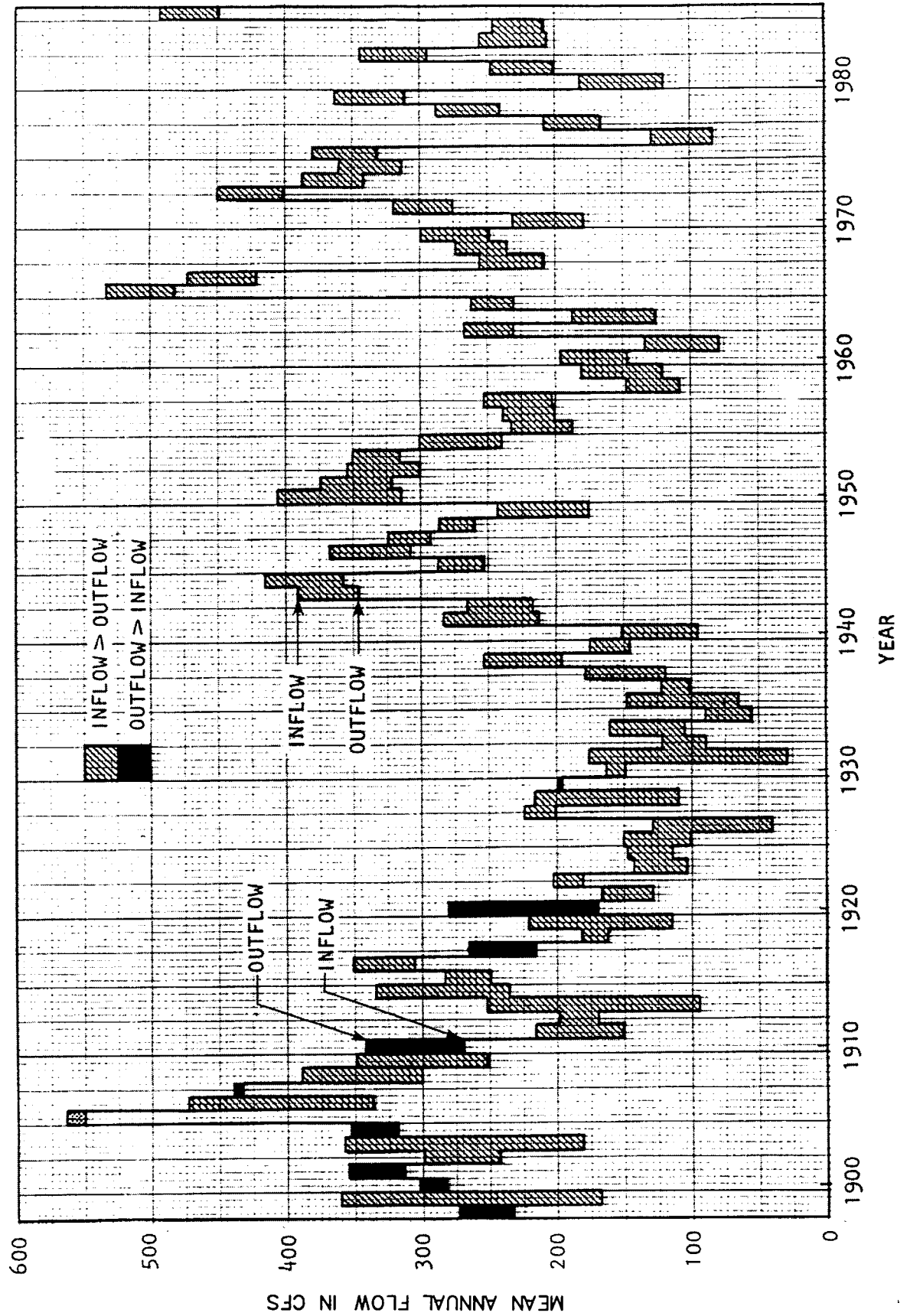
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
OUTFLOW DURATION CURVE
(1936-1985)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
MONTHLY STREAMFLOW DISTRIBUTION
INFLOW-OUTFLOW
(1936-1985)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

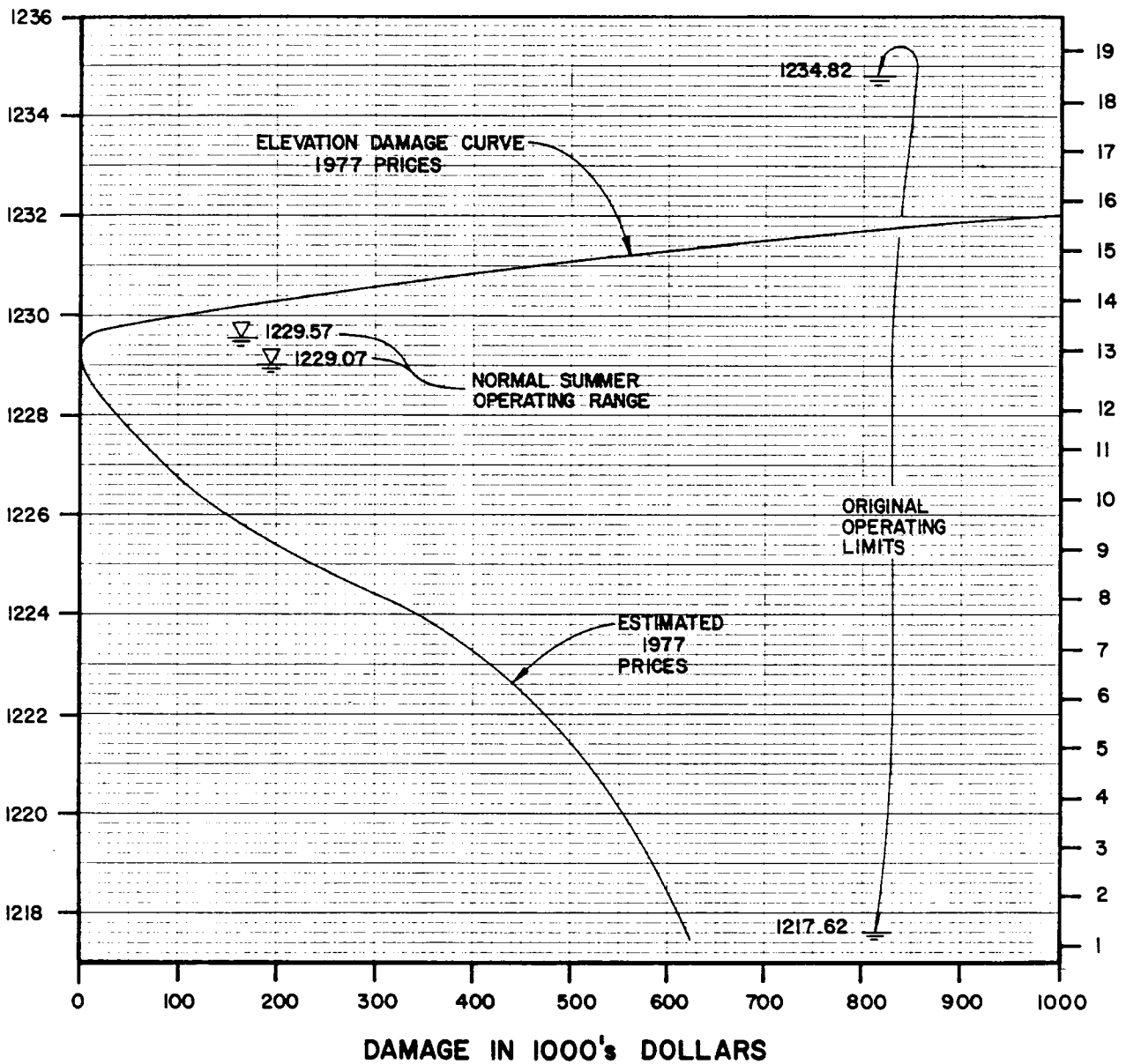
PINE RIVER RESERVOIR MEAN ANNUAL INFLOW & OUTFLOW

(1898 - 1985)



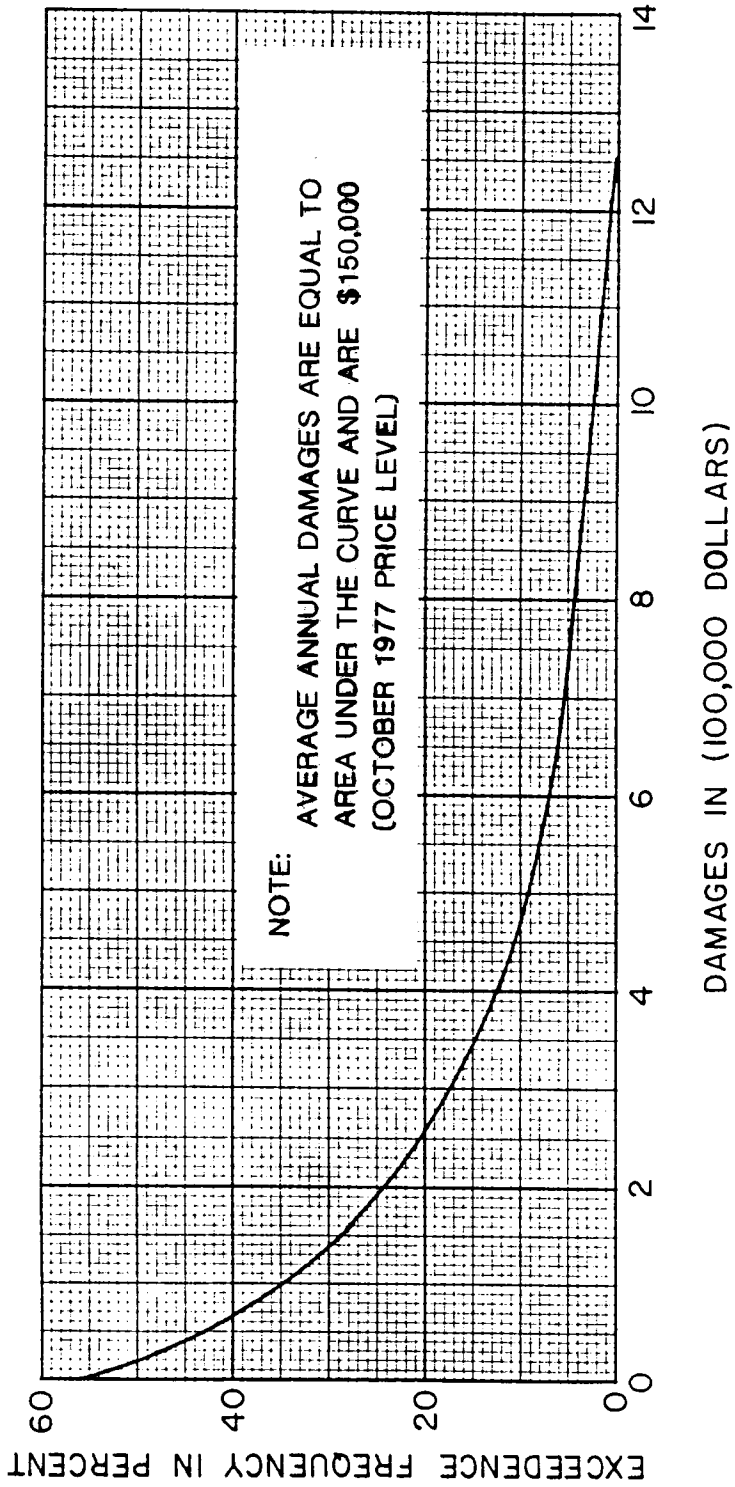
NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 5, PINE RIVER
 ANNUAL STREAM FLOW
 DISTRIBUTION
 INFLOW - OUTFLOW
 U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

ELEVATION IN FEET ABOVE M.S.L. (1929 ADJ.)



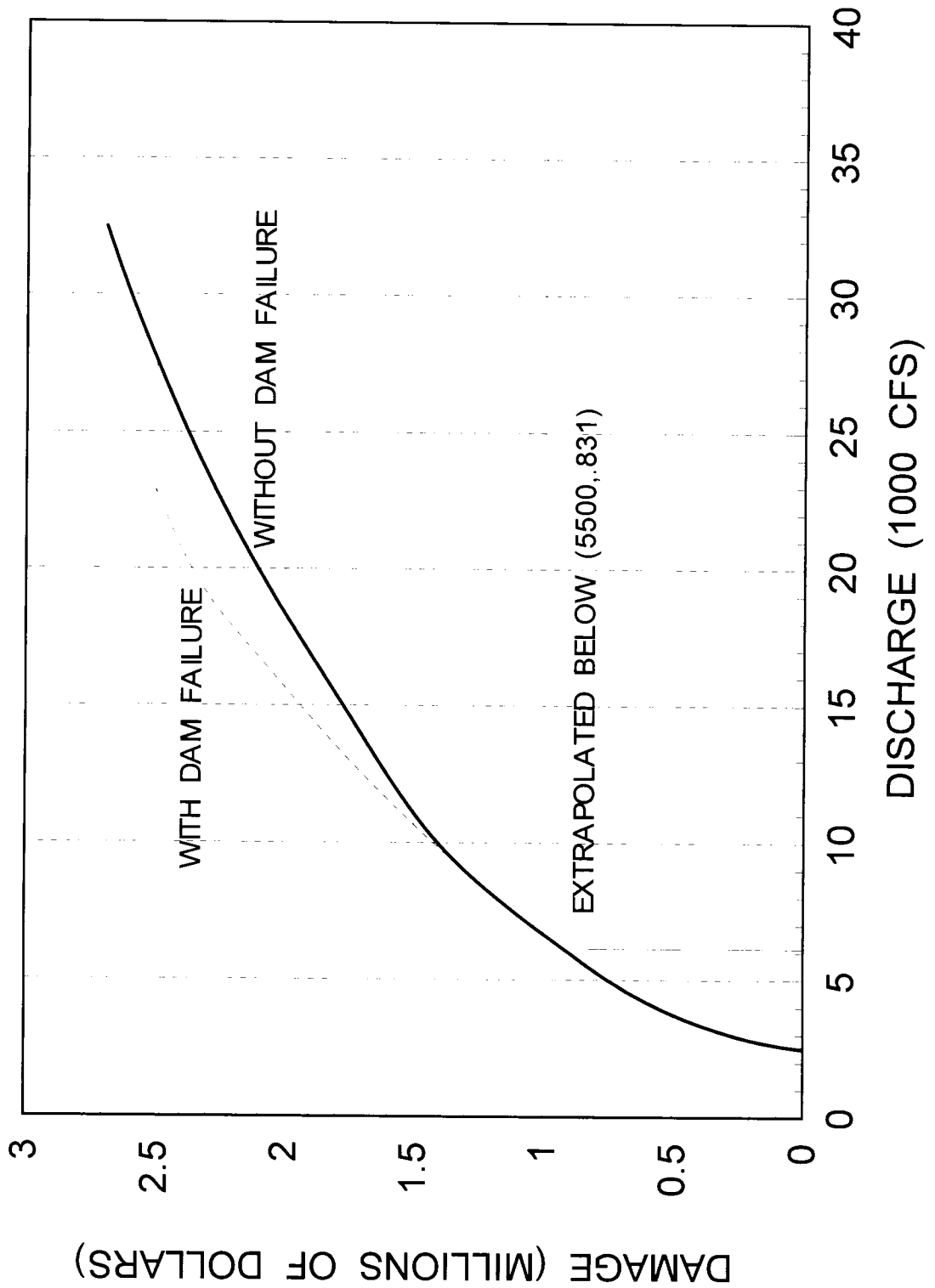
STAGE IN FEET

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
ELEVATION DAMAGE CURVE
(PINE RIVER RESERVOIR)
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

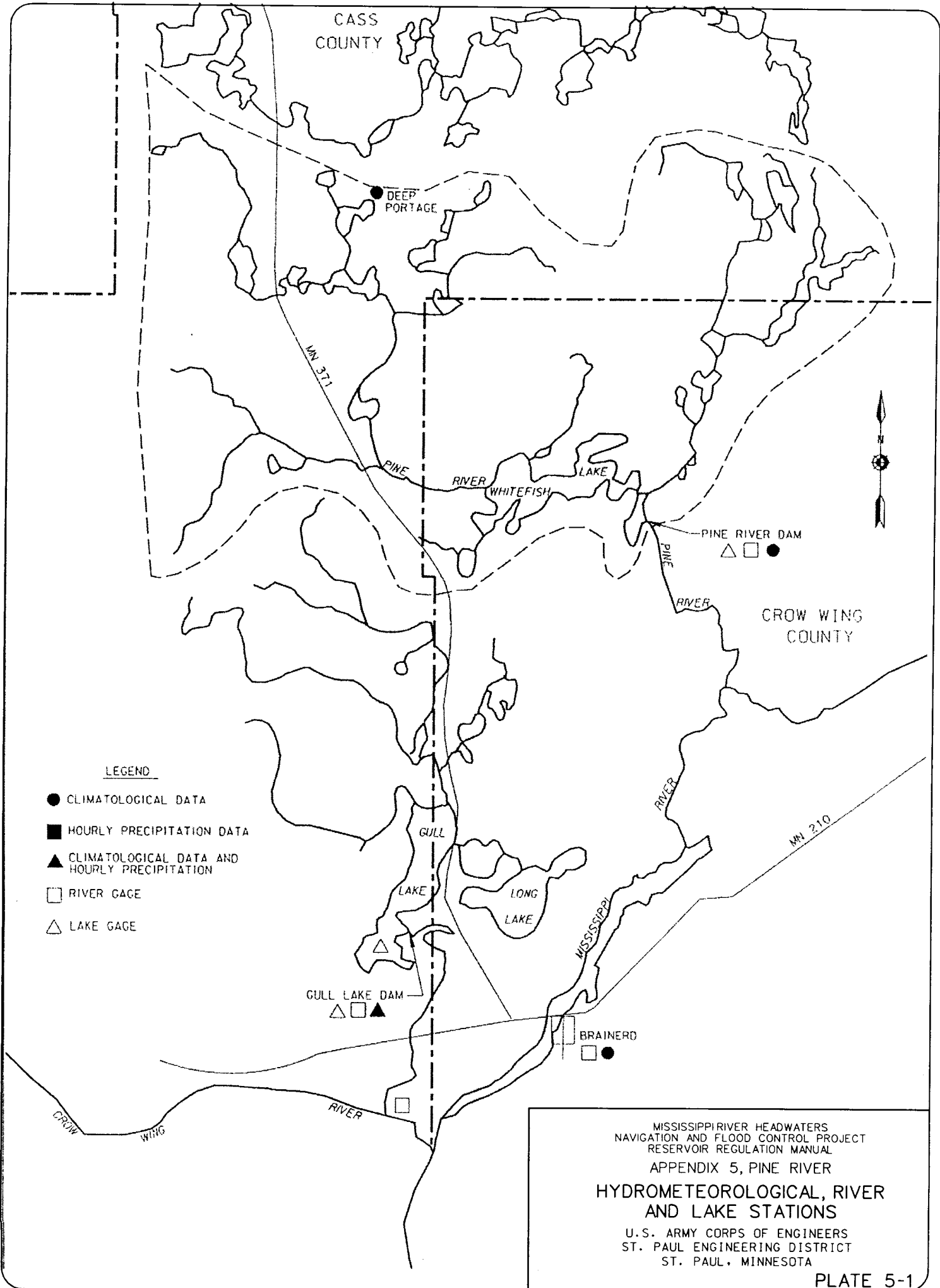


MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
HIGH WATER
FREQUENCY-DAMAGE CURVE
(PINE RIVER RESERVOIR)
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

PINE RIVER DAM DOWNSTREAM DAMAGE - DISCHARGE CURVES



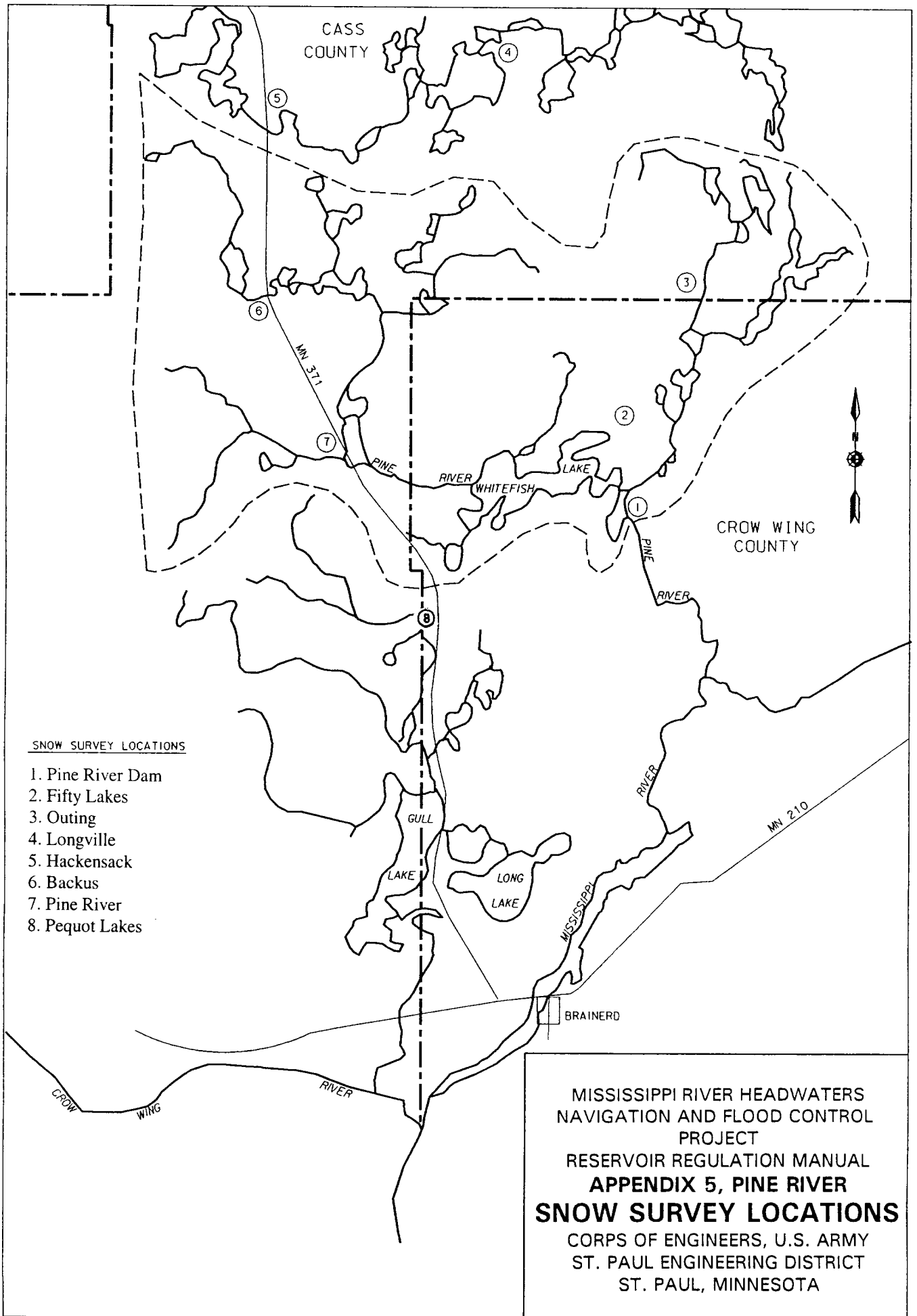
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL
 PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
DOWNSTREAM DISCHARGE-
DAMAGE CURVES
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



LEGEND

- CLIMATOLOGICAL DATA
- HOURLY PRECIPITATION DATA
- ▲ CLIMATOLOGICAL DATA AND HOURLY PRECIPITATION
- RIVER GAGE
- △ LAKE GAGE

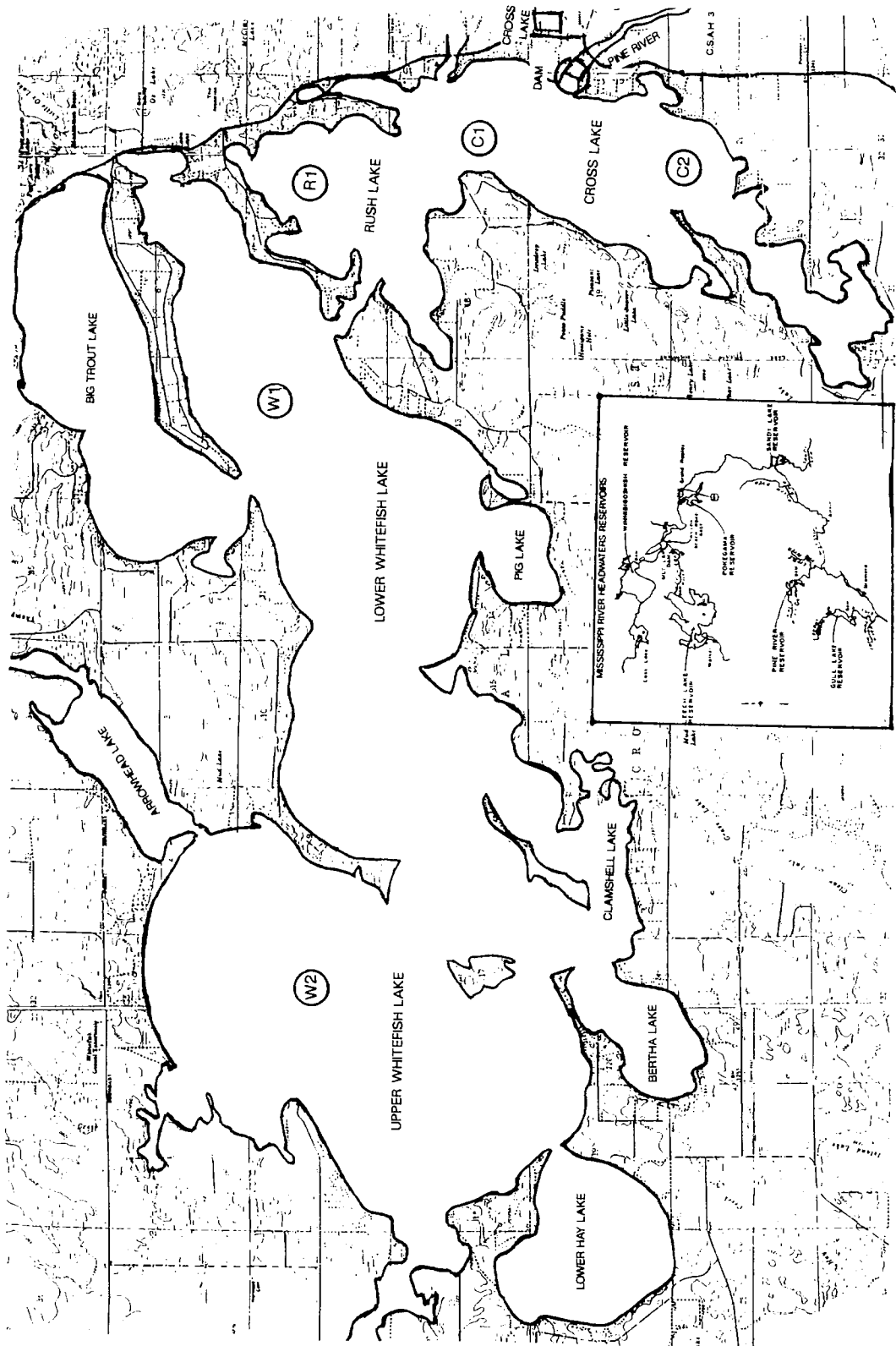
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 5, PINE RIVER
**HYDROMETEOROLOGICAL, RIVER
 AND LAKE STATIONS**
 U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



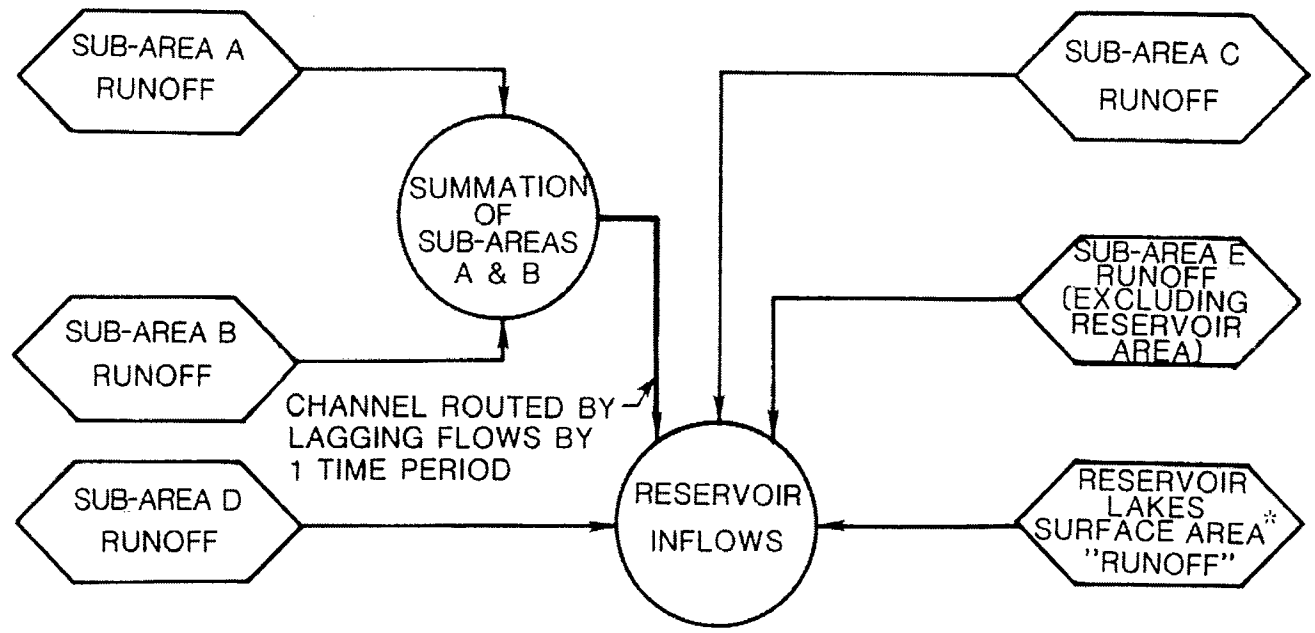
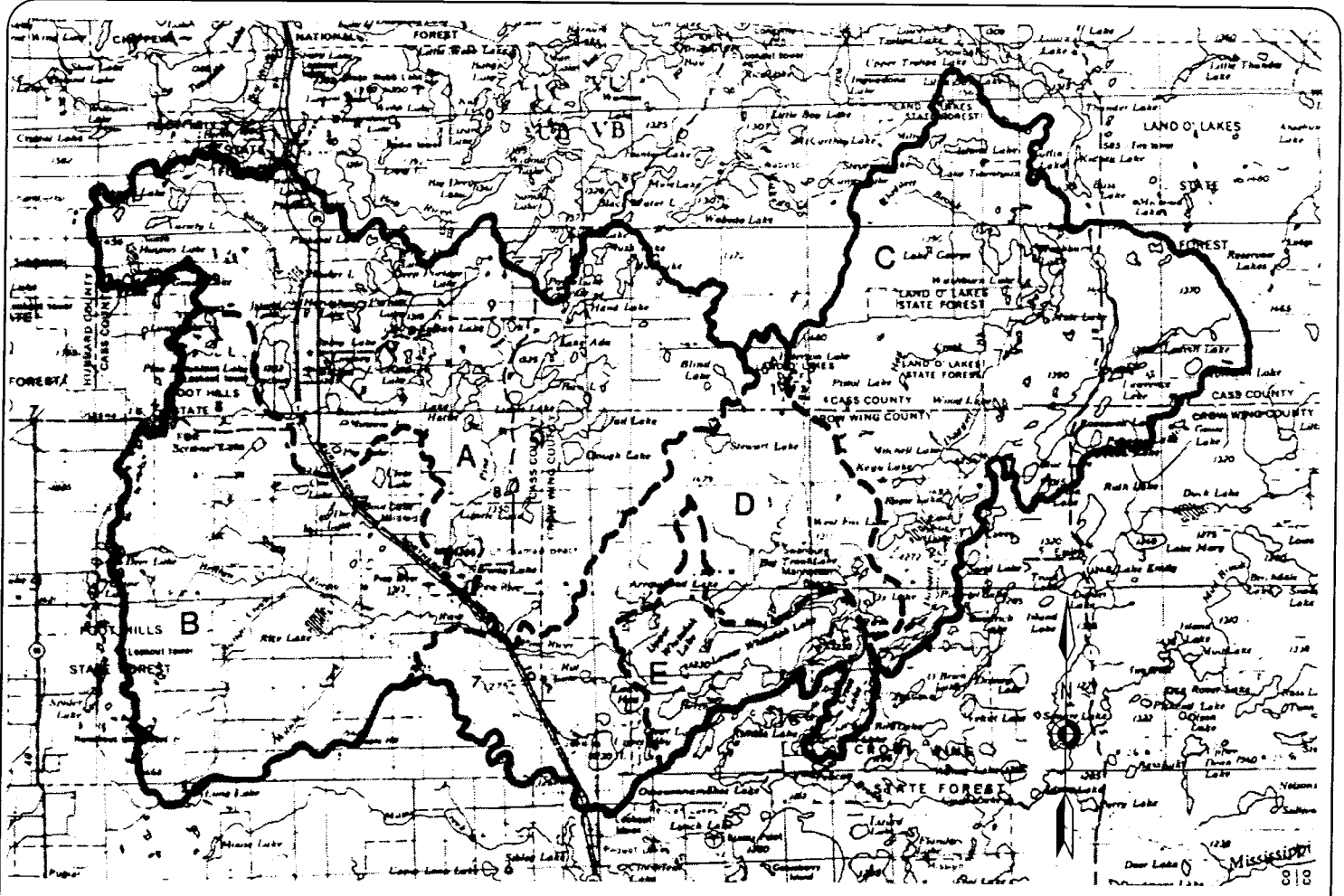
SNOW SURVEY LOCATIONS

- 1. Pine River Dam
- 2. Fifty Lakes
- 3. Outing
- 4. Longville
- 5. Hackensack
- 6. Backus
- 7. Pine River
- 8. Pequot Lakes

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL
 PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
SNOW SURVEY LOCATIONS
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

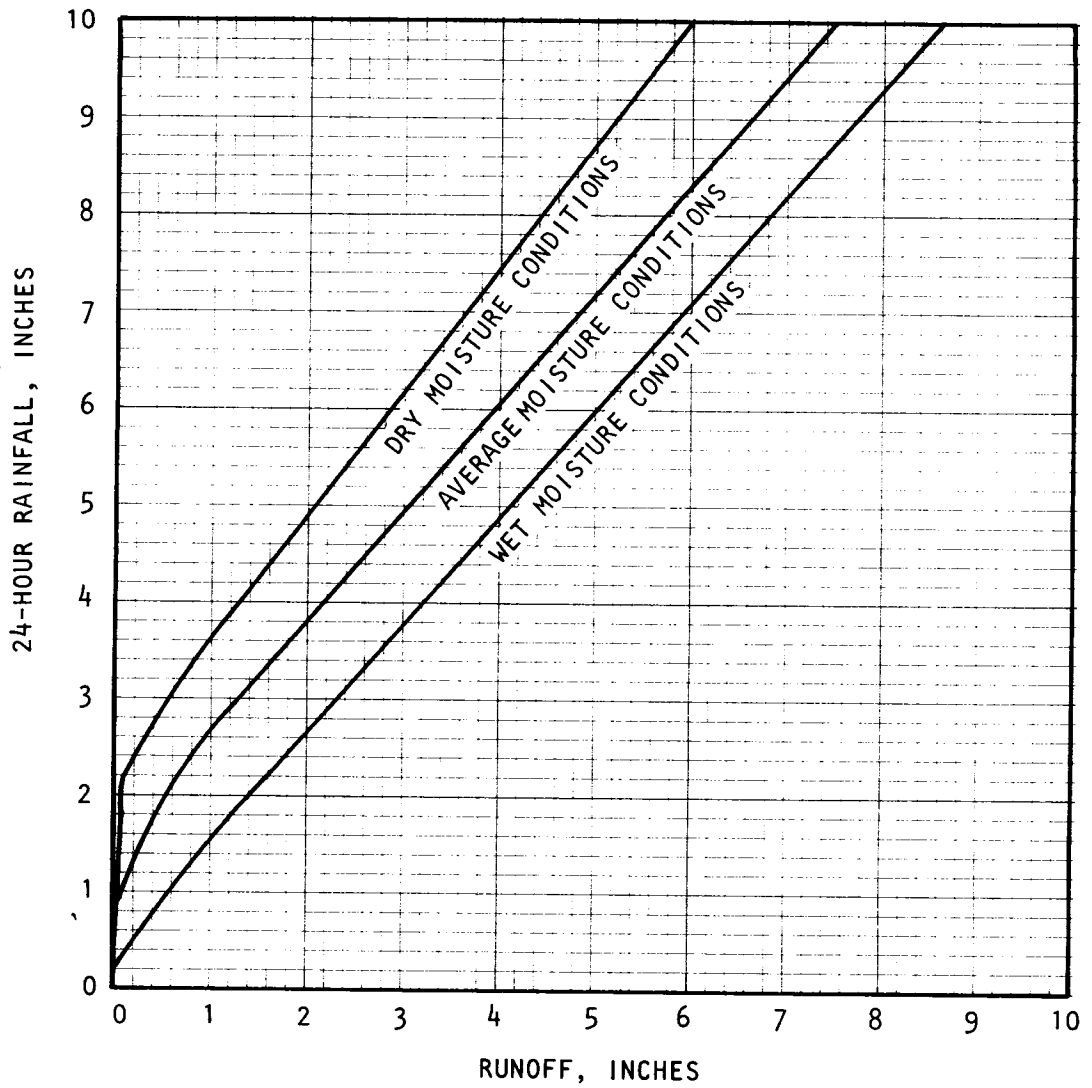


MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL
 PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
WATER QUALITY STATIONS
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



* RESERVOIR LAKES HERE INCLUDE THE UPPER AND LOWER WHITE FISH LAKES AND CROSS LAKE.

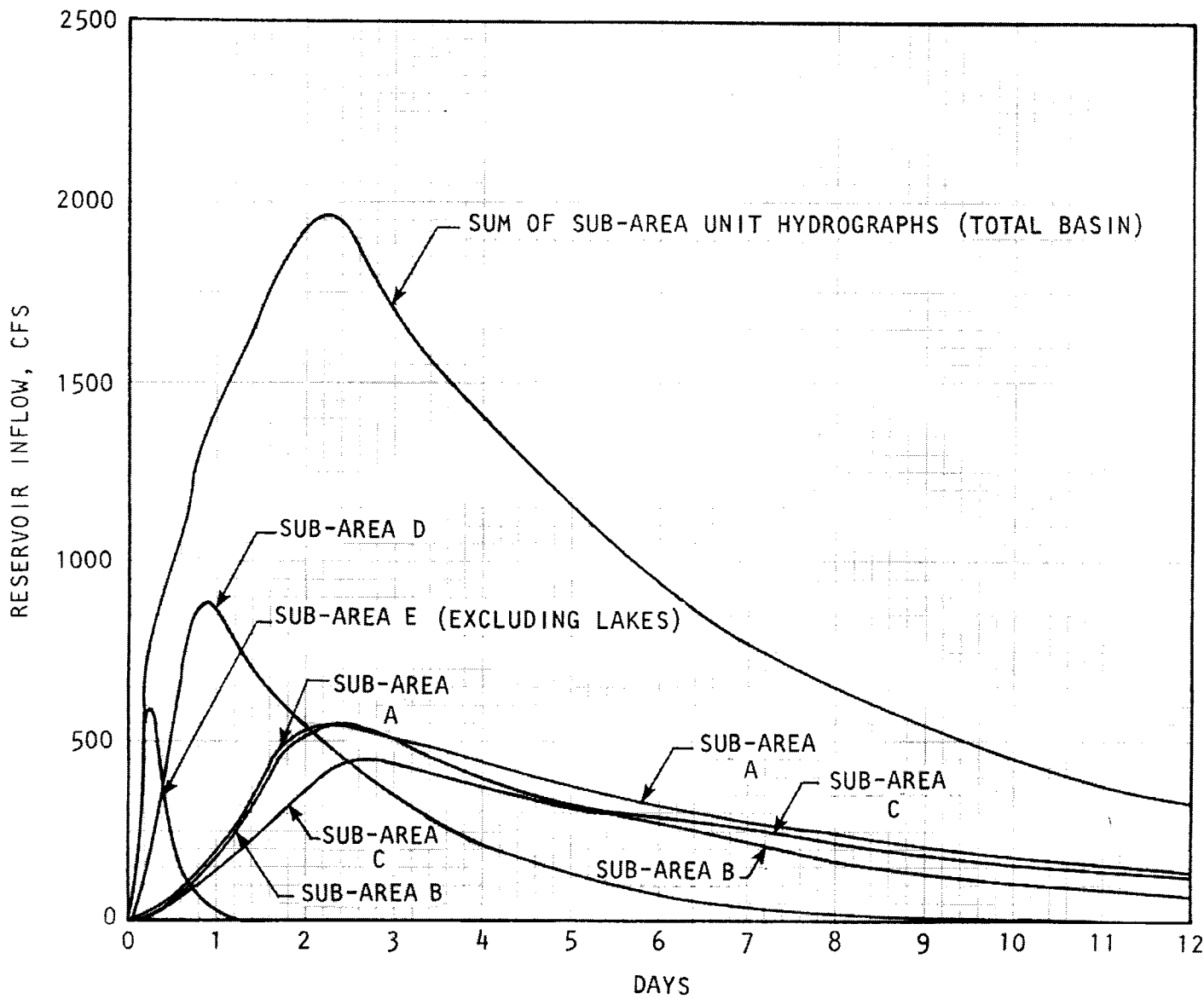
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 5, PINE RIVER
 SUBWATERSHED MAP
 AND HEC-1 SCHEMATIC
 U.S. ARMY CORPS OF ENGINEERS
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA
 PLATE 6-1



NOTE: RAINFALL AND RUNOFF ARE MEAN AREAL VALUES OVER 562 SQUARE MILE PINE RIVER RESERVOIR DRAINAGE AREA.

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
RAINFALL-RUNOFF CURVES

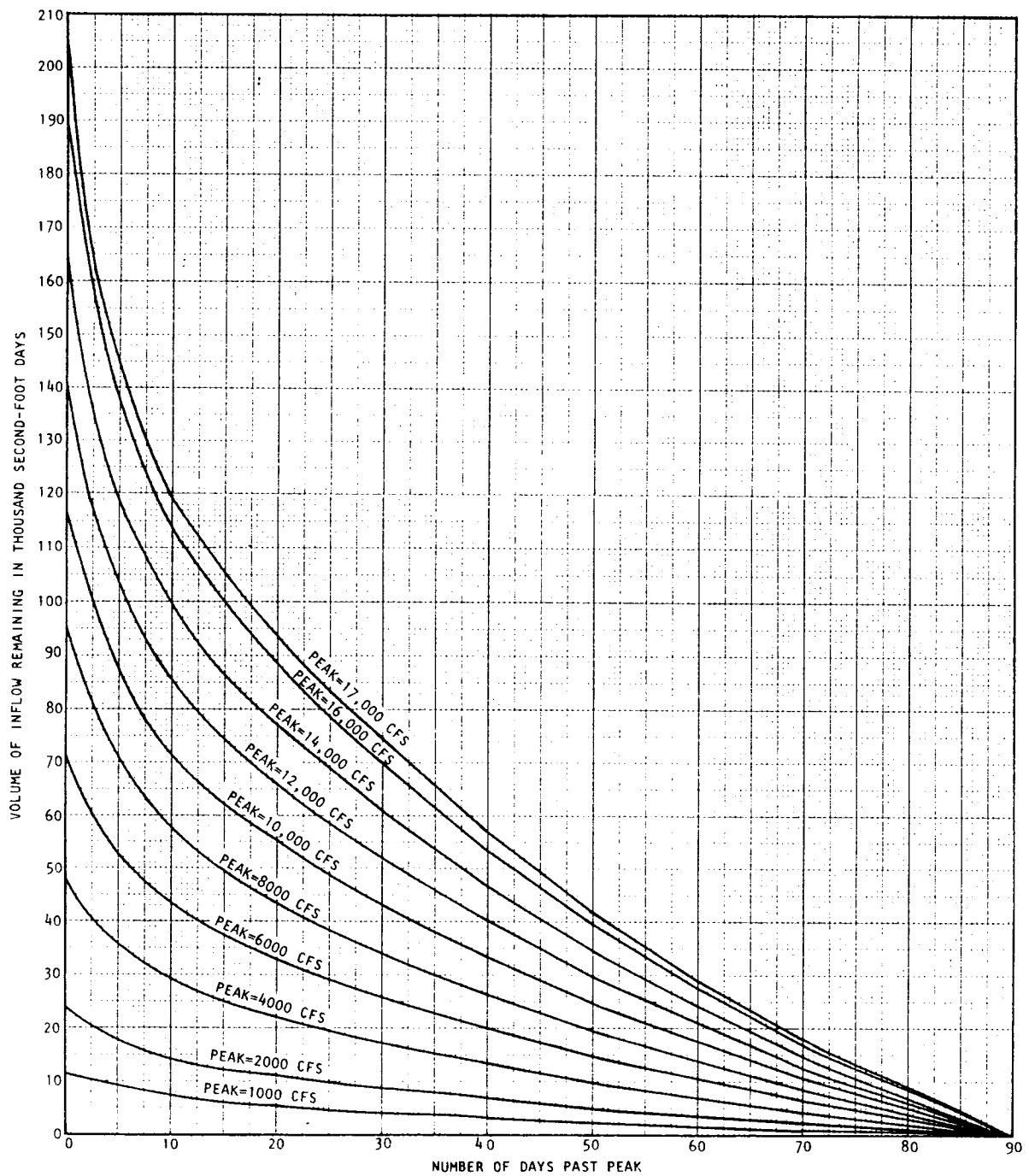
CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



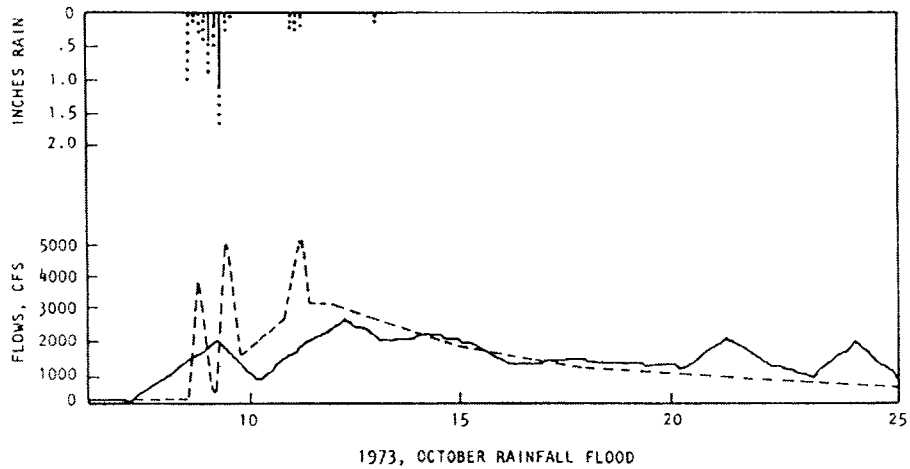
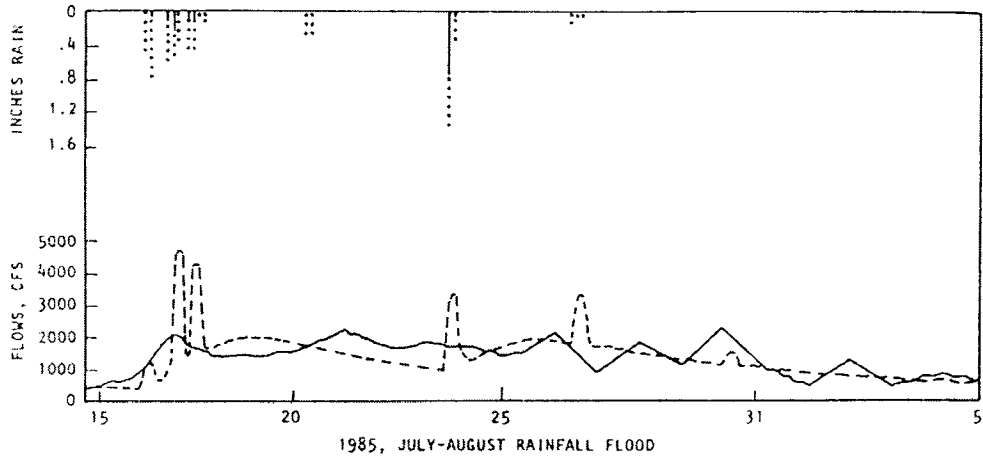
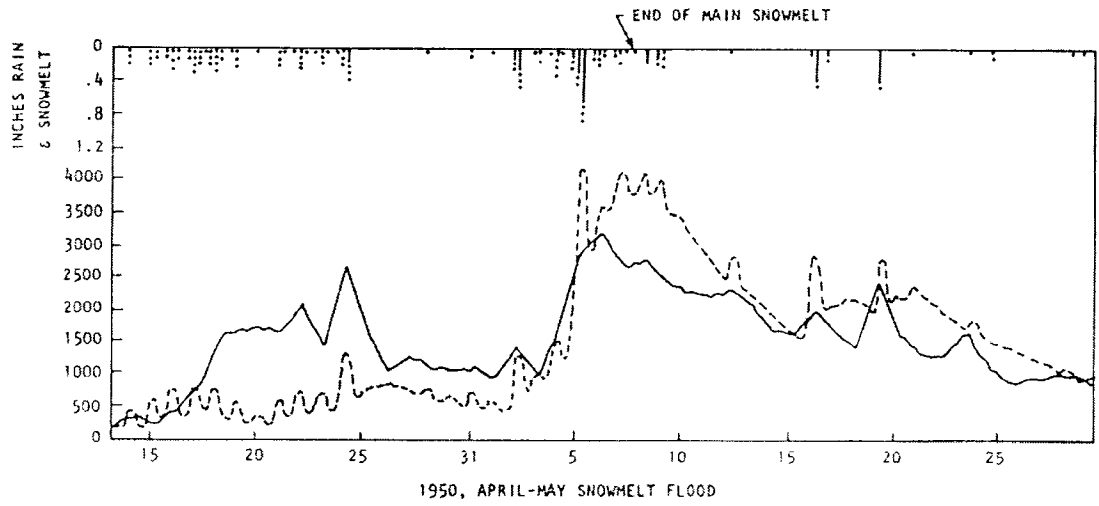
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL

APPENDIX 5, PINE RIVER
 3 - HOUR UNIT HYDROGRAPHS
 ALL SEASON

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 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
INFLOW RECESSON
VOLUME CURVE
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



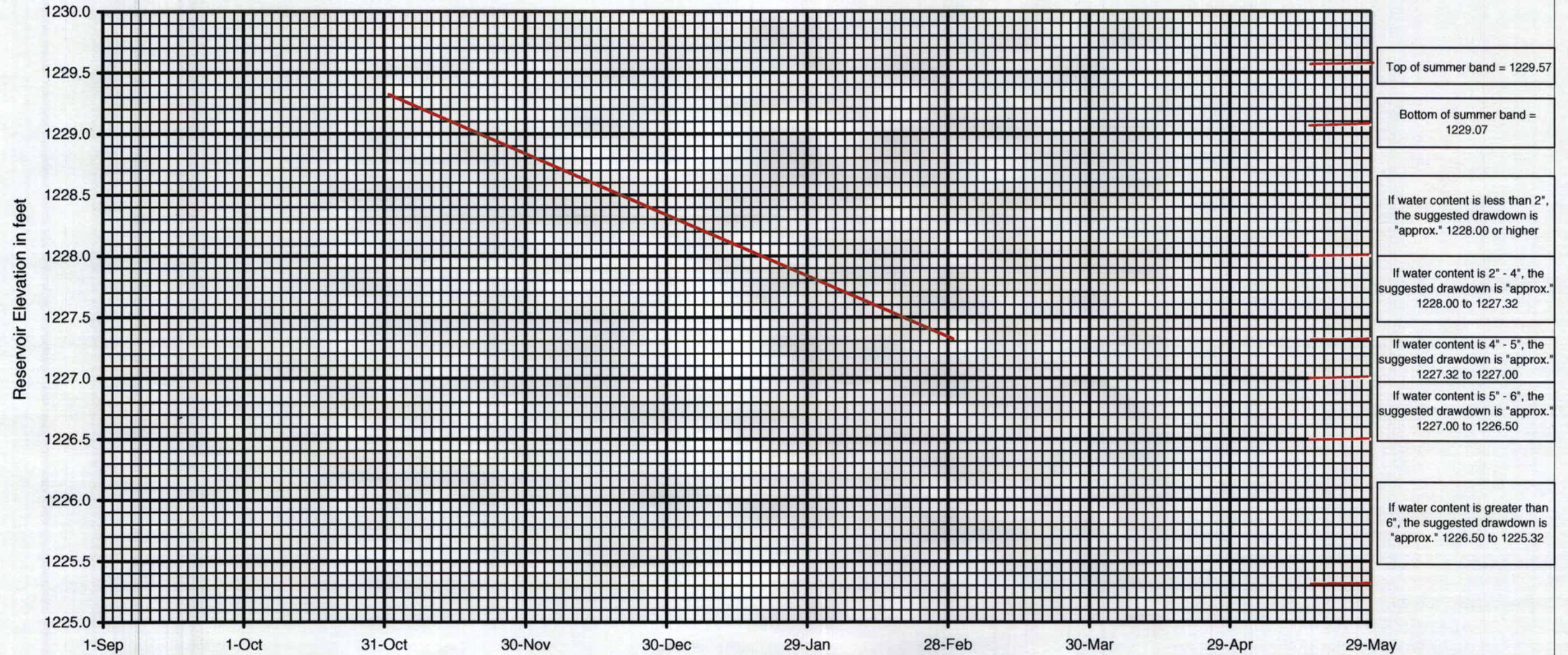
- REVERSE ROUTED INFLOW, 24-HR. AVERAGE
- - - - - HEC-1 MODELED INFLOW, 3-HR. TIME STEP
- PRECIPITATION AND/OR SNOWMELT
- PRECIPITATION EXCESS (NON-RESERVOIR AREA)

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
 APPENDIX 5, PINE RIVER

FLOOD RECONSTITUTIONS

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

Cross Lake

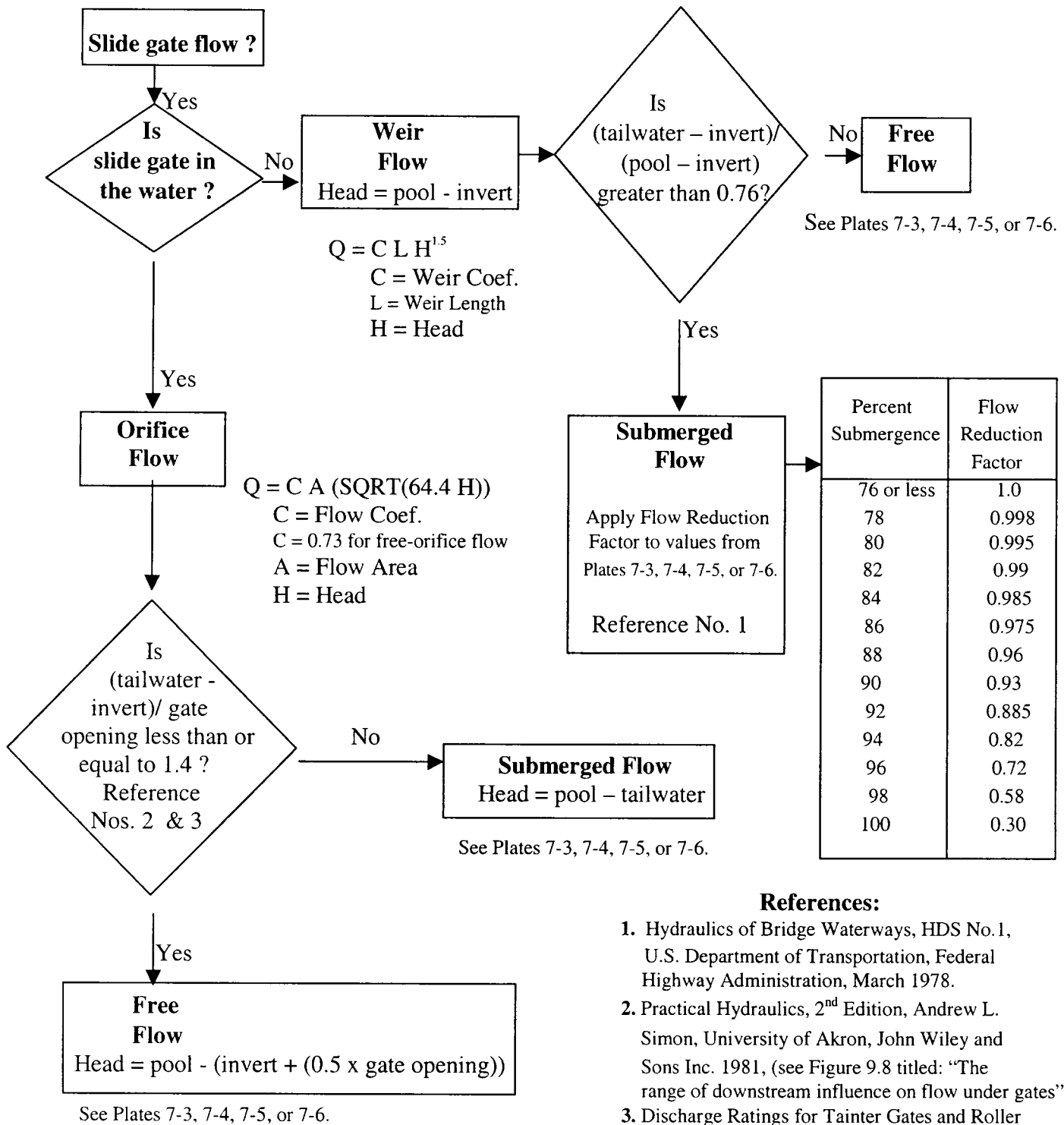


1. See Paragraph 7-05.
2. The drawdown curve should be followed until January. Snow water content should then be monitored to determine the final drawdown target elevation.
3. An average discharge from 1 November to 1 March of approximately 125 cfs above inflow is required for a drawdown from elevation 1229.32 (mid-simmer band) to 1227.32 feet. If, depending on the Whitefish spawn (see Chapter 7), the drawdown begins on 15 December, approximately 175 cfs above inflow is required.
4. All Elevations are 1929 NGVD.

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT WATER
CONTROL MANUAL

CROSS 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.

Tailwater effects: See Plate 7-7 for the Tailwater Rating Curve.

**Discharge Table for Pine River Dam Slide Gates
Flow Through One Gate Only**

Pool Elevation in Feet	Gate Opening in feet									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	Discharge in cfs, through one gate only, (#) represents the maximum of gates that can be applied									
1235.0	15.0 (13)	30.0 (13)	45.0 (12)	59.9 (10)	74.8 (9)	89.6 (8)	104.4 (8)	119.1 (8)	133.8 (7)	148.5 (7)
1234.0	14.6 (13)	29.2 (13)	43.7 (12)	58.2 (10)	72.7 (9)	87.1 (8)	101.4 (8)	115.8 (8)	130.0 (7)	144.3 (7)
1233.0	14.2 (13)	28.3 (13)	42.4 (13)	56.5 (11)	70.5 (9)	84.5 (9)	98.4 (8)	112.3 (8)	126.1 (7)	139.9 (7)
1232.0	13.7 (13)	27.5 (13)	41.1 (13)	54.7 (11)	68.3 (10)	81.8 (9)	95.3 (8)	108.7 (8)	122.1 (7)	135.5 (7)
1231.0	13.3 (13)	26.5 (13)	39.7 (13)	52.9 (11)	66.0 (10)	79.1 (9)	92.1 (9)	105.0 (8)	117.9 (8)	130.8 (7)
1230.0	12.8 (13)	25.6 (13)	38.3 (13)	51.0 (12)	63.6 (10)	76.2 (10)	88.7 (9)	101.2 (9)	113.6 (8)	126.0 (8)
1229.0	12.3 (13)	24.6 (13)	36.8 (13)	49.0 (12)	61.1 (11)	73.2 (10)	85.2 (9)	97.2 (9)	109.1 (8)	121.0 (8)
1228.0	11.8 (13)	23.6 (13)	35.3 (13)	46.9 (13)	58.6 (11)	70.1 (10)	81.6 (10)	93.0 (9)	104.4 (9)	115.8 (8)
1227.0	11.3 (13)	22.5 (13)	33.7 (13)	44.8 (13)	55.9 (12)	66.9 (11)	77.8 (10)	88.7 (10)	99.5 (9)	110.3 (9)
1226.0	10.7 (13)	21.4 (13)	32.0 (13)	42.5 (13)	53.0 (12)	63.4 (11)	73.8 (10)	84.1 (10)	94.4 (9)	104.6 (9)
1225.0	10.1 (13)	20.2 (13)	30.2 (13)	40.1 (13)	50.0 (13)	59.8 (12)	69.6 (11)	79.3 (11)	88.9 (10)	98.5 (10)

note : The numbers in parentheses in this table (e.g. 9) represent the maximum multiplier that can be applied to the discharge listed (which apply only to one gate) and still maintain the free- flow assumption that the table is based upon. Some interpolation is required between this plate and Plate 7-4 for larger settings at given reservoir levels that fall between the two curves (Plate 7-4 accounts for tailwater effects).

note : See Plate 7-5 for Slide Gate Rating Curves.

note : Each gate bay has an archway on the top as opposed to the bay being a rectangular opening. The gate sill is at approximately elevation 1216.65 feet while the top of the gate bay (top of the archway) is at elevation 1234.32 feet. The top of a dual-leaf slide gate in the closed position is at elevation 1231.73 feet which also corresponds to the location, near the top of the gate bay, where the curve of the archway begins. As a result, all thirteen of the gates must be raised to some degree to prevent water from spilling over the top of the gates when the pool is above elevation 1231.73 feet (i.e. surcharge). When the gates are raised as high as they can go, the elevation of the gate bottom is at approximately elevation 1233.60 feet which is approximately 0.72 feet below the top of the archway. The dual-leaf slide gates have a total height of 15.1 feet when closed. Each one is 6.0 feet wide which results in a spillway width of 78 feet. All Elevations are 1929 NGVD.

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
WATER CONTROL MANUAL

PINE RIVER DAM
SLIDE GATE RATING TABLE
(GATE OPENINGS ONE FOOT OR LESS)

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

Plate 7-3

**Discharge Table for Pine River Dam Slide Gates
Flow Through All Thirteen Gates Open an Equal Amount**

Pool Elevation in Feet	Gate Opening in feet										
	0.4	0.5	0.6	0.7	0.8	0.9	1.0	2.0	3.0	4.0	5.0
	Discharge in cfs (13 gates equal amount)										
1235.3								3600	5000	6150	7200
1235.0							1931	3550	4925	6075	7100
1234.0	750	925	1100	1250	1425	1600	1876	3340	4675	5800	6800
1233.0	725	900	1050	1200	1375	1550	1819	3150	4450	5500	6450
1232.0	700	850	1000	1175	1325	1500	1762	3030	4250	5275	6200
1231.0	675	825	975	1125	1275	1425	1700	2900	4100	5075	5900
1230.0	650	800	950	1075	1225	1375	1638	2800	3950	4850	5650
1229.0	625	775	900	1025	1175	1325	1573	2700	3800	4650	5400
1228.0	600	750	875	1000	1125	1250	1505	2600	3600	4400	5100
1227.0	575	725	850	950	1075	1200	1434	2500	3400	4150	4775

Pool Elevation in Feet	Gate Opening in feet											Gates out of the water
	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	
	Discharge in cfs (13 gates equal amount)											
1235.3	8100	9000	9850	10700	11450	12200	12950	13650	14400	15000	15700	16300
1235.0	8000	8875	9700	10525	11300	12000	12725	13450	14200	14800	15400	15500
1234.0	7625	8450	9225	10000	10700	11400	12025	12750	13500			13650
1233.0	7275	8050	8800	9500	10150	10800	11350	12050				12275
1232.0	6950	7675	8350	9000	9600	10200	10700					11000
1231.0	6625	7300	7925	8500	9100	9600						9900
1230.0	6300	6950	7525	8075	8600							8800
1229.0	6000	6600	7100	7600								7800
1228.0	5700	6200	6650									6800
1227.0	5300	5700										5800

note : Each gate bay has an archway on the top as opposed to the bay being a rectangular opening. The gate sill is at approximately elevation 1216.65 feet while the top of the gate bay (top of the archway) is at elevation 1234.32 feet. The top of a dual-leaf slide gate in the closed position is at elevation 1231.73 feet which also corresponds to the location, near the top of the gate bay, where the curve of the archway begins. As a result, all thirteen of the gates must be raised to some degree to prevent water from spilling over the top of the gates when the pool is above elevation 1231.73 feet (i.e. surcharge). When the gates are raised as high as they can go, the elevation of the gate bottom is at approximately elevation 1233.60 feet which is approximately 0.72 feet below the top of the archway. The dual-leaf slide gates have a total height of 15.1 feet when closed. Each one is 6.0 feet wide which results in a spillway width of 78 feet. All Elevations are 1929 NGVD.

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

MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
WATER CONTROL MANUAL

PINE RIVER DAM
SLIDE GATE RATING TABLE
(ALL 13 GATES OPEN AN EQUAL AMOUNT)

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

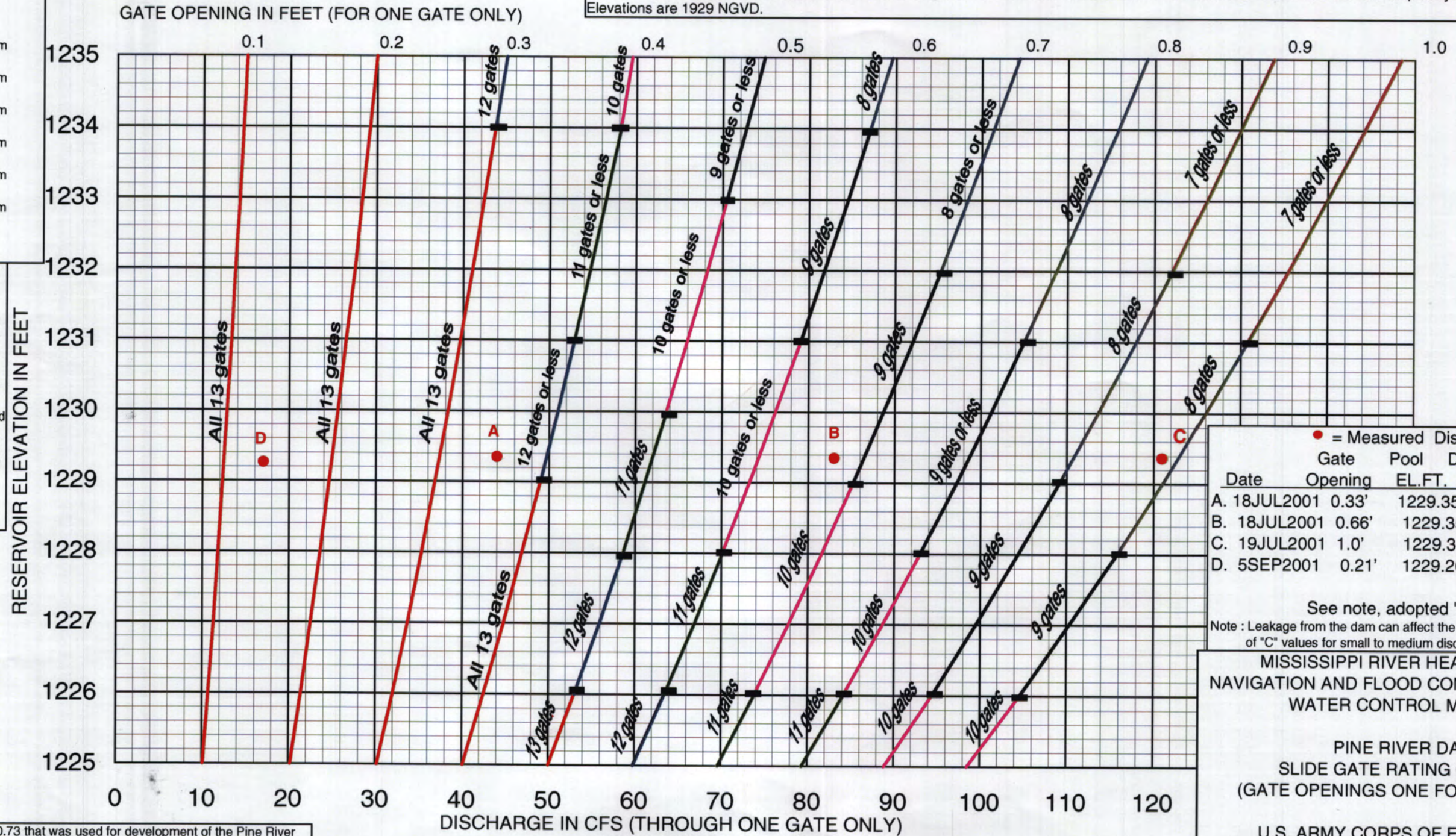
Pine River Dam

Each gate bay has an archway on the top as opposed to the bay being a rectangular opening. The gate sill is at approximately elevation 1216.65 feet while the top of the gate bay (top of the archway) is at elevation 1234.32 feet. The top of a dual-leaf slide gate in the closed position is at elevation 1231.73 feet which also corresponds to the location, near the top of the gate bay, where the curve of the archway begins. As a result, all thirteen of the gates must be raised to some degree to prevent water from spilling over the top of the gates when the pool is above elevation 1231.73 feet (i.e. surcharge). When the gates are raised as high as they can go, the elevation of the gate bottom is at approximately elevation 1233.60 feet which is approximately 0.72 feet below the top of the archway. The dual-leaf slide gates have a total height of 15.1 feet when closed. Each one is 6.0 feet wide which results in a spillway width of 78 feet. All Elevations are 1929 NGVD.

Maximum number of gates that can be open a given gate setting and still maintain free flow.

- All 13 gates
- 12 gate maximum
- 11 gate maximum
- 10 gate maximum
- 9 gate maximum
- 8 gate maximum
- 7 gate maximum

The numbers on the curves (e.g. 9 gates or less) represent the maximum multiplier that can be applied to the discharges from the X-axis (which apply to only one gate) and still maintain the free-flow assumption that the curves are based upon. Some interpolation is required between this plate and Plate 7-6 for larger gate settings at given reservoir levels that fall between the two curves (Plate 7-6 accounts for tailwater effects).



Date	Gate Opening	Pool EL.FT.	Discharge CFS	"C" Value
A. 18JUL2001	0.33'	1229.35	44	0.78
B. 18JUL2001	0.66'	1229.35	83	0.74
C. 19JUL2001	1.0'	1229.36	121	0.72
D. 5SEP2001	0.21'	1229.26	17	0.48
Average =				0.68
See note, adopted "C" value = 0.73				
Note: Leakage from the dam can affect the calculation of "C" values for small to medium discharges.				

The discharge coefficient C=0.73 that was used for development of the Pine River Dam rating curves was based upon guidance provided in Corps of Engineers Hydraulic Design Criteria for control gates and further verified with calculated coefficients based on actual discharge measurements below Pine River Dam.

See Plate 7-3 for Rating Table.
 For all 13 gates open 0.4 feet and above, see Plate 7-6.
 See Plate 7-2 to determine Free Flow versus Submerged Flow conditions.
 Whenever possible, gates should be opened evenly across the Dam.

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 WATER CONTROL MANUAL

PINE RIVER DAM
 SLIDE GATE RATING CURVES
 (GATE OPENINGS ONE FOOT OR LESS)

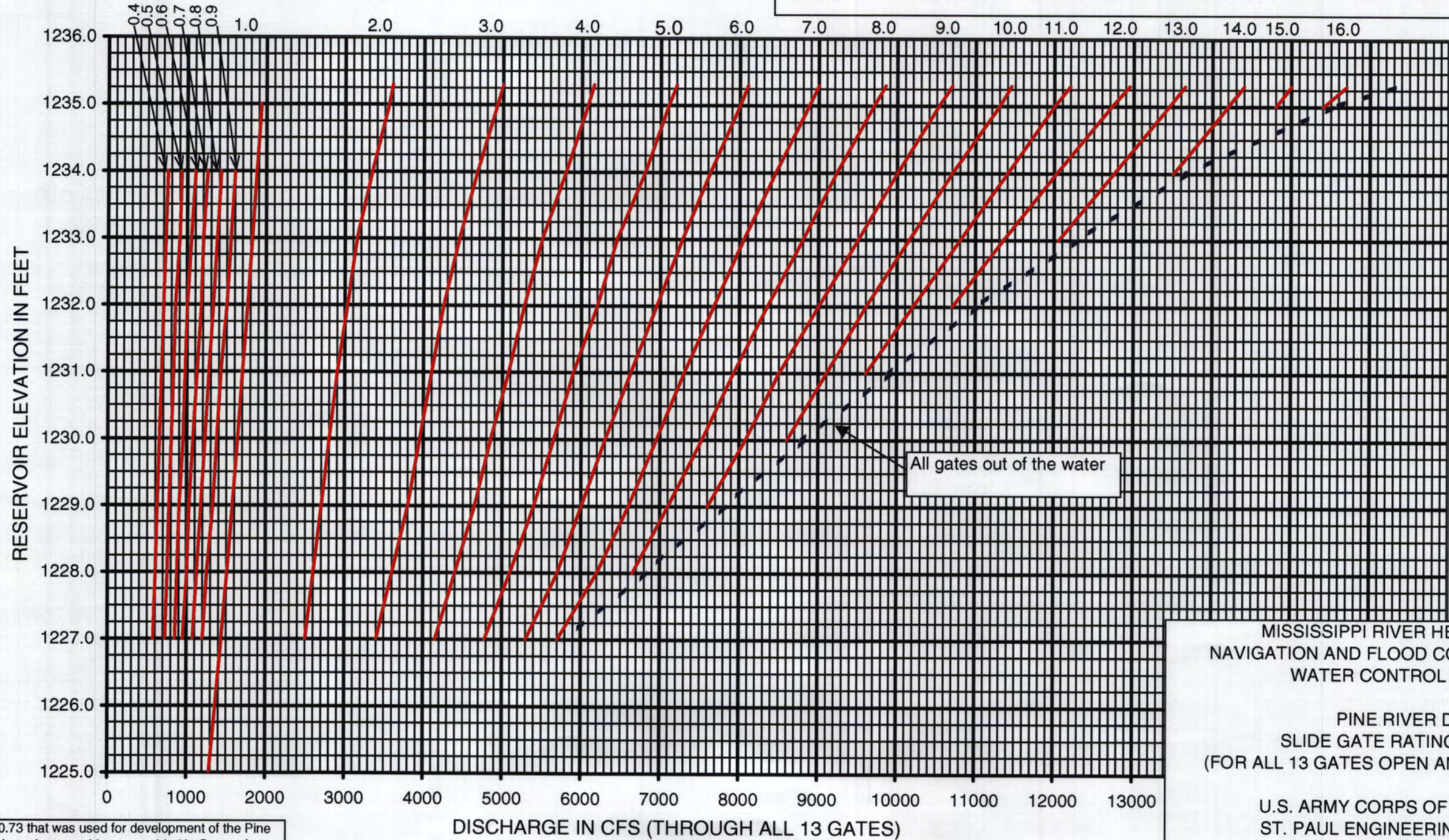
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 ST. PAUL, MINNESOTA

Pine River Dam

This plate is valid only if all 13 gates are open an equal amount. If less than 13 gates are being used, consult Plate 7-5.

GATE OPENING IN FEET (ALL 13 GATES OPEN AN EQUAL AMOUNT)

Each gate bay has an archway on the top as opposed to the bay being a rectangular opening. The gate sill is at approximately elevation 1216.65 feet while the top of the gate bay (top of the archway) is at elevation 1234.32 feet. The top of a dual-leaf slide gate in the closed position is at elevation 1231.73 feet which also corresponds to the location, near the top of the gate bay, where the curve of the archway begins. As a result, all thirteen of the gates must be raised to some degree to prevent water from spilling over the top of the gates when the pool is above elevation 1231.73 feet (i.e. surcharge). When the gates are raised as high as they can go, the elevation of the gate bottom is at approximately elevation 1233.60 feet which is approximately 0.72 feet below the top of the archway. The dual-leaf slide gates have a total height of 15.1 feet when closed. Each one is 6.0 feet wide which results in a spillway width of 78 feet. All Elevations are 1929 NGVD.



The discharge coefficient $C=0.73$ that was used for development of the Pine River Dam rating curves was based upon guidance provided in Corps of Engineers Hydraulic Design Criteria for control gates and further verified with calculated coefficients based on actual discharge measurements below Pine River Dam.

See Plate 7-4 for Rating Table.
For all 13 gates open less than 0.4 foot see Plate 7-5 or Table 7-3.
See Plate 7-2 for flow regime conditions.

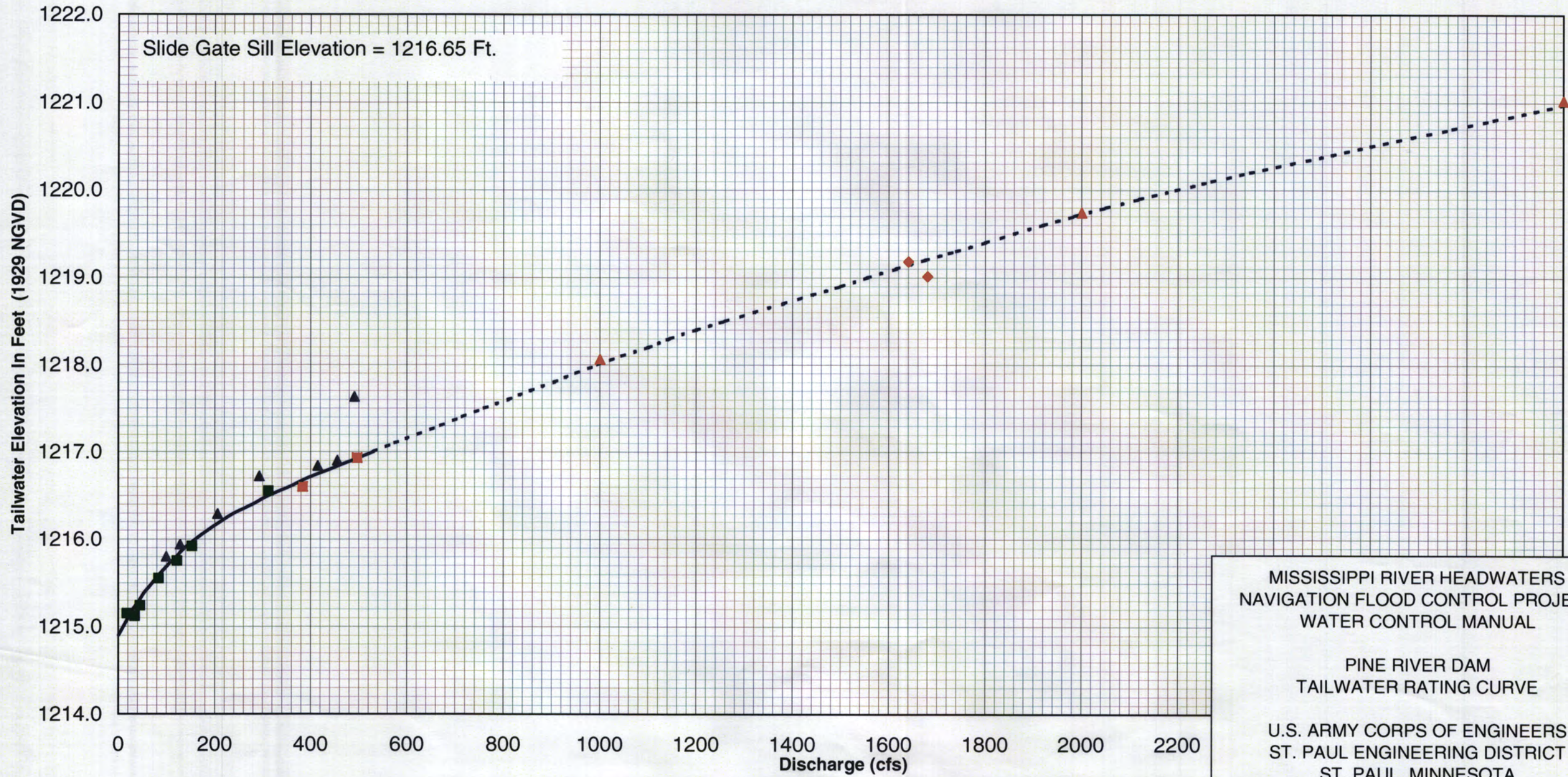
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WATER CONTROL MANUAL

PINE RIVER DAM
SLIDE GATE RATING CURVES
(FOR ALL 13 GATES OPEN AN EQUAL AMOUNT)

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ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

Pine River Below Pine River Dam - Station No. 05231000

April 15, 2002

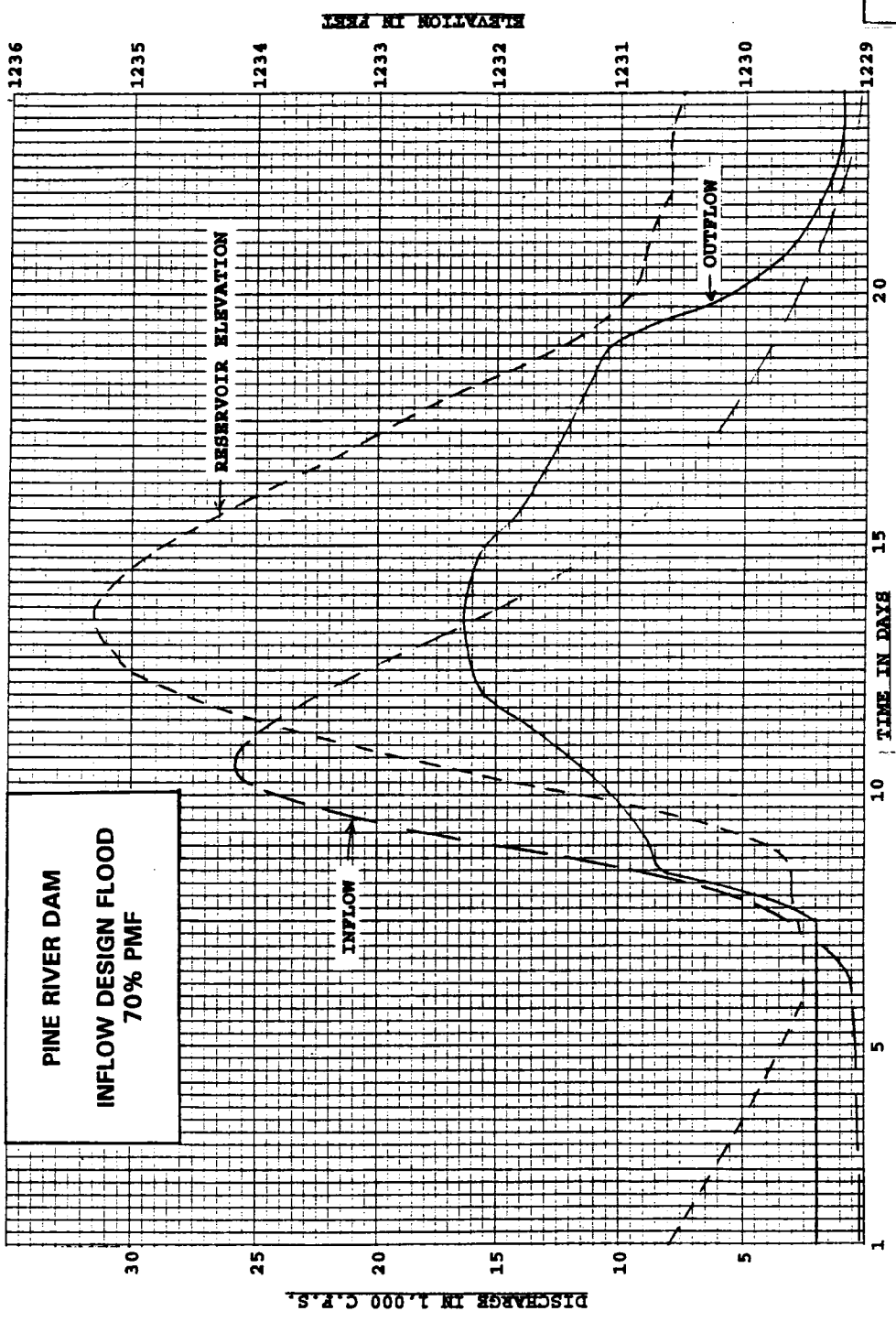


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NAVIGATION FLOOD CONTROL PROJECT
WATER CONTROL MANUAL

PINE RIVER DAM
TAILWATER RATING CURVE

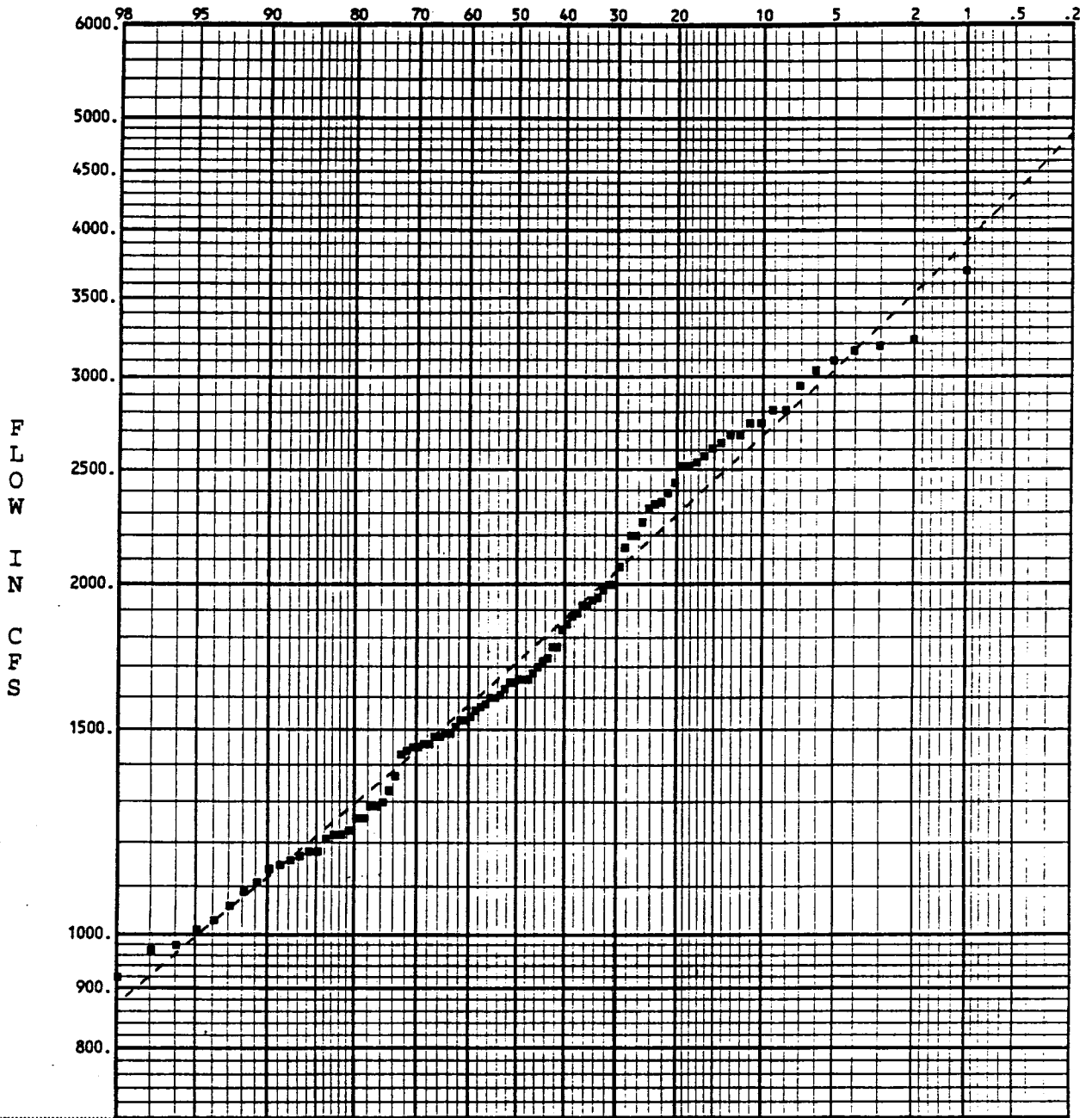
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- ▲ 1996-1999 Measured Discharge
- 2001 Measured Discharge
- ◆ 1971&1973 Measured Discharge
- 1986 & 1990 Measured Discharge
- ▲ HEC-2 Model points
- Apr. 8, 2002 Adjusted Rating Curve
- - - Apr. 8, 2002 Extended Rating Curve



MISSISSIPPI RIVER HEADWATERS
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 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
SPILLWAY DESIGN FLOOD
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 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

EXCEEDANCE FREQUENCY IN PERCENT



--- FLOW Frequency (with Exp. Prob.)
 ■ Weibull Plotting Positions

FREQUENCY STATISTICS		NUMBER OF EVENTS	
LOG TRANSFORM OF FLOW, CFS			
MEAN	3.2364	HISTORIC EVENTS	0
STANDARD DEV	.1454	HIGH OUTLIERS	0
SKEW	.1908	LOW OUTLIERS	0
REGIONAL SKEW	-.2200	ZERO OR MISSING	0
ADOPTED SKEW	.1000	SYSTEMATIC EVENTS	98

PINE RIVER DAM AND RESERVOIR

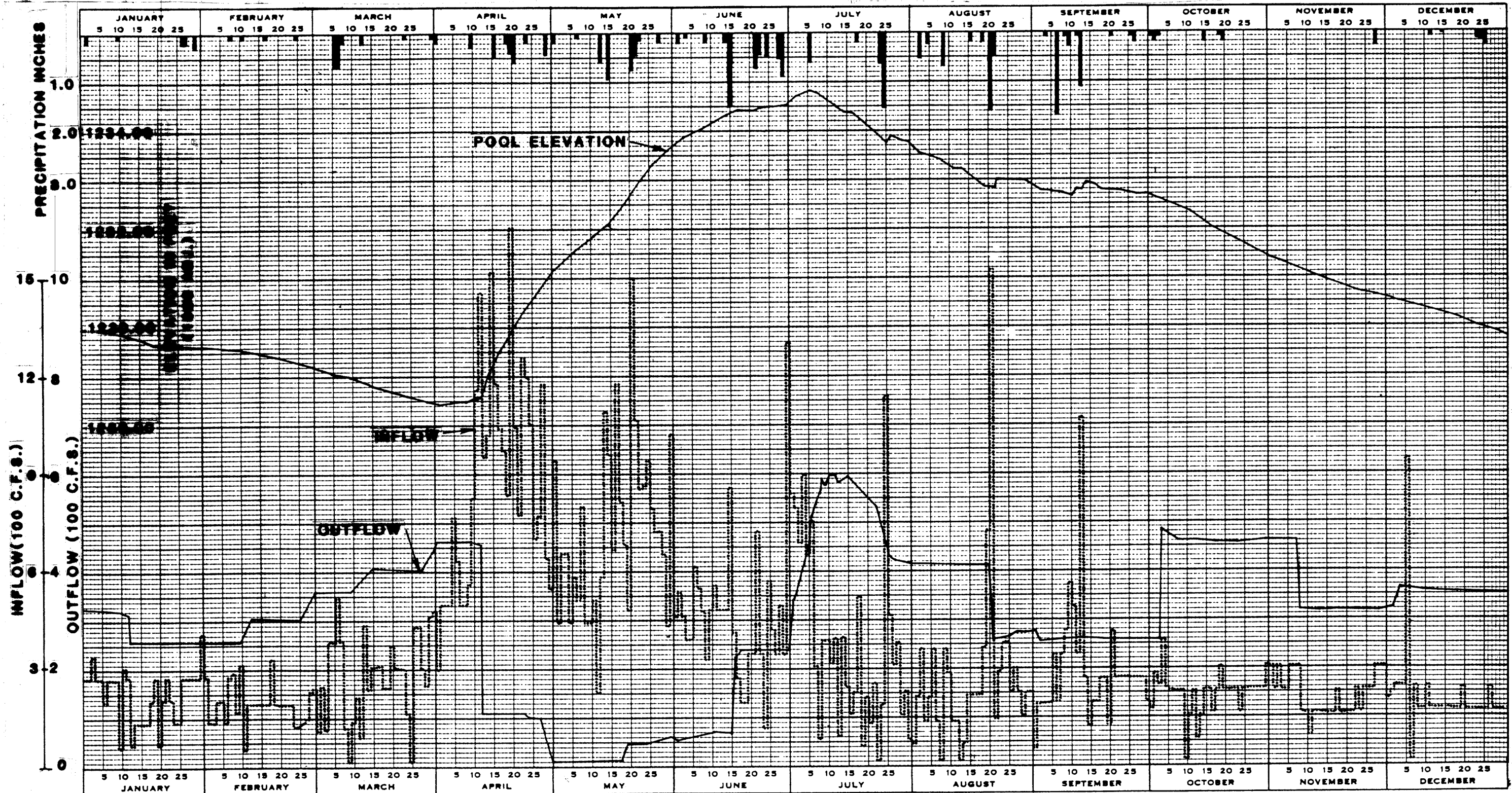
INFLOW - FREQUENCY
 Annual Mean Daily Peaks

BASIN AREA = 562 SQ MI
 WATER YEARS IN RECORD
 1898-1995

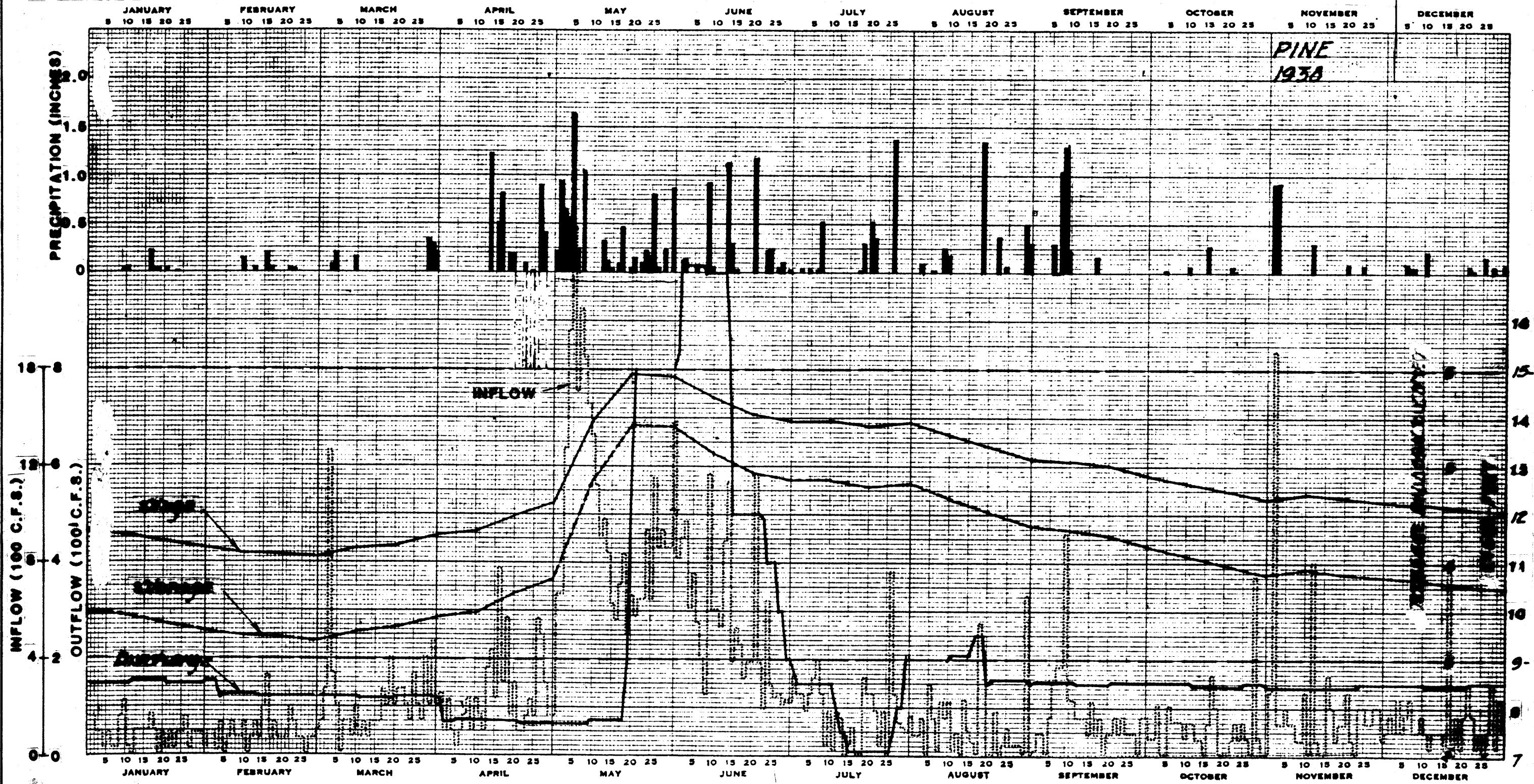
MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER

INFLOW - FREQUENCY

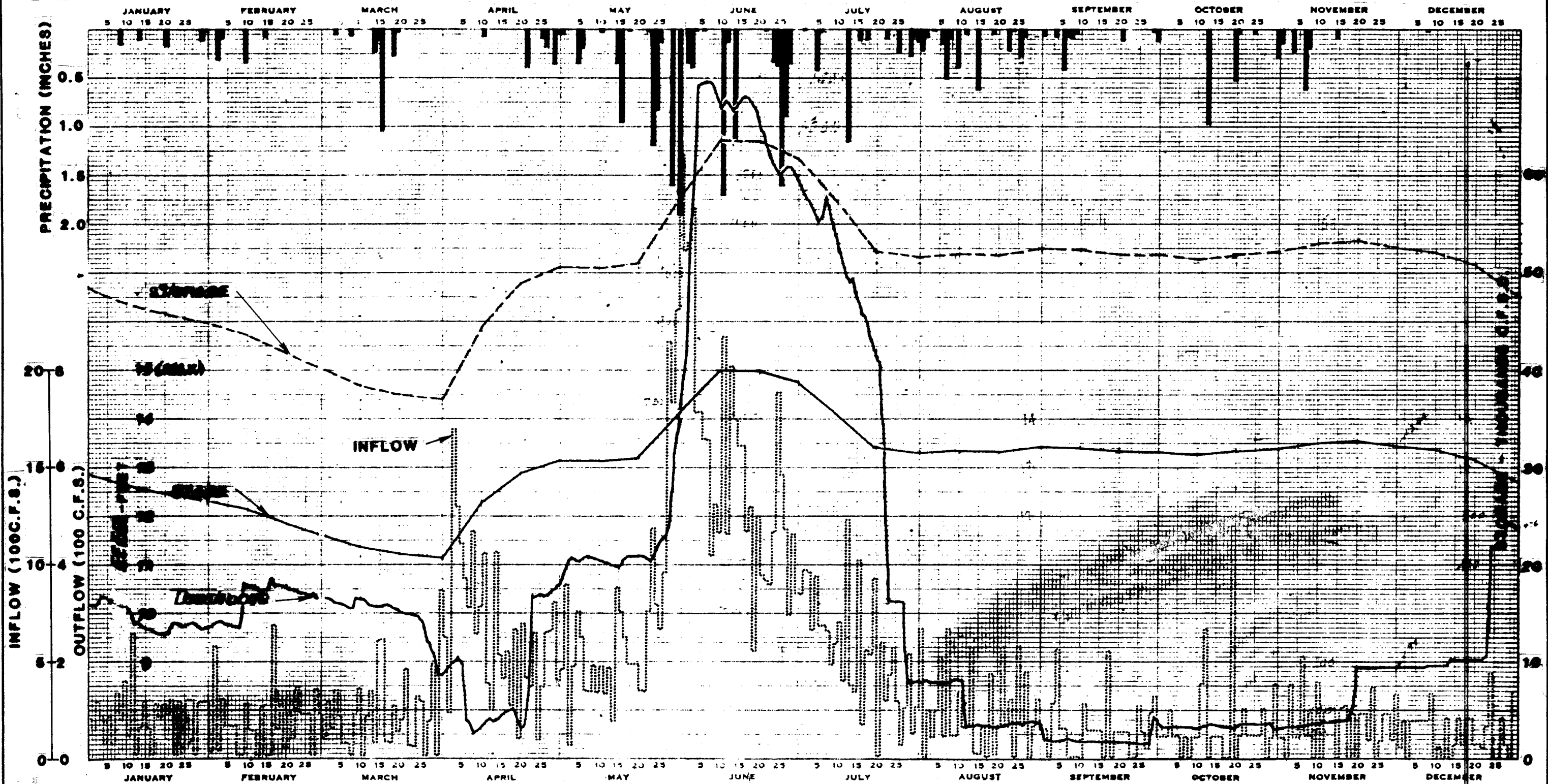
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 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
1916 FLOOD REGULATION
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA

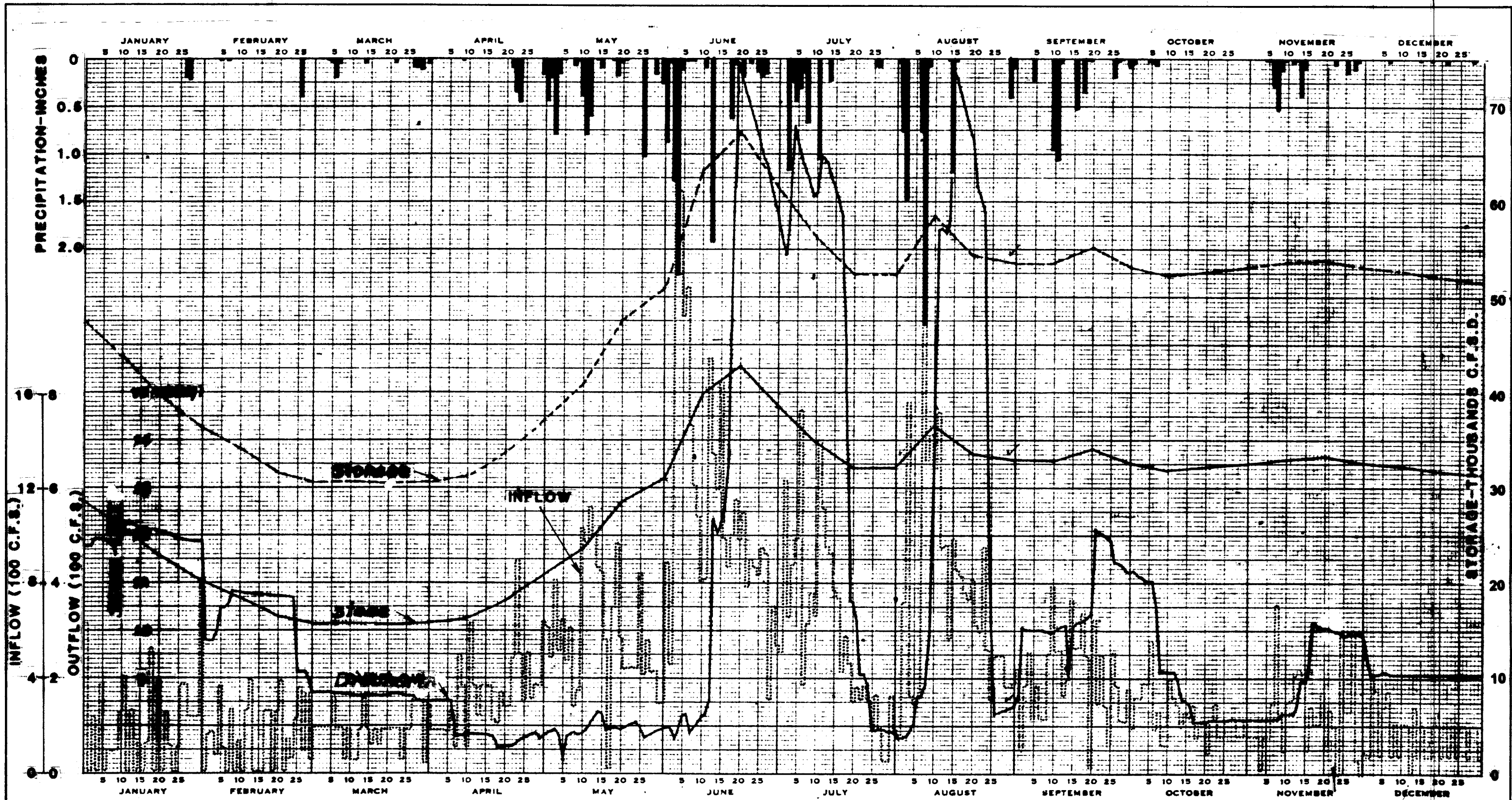


MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER
1938 FLOOD REGULATION
 CORPS OF ENGINEERS, U.S. ARMY
 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



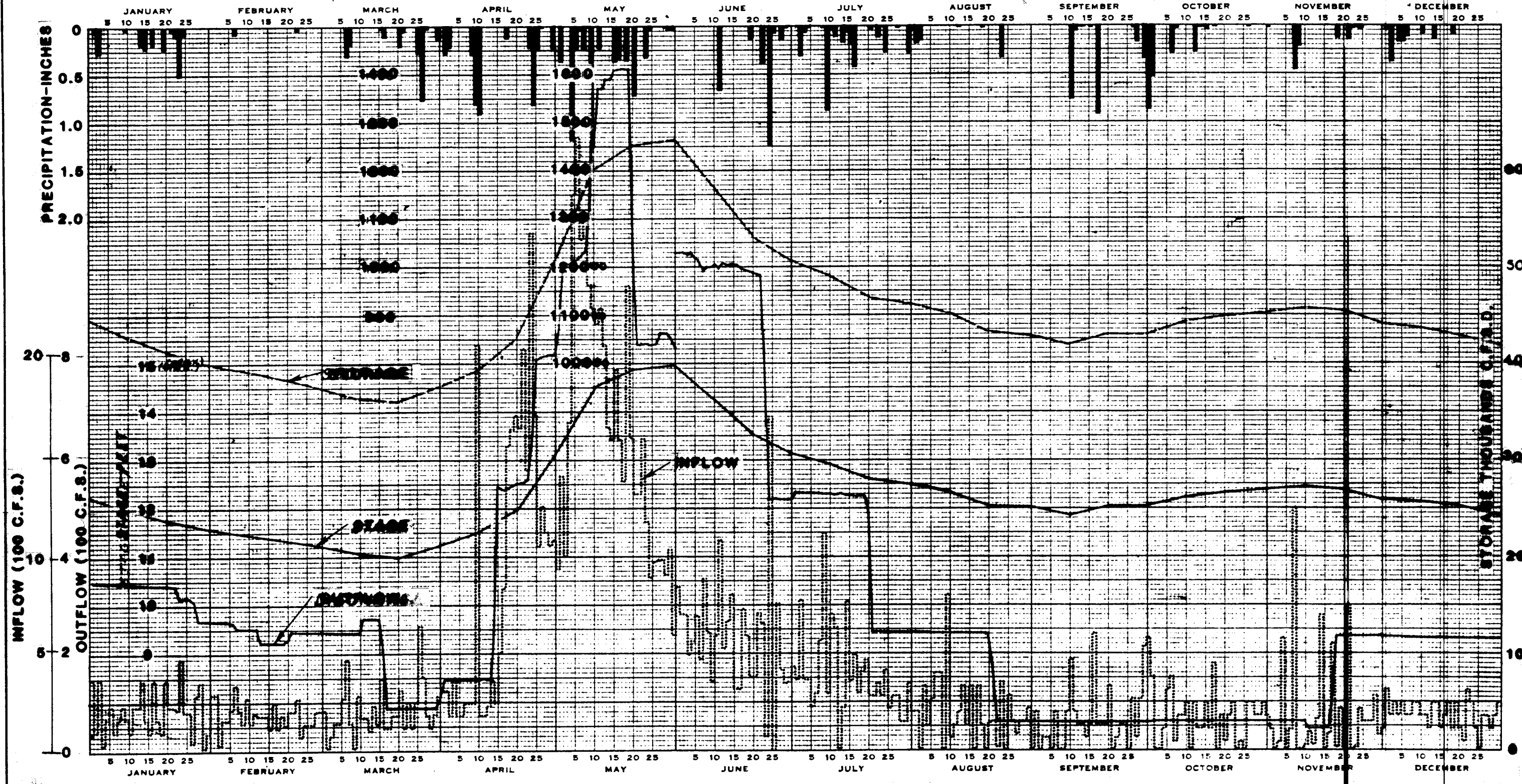
GAGE ZERO = ELEVATION 1216.32 (1929 ADJ.)

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
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APPENDIX 5, PINE RIVER
1943 FLOOD REGULATION
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GAGE ZERO = ELEVATION 216.32 (1929 ADJ.)

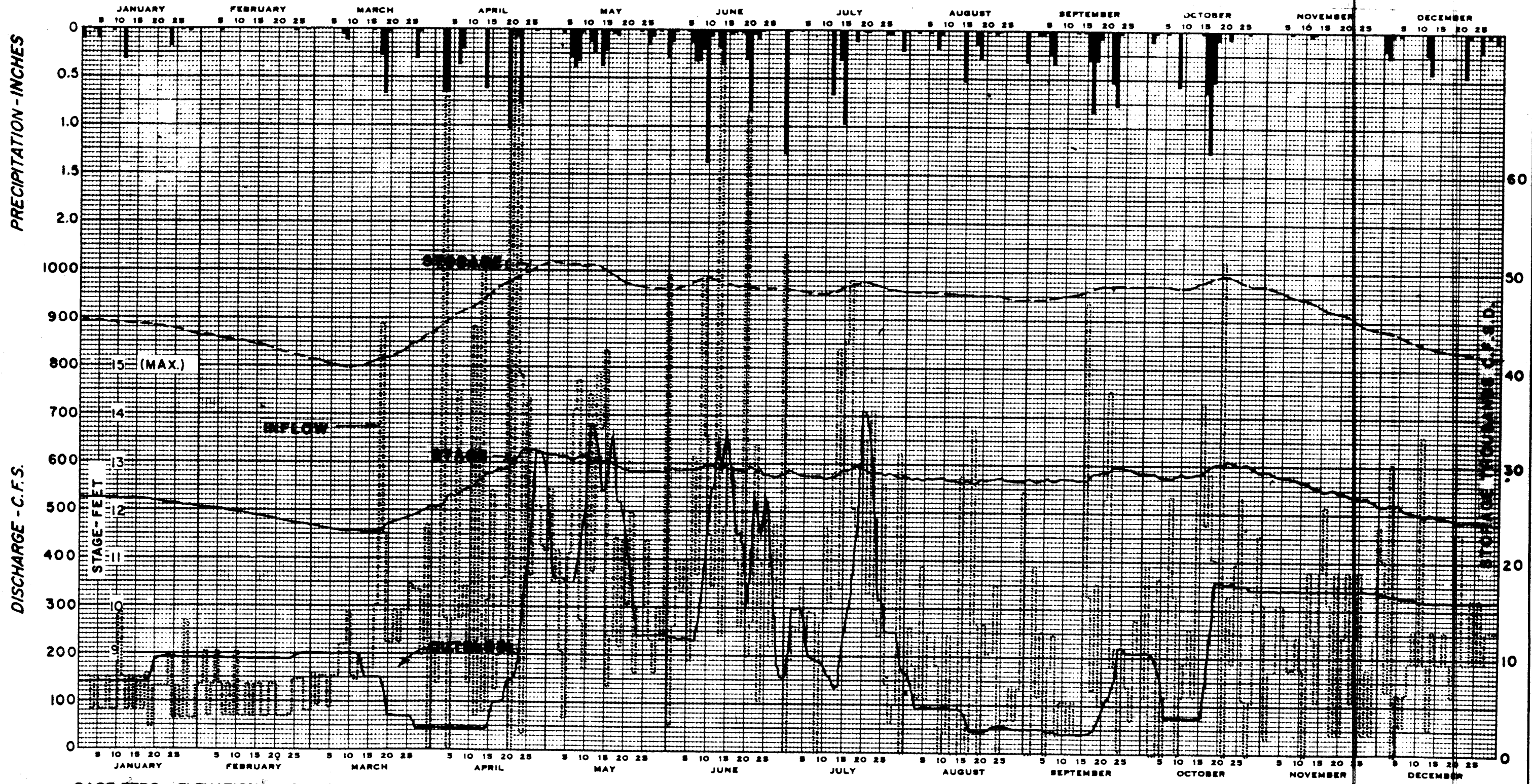
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 NAVIGATION AND FLOOD CONTROL PROJECT
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APPENDIX 5, PINE RIVER
1944 FLOOD REGULATION
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GAGE ZERO - ELEVATION 1216.32 (1929 ADJ.)

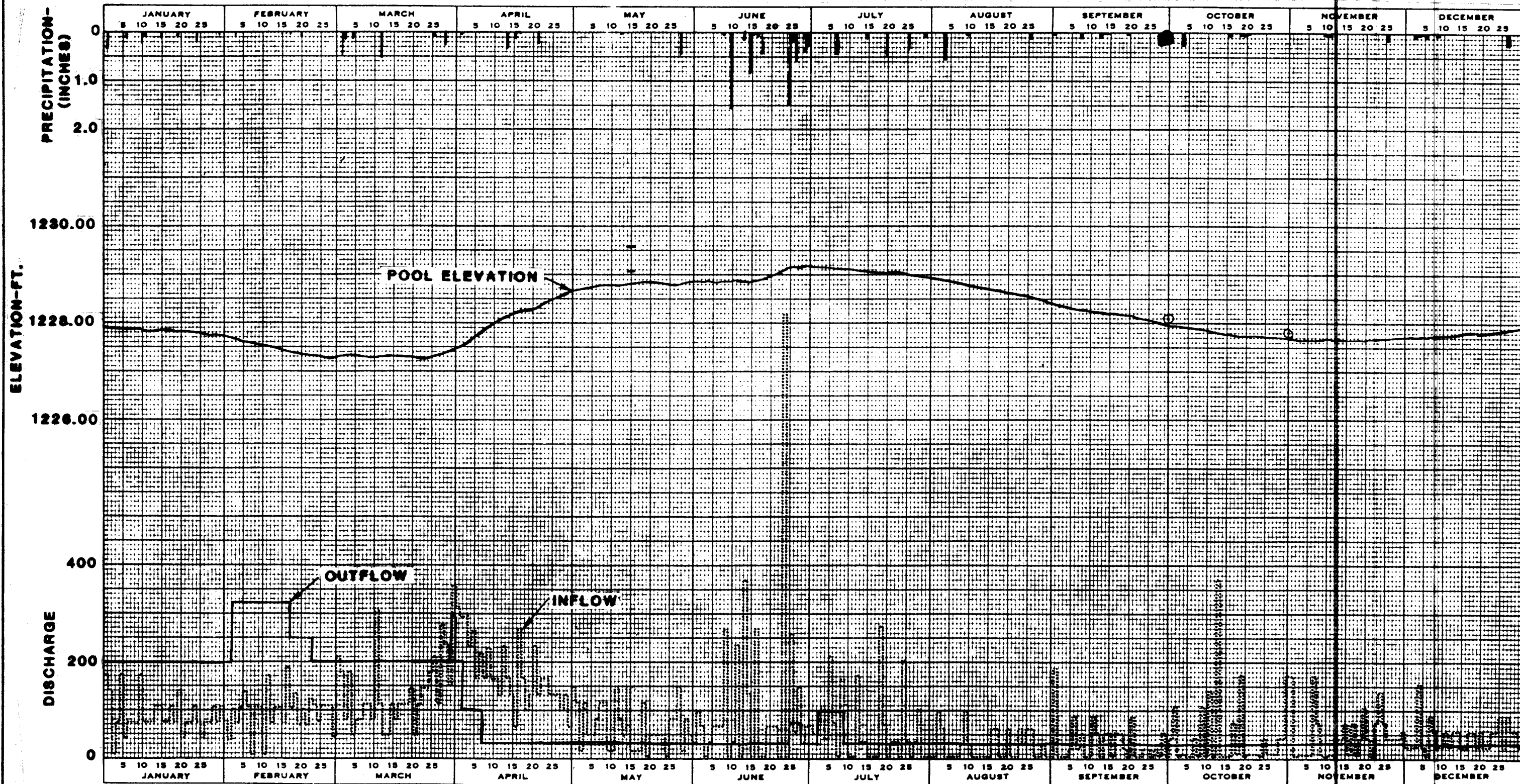
NOTE: SHIFT IN OUTFLOW SCALE BETWEEN 10 MAY AND 31 MAY

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APPENDIX 5, PINE RIVER
1950 FLOOD REGULATION
 CORPS OF ENGINEERS, U.S. ARMY
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 ST. PAUL, MINNESOTA

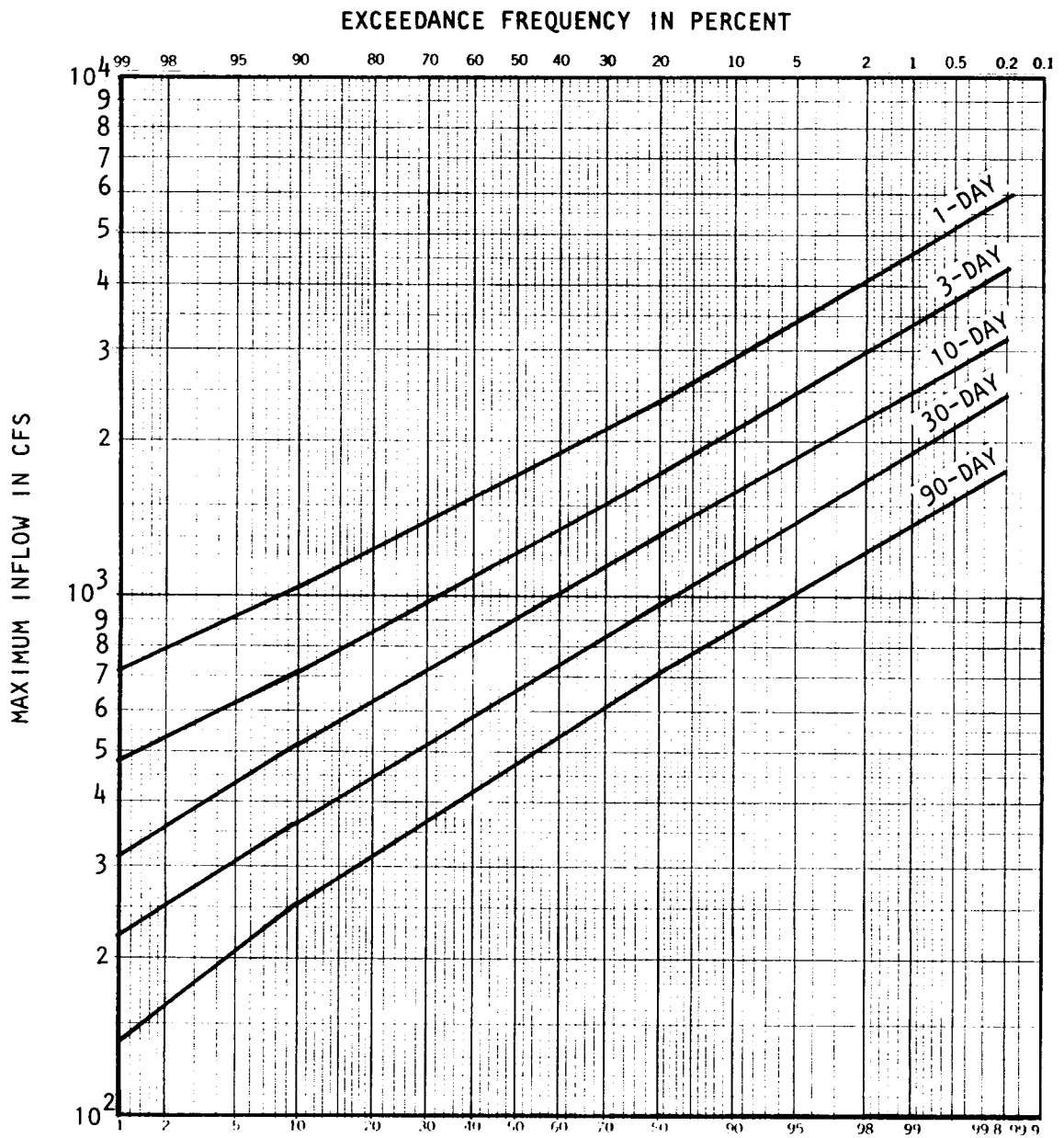


GAGE ZERO = ELEVATION 1216.32 (1929 ADJ.)

MISSISSIPPI RIVER HEADWATERS
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APPENDIX 5, PINE RIVER
1968 NORMAL REGULATION
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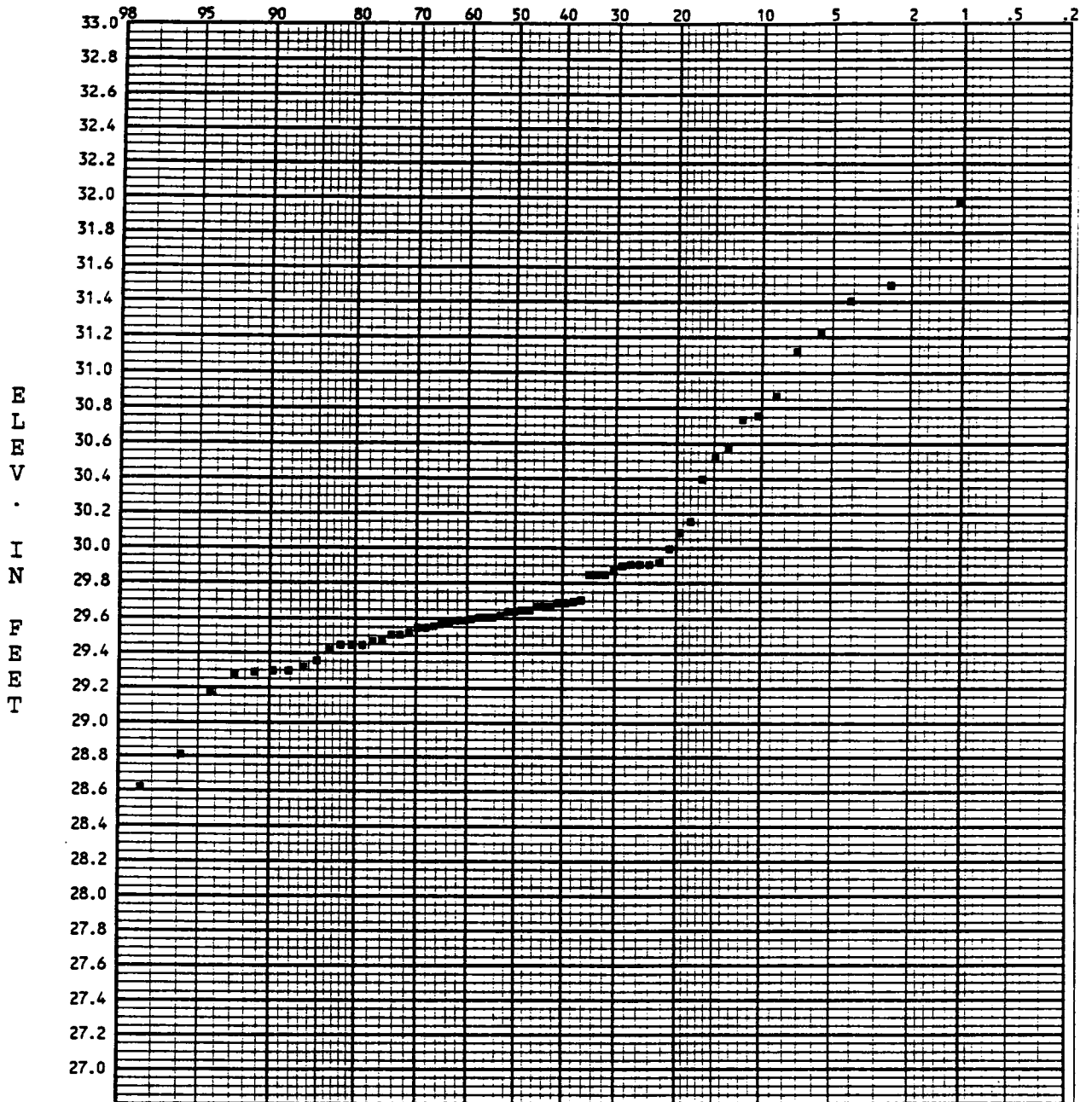


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1976 DROUGHT REGULATION
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APPENDIX 5, PINE RIVER
VOLUME-FREQUENCY CURVES
PEAK AVERAGE INFLOWS
(1898-1985)
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 ST. PAUL, MINNESOTA

EXCEEDANCE FREQUENCY IN PERCENT



PINE RIVER DAM AND RESERVOIR

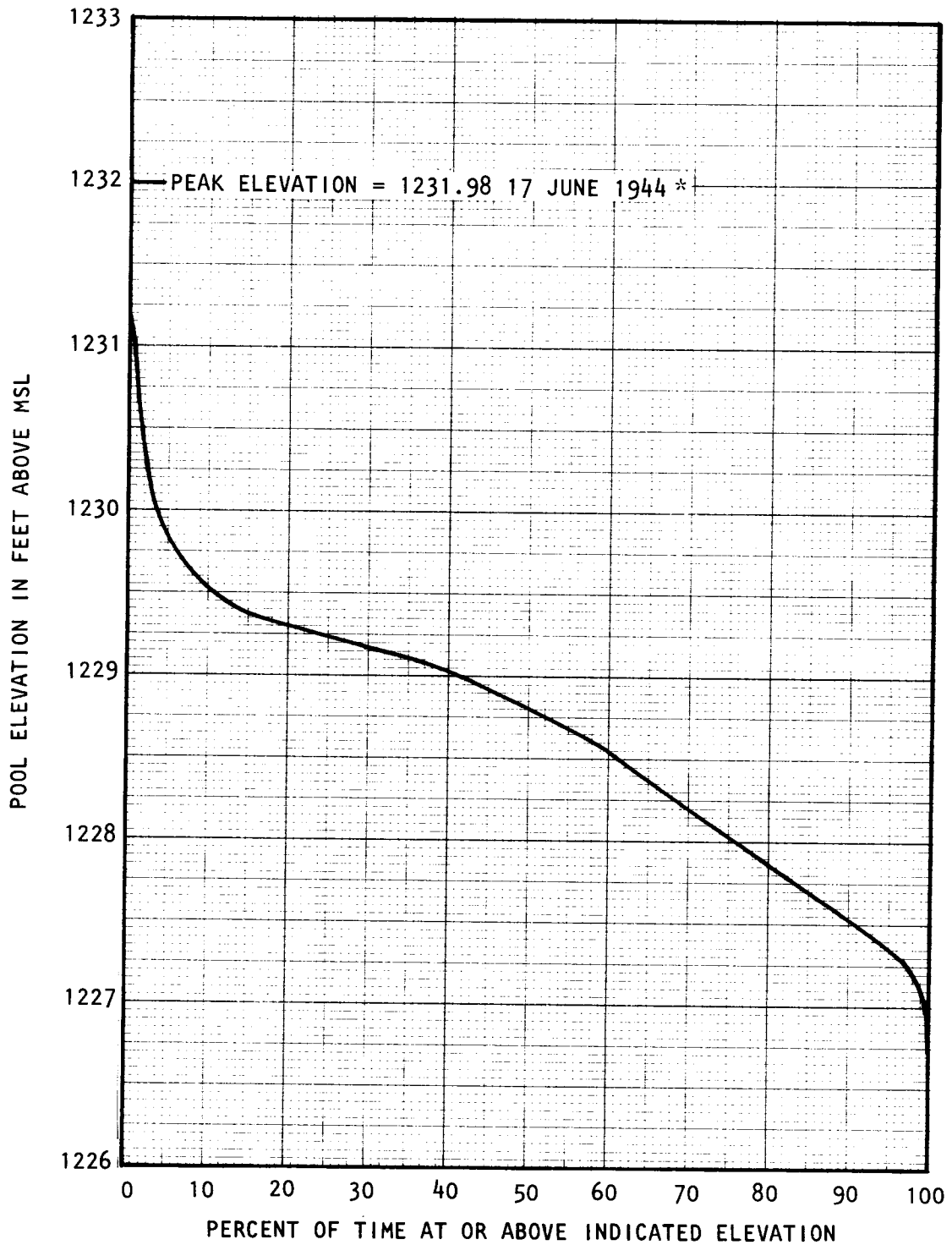
ELEVATION - FREQUENCY
 Annual Peak Elevations
 Elev in feet above 1200.00 ft.

BASIN AREA = 562 SQ MI
 WATER YEARS IN RECORD
 1931-1995

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
APPENDIX 5, PINE RIVER

ELEVATION - FREQUENCY

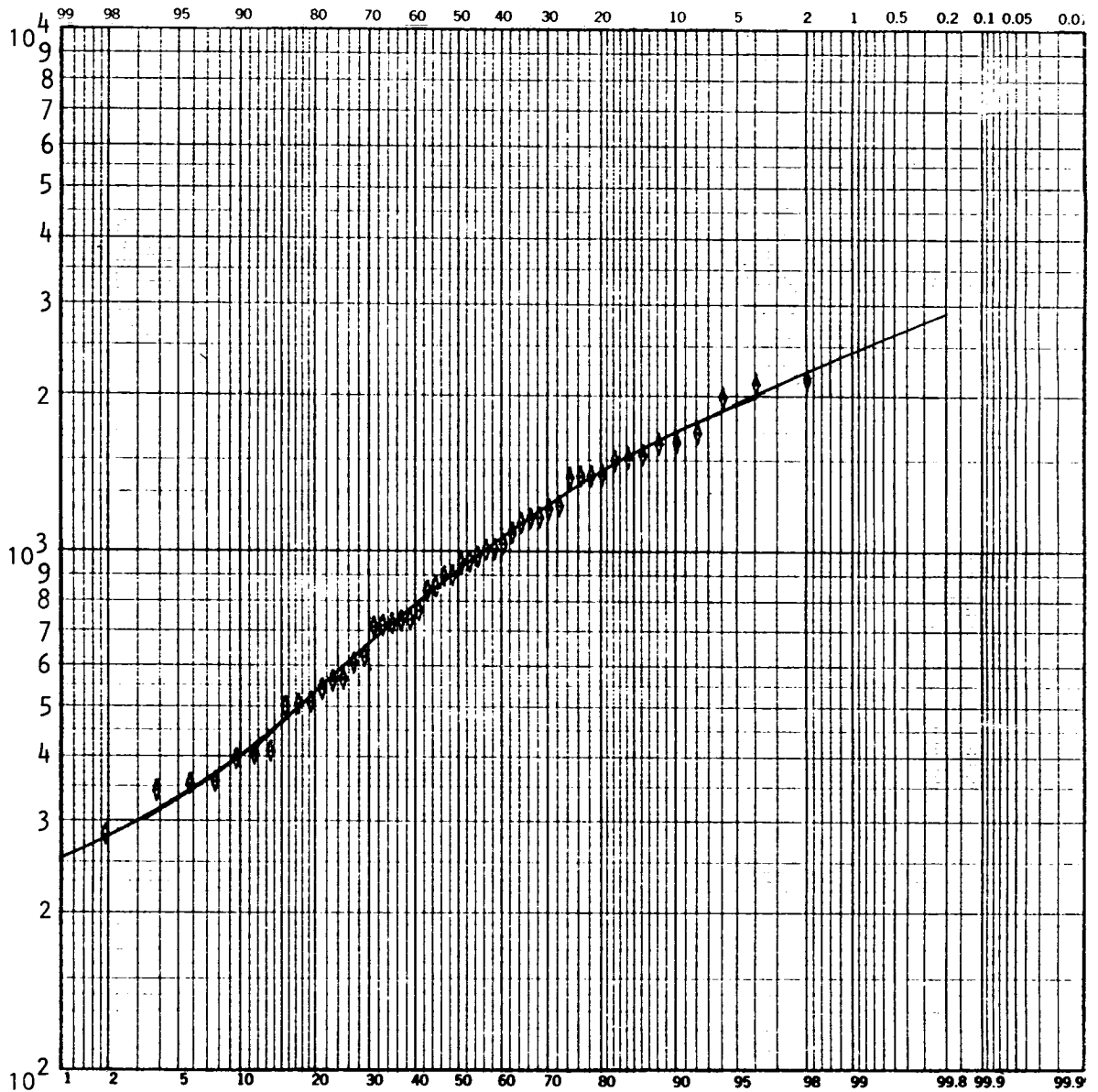
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 ST. PAUL ENGINEERING DISTRICT
 ST. PAUL, MINNESOTA



* PEAK ELEVATION SINCE CURRENT REGULATION PLAN WENT INTO EFFECT IN 1936. PEAK ELEVATION OF RECORD = 1234.73, 7 JULY 1916.

MISSISSIPPI RIVER HEADWATERS
 NAVIGATION AND FLOOD CONTROL PROJECT
 RESERVOIR REGULATION MANUAL
**APPENDIX 5, PINE RIVER
 ELEVATION-DURATION CURVE
 PINE RIVER POOL
 (1936-1985)**
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 ST. PAUL, MINNESOTA

EXCEEDANCE FREQUENCY IN PERCENT



MISSISSIPPI RIVER HEADWATERS
NAVIGATION AND FLOOD CONTROL PROJECT
RESERVOIR REGULATION MANUAL
**APPENDIX 5, PINE RIVER
DISCHARGE-FREQUENCY CURVE
PINE RIVER RESERVOIR
(1936-1985)**
CORPS OF ENGINEERS, U.S. ARMY
ST. PAUL ENGINEERING DISTRICT
ST. PAUL, MINNESOTA

EXHIBIT A
PERTINENT DATA
PINE RIVER DAM, CROSS LAKE RESERVOIR

**EXHIBIT A
PERTINENT DATA
PINE RIVER DAM, CROSS LAKE RESERVOIR**

GENERAL INFORMATION

Location Pine River Dam is located at the outlet of Cross Lake on the Pine River at Crosslake, Minnesota, 14.5 miles upstream of the confluence with the Mississippi River. The confluence is at river mile 1023.8 above the Ohio River. The dam is in Crow Wing County, 22 miles north of Brainerd, Minnesota. It is at Lat. 45° 40 '09" N, Long. 96° 06' 44" W in Section 21, T137 N, R27 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 Dam discharge records begin 26 March 1886. Timber structure complete 1887. Timber replace by concrete structure 1905 to 1908.

RESERVOIR

Cross Lake Reservoir Pine River Dam	Elevation in Feet	Area in Acres	Cumulative Storage in Acre-Feet
Maximum Operating Limit	1235.3	15,500	188,000
Normal Summer Pool Level	1229.32	13,600	101,000
Minimum Operating Limit	1225.32	12,500	49,100
Slide Gate Sill	1216.65	---	0

RESERVOIR (continued)

Maximum Pool Elevation (Historic)	1234.73 ft., 7 July 1916 event See Paragraph 4-06
Real Estate Taking Line for Easement	4 ft. above a 18.5 ft stage = Elev. 1238.82 ft. (Approximate, See Chapter 2)
Reservoir Length at Top of Summer Pool Level	8.4 miles
Shoreline Length at Top of Summer Pool Level	112.0 miles

HYDROLOGY

Drainage Area	562 square miles
One Inch of Runoff Equals	29,973 acre-feet
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 Mean Daily Inflow	Flow is very low during dry periods.
Minimum Mean Monthly Inflow	Flow is very low during dry periods.
Minimum Mean Annual Inflow	90 cfs, 1934
Maximum 24-hr. Average Inflow	3,710 cfs, 2 June 1898
Maximum Mean Monthly Inflow	1,660 cfs, May 1950
Maximum Mean Annual Inflow	550 cfs, 1905
Average Annual Inflow	270 cfs, (Period 1898-1985)

HYDROLOGY (continued)

Maximum Flood Volume	157,000 ac.-ft., 15 April - 10 June, 1950
Type of Meteorological Data Recorded at Site	Rainfall, snowfall, temperature, cloud cover, wind, See Chapter 5
Typical Maximum Snowpack	15-31 March
Number of Sediment Ranges	None

EMBANKMENT AND DIKES

Embankment

Type	Earthfill with timber diaphragm with sheet pile, concrete capped wall
Slope Protection	Riprap and grass; bituminous top (roadway)
Length	1,552 ft. (total left and right)
Height	23.9 feet
Minimum Top Elevation	1240.3 feet

Perimeter Dikes (See also **Table 3-1**)

Number	16
Purpose	Impoundment
Slope Protection	Varies; grass, some riprap and bituminous top
Length	9,805 feet total
Height	Varies; generally <20 feet
Type	Compacted earthfill
Minimum Top Elevation	1240.3 feet (some low areas, see Table 2-2)

OUTLET STRUCTURE

Type	Gated multi-bay reinforced concrete control structure with concrete apron.
Structure Length Between Abutments	150 feet
Number/Size/Type of Gates	13 - 6.0 ft wide x 17.0 ft. high slide gates

OUTLET STRUCTURE (cont)

Gate Sill Elevation	1216.65 ft.(slide gate bays)
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SPILLWAY

No Service or Emergency Spillways	Gated concrete sluiceway outlet facility only
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SPILLWAY APRON

Type:	Concrete and timber
Length:	55 feet
Width (between abutments):	150 feet
Floor Elevation:	1216.65 feet

**Mississippi River Headwaters Dams
Summary of Control Structure Features**

	Winni- bigoshish	Leech	Pokegama	Sandy	Pine	Gull
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 Bays: ¹						
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.

EXHIBIT B

RELATED MANUALS AND REPORTS

PINE RIVER DAM, CROSS LAKE RESERVOIR

EXHIBIT B

RELATED MANUALS AND REPORTS

PINE RIVER DAM, CROSS LAKE RESERVOIR

1. General. Prior reports concerning the Mississippi River Headwaters Reservoirs date from about 1868. See **Exhibit D** for additional information and copies of some of the documents.

2. *Letter Report, Major Gouverneur K. Warren, St. Paul District Engineer, 30 April 1870, This report contemplated the construction of 41 reservoirs on the St. Croix, Chippewa, Wisconsin and Mississippi Rivers.*

3. River and Harbor Acts of June 1880 and August 1882, Authorized the construction of dams at each of the six Mississippi River Headwaters Lakes for the purpose of forming reservoirs.

4. *River and Harbor Act of 11 August 1888 (25 Stat. 419; 33 U.S.C. 601), Directed the Secretary of War to establish regulations governing the operation of the six Mississippi River Headwaters Reservoirs.*

5. Letter, Regulations for the use and Administration of the reservoirs at the headwaters of the Mississippi River, Patrick J. Hurley, Secretary of War, 11 February 1931, This letter established new regulations and revoked the previous orders issued by the secretary dated 21 February 1889.

6. Letter to Representative Harold Knutson (St. Cloud, MN) from Major General Lytle Brown, Chief of Engineers, 1 April 1931, Modified the minimum level of the Pine River Reservoir.

7. Letter, Regulations for the use and Administration of the reservoirs at the headwaters of the Mississippi River, Harry H. Woodring, Acting Secretary of War, 14 May 1935, Modified the allowable discharges from some of the reservoirs.

8. Letter, Regulations for the use and Administration of the reservoirs at the headwaters of the Mississippi River, Geo. H. Dern, Secretary of War, 4 February 1936, This letter modified the allowable discharges from the some of the reservoirs. This letter established new regulations and revoked the previous orders issued by the secretary dated 11 February 1931.

9. Letter, Modifying the minimum operating level of Leech Lake Reservoir, Major H.J. Manger, Acting St. Paul District Engineer, 25 January 1945, with attached amendment from Henry L. Stimson, Secretary of War dated 29 December 1944. This letter established new regulations and revoked the previous orders issued by the secretary dated 4 February 1936.

10. Flood Control Act of 30 June 1948, House Document No. 599, 80th Congress, 2nd Session, Authorized the Aitkin Diversion Channel Project.

EXHIBIT C

DATA COLLECTION PLATFORM TRACKING CHART

PINE RIVER DAM, CROSS LAKE RESERVOIR

PINE RIVER DAM POOL & T/W READINGS

MONTH / YEAR : _____

The following DCP pool gage and Data Log readings were checked against a plot (From the COE Web Page) of the DCP data in the Water Control Data Base. Any significant deviations are noted in the remarks column.

NOTE : If DCP Pool Reading and Tape Indicator differ by more than 0.03' contact Water Control.

DATE	TIME	POOL STAFF READING	DCP POOL READING	DIFF.	DATA LOG POOL READING	DCP T/W READING	T/W STAFF READING	REMARKS / INITIALS
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31								

DCP=Sutron 8210 Goes / Sp. Mod.

DATA LOG=Sutron 8200 Datalogger

SIGNED : _____

EXHIBIT D

PROJECT LETTERS, AGREEMENTS, AND RESOLUTIONS

PINE RIVER DAM, CROSS LAKE RESERVOIR

(Primarily referenced from Chapters 2, 3, 7 and 9)

EXHIBIT D

TABLE OF CONTENTS

DOCUMENT REFERENCE NUMBER

- 1 A copy of pages 1829 through 1831 from the Annual Report of the Chief of Engineers, United States Army, to the Secretary of War, for the Year 1896, House or Representatives, 4th Congress, 2nd Session, Document No. 2, Volume II, **containing regulations dated 21 February 1889 from William C. Endicott, Secretary of War, regarding the operation of the Headwaters reservoirs.** These regulations were revoked by the 1931 regulations (see 2.b. below).
- 2
 - a. A cover letter from Lieutenant Colonel Wildurr Willing, St. Paul District Engineer, dated February 21, 1931, **transmitting the February 11, 1931 letter** from the Secretary of War (see 2.b. below), which contains regulations concerning the operation of the Headwaters reservoirs. The cover letter describes the basis for the new regulations.
 - b. A letter from Patrick J. Hurley, Secretary of War, dated February 11, 1931, containing **Regulations for the Use and Administration for the Reservoirs at Headwaters of the Mississippi River.** These regulations revoked the 1931 regulations and were later revoked by the 1935 regulations (see No. 4 below).
- 3 A letter from Major General Lytle Brown, Chief of Engineers, dated April 1, 1931, which grants permission to **utilize a higher minimum stage (11.0 ft.) at Pine River reservoir.** A nine-foot minimum stage was still permissible under the official regulations.
- 4 A letter from Harry H. Woodring, Acting Secretary of War, dated May 14, 1935, containing **Regulations for the Use and Administration for the Reservoirs at Headwaters of the Mississippi River.** These regulations revoked the 1931 regulations.
- 5
 - a. A cover letter from Major Dwight F. Johns, District Engineer, Corps of Engineers, St. Paul, Minnesota, dated February 24, 1936, **transmitting the February 4, 1936 letter** from the Secretary of War (see 5.b. below) regarding regulations concerning the operation of the Headwaters reservoirs.
 - b. A letter from Geo. H. Dern, Secretary of War, dated February 4, 1936, containing **Regulations for the Use and Administration for the Reservoirs at Headwaters of the Mississippi River.**
- 6
 - a. A letter from Colonel Lynn C. Barnes, District Engineer, Corps of Engineers, St. Paul, Minnesota, dated 9 November **1944, regarding the justification for lowering the minimum operating limit for Leech Lake** reservoir and other issues (see 6.c. below).
 - b. Exhibit C from a transcript of the **minutes of a public hearing on the regulation of Cross Lake/Pine reservoir** held in Brainerd, Minnesota on 5 September 1945. This table lists the operating levels that were in use at that time on the Headwaters reservoirs. See also **Reference 13.b.**
 - c. A letter from Major H. J. Manger, Acting St. Paul District Engineer, dated 25 January 1945, transmitting Secretary of War, Henry L. Stimson's December 29, 1944 revisions to **allow for a lower minimum stage at Leech Lake Reservoir.**
- 7 A copy of the **Code of Federal Regulations, Title 33, Section 207.340, regarding the headwaters of the Mississippi River,** which lists the latest regulations for the Mississippi River Headwaters reservoirs thru the December 29, 1944 revisions.

- 8 a. A letter from D. P. Tierney, Valuation Engineer in Charge, Land Section, St. Paul District, dated 6 January 1945, which **summarizes when the flowage rights for the Mississippi River Headwaters reservoirs were acquired.**
- b. A letter from J. Wesley Walters, Chief, Reservoirs and Permits Branch, St. Paul District, dated 28 July 1949, which **summarizes the flowage rights for the Mississippi River Headwaters reservoirs.**
- c. A letter from the United States Attorney, Department of the Justice, St. Paul, Minnesota, dated January 24, 1910, which **transmits a quit-claim deed for property on Gull Lake** plus a copy of sheet No. 6 from the **June 1943 Land Acquisition maps.** This letter is provided here for use in sorting out some discrepancies related to Gull Lake's flowage rights.
- 9 A copy of **Minnesota Statutes** 1961, Sections 110.47 through 110.53, which lead to the subsequent Finding of Fact and Plan of Operation for the Headwaters reservoirs from the State of Minnesota (see **Exhibit D, Reference Nos. 10 and 11**).
- 10 A Findings of Fact, Conclusion ORDER from Clarence Prout, Commissioner of Conservation, Department of Conservation, State of Minnesota, dated 19 April 1963. This document contains recommendations from the Department of Conservation (now the MDNR) regarding the **regulation of the Mississippi River Headwaters Reservoirs.**
- 11 a. A letter from Colonel W. B. Strandberg, District Engineer, Corps of Engineers, St. Paul, Minnesota, dated 18 December 1962, which **discusses outflow rate-of-change guidelines** proposed by the State of Minnesota for the Headwaters reservoirs (see 11.b.)
- b. A copy of the **Plan of Operation, Mississippi Headwaters Reservoirs** from Gordon Wollan, Acting Director of Game and Fish, Department of Conservation, State of Minnesota, dated 15 August 1963, which lists rate-of-change guidelines proposed by the State of Minnesota for the Headwaters reservoirs.
- 12 a. A copy of **Public Law 100-676, Section 21, November 17, 1988, Water Resources Development Act of 1988 (WRDA 1988) regarding the headwaters of the Mississippi River** the goal of which was to require the Secretary of the Army to notify Congress when the specified operating limits (both high and low) were going to be exceeded. The referenced "contingency plan" is included below as **Reference 12.b.**
- b. A copy of the **Reservoir Regulation Contingency Plan** for the Mississippi River Headwaters Reservoirs prepared to comply with the Water Resources Development Act of 1988 (WRDA 1988), Public Law 100-676, Section 21 of November 17, 1988 (see **Reference 12.a.**).
- 13 a. A copy of page 2487 from the Annual Report of the Chief of Engineers, United States Army for the Year 1914, Part 2, **containing a table listing pre-1931 maximum storage elevations for the Headwaters reservoirs.** Pine's maximum is listed as 18.5 feet, even though the February 11, 1931 regulations list 15 feet.
- b. Minutes from St. Paul District Engineer, Colonel Lynn C. Barnes' introduction at a Public Hearing on Pine Reservoir operations held in Brainerd, Minn. on 5 September 1945, which **discusses the history of operating levels on Cross Lake/Pine reservoir.** The attached General Operating Data table dated January 11, 1945 for the Mississippi River Headwaters Reservoirs was handed out at the meeting.
- c. Page 11 from the 1963 Headwaters Dams and Reservoirs, Master Reservoir Regulation Manual (Revised 17 February 1968), which indicates **the "general maximum operating level" for Pine/Cross Lake was raised from 10 feet to 11 feet** "due to shallow connecting waterways".
- d. Page 1 and A-19 from the Design Memorandum and Environmental Assessment, Dam Safety Assurance Program, Pine River Dam, Cross Lake, Minnesota, dated March 1997, which discusses the modifications made to the dam **to permit a maximum pool elevation of 1235.3 feet (18.98 ft. stage).**
- e. A letter from Tim Brastrup, Minnesota Department of Natural Resources, Area Fisheries Supervisor, dated December 4, 2002, **which discusses the drawdown of Cross Lake reservoir and its affect on whitefish spawning.**

EXHIBIT D

REFERENCE NO. 1

A copy of pages 1829 through 1831 from the Annual Report of the Chief of Engineers, United States Army to the Secretary of War, for the Year 1896, House of Representatives, 4th Congress, 2nd Session, Document No. 2, Volume II, containing regulations dated 21 February 1889, from William C. Endicott, Secretary of War regarding the operation of the Headwaters reservoirs.

The 1889 regulations were developed by the War Department to provide some guidelines for operating the newly constructed Headwaters reservoirs and were in use until the 1931 regulations were issued. The 1889 regulations do not specify any reservoir operating levels, however; operating levels were developed by the officer-in-charge based on physical limitations and engineering judgement (See **Paragraphs 2-05, 3-05 and Table 3-1**).

EXHIBIT D

REFERENCE NO. 2

a. A cover letter from Lieutenant Colonel Wildurr Willing, St. Paul District Engineer, dated February 21, 1931, transmitting the February 11, 1931 letter from the Secretary of War (see below) regarding regulations concerning the operation of the Headwaters reservoirs (see 2.b. below).

This document provides an explanation for the various provisions set forth in the February 11, 1931 regulations, which revoked the 1889 regulations. Note the reference in Paragraph 3.i to the minimum operating levels of the reservoirs being raised “substantially as requested by the Minnesota Lake Levels Association”

b. A letter from Patrick J. Hurley, Secretary of War, dated February 11, 1931, containing Regulations for the Use and Administration for the Reservoirs at Headwaters of the Mississippi River. This regulation revoked the 1889 regulations.

This letter, among other things set, for the first time, minimum flows for the dams and upper lower and reservoir limits for water levels. See the cover letter (referenced above) for more details. See also **Paragraph 3-05**.

The upper limit for Pine River is listed as 15 feet. However, research conducted for the preparation of this manual revealed that the St. Paul District office considered the maximum available for storage to be 18.5 feet.

EXHIBIT D

REFERENCE NO. 3

A letter from Major General Lytle Brown, Chief of Engineers, dated April 1, 1931, which grants permission to **utilize a higher minimum stage at Pine River reservoir.**

This was done by agreement rather than by an official change in the regulations. It appears that the agreement essentially provided for a normal spring drawdown level of 11 feet. The nine-foot minimum, set forth in the earlier 1931 regulations, was still available for emergency situations (e.g., very wet snow pack). See also **Paragraph 3-05.**

EXHIBIT D

REFERENCE NO. 4

A letter from Harry H. Woodring, Acting Secretary of War, dated May 14, 1935, containing Regulations for the Use and Administration for the Reservoirs at Headwaters of the Mississippi River. These regulations replaced the 1931 regulations.

This letter set average annual outflow values, which replaced the minimum flow values, for Pokegama, Sandy, Pine and Gull Lake reservoirs. Minimum flow values, as opposed to average annual flows, remained for Lake Winnibigoshish and Leech Lake (but were included in the 1936 regulations). The regulation lists a minimum stage of nine feet for Pine River reservoir, however; the St. Paul District had agreed to not lower the reservoir below 11 feet if possible (see **Exhibit D, Reference No. 3**). Presumably, lowering the reservoir to nine feet was still possible under a strict interpretation of the regulations. See also **Paragraph 3-05**. The upper limit for Pine River is still listed as 15 feet. However, research conducted for the preparation of this manual revealed that the St. Paul District office considered the maximum available for storage to be 18.5 feet.

EXHIBIT D

REFERENCE NO. 5

a. A cover letter from Major Dwight F. Johns, District Engineer, Corps of Engineers, St. Paul, Minnesota, dated February 24, 1936, transmitting the February 4, 1936 letter from the Secretary of War (see 5.b. below).

The letter alludes to the fact that the 1936 regulation specifies average annual discharge values for Lake Winnibigoshish and Leech Lake. Average annual values for the other four reservoirs had already been listed in the May 14, 1935 regulations.

b. A letter from Geo. H. Dern, Secretary of War, dated February 4, 1936, containing Regulations for the Use and Administration for the Reservoirs at Headwaters of the Mississippi River.

Only minimum operating limits are listed in this regulation. See also **Paragraph 3-05**. However, the regulation does not preclude the reservoirs from being operated up to the previously listed upper limits. Later correspondence indicates that storage up to the maximum limits in the reservoir could be used if necessary (see **Exhibit D, Reference 6.a. Paragraph 8.**).

EXHIBIT D

REFERENCE NO. 6

a. A letter from Colonel Lynn C. Barnes, District Engineer, Corps of Engineers, St. Paul, Minnesota, dated 9 November 1944, regarding the justification for lowering the minimum operating limit for Leech Lake reservoir and other issues.

This letter recommends that the minimum operating level for Leech lake be lowered from 1.0 foot, as specified in the 1936 regulations, to 0.0 feet in order to allow the “normal” upper limit be reduced from 3.5 feet to 3.0 feet (also called the “Ordinary Operating Limits”). However, a minimum stage of 0.0 feet was not possible without a change in the regulations. The minimum stage was officially changed on December 29, 1944 (see **6.c. below**).

b. Exhibit C from a transcript of the minutes of a public hearing on the regulation of Cross Lake/Pine reservoir held in Brainerd, Minnesota on 5 September 1945.

This table lists the operating levels that were in use at that time on the Headwaters reservoirs. See also **Reference 13.b.**

c. A letter from Major H. J. Manger, Acting St. Paul District Engineer, dated 25 January 1945, transmitting Secretary of War, Henry L. Stimson's December 29, 1944 revisions to allow for a lower minimum stage (0.0 feet) at Leech Lake Reservoir.

See **Paragraph 3-05** for a summary and **Exhibit D, Reference 6.a** for details.

EXHIBIT D

REFERENCE NO. 7

A copy of the Code of Federal Regulations, Title 33, Section 207.340, regarding the Headwaters of the Mississippi River.

This document lists the latest regulations for the Mississippi River Headwaters reservoirs through the 4 December 1936 regulations to include the later 29 December 1944 revision at Leech.

EXHIBIT D

REFERENCE NO. 8

a. A letter from D. P. Tierney, Valuation Engineer in Charge, Land Section, St. Paul District, dated 6 January 1945, which summarizes when the flowage rights for the Mississippi River Headwaters reservoirs were acquired.

b. A letter from J. Wesley Walters, Chief, Reservoirs and Permits Branch, St. Paul District, dated 28 July 1949, which summarizes the flowage rights for the Mississippi River Headwaters reservoirs.

See **Paragraph 2-05** for a summary of the flowage rights for all six of the Headwaters reservoirs. In many cases, an exact elevation cannot be assigned to the flowage rights as rights were obtained on: entire forty acre parcels; by condemnation of entire strips of land; and by other means. In some cases, the records are simply not clear on the subject or subsequent erosion has created problems.

This letter states that “the Government is restricted to a maximum stage of seven feet on Gull Reservoir.”. However, Table 2 in the April 1963 (revised 17 Feb. 1968) Master Reservoir Regulation Manual indicates that the maximum stage on Gull is 11+ feet. The research conducted for this manual, by the Water Control Section and the District’s Real Estate Division, could not find any evidence to support the 11+ feet. Sheet Nos. 1 through 18 titled “Land Acquisition, Gull Lake, June 1943”, U.S. Army Engineer Office, St. Paul, Minn. File No. RE 2/94-1 through RE 2/94-18 indicates an “approximate flowage line shown by 1197 foot contour”. An elevation of 1197 feet is a stage of seven feet referenced from the U.S. Engineer (USE) Datum in use at that time. This is equal to elevation 1194.75 feet in the 1929 NGVD that is in use now. Further support of the seven-foot figure is contained in the quit-claim deeds for the property surrounding Gull Lake, an example of which can be found in **Exhibit D, Reference 8.c.**

c. A letter from the United States Attorney, Department of the Justice, St. Paul, Minnesota, dated January 24, 1910, which transmits a quit-claim deed for property on Gull Lake plus a copy of sheet No. 6 from the June 1943 Land Acquisition maps.

This document is provided here as evidence in support of a maximum stage of seven feet on Gull Lake reservoir. The listed “flowage elevation” of 1197 feet is a stage of seven feet referenced from the USE Datum in use at that time. This is equal to elevation 1194.75 feet in the 1929 NGVD that is in use now. In addition, a copy of sheet No. 6 from the June 1943 Land Acquisition maps for Gull Lake is attached, which also indicates a “flowage line” at elevation 1197 ft. (USE datum).

EXHIBIT D

REFERENCE NO. 9

A copy of Minnesota Statutes 1961, Sections 110.47 through 110.53, which lead to the subsequent Finding of Fact and Plan of Operation for the Headwaters reservoirs from the State of Minnesota (see Exhibit D, Reference Nos. 10 and 11).

EXHIBIT D

REFERENCE NO. 10

A Findings of Fact, Conclusion ORDER from Clarence Prout, Commissioner of Conservation, Department of Conservation, State of Minnesota, dated 19 April 1963.

This document contains recommendations from the Department of Conservation regarding the regulation of the Mississippi River Headwaters Reservoirs. The guidelines listed in Table D (low flow guidelines) and Table E (high flow guidelines) of this document were adopted by the Corps in the 17 February 1968 revision of the 1963 Headwaters Dams and Reservoirs, Master Reservoir Regulation Manual.

The St. Paul District has agreed informally to follow the guidelines in Tables D and E. Note that Lake Winnibigoshish's normal summer level was lowered one foot in 1975 (which changes some of the listed values for Winnibigoshish). This document is based in part on Minnesota Statutes 1961, Sections 110.47 through 110.53 (see **Exhibit D, Reference No. 9**).

Recommendations from Gordon Wollan, Acting Director of Game and Fish, Department of Conservation (see **Para. 12 and 13 in Ref. 10**) are included in **Exhibit D, Reference No. 11**.

EXHIBIT D

REFERENCE NO. 11

a. A letter from Colonel W. B. Strandberg, District Engineer, Corps of Engineers, St. Paul, Minnesota, dated 18 December 1962, which discusses outflow rate-of-change guidelines proposed by the State of Minnesota for the Headwaters reservoirs.

It is assumed that the comments in this letter were considered, which resulted in the rate-of-change guidelines published in the 15 August 1963 Plan of Operation (see 11.b. discussion below).

b. A copy of the Plan of Operation, Mississippi Headwaters Reservoirs from Gordon Wollan, Acting Director of Game and Fish, Department of Conservation, State of Minnesota, dated 15 August 1963. See Exhibit D, Reference Nos. 9, 10 and 11.a.

This plan is referenced in Paragraph 13 of the Commissioners Order dated 19 April 1963 (see **Exhibit D, Reference No. 10**). It is not clear if the Corps agreed to informally follow any of the guidelines in this document. It is included here as the rate-of-change guidelines listed in the document were adopted for this manual (see **Table 7-5** in this manual) pending the outcome of detailed in-stream flow studies. The following is a description of the research that was done during the development of this manual, which led to the adoption of these rate-of-change guidelines.

The 1963 Headwaters Dams and Reservoirs, Master Reservoir Regulation Manual (Revised 17 February 1968) does not contain any guidelines for increasing or decreasing the outflow from the dams. A review of the literature, however, indicated the rate-of-change in the outflow was an important issue at the time. Discussions with experienced operators of the Headwaters dams indicated that, although all the sites are careful to adjust outflows in the interest of wildlife, three of the six reservoirs (Winni, Leech and Pine/Cross) have had, at one time or another, specific (but apparently unofficial) rate-of-change guidelines although no one could cite a published, official source. For example, Winnibigoshish and Leech used, for a period of time, a guideline that essentially stated: when conditions permit, any increase or decrease in discharge should be made so that the rate of outflow does not change more than 50 cfs per day, when the total change is to be less than 300 cfs, and 100 cfs per day if the change is to be more than 300 cfs. A change of 100 cfs every other day could be substituted for a change of 50 cfs per day.

The source of this information was traced to pages 63 and 66 of the report titled "Multiple Use Survey, Winnibigoshish and Leech Reservoirs". This report is not dated, however, it was received by the Corps on 25 August 1965 (see **Paragraph 1-03**). Although the guidelines on

these pages were used by the Corps at one time, a further review of the correspondence between the District and the State of Minnesota (see **Exhibit D, Reference No. 11.a**), indicates that a 50 to 100 cfs per-day restrictions at Winnibigoshish and Leech was not acceptable. Instead, limiting the rise in the tailwater (e.g., no more than 0.5 ft. per day) was suggested as being more favorable to reservoir regulation while still being acceptable to downstream interests. Concerns were also expressed about limits that were being proposed at that time at Gull and Sandy with no restriction at all being suggested for Sandy.

To confuse matters, the aforementioned “Multiple Use Survey” report also contains a copy of **Exhibit D, Reference No. 11.b.**, which contains a completely different set of rate-of-change guidelines. The report is not clear which of the two sets of guidelines were adopted (if any). These later guidelines (in **Ref. No. 11.b.**), however, correspond, for the most part with the suggestions in the 18 December 1962 letter and as such were adopted, with minor additions and clarifications, for this manual (see **Table 7-5** in this manual). See also **Exhibit D, Reference No. 14.c.**

EXHIBIT D

REFERENCE NO. 12

a. A copy of Public Law 100-676, Section 21, November 17, 1988, Water Resources Development Act of 1988 (WRDA 1988) regarding the headwaters of the Mississippi River.

The goal of this law is to require the Secretary of the Army to notify Congress when the specified operating limits (both high and low) were going to be exceeded. The referenced "contingency plan" is included below as **Reference 12.b.**

b. A copy of the Reservoir Regulation Contingency Plan for the Mississippi River Headwaters Reservoirs prepared to comply with the Water Resources Development Act of 1988 (WRDA 1988), Public Law 100-676, Section 21 of November 17, 1988 (see Reference 12.a.).

Note: Selected pages are included here. The information used to write this document was extracted from draft copies of the Water Control Manual (dated approx. 1986). The draft manuals contained errors which also appear in the Contingency Plan. Pokegama's upper notification limit should be elev. 1278.42 ft. (not 1276.42) and the dam should be wide open at 1278.42 ft. (not 1277.92). Sandy's upper notification limit should be elev. 1221.31 ft. (not 1218.31). Pine's upper notification limit should be elev. 1235.30 ft. (not 1234.82) due to the dam safety rehabilitation. Revised wording has been submitted for inclusion in WRDA 2003. Before that becomes law, the District will have to ask MVD for a deviation to operate outside of the WRDA 1988 limits.

EXHIBIT D

REFERENCE NO. 13

a. A copy of page 2487 from the Annual Report of the Chief of Engineers, United States Army for the Year 1914, Part 2, containing a table listing pre-1931 maximum storage elevations for the Headwaters reservoirs. Pine's maximum is listed as 18.5 feet even though the February 11, 1931 regulations list 15 feet.

This is provided as documentation of what the District considered the upper limits of the Headwaters reservoirs to be prior to the publication of the February 11, 1931 regulations. It appears that a stage of 18.5 feet (elev. 1234.82 ft.) was used as the upper limit at Pine even though the 1931 and later regulations list an upper limit of 15 feet (elev. 1231. 23 ft.) (see **13.b. below**). Note that Pine reached a stage of 17.0 feet in June of 1914. It exceeded 18 feet a number of times during this period (see **Table 4-3** in this manual).

b. Minutes from St. Paul District Engineer, Colonel Lynn C. Barnes' introduction at a Public Hearing on Pine Reservoir operations held in Brainerd, Minn. on 5 September 1945, which discusses the history of operating levels on Cross Lake/Pine reservoir. The attached General Operating Data table dated January 11, 1945 for the Mississippi River Headwaters Reservoirs was handed out at the meeting.

These minutes discuss the 1944 agreement to informally change Pine's ordinary operating limits from 11 to 15 feet (elev. 1227.32 to 1231.32 ft.) (see **Exhibit D, Reference 3**) to 10 to 14 feet (elev. 1226.32 to 1230.32 ft.) . Like the 1931 change, this was done by agreement rather than by an official change in the regulations. It appears that the agreement essentially provided for a normal spring drawdown level of 10 feet (elev. 1226.32 ft). This was later changed back to 11 feet (elev. 1227.32 ft) (see **13.c.** below). The nine-foot minimum (elev. 1225.32 ft.), set forth in the earlier 1931 regulations, was still available for emergency situations (e.g., very wet snow pack). The attached table indicates the upper operating limit at Pine is 18.5 feet (elev.1234.82 ft.) during this period (see **6.a. above**). See also **Paragraph 3-05**.

c. Page 11 from the 1963 Headwaters Dams and Reservoirs, Master Reservoir Regulation Manual (Revised 17 February 1968), which indicates the "general maximum operating level" for Pine/Cross Lake was raised from 10 feet to 11 feet "due to shallow connecting waterways".

This resulted in the Ordinary Operating Limits (11 to 14 ft. stage, elev. 1227.32 to 1230.32 ft.) that are still in place today. See also **Paragraph 3-05**.

d. Page 1 and A-19 from the Design Memorandum and Environmental Assessment, Dam Safety Assurance Program, Pine River Dam, Cross Lake, Minnesota, dated March 1997, which discusses the modifications made to the dam to permit a maximum pool elevation of 1235.3 feet (18.98 ft. stage).

This dam safety study resulted in the rehabilitation and raising of the perimeter dikes, the main embankment and the control structure. As a result, the dam can safely handle a maximum pool elevation of 1235.3 feet (18.98 ft. stage).

e. A letter from Tim Brastrup, Minnesota Department of Natural Resources, Area Fisheries Supervisor, dated December 4, 2002, which discusses the drawdown of Cross Lake reservoir and its affect on whitefish spawning.

This letter suggests that beginning the winter drawdown of Cross Lake reservoir on or about October 1 should not result in negative impacts to whitefish spawning. The MDNR is going to continue to research this (with netting etc.). They reserve the option to provide additional input at a later date.

EXHIBIT E
STAGE-DISCHARGE TABLES
PINE RIVER DAM, CROSS LAKE RESERVOIR

EXHIBIT E

STAGE-DISCHARGE TABLES

TABLE	GAGE TITLE	PAGE
E-1.	MISSISSIPPI RIVER AT AITKIN, MINNESOTA, U.S.G.S. GAGE NO. 05227500, STAGE-DISCHARGE NO. 17.0	E-1
E-2.	MISSISSIPPI RIVER AT BRAINERD, MINNESOTA, U.S.G.S. GAGE NO. 05242300, STAGE-DISCHARGE NO. 6.0	E-6

Table E-1

Water Control Manual, Cross Lake Reservoir, Pine River Dam
January 2003

Table E-1

Table E-1

Table E-1

Table E-1

Table E-2

Table E-2

Table E-2

Table E-2

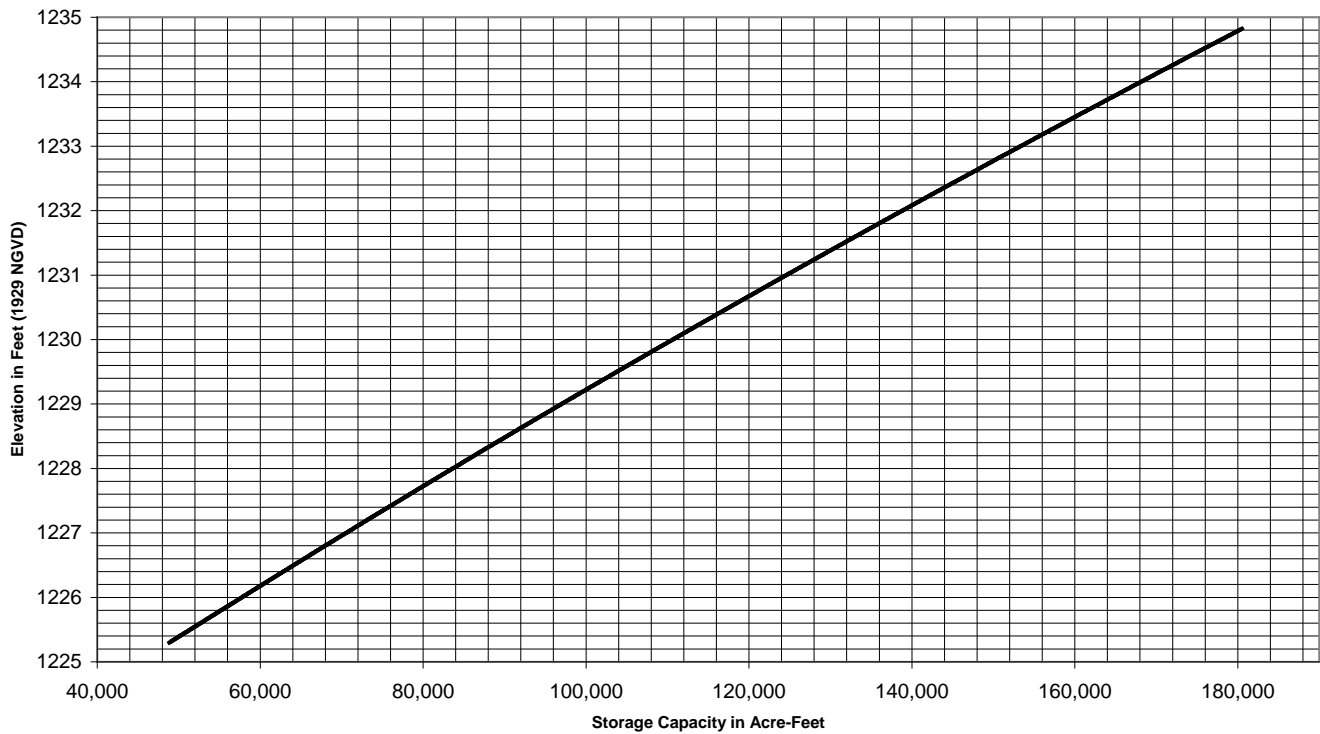
EXHIBIT F

ELEVATION - STORAGE CURVE / TABLE AREA CAPACITY CURVE

PINE RIVER DAM, CROSS LAKE RESERVOIR

Cross Lake Reservoir, Pine River Dam
(extrapolated and smoothed)

Elevation versus Storage Capacity



This graph and table have been extended from the original data published in the report titled "Area Capacity Table Reevaluation for the Mississippi River Headwater Study" dated August 1983 to include the minimum and maximum elevations by extrapolating the pattern of differences in storage capacity. Also inconsistencies in the data were fitted to a smooth curve using the pattern of differences in storage capacity. These changes are reflected in bold in the tables.

PINE RIVER DAM, CROSS LAKE 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
1225.3	48856	48983	49110	49237	49364	49491	49618	49745	49872	49999
1225.4	50126	50253	50380	50507	50634	50761	50888	51015	51142	51269
1225.5	51396	51523	51650	51777	51904	52031	52158	52285	52412	52539
1225.6	52666	52793	52920	53047	53174	53301	53428	53555	53682	53809
1225.7	53936	54063	54190	54317	54444	54571	54698	54825	54952	55079
1225.8	55206	55333	55460	55587	55714	55841	55968	56095	56222	56349
1225.9	56476	56603	56730	56857	56984	57111	57238	57365	57492	57619
1226.0	57746	57873	58000	58127	58254	58381	58508	58635	58762	58889
1226.1	59016	59143	59270	59397	59524	59651	59778	59905	60032	60159
1226.2	60286	60413	60540	60667	60794	60921	61048	61175	61302	61429
1226.3	61556	61683	61810	61939	62068	62197	62326	62455	62584	62713
1226.4	62842	62971	63100	63227	63354	63481	63608	63735	63862	63989
1226.5	64116	64243	64370	64499	64628	64757	64886	65015	65144	65273
1226.6	65402	65531	65660	65787	65914	66041	66168	66295	66422	66549
1226.7	66676	66803	66930	67059	67188	67317	67446	67575	67704	67833
1226.8	67962	68091	68220	68349	68478	68607	68736	68865	68994	69123
1226.9	69252	69381	69510	69641	69772	69903	70034	70165	70296	70427
1227.0	70558	70689	70820	70948	71076	71204	71332	71460	71588	71716
1227.1	71844	71972	72100	72229	72358	72487	72616	72745	72874	73003
1227.2	73132	73261	73390	73521	73652	73783	73914	74045	74176	74307
1227.3	74438	74569	74700	74831	74962	75093	75224	75355	75486	75617
1227.4	75748	75879	76010	76141	76272	76403	76534	76665	76796	76927
1227.5	77058	77189	77320	77451	77582	77713	77844	77975	78106	78237
1227.6	78368	78499	78630	78761	78892	79023	79154	79285	79416	79547
1227.7	79678	79809	79940	80071	80202	80333	80464	80595	80726	80857
1227.8	80988	81119	81250	81383	81516	81649	81782	81915	82048	82181
1227.9	82314	82447	82580	82713	82846	82979	83112	83245	83378	83511
1228.0	83644	83777	83910	84041	84172	84303	84434	84565	84696	84827
1228.1	84958	85089	85220	85352	85484	85616	85748	85880	86012	86144
1228.2	86276	86408	86540	86673	86806	86939	87072	87205	87338	87471
1228.3	87604	87737	87870	88003	88136	88269	88402	88535	88668	88801
1228.4	88934	89067	89200	89335	89470	89605	89740	89875	90010	90145
1228.5	90280	90415	90550	90683	90816	90949	91082	91215	91348	91481

PINE RIVER DAM, CROSS LAKE 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
1228.6	91614	91747	91880	92015	92150	92285	92420	92555	92690	92825
1228.7	92960	93095	93230	93363	93496	93629	93762	93895	94028	94161
1228.8	94294	94427	94560	94697	94834	94971	95108	95245	95382	95519
1228.9	95656	95793	95930	96064	96198	96332	96466	96600	96734	96868
1229.0	97002	97136	97270	97405	97540	97675	97810	97945	98080	98215
1229.1	98350	98485	98620	98755	98890	99025	99160	99295	99430	99565
1229.2	99700	99835	99970	100107	100244	100381	100518	100655	100792	100929
1229.3	101066	101203	101340	101477	101614	101751	101888	102025	102162	102299
1229.4	102436	102573	102710	102845	102980	103115	103250	103385	103520	103655
1229.5	103790	103925	104060	104197	104334	104471	104608	104745	104882	105019
1229.6	105156	105293	105430	105567	105704	105841	105978	106115	106252	106389
1229.7	106526	106663	106800	106936	107072	107208	107344	107480	107616	107752
1229.8	107888	108024	108160	108299	108438	108577	108716	108855	108994	109133
1229.9	109272	109411	109550	109689	109828	109967	110106	110245	110384	110523
1230.0	110662	110801	110940	111077	111214	111351	111488	111625	111762	111899
1230.1	112036	112173	112310	112449	112588	112727	112866	113005	113144	113283
1230.2	113422	113561	113700	113839	113978	114117	114256	114395	114534	114673
1230.3	114812	114951	115090	115228	115366	115504	115642	115780	115918	116056
1230.4	116194	116332	116470	116611	116752	116893	117034	117175	117316	117457
1230.5	117598	117739	117880	118019	118158	118297	118436	118575	118714	118853
1230.6	118992	119131	119270	119411	119552	119693	119834	119975	120116	120257
1230.7	120398	120539	120680	120819	120958	121097	121236	121375	121514	121653
1230.8	121792	121931	122070	122211	122352	122493	122634	122775	122916	123057
1230.9	123198	123339	123480	123620	123760	123900	124040	124180	124320	124460
1231.0	124600	124740	124880	125021	125162	125303	125444	125585	125726	125867
1231.1	126008	126149	126290	126433	126576	126719	126862	127005	127148	127291
1231.2	127434	127577	127720	127861	128002	128143	128284	128425	128566	128707
1231.3	128848	128989	129130	129271	129412	129553	129694	129835	129976	130117
1231.4	130258	130399	130540	130683	130826	130969	131112	131255	131398	131541
1231.5	131684	131827	131970	132112	132254	132396	132538	132680	132822	132964
1231.6	133106	133248	133390	133533	133676	133819	133962	134105	134248	134391
1231.7	134534	134677	134820	134963	135106	135249	135392	135535	135678	135821
1231.8	135964	136107	136250	136395	136540	136685	136830	136975	137120	137265
1231.9	137410	137555	137700	137843	137986	138129	138272	138415	138558	138701

PINE RIVER DAM, CROSS LAKE 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
1232.0	138844	138987	139130	139274	139418	139562	139706	139850	139994	140138
1232.1	140282	140426	140570	140713	140856	140999	141142	141285	141428	141571
1232.2	141714	141857	142000	142145	142290	142435	142580	142725	142870	143015
1232.3	143160	143305	143450	143595	143740	143885	144030	144175	144320	144465
1232.4	144610	144755	144900	145047	145194	145341	145488	145635	145782	145929
1232.5	146076	146223	146370	146515	146660	146805	146950	147095	147240	147385
1232.6	147530	147675	147820	147964	148108	148252	148396	148540	148684	148828
1232.7	148972	149116	149260	149405	149550	149695	149840	149985	150130	150275
1232.8	150420	150565	150710	150859	151008	151157	151306	151455	151604	151753
1232.9	151902	152051	152200	152346	152492	152638	152784	152930	153076	153222
1233.0	153368	153514	153660	153807	153954	154101	154248	154395	154542	154689
1233.1	154836	154983	155130	155277	155424	155571	155718	155865	156012	156159
1233.2	156306	156453	156600	156747	156894	157041	157188	157335	157482	157629
1233.3	157776	157923	158070	158217	158364	158511	158658	158805	158952	159099
1233.4	159246	159393	159540	159688	159836	159984	160132	160280	160428	160576
1233.5	160724	160872	161020	161169	161318	161467	161616	161765	161914	162063
1233.6	162212	162361	162510	162659	162808	162957	163106	163255	163404	163553
1233.7	163702	163851	164000	164149	164298	164447	164596	164745	164894	165043
1233.8	165192	165341	165490	165638	165786	165934	166082	166230	166378	166526
1233.9	166674	166822	166970	167119	167268	167417	167566	167715	167864	168013
1234.0	168162	168311	168460	168611	168762	168913	169064	169215	169366	169517
1234.1	169668	169819	169970	170121	170272	170423	170574	170725	170876	171027
1234.2	171178	171329	171480	171628	171776	171924	172072	172220	172368	172516
1234.3	172664	172812	172960	173111	173262	173413	173564	173715	173866	174017
1234.4	174168	174319	174470	174621	174772	174923	175074	175225	175376	175527
1234.5	175678	175829	175980	176133	176286	176439	176592	176745	176898	177051
1234.6	177204	177357	177510	177660	177810	177960	178110	178260	178410	178560
1234.7	178710	178860	179010	179161	179312	179463	179614	179765	179916	180067
1234.8	180218	180369	180520							

EXHIBIT G

MISSISSIPPI HEADWATER REGULATION WORKSHEET

PINE RIVER DAM, CROSS LAKE RESERVOIR

Mississippi Headwater Regulation Worksheet										Date:
Project	Summer Band Center	Normal Drawdown	Lake levels / outflows/inflows 2days ago yesterday / this a.m.	Mfn. release/ change/day	Quantitative Precipitation Forecast			Mean Areal Precipitation Last 24 hours	Wind Direction & Speed effect: 0.1' per 10mph to dam (+ away (-))	Date:
					24-hr	48-hr	72-hr			
					Damtender release preference		Coordinated release order			
Pokegama Jeff ##055 or 218-326-6128	1273.17 to 1273.67 1273.42	1270.42	/	sum of V&L 20-30%	USGS Grand Rapids Q =	prec.____			S 180deg	N 360deg
Winnibigoshish Jeff ##055 or 218-326-6128	1297.94 to 1298.44 1298.19	1296.94	/	100 200		prec.____			WNW 270-315	ESE 90-135
Leech Tim/Jason##054 or 218-654-3145	1294.50 to 1294.90 1294.7	1293.8	/	100 100		prec.____			SWW 225-315	ENE 45-135
Red Lake Tim/Jason##054 or 218-654-3145	1174.00 Highlanding/8.75	1173.50	/	75 any	AVERAGE(Pool, SAJM5, & WSKM5) =	prec.____				
Sandy Jeff/Terry##056 or 218-426-3482	1216.06 to 1216.56 1216.31	1214.31	/	20 20-30%	WSKM5 =	prec.____			ESE 90-135	W 270deg
Cross/Pine Ray ##052 or 218-632-2025	1229.07 to 1229.57 1229.32	1227.32	/	30 60		prec.____			WNW 270-315	ESE 45-135
Gull Greg ##060 or 218-829-2797	1193.75 to 1194.00 1193.88	1192.75	/	20 20-30%		prec.____				N S
Aitkin =	(FS = 12.0)				Consider:					
WILLM5 =	(MAX 81.50)				* Grand Rapids low flow trigger = 400 cfs, no more than 10% change in flow in 2 hrs. @ Pokeg & Winni.					
DAYM5 =	(MIN 71.50)				* Leech Lake, pool needs to be atleast 94.40 by 1 May (thur 1 OCT) or sailboats start to have problems at Walker Bay.					
Mud Lake Dam Pool =					* 5 days following March 1 minimum temp at Grand Rapids greater than 32 degrees, peak at Aitkin occurs 10-14 days later.					
Mud Lake Dam Tail =					* Ideally reduce Winnibigoshish & Leech discharge 10 > 15 days before NWS forecast peak at Aitkin.					
Mud Lake Dam Operation Plan : winter = 1279, spring = 1279.5, summer = hold stable, fall = 1280, 1282 or higher can cause floating bog problems, 1282 or higher erosion begins on County Road 139					* Maximum Winnibigoshish & Leech winter Q = 2200 c.f.s. * Take Pokegama back to 1271.0 if DAYM5 is less than 71.50					
Knutson Dam Pool =					* Travel times : * Winni > Pokeg about 3 days * Sandy > Aitkin about 1 day * Leech > Pokeg about 3 days * Red Lake Dam > Highland about 1.5 days * Pokeg > Aitkin about 3 days * Red Lake Dam > Crookston about 5.5 days					
Knutson Dam Tailwater =					* Winni - Fish Spawn - target reservoir 1297.44 to 1297.75 by 25 APR, 1297.75 top of stripping boards. (hard to do)					
Knutson Dam Q =					* Gull - discharge goal of 100 - 200 cfs for opening week-end.					
Knutson summer pool 1301.4 to 1301.7					* Sandy - Fish Spawn - Hold middle of S.B. middle April to 1 May so spawn does not dry out.					
Operating Limits 1300.25 to 1302.25					* Normal ice-out about 20 April (from 1 April to 10 May)					
					* Normal pool for ice-out : Winni < 1297.94, Leech < 1294.5, Pokeg < 1272.6					
					* Normal pool for ice-out : Sandy < 1214.8, Cross < _____, Gull < 1193.5					
					* Wild Rice harvest is usually completed by the middle of SEP.					