



US Army Corps
of Engineers®
St. Paul District

WATER CONTROL MANUAL

MISSISSIPPI RIVER NINE FOOT CHANNEL NAVIGATION PROJECT



LOCK AND DAM NO. 4

ALMA, WISCONSIN

APPENDIX 4 OF THE MASTER WATER CONTROL MANUAL

UPDATED NOVEMBER 2002

WATER CONTROL MANUAL

**LOCK AND DAM No. 4
ALMA, WISCONSIN**

**UPPER MISSISSIPPI RIVER BASIN
MISSISSIPPI RIVER – NINE FOOT CHANNEL
NAVIGATION PROJECT**

**APPENDIX No. 4
of the
MASTER WATER CONTROL MANUAL**



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

NOVEMBER 2002

**Updated from
Reservoir Regulation Manual, September 1969
Operation of Navigation Pools, February 1943**

LOCK AND DAM No. 4

ALMA, WISCONSIN



Aerial View Looking Downstream – 1997

**6 Roller Gates and 22 Tainter Gates
Project Pool 667.0 feet (1912 Adjustment)**

LOCK AND DAM No. 4

ALMA, WISCONSIN



**Lock and Dam No. 4 Control House
Dedicated 7 September 1994**

Entrance to Lock Chamber and Upper Miter Gates in Right Foreground

NOTICE TO USERS OF THIS MANUAL

This Water Control Manual complies with the latest US Army Corps of Engineers guidelines regarding management of water control systems and preparation of water control manuals. The St. Paul District prepared the *Preliminary Report on Operation of Navigation Pools* on 16 February 1943. This document provided the operational information for Lock and Dam Numbers 1 through 10. This was replaced by a Master Regulation Manual in September 1969. Appendices for each lock and dam were added during the years 1969 through 1972, with Appendix No. 4 being completed in September 1969. This manual is an update of Appendix No. 4. The manual is published in loose-leaf form to facilitate modifications. In the future, only those sections, or parts thereof, requiring changes will be revised and replaced.

EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise (e.g. gate failure, excessive rainfall), the Lockmaster, Area Lockmaster, and Water Control should be notified as to the extent of the event. During normal water control duty hours (i.e. 0630 to 1730 hrs weekdays and 0630 to 1030 hrs weekends and holidays), contact with water control can be made at 651-290-5624 or 651-290-5474. On weekends and holidays, the Mississippi River Duty Regulator Pager number can be used. If communication with Water Control cannot be established, the following list can be used as a guide for establishing contact.

Water Control Regulation Assistance		
Scott R. Bratten	Primary Mississippi River Regulator scott.r.bratten@usace.army.mil	Duty: 651-290-5624 Non-Duty: [REDACTED]
Duty Regulator	Mississippi River Duty Regulator; Pager and Fax	Pager: 612-660-8053 Fax: [REDACTED]
Dennis D. Holme	Physical Scientist dennis.d.holme@usace.army.mil	Duty: 651-290-5614 Non-Duty: [REDACTED]
Theodore D. Pedersen	Water Control Gage Crew theodore.d.pedersen@usace.army.mil	Duty: 651-290-5253 Non-Duty: [REDACTED]
Ferris W. Chamberlin	Hydraulic Engineer ferris.w.chamberlin@usace.army.mil	Duty: 651-290-5619 Non-Duty: [REDACTED]
Kenton. E. Spading	Hydraulic Engineer kenton.e.spading@usace.army.mil	Duty: 651-290-5623 Non-Duty: [REDACTED]
Robert G. Engelstad	Chief, Water Control Section robert.g.engelstad@usace.army.mil	Duty: 651-290-5610 Non-Duty: [REDACTED]
Michael R. Knoff	Chief, Hydraulics & Hydrology Br michael.r.knoff@usace.army.mil	Duty: 651-290-5600 Non-Duty: [REDACTED]
John J. Bailen	Chief, Engineering Division john.j.bailen@usace.army.mil	Duty: 651-290-5303

**Lock and Dam No. 4
Alma, Wisconsin**

**U.S. Army Corps of Engineers
St. Paul District –November 2002**

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PERTINENT DATA

Location: Lock and Dam No. 4 is located on the Mississippi River, 752.8 river miles above the mouth of the Ohio River, 44.2 river miles below Lock and Dam No. 3, and 14.7 river miles above Lock and Dam No. 5. The lock is on the left bank of the river adjacent to the city of Alma, Wisconsin at approximate latitude 44° 19' 30"N and longitude 91° 55' 24" W.

Drainage Area: 57,100 square miles

Datum: MSL - 1912 Adjustment

Fixed Height Dam

Type:	Earth Dike
Total Length:	5,496 feet
Crest Elevation:	677.0 feet
Top Width:	20 feet
Max Height:	29 feet

Moveable Dam

Roller Gates:	6 Gates	60 feet by 20 feet
Tainter Gates:	22 Gates	35 feet by 15 feet
Roller Gate Sill:	Elevation 647.0 feet	
Tainter Gate Sill:	Elevation 652.0 feet	
Top of Bridge Deck:	Elevation 695.0 feet	
Roller and Tainter Gate End Sill:	Elevation 650.0 feet	

Lock

Main Lock Chamber:	110 feet by 600 feet
Top of Lock Walls:	Elevation 672.0 feet
Top of Upper Gate Sill (Main):	Elevation 650.0 feet
Top of Upper Gate Sill (Auxiliary):	Elevation 650.0 feet
Top of Lower Gate Sill:	Elevation 647.0 feet
Lock Floor:	Elevation 646.0 feet
Height of Upper Miter Gates (Main):	20.0 feet + 2-foot Splash Guard
Height of Upper Miter Gates (Aux.):	20.0 feet
Height of Lower Miter Gates:	23.0 feet + 2-foot Splash Guard
Top Upper/Lower Miter Gates:	Elevation 672.0 feet

Pool

Normal (Project) Upper Pool:	Elevation 667.0 feet
Normal (Project) Lower Pool:	Elevation 660.0 feet
Total Pool Area (at Project Pool):	38,820 acres
Primary Control Point:	Wabasha, MN, Elev. 667.0 ft
Secondary Control Point:	Lock & Dam 4 Elev. 666.5 ft

Notes: 1. Roller gates are submergible to 3.0 feet below Normal Pool (667.0 feet).
2. Four tainter gates are submergible to 2.0 feet below Normal Pool (667.0 feet).

I – INTRODUCTION

1-01 Authorization for Preparation of this Manual. Pursuant to the instructions from the Chief of Engineers dated 15 May 1942 and 29 August 1942, subject “Operation of Flood Control and Multiple-Purpose Reservoirs”, the methods and technique used in operating the navigation pools on the Mississippi River in the St. Paul District was documented in February 1943. Authority to prepare “Regulation Manuals” for the locks and dams was granted by Engineering Regulation (ER) 1110-2-240, *Reservoir Regulation*, 1958. While ER 1110-2-240 has been updated and amended many times since the date of issuance, the document continues to give the Corps of Engineers authority to prepare what became known as “Water Control Manuals” by ER 1110-2-240, *Water Control Management*, 1982. This manual supercedes Lock and Dam No. 4 Regulation Manual dated September 1969 and was prepared in compliance with the guidelines presented in:

- a. Engineering Regulation, ER 1110-2-240, *Water Control Management*, 8 October 1982, amended 30 April 1987 and 1 March 1994.
- b. Engineering Manual, EM 1110-2-3600, *Management of Water Control Systems*, 30 November 1987.
- c. Division Regulation, DIVR 1110-2-240, *Water Control Management, Preparation of Water Control Plans and Manuals*, 1 January 1992.
- d. Engineering Regulation, ER 1110-2-8156, *Preparation of Water Control Manuals*, 31 August 1995.

1-02 Purpose and Scope. The purpose of this manual is to provide guidance and instruction for project personnel and to serve as a reference source for others who may be involved with the regulation of this project. The manual is for daily use in Water Control Section activities for most foreseeable conditions and occurrences. The manual covers all water control management activities as they relate to the hydraulic and hydrologic aspects of the project.

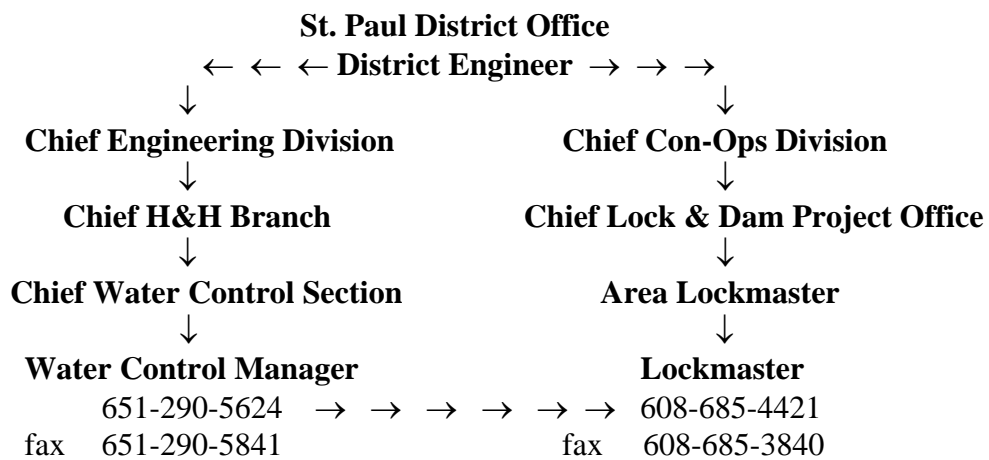
1-03 Related Manuals and Reports. The Upper Mississippi River Lock and Dam system was authorized when Congress approved the nine-foot channel on 3 July 1930. A general scheme of operation was developed on 28 March 1935. Lock

and Dam No. 4 was put into operation on 26 June 1935. The following is a list of related Manuals and Reports in chronological order.

- a. *Survey of Mississippi River Between Missouri River and Minneapolis*, Letter from The Secretary of War, 72 Congress, 1st Session, House Document No. 137, Part 1 – Report, 9 December 1931.
- b. *Report on General Scheme of Operation for the Dams of the 9-Foot Channel Project*, by J. A. Grant, Senior Engineer, War Department, Office of the Chief of Engineers, 28 March 1935.
- c. *Preliminary Report on Operation of Navigation Pools*, War Department, U.S. Engineer Office, St. Paul District, St. Paul, Minnesota, 16 February 1943.
- d. *Master Regulation Manual for Mississippi River Nine-Foot Channel Navigation Projects*, U.S. Army Corps of Engineers, St. Paul District, September 1969.
- e. *Mississippi River Nine-Foot Channel Navigation Project, Reservoir Regulation Manual, Appendix 4, Lock and Dam No. 4, Alma, Wisconsin*, U.S. Army Corps of Engineers, St. Paul District, September 1969.
- f. *Creativity, Conflict & Controversy: A History of the St. Paul District*, U.S. Army Corps of Engineers, by Raymond H Merritt, 1979.
- g. *Upper Mississippi River, Land Use Allocation Plan*, Master Plan for Public Use Development and Resource Management, Part I and Part II, U.S. Army Corps of Engineers, St. Paul District, September 1983.
- h. *Emergency Plan for Lock and Dam No. 4, Alma, Wisconsin*, U.S. Army Corps of Engineers, St. Paul District, July 1985.
- i. *Scour Protection for Locks and Dams 2-10, Upper Mississippi River*, Technical Report HL-87-4, Waterways Experiment Station, U.S. Army Corps of Engineers, Vicksburg, Mississippi, April 1987.
- j. *Commerce and Conservation on the Upper Mississippi River*, by John O. Anfinson, District Historian, U.S. Army Corps of Engineers, St. Paul District, 1990.
- k. *Gateways to Commerce*, The U.S. Army Corps of Engineers' 9-Foot Channel Project on the Upper Mississippi River, National Park Service, Rocky Mountain Region, 1992.
- l. *Authorized and Operating Purposes of Corps of Engineers Reservoirs*, U.S. Army Corps of Engineers, Washington D. C., July 1992.
- m. *Channel Maintenance Management Plan*, Upper Mississippi River Navigation System, U.S. Army Corps of Engineers, St. Paul District, 1996.
- n. *Zebra Mussel Response Plan*, U.S. Army Corps of Engineers, St. Paul District, November, 1997.
- o. *Locks and Dams Sounding Reports, Volume 2*, U.S. Army Corps of Engineers, St. Paul District, 1999.
- p. *2001 Annual Report - Water Quality Management Program*, U.S. Army Corps of Engineers, St. Paul District, January 2002.

1-04. Project Owner. The United States Government is the owner of Lock and Dam No. 4. It is regulated, operated, and maintained by the U.S. Army Corps of Engineers, St. Paul District.

1-05. Operating Agency. Regulation is the responsibility of Engineering Division, while operation and maintenance is the responsibility of Construction and Operations (Con-Ops) Division. The following chart shows the command structure for Lock and Dam No. 4.



The project is attended 24 hours a day, every day of the year. The Chief, Con-Ops Division and the Chief, Engineering Division are located in the St. Paul District Office, whereas the Lock and Dam Project Office is located in Fountain City, Wisconsin and the Area Lockmaster is stationed at Lock and Dam No. 6.

1-06. Regulating Agency. Regulation of Lock and Dam No. 4 is under the supervision of the Water Control Section as by the above command structure.

II – DESCRIPTION OF PROJECT

2-01. Location. Lock and Dam No. 4 is located on the Mississippi River, 752.8 river miles above the mouth of the Ohio River, 44.2 river miles below Lock and Dam No. 3, and 14.7 river miles above Lock and Dam No. 5. The lock is on the left bank of the river at the city of Alma, Wisconsin at approximate latitude 44° 19' 30" N and longitude 91° 55' 24" W. The project is bordered by Buffalo County on the Wisconsin side and Wabasha County on the Minnesota side. The project location is shown on **Plate 2-1**.

2-02. Purpose. Lock and Dam No. 4 is a unit of the Inland Waterway Navigation System of the Upper Mississippi River Basin. The system includes 29 locks and dams, which provides a “stairway of water” from Minneapolis, Minnesota to St. Louis Missouri. The primary purpose of the dams is to maintain a depth of nine feet for navigation. The authorized purposes for Lock and Dam No. 4 are navigation and recreation under Public Laws PL 71-250 and PL 78-534, respectively. Access and facilities are provided for recreation, but water is not controlled for that purpose.

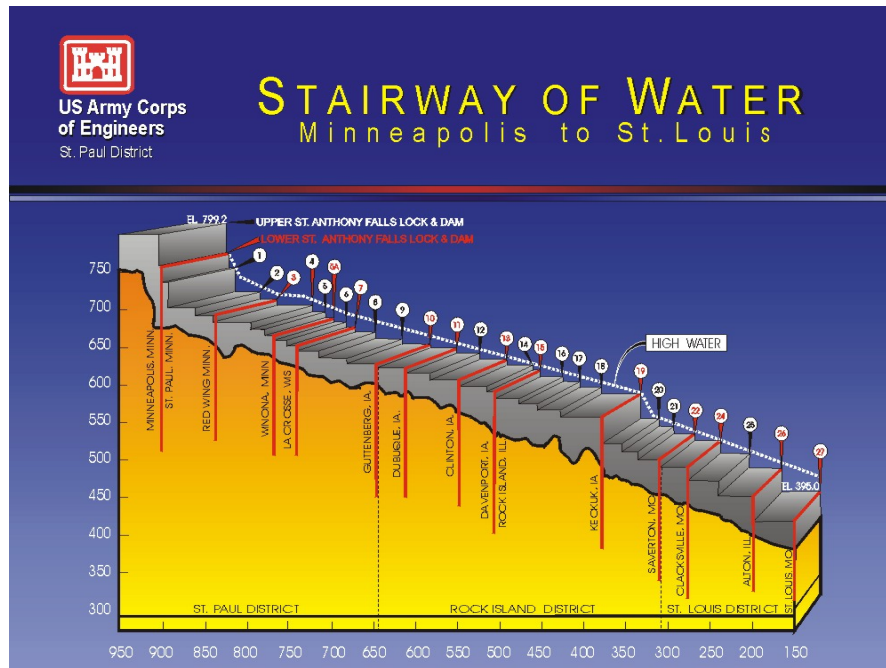


Figure 2-1. Stairway of Water, Minneapolis to St. Louis

2-03. Physical Components. Lock and Dam No. 4 consists of a main and uncompleted auxiliary lock, a movable dam section, and an earthen dike. The locks and moveable dam are supported on timber piling driven into sand and gravel and include sheet pile cutoff walls. The earthen dike has a steel sheet pile cutoff wall that extends 850 feet from the abutment. The following describes the hydraulic feature of each component in detail.



Figure 2-2. Lock and Dam No. 4 (Looking East)

- a. Lock.** Lock and Dam No. 4 has a main and an uncompleted auxiliary lock (Plate 2-1). The upper and lower miter gates of the main lock have a height of 20.0 feet and 23.0 feet, respectively. The respective sill elevations are 650.0 feet and 647.0 feet (1912 adjustment). Therefore the top of the miter gates is elevation 670.0 feet. A steel splash guard was welded on to the top of the miter gates essentially increasing their heights by two feet (i.e. 22.0 ft and 25.0 ft), thereby putting the top of the miter gates at same elevation as the lock walls (672.0 feet). A walkway is located atop the miter gates such that it is the same elevation as the lock walls. While the main lock is fully functional, the

auxiliary lock consists of only an upper gate bay. The miter gates on the auxiliary lock are 20 feet high with a sill elevation of 650.0 feet. The gates of the auxiliary lock have no machinery and therefore are inoperable. However, should an upper miter gate in the main lock become damaged, a miter gate from the auxiliary lock can be pulled to serve as a replacement. This operation requires assistance from Rock Island District because they have the necessary equipment and expertise.

The main lock is 110 feet wide with a clear length of 600 feet. The filling and emptying of the lock chamber is controlled by tainter valves; two at the upstream (upper) end of the lock and two at the downstream (lower) end. During the filling or emptying process, the miter gates are closed thus sealing the lock chamber. For a filling operation, the upper tainter valves are opened allowing flow to enter the culverts (**Plate 2-2**, Section A-A). Flow then enters the lock chamber through ports along the lock wall (Section X-X) and the water level in the lock chamber rises until it equals the pool elevation. The upper tainter valves are then closed and the lower tainter valves are opened thus emptying the lock chamber. Under normal conditions, filling and emptying times are about seven minutes.

Periodically, the lock chamber is flushed of sediment and debris. This is accomplished at the end of an emptying cycle. The upper miter gates and lower tainter valves are in the closed position, the lower miter gates are opened in the recessed position, and the upper tainter valves are operated to provide the flushing action.

Guidewalls are located upstream and downstream of the lock to provide a landing for down bound and up bound tows (**Plate 2-1**). The upper guide wall extends 521 feet upstream of the lock and the lower guide wall extends 504 feet downstream of the lock. It was proposed to extend the upper guidewall in 1977; however, it was not deemed economically feasible.

b. Moveable Dam. The moveable dam section extends from the auxiliary lock to the right bank of the main channel (see **Plate 2-1**). The moveable dam consists of six roller gates, 60-feet wide by 20-feet high, and 22 tainter gates, 35-feet wide by 15-feet high (**Figure 2-2**). The sill elevation of the roller gates is 647.0 feet (1912 adjustment), while the tainter gates sill elevation is 652.0 feet. The end sill elevations for the roller and tainter gates are both 650.0 feet. The roller gates can be submerged up to three feet below normal pool (elevation 667.0 feet). Four of the 22 tainter gates can be submerged up to two feet below normal pool.



Figure 2-3. Roller Gate Position Indicator

Each roller gate is equipped with an individual electrically operated hoist enclosed in an operating house located on the pier. The roller gates are driven from one end only. The travel rate of the gate is approximately 0.75 feet per minute. A position indicator, marked in increments of 0.1 feet, is attached to the hoist mechanism. There are six bulkheads stored on site, measuring 4 feet-2 inches by 62 feet-6 inches. The sill elevation is 647.0 feet; therefore, with five bulkheads in place, the top elevation would be 667.83 feet (i.e. 667 feet-10 inches).

Each tainter gate is individually operated by machinery consisting of an electrically operated central driving unit and two chain hoisting units. The electric controls consist of push buttons located on the deck rail. A position indicator is mounted on the pier about midway between the trunion and the gate surface. The indicator is marked in 0.1-foot increments. The tainter gates move at a rate similar to the roller gates. There are eight bulkheads stored on site measuring 4 feet-2 inches by 36 feet-6 inches, however only four bulkheads are used for a single tainter gate. The sill is at elevation 652.0 feet; therefore, the top of the bulkheads would be at elevation 668.67 feet (i.e. 668 feet-8 inches).



Figure 2-4. Tainter Gate Position Indicator

A service bridge, at elevation 695.0 feet, spans the entire length of the moveable dam and storage yard and provides for the operation of the crane. The 45-foot boom crane, with 20-ton capacity, was replaced in 1981. The new crane has a boom length of 60 feet and a capacity of 25 tons.

- c. **Channel Protection.** Immediately upstream and downstream of the moveable dam, the channel is protected by a stilling basin followed by stone protection. Section B-B and C-C of **Plate 2-2** shows the original derrick stone protection. Over the years, scour upstream and downstream of the derrick stone caused

some unraveling of the derrick stone. In 1984, riprap protection was extended upstream and downstream in the form of capstone and rockfill. **Plates 2-3 and 2-4** shows four transects of the added protection. The following gives a description of the riprap protection near the roller gates, tainter gates, lock, auxiliary lock, and storage yard.

(1) Roller Gates. Downstream protection originally consisted of derrick stone, 4-feet thick with a top of rock elevation of 650.0 feet (1912 adjustment). The derrick stone extended 25 feet downstream of the end sill. Upstream protection consisted of a 12-foot wide, 3-foot thick section of derrick stone with a top elevation of 647.0 feet. The scour holes that formed upstream and downstream of the derrick stone were filled in 1984. The upstream scour protection consisted of a horizontal capstone section 42-inches thick, underlain by a rockfill section a minimum of 30-inches thick. The capstone extended approximately 55 feet downstream of the end sill and 45 feet upstream of the dam. The horizontal capstone was placed to the same elevation as the original derrick stone upstream (elevation 647.0 feet) and downstream (elevation 650.0 feet).

(2) Tainter Gates. Downstream protection originally consisted of derrick stone 4-feet thick with a top of rock elevation of 650.0 feet (1912 adjustment). Depending on its location, it extended 25 or 40 feet downstream of the end sill. Upstream, the derrick stone section was 12-foot wide and 3-feet thick with a top of rock elevation of 652.0 feet. The scour holes upstream and downstream of the tainter gates were filled in 1984. The upstream scour protection consisted of a horizontal capstone section 42-inches thick, underlain by a rockfill section a minimum of 30-inches thick. The capstone extended approximately 55 feet downstream of the end sill and 40 feet upstream from the dam. The horizontal capstone was placed to the same elevation as the original derrick stone upstream (elevation 652.0 feet) and downstream (elevation 650.0 feet).

(3) Lock and Guidewalls. The original downstream protection for the locks and downstream guidewall consisted of a combination of rock filled cribs and derrick stone. A 20-foot wide by 400-foot long section of riprap filled cribs was placed on the riverward side of the intermediate lock wall. A 12-foot wide section of derrick stone protection was provided from the downstream end of the concrete paving on the auxiliary lock, downstream along the riverward side of the intermediate lock wall riverward of the timber cribs, along the concrete apron on the downstream side of the landward lock, and 100 feet downstream along the lower guidewall. The derrick stone section was 3-feet thick with a top of rock elevation of 644.0 feet (1912 adjustment) downstream of the auxiliary lock and along the timber cribs adjacent to the intermediate lock wall and to elevation 645.0 feet along the downstream apron of the landward lock and along the lower guidewall. In 1982-83, additional scour protection was placed along the lock apron between the landward and intermediate lock wall as well as along the entire length of the lower guidewall, except for an 80-foot long reach. Scour protection for the lock apron consisted of a 30-inch thick layer of riprap underlain by 12-inches of bedding with a top of rock elevation the same as the apron. Scour protection extended horizontally for a distance of 20 feet after which it sloped down to meet the channel at a slope of 1V:2H and 1V:3H for the guidewall and apron, respectively.

The original protection upstream of the locks consisted of derrick stone placed at two locations. Three hundred cubic yards was placed in a circular pattern at the upstream end of the riverward wall of the auxiliary lock. Four hundred cubic yards was placed in a circular pattern at the upstream end of the intermediate wall between the two locks. In 1982-83, additional scour protection was placed along the entire length of the upper guidewall as well as upstream of the upper lock sill. Filling and shaping of the channel bed were required to provide a suitable base for the scour protection. Along the upper guidewall, scour protection consisted of a 30-

inch riprap section with a maximum top of rock elevation of 652.0 feet, which extended horizontally for a distance of 20 feet out from the wall. At that point the riprap sloped at 1V:2H until it intersected the channel bed. The riprap was underlain by a 12-inch bedding layer. The scour protection upstream of the upper sill is similar to the upper guidewall protection except that from the end of the horizontal section it sloped down at 1V:3H to meet the channel bed.

(4) Storage Yard. Original scour protection downstream of the storage yard consisted of 12-inch thick riprap placed on a 1V:5.5H slope down to elevation 655.0 feet (1912 adjustment). Upstream scour protection consisted of 12-inch thick riprap placed on a 1V:3H slope down to elevation 655.0 feet.

d. Earthen Dam. An earthen dam, 5,496 feet in length, extends from the end of the moveable dam section to high ground on the Minnesota side of the river (**Plate 2-1**). The dam has a crest elevation of 677.0 feet (1912 adjustment), a top width of 20 feet, and a maximum height of 29 feet (**Plate 2-2**). The pool side slope is 1V:3H and the tailwater slope is 1V:5.5H. The side slopes are protected by 12-inch riprap. Protection on the pool-side extends to the dam crest, whereas protection on the tailwater slope extends to two feet above the lower project pool elevation (i.e. $660.0 + 2.0 = 662.0$ ft).

Below the dam there are five lakes known as the Finger Lakes. Individually they are named, Clear Lake, Lower Peterson Lake, 3rd Lake, 2nd Lake, and 1st Lake (see **Plate 2-11**). Culverts were installed through the dam to provide flow to the lakes. Clear Lake and 3rd Lake have 36-inch reinforced concrete pipes (RCP) controlled by sluice gates. Lower Lake Peterson has a gated 48-inch corrugated metal pipe (CMP), also controlled by a sluice gate. A single 48-inch RCP provides inflow to 2nd and 1st Lake. At the downstream end of the culvert is a junction box from which two 48-inch RCP's branch off, one

going to 1st Lake and the other to 2nd Lake. The main culvert is controlled by a sluice gate at the inlet and the two branch pipes are controlled by sluice gates located within the junction box.

2-04. Related Control Facilities. There are no related control facilities to Lock and Dam No. 4.

2-05. Real Estate Acquisition. In the area between Lock and Dam No. 4 and the Chippewa River, the Corps of Engineers acquired flowage easements to elevation 670.0 feet (1912 adjustment), 3 feet above project pool, and holds title to 6,605 acres of land and water area for the Lock and Dam No. 4 project.

2-06. Public Facilities. Lock and Dam No. 4 has two observation platforms available for public use. One platform is located along the middle of the lock chamber and the other is near the upstream end of the lock chamber. One of the platforms is handicap accessible. In addition to the public facilities located at the dam, there are numerous other facilities including parks and marinas located throughout the pool (**Table 2-1**).

**Table 2-1
Pool No. 4 Recreation Facilities**

River Mile	Name	Manager	Fee	Slips	Parking	Camp Sites	Toilet	Picnic Tables
794.2L	Evert's Landing	Private	Yes		10	Yes	Yes	No
792.7L	WI Channel Ramp	WDNR	No		35	No	No	No
792.7L	Mr. Sippi	Private			25	Yes	Yes	Yes
791.4R	Ole Miss Marina, Bay Point	Concession		145	50	No	Yes	Yes
791.4R	Bay Point Municipal Access	Red Wing	No		125	No	Yes	Yes
791.2R	Red Wing Marina	Concession		22	15	No	Yes	Yes
790.8L	Trenton Island Yacht Club	Private		60	30	Yes	Yes	Yes
790.6L	Island Campground	Private	Yes	72	20	Yes	Yes	Yes
790.9R	Levee Park	Red Wing			25	No	Yes	No
788.9R	Bills Bay Marina	Concession		54	50	No	Yes	No
788.6R	Ole Miss Colvill	Concession		150	130	No	Yes	Yes
786.6L	Bay City Park Access	Bay City			10	Yes	Yes	Yes
779.7L	Maiden Rock Access	Maiden Rock			15	No	Yes	Yes
778.8R	Florence Beach	Florence TSP			10	No	No	No
776.4R	Hansen's Harbor	Private		70	30	No	Yes	No
775.4R	Hok-Si-La Park Access	MDNR/Lake City			40	No	Yes	Yes
774.2L	Stockholm Access	Stockholm			10	Yes	Yes	Yes
774.2R	Diggers	Private		10		No		No
772.8R	Lake City Marina	Concession	Yes		50	No	Yes	No
772.0R	Roche Park Access	Lake City			50	No	Yes	Yes
770.3L	Deer Island Landing				10	Yes	No	Yes
767.2R	Maple Springs	MDNR			15	No	No	No
767.1L	Dan's Pepin Marina	Concession	Yes	110	80	No	Yes	No
767.0L	Pepin Landing	Pepin			40	No	Yes	Yes
764.9R	Camp Lacupolis Resort	Private		10	10	Yes	Yes	No
763.1R	Reads Landing	Private				No	No	No
760.6R	Parkside Marina	Concession		20	30	No	Yes	No
760.4R	Wabasha Park	Wabasha	Yes		40	No	Yes	Yes
760.2R	Wabasha Municipal Dock	Wabasha			10	No	No	No
760.0L	Indian Slough Landing	FWS			15	No	No	No
760.0L	Pontoon Slough Landing	FWS/Bufalo City			10	No	No	No
760.0L	Beef Slough Landing	FWS			10	No	No	No
759.4R	Wabasha Marina	Private		140		Yes		No
756.4R	Wilcox Landing	MDNR			15	No	Yes	No
755.0L	Reicks Landing	Alma			30	Yes	Yes	Yes
754.7R	Peterson Lake Landing	MDNR			3	No	No	No
754.0L	Alma Marina	Concession		84	30	No	Yes	No
753.8L	Tank Pond	Alma			5	No	No	No
753.0R	Pioneer Supper Club	Private		30	30	No	Yes	No
758.5L	Cedar Ridge Resort	Private			10	Yes	Yes	Yes

III – HISTORY OF PROJECT

- 3-01. Authorization.** The Lock and Dam No. 4 project was authorized on 3 July 1930 when the 71st Congress, second session, passed an act that modified the existing Mississippi River six-foot channel project in accordance with the plan for a comprehensive project to procure a channel of nine-foot depth, submitted in House Document No. 290. The nine-foot channel was to be achieved by construction of a system of locks and dams, supplemented by dredging.
- 3-02. Planning and Design.** The lock and dam system is necessary to provide a nine-foot channel during low to moderate flows. The dam is operated to accommodate river flow conditions. In normal operation, all gates are partially open to allow water through. As the river flow increases or decreases, the gate openings are increased or decreased accordingly. If there were no flow in the pool, the pool would be level throughout its entire length. This is the “project pool” level that ensures a nine-foot channel depth. When there is flow, there is a slope to the water surface. The upstream end of the pool rises with the discharge while the downstream end of the pool falls as the discharge through the dam increases, resulting in a drawdown at the dam. Drawdown at the dam is such that the water surface will be maintained at project pool elevation at a predetermined point, upstream of the dam, known as the “primary control point”. Its location is near the point of intersection of the “project pool” (flat pool level) and the “ordinary high water” profile. The ordinary high water mark can be considered “the point up to which the presence and action of the water is so continuous as to destroy the value of the land for agricultural purposes by preventing the growth of vegetation, constituting what may be termed any ordinary agricultural crop”. The government of the United States holds an easement to use the riparian lands up to the ordinary high water, in the public interest. Therefore, land inundated by the lock and dam above the ordinary high water profile was purchased in fee. This land lies between the primary control point and the dam. The primary control point for Lock and Dam No. 4 was located at river mile 760.5 at Wabasha, Minnesota.

Because of the poor channel conditions between the Chippewa River mouth and the site of Lock and Dam No. 4, it was given the highest priority and was scheduled as the first lock and dam to be completed. The location of the lock and dam was unique in that it was situated below Lake Pepin, which has a total length of about 22 miles and offers considerable storage. The Chippewa River enters from the left bank of the Mississippi River about 2 miles below Lake Pepin and 10 miles above the project site (**Plate 2-9 and 10**). It carries large quantities of sand into the river, which initially provided the impoundment for Lake Pepin. This made for poor channel conditions below its mouth and the project site. The possibility of diverting the Chippewa River into Lake Pepin was investigated but was eliminated in favor of allowing the dam to cause water to back up the Chippewa River, resulting in deposition of sediment in the Chippewa Valley during low water, thereby reducing the need for dredging in the navigation channel. The original design of the dam provided for four roller gates 100-feet wide by 20-feet high for ice passage. The number and dimensions of the roller gates were later altered to the current six roller gates 60-feet wide by 20-feet high. The dam also includes twenty-two tainter gates 35-feet wide by 15-feet high.

The project pool elevation of 667.0 feet (1912 adjustment) is maintained at the primary control point (Wabasha) until discharge at the dam is sufficient to allow for a drawdown at the dam. A maximum drawdown of 4.0 feet, or elevation 663.0 feet, was established in 1941. It was soon discovered that it was very difficult to maintain a four-foot drawdown; therefore, in 1943 it was reduced to 2.5 feet. In an effort to maintain more stable water surface elevations in the lower pool, drawdown was further reduced to 1.5 feet in 1960. Finally, with the elimination of over-dredging in 1970, maximum drawdown was established at 0.5 feet (elevation 666.5 ft) in 1971. Therefore, as discharges increase, the gates are raised to maintain project pool at the primary control point. As discharge continues to increase, maximum drawdown is finally achieved. As discharge continues to increase, maximum drawdown is maintained until eventually all the

gates are raised above the water surface and open river conditions exist. When this condition occurs, the dam is said to be “out of control”.

The total number of gates required at each site is based on the allowable swellhead at extreme high water. The project design flood for Lock and Dam No. 4 was the flood of 1880. The design high water was elevation 673.3 feet with a flow rate of 175,000 cfs. Swellhead for all locks and dams above Rock Island was limited to less than one foot. This limitation required that the available floodway area be utilized to the greatest possible degree. As a consequence gate sills were set to the lowest possible elevation. The double locks occupy a large portion of the main channel but still allowed for six roller gates and 22 tainter gates. The total spillway area of the movable dam was sufficient to negate the necessity for an additional spillway in the earthen dike as was necessary for many of the other locks and dams.

Below the dam there are five lakes known as the Finger Lakes. Individually they are named, Clear Lake, Lower Peterson Lake, 3rd Lake, 2nd Lake, and 1st Lake (see **Plate 2-11**). A corrugated metal culvert was installed within the earthen dam in 1967 to provide flow to Lower Peterson Lake. At project pool elevation 667.0 feet, a continuous flow of 100 cfs was maintained until 1994. In 1994, a slide gate was added to the culvert inlet to regulate discharge. Culvert discharge is set to 5 cfs in the winter and 40 cfs in the summer. Also installed in 1994 were three additional gated reinforced concrete pipe (RCP) culverts within the earthen dike to provide aeration and further improve habitat conditions in the remainder of the Finger Lakes. A single inlet culvert services 1st and 2nd Lake. Attached to the single culvert is a junction box from which two pipes branch off, one going to 1st Lake and the other to 2nd Lake. The junction box has two slide gate controls. Because the pipe is not allowed to be pressurized within the dike, one outlet is required to be fully opened, while the inlet slide gate controls inflow to the junction box. **Table 3-1** provides a summary of the culvert size, type, and flow regulation for the Finger Lakes culverts.

Table 3-1 Culverts Installed in Earthen Dike					
Location	Size	Type	Year	Winter Flow (cfs)	Summer Flow (cfs)
Clear Lake	36-inch	RCP	1994	5	40
Lower Peterson Lake ¹	48-inch	CMP	1967	5	40
3 rd Lake	36-inch	RCP	1994	3	40
2 nd Lake ²	48-inch	RCP	1994	1	20
1 st Lake ²				2	20
<p>1. As constructed in 1967, this culvert originally provided a constant flow of 100 cfs at project pool. A slide gate installed in 1994 is now used to regulate the flow.</p> <p>2. A single culvert provides inflow to a junction box where it branches into two pipes. Flow through the pipes is controlled by sluice gates upstream and at the junction box.</p>					

3-03. Construction. Construction of the lock began on 19 September 1932 and was completed on 5 January 1934. Construction of the dam began on 7 October 1933 and was completed on 26 June 1935. The project was placed in operation on 25 May 1935.

3-04. Related Projects. Lock and Dam No. 4 is one part of the 29 locks and dams on the Mississippi River necessary to maintain the nine-foot navigation channel between Minneapolis, Minnesota and St. Louis, Missouri. Thirteen of the 29 locks and dams are located in the St. Paul District. These include Upper and Lower St. Anthony Falls Locks and Dams, and Lock and Dam No. 1 through 10.

3-05. Modifications to Regulation.

a. 1943 Modification. The original maximum allowable drawdown for Lock and Dam No. 4 was set at 4.0 feet and was established in 1941. Maximum drawdown was based on the fact that further drawdown may result in jeopardizing navigation depths upstream of the dam, and would have no effect on the water surface elevation at the primary control point. It was soon realized that a drawdown of this magnitude did indeed impact navigation and was reduced to 2.5 feet (elevation 664.5 feet) in 1943. This drawdown elevation remained in effect until 1960.

- b. 1948 Modification.** The nine-foot channel depth was only important during the navigation season. Therefore, the pool could be drawn down over the winter months whenever it was considered necessary. By the 19 June 1948 amendment to the act of Congress dated 10 March 1934, entitled “An act to promote the conservation of wildlife, fish and game, and for other purposes”, drawdown of the pool was prevented. The amendment states the “...dam structures shall generally operate and maintain pool levels as though navigation was carried on throughout the year.”
- c. 1960 Modification.** To reduce the adverse effects of the draw down at the dam on navigation, riverfront property, and conservation interests, the maximum allowable draw down was reduced to 1.5 feet (elevation 665.5 feet). This drawdown elevation remained in effect until 1971.
- d. 1967 Modification.** A 48-inch corrugated metal culvert was installed through the earth dike to improve water quality conditions in Lower Lake Peterson. At project pool (elevation 667.0 feet) a continuous flow of 100 cfs was maintained through the culvert.
- e. 1971 Modifications.** In an attempt to reduce the frequency of dredging, the channel was often over dredged. This practice stopped in 1970. Therefore, drawdown at the dam was reduced from 1.5 feet to 1.0 foot, or elevation 630.0 feet (1912 adjustment). This remains today as the secondary control elevation.

The discharge through the dam was reevaluated in 1971. This resulted in a slight change in the discharge per foot of opening on the roller and tainter gates. Therefore, there was a need to revise the Gate Regulation Schedule. Included in this revision was a redistribution of flow across the dam. The previous Gate Regulation Schedule had a more even flow distribution across the dam; however, to achieve that, the recommended tainter gate settings

hugged the maximum allowable outflow velocity (4.5 feet per second). The new Gate Regulation Schedule, distributed flow across the dam based on a more equal distribution of outflow velocities. This schedule remained in effect until 1984.

- f. 1984 Modification.** In 1981 the Waterways Experiment Station began a study of the scour protection upstream and downstream of the Mississippi River dams and published their results in *Scour Protection for Locks and Dams 2-10, Upper Mississippi River*, Technical Report HL-87-4, April 1987. Since 1952, hydrographic surveys indicated that scour had occurred upstream and downstream of the dam. The purpose of the study was to develop a riprap design that would stabilize the existing conditions. Based on the preliminary results of the study, additional riprap protection was placed upstream and downstream of the dam in 1984. The riprap was designed to remain stable for the following condition; full open or half open single gate with normal pool and minimum tailwater. Before placement of the riprap, the maximum allowable gate openings were based on a flow velocity of 4.5 feet per second; however, for emergency purposes, it was permissible for flow velocities to go as high as 6.0 feet per second. Because of the additional channel stability, the maximum outflow velocity for routine gate movements was raised to 6.0 feet per second. Therefore, a new Gate Regulation Schedule was developed showing the new maximum allowable gate openings. This schedule remained in effect until 2002, when minor modifications were made.
- g. 1990 Modification.** The motors that operate the lock miter gates were raised in 1990. Before this, the motors were pulled when the pool reached elevation 669.5 feet and the lock was closed to navigation. Since the motors were raised, the lock does not go out of operation until the pool is within half a foot of the top of the lock wall or elevation 671.5 feet (1912 adjustment).

- h. 1994 Modification.** A slide gate was added to the 48-inch diameter corrugated metal culvert that provides flow to Lower Peterson Lake. Site personnel control the slide gate. Gate settings provided by the US Fish and Wildlife Service (USFWS) are such that winter flow is 5 cfs and summer flow is 40 cfs. The sluice gates on the remaining culverts servicing the Finger Lakes are controlled by the USFWS. Culvert specifications and flow regulation are provided in **Table 3-1**.
- i. 1995 Modification.** Historically, winter regulation allowed a tolerance of plus or minus 0.3-foot at the primary control point. The added tolerance was for the purpose of providing for delays in gate operations due to ice. The Water Level Management Task Force, which is a subcommittee of the River Resource Forum, requested that Water Control operate on the high side of the band during winter regulation on a trial basis. Therefore, during the winter months, the primary control point at Wabasha was maintained between elevation 667.0 and 667.3 feet. The purpose being to keep as much volume of water as possible in the backwater areas to avoid or delay dissolved oxygen depletion. The trial continued until the year 2000, at which time the committee made an official request to Water Control to adopt this change in operation. Since then it has been incorporated as a routine part of the operating plan.
- j. 2002 Modification.** Changes in the Operating Curves and a check of Roller Gate and Tainter Gate end sill velocities necessitated minor modifications to the existing Gate Regulation Schedule. The new Gate Regulation Schedule is presented in **Table 7-2**.

3-06. Principal Regulation Problems. Besides an outdraft problem for down bound tows at flows greater than 60,000 cfs, there are no principal regulation problems at Lock and Dam 4. However, the infestation of zebra mussels has had a minor impact on lock operations, which could develop into significant problems for

future operations. Zebra mussel populations are present at all St. Paul District locks and dams on the Upper Mississippi River. It is possible that they may foul the gage wells, concrete surfaces, and untreated metal surfaces such as the lock miter gates. Masses of dead zebra mussels could accumulate in the gate recesses, hindering operation. When the lock was dewatered for inspection during the winter of 2000-2001, it was noted that zebra mussels had attached themselves in multiple layers on the miter gates, the lock chamber walls, and along the lock culverts. While dewatered, many of the mussels were physically removed.

The St. Paul District developed a “Zebra Mussel Response Plan” in November 1997. There were five methods for short-term control identified for locks and dams. The following tables show the possible problems and the recommended control techniques identified in the study.

Table 3-2 Zebra Mussel Control Techniques		
Code	Method	Description
A	Physical Removal	Removed by scraping, brushing, or high-pressure water or steam spraying.
B	Molluscicides	Primarily oxidizing biocides (chlorine) with possibility of periodic use of nonoxidizing biocides.
C	Thermal Treatments	Hot water, steam, or air injection periodically to kill adult and larval zebra mussels.
D	Dewatering Dislocation	Isolation of susceptible components from the river. Components removed from river if possible.
E	Replacement Components	Replacement components which can be easily removed should infestation occur.

**Table 3-3
Proposed Zebra Mussel Control Techniques for Locks and Dams**

Component	Potential Problem	Method
Lock Walls	Heavy encrustations can be expected. Structural damage limited to abrasion during cleaning.	A,D
Gages	Occlusion of the pipe leading from the well to the river. Encrustation of level markings.	A,B,C,D
Thermometers	Encrustations could reduce reliability of readings.	A
Miter Gates	Increased corrosion of metal surface, paint deterioration, and unbalanced loading.	A,D
Bulkhead Slots	Accumulation along the sealing surfaces.	A,D
Lock Culverts	Reduced flow area and increased roughness could cause increased emptying and filling times.	A,D
Roller Gates	Increased gate weight and corrosion.	A,D
Side Seals	Accelerated deterioration of seals.	A,D,C,E
Tracks, Chains, Cables	Accumulation could prevent movement of roller gates. Metal and paint deterioration.	A,D

IV – WATERSHED CHARACTERISTICS

- 4-01. General Characteristics.** The drainage area of Pool No. 4 totals 57,100 square miles in Minnesota and Wisconsin. Except for several small rivers and creeks, the only major tributary that flows into Pool No. 4 is the Chippewa River with a total drainage area of 9,480 square miles. The Chippewa River enters the pool from the Wisconsin side of the Mississippi River about 2 miles downstream of Lake Pepin and 10 miles upstream of the dam. At project pool elevation of 667.0 feet (1912 adjustment), the pool has an area of 38,820 acres
- 4-02. Topography.** The Master Water Control Manual for the Locks and Dams contains a description of the topography for the Upper Mississippi River basin. Tributaries to Pool No. 4 include the Cannon River, Isabelle River, Rush River, Chippewa River, Buffalo River and several small creeks. Of these, the only major tributary to Pool No. 4 is the Chippewa River. The Chippewa River has a total drainage area of 9,480 square miles, of which 6,630 square miles is upstream of Eau Claire, Wisconsin. The basin includes all or part of 19 counties in Wisconsin and Upper Michigan. The Chippewa River rises in the northern Wisconsin lake region, which includes a small part of Upper Michigan. It flows generally to the southwest across Northwestern Wisconsin to its confluence with the Mississippi River at the lower end of Lake Pepin, near Mississippi river mile 763. The largest tributary to the Chippewa River is the Eau Claire River, which joins the Chippewa River at Eau Claire and drains an area of about 880 square miles. Other important tributaries are the Eau Galle, Red Cedar, Yellow, Jump, and Flambeau Rivers. Basin topography in the upper reaches is typified by gently rolling low hills with numerous potholes, lakes, marshes, and swamps. Runoff is very low in this area. In the lower reaches of the basin, the country is more hilly and consists of coulees and uplands, some of which rise to a height of 200 to 400 feet above the floodplain. There is rapid runoff from the upland areas. The overall slope of the Chippewa River is 4 to 5 feet per mile and is controlled by a resistant crystalline bedrock surface. The flattest slopes are in the uppermost and lowermost reaches of the basin. In the uppermost reaches, including the Flambeau-Manitowash

headwater system, drainage is through a glacial outwash plain. Here the slope is only 1.3 feet per mile. In the lower reach, below Eau Claire, the river has a uniform slope of about 1.5 feet per mile and meanders broadly over its 1-to-2 mile wide floodplain. Over the middle reaches, the river has an average slope of about 5.8 feet per mile. This part of the river is characterized by numerous rapids and falls, which create locally steep-sloped areas. Dams and impoundments, primarily for generating electric power, are located at a number of these steep gradient reaches. Many rapids, however, remain untouched; their primary uses being recreational. About 75 percent of the land in the basin consists of deciduous and coniferous forest, and wetland. The remainder, mostly in the lower reaches, is cropland. Major land uses are recreation, forest management, and agriculture. In the north, forests provide wood harvesting and related manufacturing and, along with the lakes and streams, offer recreation opportunities. Agriculture is dominant in the south.

4-03. Sediment. Part of the nine-foot navigation plan authorized by Congress included periodic dredging of sediment. There are ten sites within Pool No. 4 navigation channel that require periodic dredging. Also requiring periodic dredging is the lower approach to Lock No. 4 (Pool No. 5). Quantities and frequency of dredging these areas is presented in **Paragraph 5-03**.

4-04. Climate. The National Weather Service maintains temperature and precipitation records for Lock and Dam No. 4. Pan evaporation data was collected at Lock and Dam No. 6, but stopped after 1997. Temperature and precipitation data shown in the following tables were taken from National Oceanic and Atmospheric Administration's *Climatological Data Annual Summaries*, for Alma Dam No. 4, Wisconsin. Pool evaporation was estimated by assuming a pan coefficient of 0.7.

Table 4-1 30-Year Normal Monthly Temperature in Degrees Fahrenheit												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
13.0	18.0	31.4	46.8	58.7	68.4	72.9	70.3	60.8	49.9	34.3	19.0	45.3

Table 4-2 30-Year Normal Monthly Precipitation in Inches												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0.89	0.64	1.81	2.90	3.70	4.29	4.67	3.92	4.02	2.60	1.74	1.08	32.26

Table 4-3 Pan and Pool Monthly Evaporation in Inches Located at Lock and Dam No. 6								
	Apr	May	Jun	Jul	Aug	Sep	Oct	Period of Record
Pan Evaporation	0.26	3.35	3.92	5.15	4.66	2.88	0.65	(1983 – 1997)
Pool Evaporation	0.18	2.35	2.74	3.61	3.26	2.02	0.46	(1983 – 1997)

Wind speed and direction are recorded each morning at Lock and Dam No. 4. While this information is valuable for the regulation of the dam, it is of little value for presenting monthly highest wind speeds and directions. The *Climatic Atlas of the United States* (June 1968) contains monthly Fastest Mile information for La Crosse, Wisconsin. Fastest Mile wind speeds are defined as the fastest speed at which wind travels one mile measured over one month. Fastest Mile wind speeds are typically obtained from a short period of time, usually less than two minutes duration. The Fastest Mile wind speeds presented in the Atlas were modified to time-dependant (1-hour) average wind speeds using procedures presented in the US Army Corps of Engineers' *Shore Protection Manual* (1984).

Table 4-4 Highest Monthly Wind Speed and Direction in MPH for La Crosse, WI												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direction	NNW	WNW	NNW	SSW	E	NNW	N	N	SSW	WNW	S	NNW
Fastest Mile	35	36	40	50	58	60	36	46	36	38	46	43
1-Hour	29.5	30.3	33.3	41.0	46.8	47.2	30.3	37.9	30.3	31.8	37.9	38.1

Because of the bluffs along the river, winds tend to be channeled to either up river or down river. The wind blowing across the pool surface exerts a horizontal force

on the water surface and induces a surface current in the general direction of the wind. The horizontal currents induced by the wind essentially cause water to “pile up” on the downwind side, resulting in a water level rise downwind and a water level drop upwind. The change in water level is due to “wind setup”. The rise in water can be estimated by (EM 1110-2-1414):

$$S = (U^2 F)/(1400 D)$$

Where,

S = Wind Setup (ft)
U = Wind Speed (mph)
F = Fetch Length (miles)
D = Average Depth over Fetch (ft)

The above equation neglects the time required for the full wind setup to occur. The stronger the wind, the more time required. While it is recognized that the relationship is not linear, a rule of thumb has been developed that seems to work quite well for the lock and dam pools. For each ten miles per hour of wind speed, figure the change in the pool level to be 0.1 feet. Therefore, a northern wind at 20 mph would cause a 0.2 feet rise in the water surface at the dam, and conversely, a southern wind of 10 mph would result in a lowering of the water surface at the dam by 0.1 feet.

4-05. Storms and Floods. While an isolated storm over the Chippewa River basin can have a significant impact on water levels in Pool No.4 during low to moderate flows, it is high inflows from upstream that typically produce flooding of the pool. After construction of the Lock and Dam in 1935, the first significant flood event did not occur until the spring of 1951. On the 17th of April, the Mississippi River at Wabasha crested at 4.4 feet above flood stage with a gage height of 16.4 feet (elevation 674.4 ft -1912 adjustment). This stage was exceeded the following year. On the 20th of April 1952, the Wabasha gage peaked at 16.71 feet (elevation 676.71 ft). Estimated discharge was 187,000 cfs. This remained the flood of record until 1965. **Table 4-5** gives a summary of peak elevations and discharges followed by a brief description of some of the larger events.

Table 4-5 Summary of Peak Stages/Elevations and Discharges						
Wabasha, MN – Control Point			Lock and Dam No. 4			
Date	Stage (feet)	Elev. (feet)	Date	Pool (feet)	Tailwater (feet)	Discharge (cfs)
17-Apr-51	16.40	676.40	17-Apr-51	672.97	672.15	-
18-Apr-52	16.71	676.71	19-Apr-52	673.30	672.30	187,000
19-Apr-65	20.05	680.05	19-Apr-65	676.45	675.78	269,000
5-Apr-67	15.46	675.46	5-Apr-67	672.05	671.35	175,500
18-Apr-69	17.63	677.63	18-Apr-69	674.20	673.53	222,000
25-Jun-93	15.30	675.30	25-Jun-93	671.65	670.93	166,800
11-Apr-97	16.50	676.50	11-Apr-97	673.15	672.40	200,000
16-Apr-01	18.22	678.22	16-Apr-01	675.10	674.15	239,600

a. **April - May 1965.** Because of the magnitude of the snow-water content on the ground, forecasts and warnings of floods were issued by the Weather Bureau (now the National Weather Service). An advisory on the flood potential in the Upper Mississippi River basin was published as early as the 19th of March 1965. The forecast predicted a stage of 14.0 feet at Red Wing, Minnesota (flood stage is 14.0 feet) and 12.5 feet on the Chippewa River at Durand, Wisconsin (flood stage is 11.0 feet) with normal precipitation and a snowmelt of more than three days. The forecast cautioned that if rainfall of one inch should occur before or during the crest, the resulting peak stages would be near those recorded in the 1952 flood. Almost four inches of rain fell in the first two weeks of April. The Weather Bureau revised the forecast for Red Wing and Durand, predicting stages of 18.5 feet and 14.5 feet, respectively, and by 15 April it was apparent that the peak stage at Red Wing would approach 20.5 feet. Based on this, the lock miter gate operating machinery and tow haulage motors were removed. The central control station and esplanade were protected by walls of sand bags and the earthen dike was raised and strengthened where necessary. The rapid increase of inflow began on the 2nd of April when the discharge rose from 16,600 cfs on this date to 71,000 cfs on the 7th of April. By this time the head at the dam had been reduced to 0.55 feet and the gates were removed from the water. The

Mississippi River crested at a stage of 20.7 feet at Red Wing on the 18th of April. This was 6.7 feet above flood stage and was nearly four feet higher than the peak stage of 1952. The flood crested at Lock and Dam No. 4 on the 19th of April with a pool elevation of 676.45 feet and a flow of 269,000 cfs. On the recession, the pool returned to secondary control (in 1965 secondary control elevation was 665.5 ft) on the 26th of May, and the movable dam was returned to operation. The lock was closed to navigation for 26 days between the 10th of April and the 6th of May.

- b. April 1997.** The magnitude of the snow-water content on the ground indicated a high potential for flooding along the Upper Mississippi River. On the 13th of March, the National Weather Service outlook predicted a stage of 17.0 feet at Red Wing, Minnesota. On the 12th of April, Red Wing crested at 17.18 feet (elevation 682.33 – 1912 adjustment). The pool at the dam crested on the 11th of April at elevation 673.15 feet. Peak discharge was approximately 200,000 cfs. The motors that operate the lock miter gates were relocated to higher elevation in 1990 and therefore did not require removal; however, the lock closes to navigation when the pool elevation is within half a foot of the top of the miter gates or elevation 669.5 feet. Because of this, the lock was closed to navigation for 17 days from the 6th to the 23rd of April.
- c. April 2001.** The National Weather Service’s 2001 Spring Snowmelt Flood Outlook predicted minor to moderate flooding for Pool No. 4. This forecast was primarily due to the significant autumn precipitation the year before and the heavy winter snowfall. A less than ideal snowmelt followed by record breaking April precipitation resulted in producing the second highest flood stages in Pool No. 4. In the morning of 16 April, the stage at Wabasha, Minnesota peaked at 18.22 feet. On the 17th of April, the pool at Lock and Dam No. 4 peaked at elevation 674.95 feet (1912 adjustment) with a discharge of 239,600 cfs. The pool reached the lock closure elevation of 669.5 feet on the 11th of April and did not fall below elevation 669.5 feet until the 9th of

May. Additional rainfall runoff had resulted in a second crest of elevation 674.35 feet on the 28th of April. While the lock may have been able to operate before the 11th of April, the Coast Guard closed the river to navigation from the 9th of April to the 9th of May.

4-06. Runoff Characteristics. The mean annual discharge at Lock and Dam No. 4 is 30,700 cfs, based on a period of record from 1959 to 1993. The following table shows the monthly average discharges.

Table 4-6 Monthly Average Flow in cfs – (Years 1959 to 1993)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15,600	15,700	31,100	65,000	52,000	40,300	32,000	21,500	23,900	25,800	26,100	19,500

The maximum discharge of 269,000 cfs occurred, at the dam, on 19 April 1965 (**Table 4-5**). The minimum discharge occurred during the construction of the dam in 1934. During the month of August, the extreme low water that year produced a pool elevation of 655.22 feet and a tailwater elevation of 652.95 feet, with a discharge of 2,200 cfs. For comparison purposes, the lowest discharge recorded during the 1988 drought was 5,600 cfs on the 3rd of August. It is not unusual during the winter months for discharges to become quite low (e.g. <8,000 cfs); however, it is often of very short duration. **Table 4-7** shows the discharge-duration at the dam. A discharge frequency curve for the Mississippi River at the Chippewa River confluence is shown on **Figure 8-1**.

Table 4-7
Discharge-Duration at Lock and Dam No. 4
Percent Time At or Above Indicated Discharge (Years 1972-2000)

Discharge	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
200,000				0.1									
195,000				0.5									
190,000				0.6									
185,000				0.8									
180,000				0.9									
175,000				1.0									
170,000				1.2									
165,000				1.3		0.2							0.1
160,000				1.7	0.2	0.6							0.2
155,000				2.1	0.3	0.8							0.3
150,000				2.4	0.4	0.8	0.2						0.3
145,000				2.6	0.6	0.8	0.2						0.4
140,000				3.2	0.7	0.8	0.3						0.4
135,000			0.2	3.8	0.8	0.9	0.6						0.5
130,000			0.6	4.1	0.9	0.9	0.7		0.2				0.6
125,000			0.8	5.1	1.1	0.9	1.0		0.6	0.1			0.8
120,000			1.0	6.0	1.6	0.9	1.8		0.6	0.2			1.0
115,000			1.3	7.1	2.3	1.0	1.9		0.7	0.3			1.2
110,000			1.3	8.2	3.1	1.0	2.0		0.7	0.4			1.4
105,000			1.6	9.9	4.1	1.3	2.1		0.7	0.4			1.7
100,000			2.1	12.6	5.3	1.6	2.2		0.7	0.6			2.1
95,000			2.3	16.6	6.8	2.2	2.6	0.1	0.8	0.7			2.7
90,000			3.0	20.0	8.1	2.9	2.8	0.2	0.8	0.8			3.2
85,000			3.9	24.3	10.5	3.7	3.3	0.3	0.8	1.3			4.0
80,000			6.2	30.7	15.0	4.3	3.8	0.3	0.9	2.2			5.3
75,000			8.6	35.8	20.8	5.1	4.9	0.4	0.9	3.5			6.7
70,000			10.2	43.2	28.1	7.0	6.5	0.8	1.0	4.0	0.3		8.5
65,000			12.0	50.6	36.0	11.0	8.0	2.2	1.4	5.1	0.7		10.6
60,000		0.2	14.6	57.2	44.2	14.5	12.7	4.5	2.4	6.6	2.8		13.3
55,000		0.6	17.9	64.6	49.7	20.1	19.2	6.1	5.2	9.6	5.1		16.6
50,000		0.9	22.4	70.3	54.1	28.2	26.3	7.9	7.9	12.4	8.3	0.7	20.0
45,000		1.1	26.3	75.9	59.4	38.4	33.0	11.7	12.0	15.1	12.2	1.8	24.0
40,000		1.5	30.4	79.4	66.6	51.2	39.0	15.0	18.1	17.9	16.8	2.9	28.3
35,000	0.3	2.3	37.0	81.6	70.9	62.8	48.4	21.3	25.2	25.1	26.7	7.7	34.2
30,000	2.8	4.2	48.2	85.1	76.8	71.0	58.2	31.2	32.5	33.3	41.0	19.0	42.1
25,000	14.4	12.4	61.0	91.8	82.9	77.7	68.1	44.5	44.5	43.5	56.9	36.3	53.0
20,000	33.3	31.5	72.2	98.3	89.2	83.9	74.8	60.5	59.7	59.3	72.1	52.7	65.7
15,000	62.7	60.1	86.9	99.7	94.7	92.3	82.5	78.9	76.6	74.4	90.3	71.4	80.9
10,000	90.2	89.9	97.9	100.0	100.0	97.5	93.4	91.3	95.1	95.0	95.5	88.0	94.5
5,000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.0	99.9

Construction of the lock and dam greatly influenced stage-duration curves throughout the pool. Based on a period of record from 1972 to 2000, the following four elevation-duration tables were developed for the pool, tailwater, primary control point at Wabasha, Minnesota, and the gage at Lake City, Minnesota. The tables indicate the percent of time the water surface is at or above the indicated elevation (1912 adjustment). Gage zero for the Wabasha gage is elevation of 660.0 feet and the Lake City gage zero is elevation 661.10 feet.

Table 4-8
Elevation-Duration for Wabasha, MN
Percent of Time At or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
676.5				0.1									
676.0				0.7									
675.5				0.9									
675.0				1.4		0.7							0.2
674.5				2.2	0.2	0.8	0.1						0.3
674.0				2.9	0.4	0.9	0.3						0.4
673.5			0.1	3.7	0.7	0.9	0.6		0.3				0.5
673.0			0.7	5.4	1.2	0.9	1.7		0.7	0.2			0.9
672.5			1.1	7.7	2.7	1.0	2.0		0.7	0.4			1.3
672.0			1.8	11.7	5.2	2.0	2.2		0.8	0.6			2.0
671.5			2.7	20.0	7.9	2.9	3.0	0.2	0.8	0.8			3.2
671.0			4.9	27.8	14.4	4.1	3.8	0.3	0.9	1.8			4.9
670.5			8.3	36.1	23.0	5.4	5.5	0.6	1.0	3.6		0.1	7.0
670.0			11.0	45.6	33.7	10.9	8.8	2.1	1.4	4.5	0.6	0.5	10.0
669.5	0.8	0.3	14.8	56.6	44.8	16.5	15.7	5.1	2.9	7.2	3.2	1.4	14.2
669.0	0.8	0.9	19.9	67.2	52.3	28.4	25.6	8.0	7.4	11.2	6.9	3.0	19.5
668.5	1.6	1.1	26.6	74.9	59.6	40.9	33.9	13.2	12.6	15.7	13.0	6.9	25.2
668.0	4.0	1.9	35.6	80.5	68.9	60.5	46.4	20.2	24.0	24.3	22.3	18.7	34.2
667.5	18.1	10.1	50.4	86.8	79.2	74.0	64.5	37.2	39.0	37.4	48.7	43.2	49.4
667.0	79.3	75.6	86.1	98.7	95.6	96.2	93.3	90.6	90.2	91.6	93.5	85.4	89.8
666.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4-9
Elevation-Duration for Lake City, MN
Percent of Time At or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
680.0				0.1									
679.5				0.7									
679.0				0.9									
678.5				1.2	0.2	0.2							0.1
678.0				2.3	0.4	0.7							0.3
677.5				2.5	0.7	0.8	0.2						0.4
677.0			0.1	4.0	0.9	0.8	0.4						0.5
676.5			0.8	5.5	1.2	0.9	1.1		0.1				0.8
676.0			1.2	7.0	2.7	0.9	1.8		0.6	0.2			1.2
675.5			1.9	10.0	4.0	1.6	2.0		0.7	0.3			1.7
675.0			2.3	15.9	5.6	2.3	2.5	0.1	0.7	0.4			2.5
674.5			3.0	21.7	7.9	2.8	3.0	0.2	0.8	0.7			3.4
674.0			5.1	26.6	11.9	3.9	3.6	0.3	0.8	0.9			4.5
673.5			6.2	32.1	16.9	4.7	4.3	0.4	0.9	1.8			5.7
673.0			7.7	36.2	23.8	5.4	5.8	0.6	0.9	2.9			7.0
672.5			10.0	43.7	31.2	8.7	8.3	1.3	1.0	3.7	0.2		9.1
672.0			12.5	50.7	39.3	13.5	11.5	3.2	1.2	5.3	0.9		11.6
671.5		0.4	15.1	57.7	47.2	18.1	16.1	4.8	2.2	7.2	3.3	0.4	14.5
671.0	0.2	0.9	18.8	64.7	52.2	24.0	21.0	6.7	5.4	10.8	5.5	0.7	17.8
670.5	0.6	1.0	23.0	71.0	56.6	31.4	28.7	9.1	8.5	13.5	7.7	3.0	21.4
670.0	1.2	1.2	27.7	76.3	61.1	42.3	33.6	12.2	13.1	16.9	11.4	4.5	25.4
669.5	1.8	2.0	32.2	79.2	66.0	51.8	39.3	15.7	19.1	21.5	17.1	7.1	29.7
669.0	3.5	2.7	38.7	82.3	70.6	62.8	47.9	23.5	26.7	26.3	25.2	15.1	35.8
668.5	9.5	4.5	47.5	85.3	76.9	70.7	59.4	33.2	32.1	32.8	42.9	28.6	44.0
668.0	24.0	19.9	62.2	91.3	83.9	77.9	68.1	43.2	42.6	45.1	59.3	50.9	56.0
667.5	63.4	57.5	83.4	98.2	92.7	89.2	81.9	69.3	67.0	66.2	82.6	75.8	77.4
667.0	95.7	97.5	99.6	100.0	99.8	99.8	99.9	99.4	99.7	98.8	98.8	98.8	99.0
666.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4-10
Elevation-Duration, Lock and Dam No. 4 Pool
Percent of Time At or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
673.0				0.3									
672.8				0.5									
672.6				0.6									
672.4				0.8									
672.2				0.9									
672.0				1.0									
671.8				1.2									
671.6				1.3		0.2							0.1
671.4				1.5	0.2	0.3							0.2
671.2				1.8	0.2	0.6							0.2
671.0				2.0	0.3	0.8							0.3
670.8				2.4	0.3	0.8	0.1						0.3
670.6				2.4	0.4	0.8	0.2						0.3
670.4				2.8	0.6	0.8	0.2						0.4
670.2				2.8	0.6	0.8	0.3						0.4
670.0				3.0	0.7	0.8	0.3						0.4
669.8			0.1	3.7	0.7	0.9	0.4						0.5
669.6			0.3	4.3	0.8	0.9	0.6						0.6
669.4			0.7	4.4	0.9	0.9	0.7		0.2				0.6
669.2			0.7	4.7	1.0	0.9	0.8		0.3				0.7
669.0			0.8	5.4	1.3	0.9	1.3		0.6	0.1			0.9
668.8			1.0	6.1	1.9	0.9	1.8		0.7	0.1			1.0
668.6			1.0	6.7	2.2	0.9	1.8		0.7	0.2			1.1
668.4			1.2	7.2	2.6	1.0	1.9		0.7	0.2			1.2
668.2			1.5	7.9	3.0	1.0	2.0		0.7	0.3			1.4
668.0			1.6	8.5	3.8	1.0	2.1		0.8	0.3	0.1		1.5
667.8			1.7	9.7	4.0	1.2	2.1		0.9	0.4	0.3		1.7
667.6			2.1	10.8	4.2	1.3	2.7	0.2	1.0	1.0	0.6		2.0
667.4	0.1	0.1	3.2	13.0	4.9	2.2	5.5	1.1	2.5	1.7	1.8	1.6	3.2
667.2	2.0	1.7	5.6	16.3	6.8	6.3	9.5	6.7	11.0	7.2	5.2	6.4	7.1
667.0	12.8	8.7	15.8	22.2	12.6	15.5	21.4	23.7	30.2	28.7	18.6	23.2	19.5
666.8	36.6	36.7	33.6	36.0	25.7	32.9	37.6	47.4	54.3	57.1	45.4	52.2	41.3
666.6	68.1	71.7	70.9	63.5	57.5	67.2	67.7	77.0	76.9	81.7	78.7	78.4	71.6
666.4	93.3	93.7	94.6	92.6	90.6	94.3	92.7	95.8	96.2	96.2	95.8	92.7	94.0
666.2	98.9	99.2	99.4	99.9	99.9	99.7	100.0	100.0	100.0	100.0	99.8	97.5	99.5
666.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4-11
Elevation-Duration, Lock and Dam No. 4 Tailwater
Percent of Time At or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
672.0				0.6									
671.5				0.9									
671.0				1.2									
670.5				1.8	0.2	0.6							0.2
670.0				2.3	0.3	0.8	0.2						0.3
669.5				2.9	0.6	0.8	0.3						0.4
669.0			0.3	3.9	0.8	0.9	0.7						0.6
668.5			0.8	5.2	1.2	0.9	1.1		0.6	0.1			0.8
668.0			1.0	6.7	2.0	1.0	1.8		0.7	0.2			1.1
667.5			1.6	8.3	3.2	1.1	2.1		0.7	0.4			1.4
667.0			2.1	11.0	4.5	1.2	2.2		0.8	0.6			1.9
666.5			2.5	16.3	6.8	2.3	2.5	0.1	0.8	0.7			2.7
666.0			3.5	21.6	8.8	2.9	3.0	0.2	0.8	1.0			3.5
665.5			4.8	26.5	13.8	3.8	3.7	0.4	0.9	1.8			4.6
665.0			7.2	32.6	19.6	4.7	4.6	0.4	0.9	2.8			6.1
664.5			9.3	39.2	26.8	7.0	5.8	0.8	1.2	3.6	0.2	0.3	7.9
664.0			11.8	46.3	34.6	10.6	8.5	2.3	1.5	4.3	0.6	0.7	10.1
663.5			13.9	54.9	42.8	14.4	12.9	4.9	2.2	5.8	2.1	1.0	12.9
663.0		0.5	17.0	62.5	49.4	20.8	19.0	6.1	4.5	8.6	4.6	1.7	16.3
662.5		0.8	22.3	69.9	54.8	30.2	27.3	8.9	7.7	12.6	7.2	5.9	20.4
662.0	0.3	1.2	27.3	75.2	61.2	41.0	33.4	13.0	13.1	15.7	12.4	4.8	25.0
661.5	2.9	2.5	36.1	79.7	67.7	55.5	44.1	18.0	21.0	21.6	19.9	13.7	32.0
661.0	16.2	11.8	48.4	83.9	76.5	70.8	56.3	29.5	30.9	32.3	39.7	29.8	44.0
660.5	48.0	41.5	68.0	93.4	85.0	80.7	70.7	54.9	54.0	56.7	67.8	60.0	65.1
660.0	92.1	95.7	94.8	99.7	98.3	99.2	97.4	97.0	97.1	97.8	97.5	91.4	96.5
659.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

At a flat pool elevation of 667.0 feet (project pool), the storage volume in Pool No. 4 is 560,000 acre-feet. At moderate flows, there is a maximum 0.5-foot drawdown at the dam. That is, while the elevation at the dam is 666.5 feet, the elevation at the control point (Wabasha) is 667.0 feet, at a minimum. For the purpose of computing the storage volume in Pool No. 4, the pool is divided into 3 reaches; namely, Red Wing up to the tailwater of Lock and Dam No. 3 (**Table 4-12**), Wabasha down to the pool of Lock and Dam No. 4 (**Table 4-13**), and Red Wing down to Wabasha (Lake Pepin) (**Table 4-14**). The total storage is the sum of the storage in the three reaches. Assuming an elevation of 666.5 feet at the dam, 667.0 feet at Wabasha, 668.0 feet at Lake City, 669.0 feet at Redwing, and 671.0 feet at the tailwater of Lock and Dam No. 3, the approximate volume of Pool No. 4 would be 595,000 acre-feet (40,000 + 48,000 + 507,000 ac-ft). At an average April flow of 65,000 cfs, it would take about five days to exchange the storage in Pool 4. A relationship of storage to discharge is shown on **Plate 4-1**.

Table 4-12
Storage Volume of Pool No. 4 in 1,000 Ac-Ft
Between Red Wing, Minnesota and Tailwater of Dam 3

TW Elev. at Dam 3	Elevation at Red Wing, MN																				
	682	681	680	679	678	677	676	675	674	673	672	671	670	669	668	667	666	665	664	663	662
683	192	182																			
682	189	179	169																		
681		175	166	157																	
680			163	153	144																
679				149	140	131															
678					136	127	118														
677						123	114	105													
676							110	102	93												
675								98	89	80											
674									86	79	68										
673										74	66	58									
672											64	56	49								
671												55	48	40							
670													46	39	33						
669														39	32	26					
668															32	26	21				
667																25	20	16			
666																	20	16	13		
665																		16	13	10	
664																			12	10	7
663																				9	7

**Table 4-13
Storage Volume of Pool No. 4 in 1,000 Ac-Ft
Between Wabasha, MN and Lock and Dam N. 4**

Pool Elev. at Dam 4	Elevation at Wabasha, MN																				
	678	677	676	675	674	673	672	671	670	669	668	667	666	665	664	663	662	661	660	659	658
672	220	198	176																		
671	216	194	174	157	140																
670		192	172	154	137	122															
669			169	150	132	118	104														
668				139	125	112	100	89	79												
667						106	95	85	75	66	58	51									
666							92	81	71	62	53	45	39								
665								77	66	57	49	42	37								
664									62	54	47	41	36	32							
663										52	46	40	34	30	26						
662										51	44	38	33	28	25	21					
661											43	37	32	28	24	21					
660												36	31	27	24	20	18				
659													30	26	23	20	17				
658														25	22	19	17				
657																18	16	14			
656																18	15	12	10		
654																	14	11	9	8	
652																			9	8	7

Table 4-14
Storage in Lake Pepin
River Mile 784.0 to 765.5 (Between Red Wing and Wabasha)

Lake City Stage (ft)	Storage (1000 ac-ft)	Lake City Stage (ft)	Storage (1000 ac-ft)	Lake City Stage (ft)	Storage (1000 ac-ft)	Lake City Stage (ft)	Storage (1000 ac-ft)
660.0	329	665.0	438	670.0	552	675.0	673
660.5	339	665.5	450	670.5	565	675.5	686
661.0	349	666.0	461	671.0	577	676.0	698
661.5	361	666.5	472	671.5	589	676.5	710
662.0	371	667.0	484	672.0	600	677.0	722
662.5	381	667.5	496	672.5	613	677.5	735
663.0	392	668.0	507	673.0	624	678.0	747
663.5	403	668.5	519	673.5	637	678.5	760
664.0	415	669.0	530	674.0	648	679.0	772
664.5	426	669.5	541	674.5	661	679.5	784

4-07. Water Quality. The St. Paul District does not collect water quality information for Pool No. 4. However, as an element of the Environmental Management Program (EMP), the Corps of Engineers oversees the Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System. The LTRMP was implemented to provide decision makers with the information needed to maintain the Upper Mississippi River System as a viable multiple-use large river ecosystem. The LTRMP is being implemented by the US Geological Survey (USGS) in cooperation with the states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin with guidance and overall program responsibility by the Corps of Engineers. Recent projects in Pool No. 4 include channel improvements and habitat restoration in the Indian Slough area and channel modifications in the Peterson Lake area to reduce sedimentation in the lake and improve fish habitat.

4-08. Channel and Floodway Characteristics. The top of the lower lock sill elevation at Lock and Dam No. 3 is elevation 653.0 feet and the top of the upper lock sill elevation at Lock and Dam No. 4 is elevation 650.0 feet. Therefore, there is a 3-foot drop in sill elevation along the pool, which has a length of 44.2 miles as measured along the navigation channel. The navigation channel is 300 feet in

width in the straight stretches, and varies from 300 feet to 550 feet in the bends. The line of navigation is shown on **Plates 2-5 through 2-11**.

4-09. Upstream Structures. Lock and Dam No. 3 is located 44.2 miles upstream of Lock and Dam No. 4. The drainage area above Lock No. 3 is 45,170 square miles. The lock and dam system continues upstream to the Upper St. Anthony Falls Lock and Dam located in Minneapolis, Minnesota.

4-10. Downstream Structures. Lock and Dam No. 5 is located 14.7 miles downstream of Lock and Dam No. 4. The drainage area above Lock No. 5 is 58,845 square miles. The lock and dam system continues downstream to Lock and Dam No. 27 in St. Louis, Missouri; however, St. Paul District terminates with Lock No. 10.

4-11. Economic Data. Pool No. 4 lies on the Minnesota-Wisconsin border. Goodhue and Wabasha counties are located on the western side and Pierce, Pepin, and Buffalo counties are located on the eastern side. Based on the US Census Bureau, county populations have increased slightly.

Table 4-15 County and City Populations Near Pool No. 4				
	1990	2000	Difference	Change
County				
Wabasha, MN	19,744	21,610	1,866	9.5%
Goodhue, MN	40,690	44,127	3,437	8.4%
Pierce, WI	32,765	36,804	4,039	12.3%
Pepin, WI	7,107	7,213	106	1.5%
Buffalo, WI	13,584	13,804	220	1.6 %
City				
Red Wing, MN	15,134	16,116	982	6.5%
Wabasha, MN	2,384	2,599	215	9.0%
Lake City, MN	4,391	4,950	559	12.7%
Pepin, WI	873	878	5	0.6%

The following table gives a break down of the employment by industry. The data were taken from the US Census Bureau's 1997 Industry Report.

**Table 4-16
Employment by Industry – Counties on Pool No. 4 (1997)**

Industry	Wabasha	Goodhue	Pierce	Pepin	Buffalo
Manufacturing	1,934	5,522	942		
Wholesale Trade	199	1,051	375	90	180
Retail Trade	882	2,390	1,047	434	305
Real Estate, Rental, Leasing	28	107	185	6	17
Professional, Scientific, Tech Ser	71	286	158	29	39
Admin & Support, Waste Mngt	45	512	125	10	77
Education Services		10	10		
Health Care & Social Services	316	764	646	117	169
Arts, Entertainment & Recreation	35	1,829	47	10	28
Accommodations & Food Services	375	1,623	994	175	375
Other Services	90	383	168	29	38
Totals	3975	14,477	4697	900	1,228

V - DATA COLLECTION AND COMMUNICATION NETWORKS

5-01. Hydrometeorological Stations.

- a. **Facilities.** The regulation and proper operation of the dam site requires the collection and evaluation of several hydraulic and hydrologic parameters. The Corps of Engineers (COE), US Geological Survey (USGS), and the National Weather Service (NWS) are involved in the data collection network. There are numerous gage facilities associated with Lock and Dam No. 4. About 7.5 miles upstream of Lock No. 4 is the Pool No. 4 primary control point gage house (**Figure 5-1**). It is located just upstream of the Highway 25 bridge crossing the Mississippi River at Wabasha, Minnesota. An additional pool gage is located in Lake City, along the western shore of Lake Pepin (**Figure 5-2**). Both sites have stilling wells equipped with Sutron Data Recorders and transmit hourly water surface elevation/stage to Water Control. The Lake City gage also transmits hourly wind speed and direction as well as precipitation.



Figure 5-1. Wabasha Gage



Figure 5-2. Lake City Gage

There are actually two water surface gages at the Lake City gage site. A stilling well is located down the center of the pipe and attached to the side (see photo) is a pipe carrying the line for the Design Analysis H-310 pressure transducer. Both gages monitor water surface information. However, during the winter months, the float in the stilling well is raised clear of the water and the well is allowed to freeze, leaving only the pressure transducer sensing water surface data.

The main tributary to the pool is the Chippewa River, which enters the Mississippi River just downstream of Lake Pepin, about 10.5 miles upstream of the lock and dam. A gage is located 17.6 miles upstream of the confluence at Durand, Wisconsin (**Figure 5-3**). The site is equipped with a Campbell Data Recorder and transmits hourly stage and precipitation data to Water Control. **Exhibit B** contains the USGS rating table.



Figure 5-3. Durand Gage



Figure 5-4. Pool Gage

The COE operates and maintains the pool and tailwater gages at the lock. The tailwater gage house is located on the lower guide wall about 500 feet from the lock chamber while the upper gage house is located in the esplanade near the upstream end of the upper guide wall (**Figure 5-4**). Each gage house has a well with a float and tape system that reports elevation to the Stevens PAV-C Recorder (**Figure 5-5**) located in the Central Control Station. Staff gages are mounted inside the gage houses and serve as backup or are used for verification of the tape in the well. The locations of these gage sites are shown on **Plate 5-1**.



Figure 5-5. Stevens PAV-C Strip Chart Recorders

A water temperature sensor, reading in degrees Fahrenheit, is located in the upper ladder recess. A standard eight-inch precipitation gage is located north of the Central Control Station in the esplanade about halfway up the upper guide wall (**Figure 5-6**). The site is equipped with a measuring rod for snow depth and a snow tube and scale for determining snow-water content. An anemometer is located on the roof of Roller Gate Pier No. 2. The NWS has a Fisher-Porter automatic weighing, punched tape, binary decimal recording gage installed at the site next to the COE precipitation gage. Data types and equipment are listed in **Table 5-1**.



Figure 5-6. Corps and NWS Precipitation Gages

Table 5-1 Hydrometeorological Stations			
Location	Data Type	Equipment	Notes
Mississippi River at Lake City, MN	Elevation / Stage Wind Speed & Direction Precipitation	Sutron 8210 Data Recorder Stilling Well and H-310 Pressure Transducer GOES Telemetry Voice Modem	Gage Zero: 661.1 (1912) Flood Stage: 16.0 ft Maintained by Corps
Mississippi River at Wabasha, MN	Water Surface Elevation / Stage	Sutron 8210 Data Recorder Stilling Well GOES Telemetry Voice Modem	Gage Zero: 660.0 (1912) Flood Stage: 12.0 ft Maintained by Corps
Chippewa River at Durand, WI	Stage Precipitation	Campbell CR10 Data Recorder Stilling Well GOES Telemetry Voice Modem	Gage Zero: 694.59 (1929) Flood Stage: 11.0 ft Co-Op Gage
Lock & Dam No. 4 Upper Guide Wall	Pool Elevation	Stilling Well Stevens PAV-C Strip Recorder Staff Gage	Continuous Strip Chart record of pool elevations.
Lock & Dam No. 4 Lower Guide Wall	Tailwater Elevation	Stilling Well Stevens PAV-C Strip Recorder Staff Gage	Continuous Strip Chart record of TW elevations.
Lock & Dam No. 4	Snow Depth & Water Content	Snow Rod, Snow Tube, Scale	Maintained by Corps Gage Crew.
Lock & Dam No. 4 Pier No. 2 Roof	Wind Speed & Direction	Anemometer	Maintained by site personnel.
Lock & Dam No. 4 Upper Ladder Recess	Water Temperature	Water Temperature Sensor	Electronically transmitted to Central Control Station.
Lock & Dam No. 4	Precipitation	Standard 8-inch Rain Gage	Recorded daily.
Lock & Dam No. 4	Precipitation	Fischer-Porter Weighted Punch Tape	Owned and maintained by the NWS.

b. Reporting. Data are reported in four-hour, eight-hour, 24-hour (daily), and weekly increments. Log sheets begin with the 0400-hour readings. Data collected between 0600 and 0630-hours are recorded as 0800-hour readings. Four-hour data includes water surface elevations on the Mississippi River at the pool, tailwater, and Alma. Pool and tailwater elevations are read in the control house and are recorded on a Stevens PAV-C strip chart. The strip charts are mailed to Water Control at least once a year where they are then periodically micro filmed. While Alma is the control point for Pool No. 5, its close proximity to Lock and Dam No. 4 makes it necessary to record for local information. Alma does not have a voice modem and therefore the elevation is obtained from the Water Control web site. Also included in the four-hour incremental data are gate settings and discharge. Discharges are automatically computed based on gate settings or the tailwater rating curve.

Eight-hour incremental data begin at 0800-hours. Again, data collected between 0600 and 0630-hours are reported as 0800-hours. Data include water surface elevations at Wabasha, Lake City, and stage and discharge for the Chippewa River at Durand. Wabasha and Lake City elevations are obtained by calling the voice modems at the gage sites, as is the stage at Durand. The discharge at Durand is obtained from the latest USGS rating table. Other eight-hour incremental data include wind speed, wind direction, and air temperature.

Daily data reported include precipitation, water temperature, and maximum and minimum air temperature. Precipitation and water temperature are collected between 0600 and 0630-hours and are reported as 0800-hour readings. Max and min air temperatures are taken at 1900-hours but are recorded as 2400-hour readings.

Weekly incremental data are collected during the winter months. They include percent of ice coverage over the lower pool and upper tailwater, ice

thickness of the pool and tailwater, snow depth, and snow-water content (all measurements are in inches). These are recorded on Sundays. The snow-water content is determined by instructions contained in the National Weather Service Observing Handbook No. 2.

- c. **Maintenance.** The equipment for all the stream gages (i.e. pool, tailwater, Lake City, Wabasha, and Durand) is the property of the Corps of Engineers; however, the US Geological Survey maintains the Durand gage under a cooperative agreement. The Water Control Gage Crew is responsible for all other gages. They also provide emergency backup for the Durand gage. Dam personnel maintain the Stevens PAV-C strip chart recorders with the Gage Crew used as a backup if necessary. The anemometer, water temperature sensor, and standard precipitation gage are maintained by site personnel; however, should the precipitation gage become damaged, Water Control would mail a new one to the site. The Fischer-Porter precipitation gage is owned and maintained by the National Weather Service. Repair of the snow survey equipment is the responsibility of the Water Control Gage Crew.

5-02. Water Quality Stations. There are no water quality stations in Pool No. 4; however, site personnel may be asked, on occasion, to assist district office personnel or contractors to collect water samples and/or water quality measurements in the project area.

5-03. Sediment Stations. Discrete sediment samples were taken at the Chippewa River at Durand gage between 1964 and 1994. There has been no sampling in Pool No. 4; however, routine dredging of sediment is part of the nine-foot navigation plan. There are several sites in Pool No. 4 that require periodic dredging due to sedimentation. Dredging is the responsibility of the St. Paul District's Fountain City Boat Yard located at Fountain City, Wisconsin. As soon as the ice leaves the river, hydrographic surveys are made to get an early indication of channel conditions. After spring high water, surveys of the historic problem spots are

performed. Equipment is lined up and a priority list is made. **Table 5-2** gives a summary of dredging in Pool No. 4 and in the lower lock approach since 1970.

Table 5-2 Summary of Dredging Activity – 1970 through 2000					
Cut Name	River Mile	Avg. Vol. Per Year	Avg. Vol. Per Job	Freq. Of Dredging	Last Year Dredged
Trenton	794.0 to 794.6	3,722	57,690	6%	1975
Cannon River	792.1 to 793.5	9,829	33,856	29%	2000
Red Wing Hwy Bridge	789.5 to 791.2	4,706	72,940	6%	1972
Head of Lake Pepin	785.2 to 785.4	1,467	22,739	6%	2000
Chippewa Delta	763.2	75,248	259,188	29%	2000
Reads Landing	761.8 to 763.8	37,148	67,740	55%	1998
Crats Island	759.0	62,980	81,349	77%	2000
Teepeeota Point	757.0 to 757.9	34,124	58,770	58%	2000
Grand Encampment	755.8 to 756.9	22,461	38,682	58%	2000
Beef Slough	753.8 to 754.1	5,526	17,132	32%	1999
Lower Approach LD 4	753.0	509	5264	10%	1976

5-04. Recording Hydrologic Data. Pool and tailwater elevations, roller and tainter gate settings, Mississippi River elevations at Alma, Lake City, and Wabasha, stage and discharge for the Chippewa River at Durand, wind speed and direction, precipitation, water temperature, current air temperature, and max and min air temperature are entered on log sheets. Up until 2001, log sheets were mailed to Water Control where they were periodically micro filmed. Beginning in 2001, log sheets started to be stored electronically. Data has been back entered such that electronic copies of log sheets are now available back to January 1993. They can be seen on the Water Control web site at www.mvp-wc.usace.army.mil. The weekly winter data including percent of pool and tailwater ice coverage, ice thickness, snow depth, and snow-water equivalent began being stored

electronically in November 1998. Water Control maintains electronic files of hourly stage/elevation data for the gages located at Lake City, Wabasha, and Durand beginning 1 December 1997. Electronic files for hourly cumulative precipitation, water temperature, and wind speed and direction at Lake City begin in May 2000. Hourly cumulative precipitation at Durand begins in 1997. Note that the tipping buckets (i.e. rain gages) are covered during the winter months. All daily and hourly data received by Water Control from the dam site is compiled and archived using Hydraulic Engineering Center's Data Storage System (HEC-DSS) and is accessible from the Water Control web site. The US Geological Survey (USGS) is responsible for maintaining a discharge record for Durand. The data are archived in the USGS WATSTORE database in Reston, Virginia and are available from the annual publications of the *USGS Water-Data Report, Water Resources Data, Wisconsin*. The daily record of max-min temperature, precipitation, weather characteristics, river stages and general remarks are recorded on National Weather Service (NWS) Form B-91. This form is mailed at the end of each month, along with the punched tape from the Fischer-Porter gage, to the NWS in La Crosse, Wisconsin.

5-05. Communication Network. The communication network consists of computer terminal, T1 line, telephone, pager, facsimile, FM radio, voice modem, satellite, and the US Postal Service. Computer communication is done via e-mail, and "sig-na-term" which allows remote access to the Water Control network. When the computer is down, the transfer of data is by facsimile, telephone, and/or FM radio. During non-duty hours on weekends and holidays, dam personnel can contact the river regulator by calling the pager number (612-660-8053). The gage sites at Lake City, Wabasha, and Durand, send stage/elevation data hourly via satellite to Water Control. In addition, the Lake City and Durand gages send hourly cumulative precipitation. This information is made available to the dam site from the Water Control web site; www.mvp-wc.usace.army.mil. All four gages have voice modem and can be contacted by telephone for immediate stage information. A T1 line ensures communication between Water Control and the

Mississippi River Valley Division Office (MVD) in Vicksburg, Mississippi. Bulk items like Stevens PAV-C strip charts are delivered to Water Control through the postal service.

5-06. Communication with Project.

a. Regulating Office with Project Office. Dam site personnel input and transmit their data, via computer, to Water Control every day by 0630-hours. Water Control issues orders to Lock and Dam No. 4 every morning at approximately 0800-hours during the navigation season and around 0730-hours during the non-navigation season. Orders are typically delivered via e-mail; however, FM radio is available as backup, with the telephone serving as backup to the radio. Should the dam site have computer problems, such that the transfer of data is not possible, a facsimile is then sent to Water Control (651-290-5841). The Water Control river manager then enters the information into the Regulation Program and Information Management (IM) is notified of the computer problem. Communication with the project after orders are delivered is typically by telephone.

b. Between Project Office and Others. The general public has access to river level and discharge data by calling Water Control's "Corps of Engineers River Information Service" at 651-290-5861. This service provides a recording of daily stages and discharges along the Mississippi River. In addition, the Water Control web site at www.mvp-wc.usace.army.mil also provides river information to the general public. From here the public can access current water surface elevations and discharges for the Mississippi River as well as the daily log sheets for the locks and dams. Notifications of severe weather or impending unusual conditions are handled through local law enforcement, civil defense authorities, and the National Weather Service.

5-07. Project Reporting Instructions. The project staff reports hydrologic and climatic conditions to Water Control every morning. The lock operator may

make gate changes required to remain within the pool band issued by Water Control provided it is less than 10 percent of the total flow. If the pool goes out of the band after 0400-hours, no gate changes are to be made by project staff until Water Control issues its morning orders. Gate changes to aid work efforts (e.g. painting of gates) are to be coordinated with Water Control. Problems with machinery that operate the gates are to be reported to Water Control Section and Construction-Operations Division.

5-08. Warnings. In the event the lock operator makes a gate change to remain within the pool band issued by Water Control, Lock No. 4 personnel should notify Lock No. 5 of the cut or opening that was made. In the event of a gate failure, communications must be established as quickly as possible with the Water Control Section and the Construction-Operations Division. The installation of any bulkheads must be coordinated with Water Control.

VI – HYDROLOGIC FORECASTS

6-01. General. During periods of low flow, the gates at the dam are regulated to pass inflow under pooled conditions, while during high flow they are raised free of the water surface and except for a slight swellhead due to the effect of the piers, the dam offers little obstruction to the flow. The storage capacity created by the dam is relatively small as compared with the volume of flow and inasmuch as the dam is out of operation at high discharges, the use the dam to control floods is not possible. The lock goes out of operation at elevation 671.5 feet (1912 adjustment) at which time water is within half a foot of the top of the lock walls. The timing and elevation of a flood crest is important for planning sand bagging operations and forecasting when the lock will go out of operation. In addition, the timing on the receding limb of the hydrograph aids in determining when the lock will go back into service. In 1997, the St. Paul District developed an unsteady-flow model of the Mississippi River. The Mississippi Basin Model System utilizes the computer program UNET for forecasting purposes.

a. Role of the Corps. The St. Paul District previously relied solely on the National Weather Service (NWS) for Mississippi River forecasts, which forecasts for designated sites along the Mississippi River. The NWS forecasts include Alma, Wisconsin, Lake City, Minnesota, and Wabasha, Minnesota. The NWS forecast typically is a five-day forecast with a projected crest height and date. The District saw a need for a model to forecast not only the time and elevation of the crest at the dam, but also the receding limb for forecasting when the lock may go back into operation. In 1997, the District developed the Mississippi Basin Model System (MBMS) that utilizes the unsteady flow program UNET. The river regulator in Water Control runs the MBMS model every morning. For the flood events of 1997 and 2001, the model provided excellent predictions of when the crest would occur and when the lock would be placed back into operation. This was of great use to planning sand bagging efforts, work scheduling, and keeping the towing industry abreast of the flooding situation.

b. Roles of Other Agencies. The National Weather Service (NWS) electronically provides the District forecasted flow hydrographs of the major tributaries to the Mississippi River by 0830-hours daily. Water Control inputs these hydrographs into the Mississippi Basin River System model and makes a run. The results are then electronically transferred to the NWS River Forecast Center in Chanhassen, Minnesota by 0930-hours. The NWS uses the UNET results and the results from their Mississippi River forecast model to provide stage forecasts at various points along the Mississippi River, including Lake City, Wabasha, and Alma.

6-02. Flood Condition Forecasts. Since 1997, St. Paul District has been using the Mississippi Basin Modeling System (MBMS) to forecast flood conditions at Lock and Dam No.4. The system utilizes UNET, which is an unsteady flow computer program. UNET was modified to simulate navigation dams according to operating rules. While the program allows the operating rules to vary according to the season, it does not account for gate operation. Therefore, model results are limited while the dam is in a regulated condition. Flow and stage data are required to provide the boundary conditions that drive the model. Observed stages are updated daily. The model is dependent upon forecasted tributary inflow. The National Weather Service electronically mails the five-day forecasted stage hydrographs for the major tributaries to Water Control by 0830-hours daily. The hydrographs typically include the 24-hour quantitative precipitation forecast (QPF). Water Control extrapolates the tributary stage hydrographs to 30-days. Forecasts beyond five to seven days are very approximate due to unknowns such as additional rainfall. Because of these uncertainties, the 30-day forecast is only available to Corps of Engineers staff and the NWS. The MBMS model is run in Water Control every day between the hours of 0830 and 0930. The seven day model projection is available to the public and can be obtained from the Water Control web site; www.mvp-wc.usace.army.mil.

Modeling efforts as part of the Corps of Engineers Water Management System (CWMS) began 2001. CWMS will provide models for the District's reservoirs and the locks and dams. When the Mississippi River portion of CWMS becomes deployed and operational, the functionality of the MBMS model will be replaced. Rather than using UNET, CWMS will use a HEC-RAS unsteady flow model. The sharing of data with the NWS will remain unchanged.

6-03. Long-Range Forecasts. The Mississippi Basin Modeling System (MBMS) is used for making long-range forecasts. It is run everyday at about 0930-hours. The model forecasts elevation and discharge for the locks and dams and control points 30-days out. However, as previously noted, the five-day tributary inflow provided by the National Weather Service only includes the 24-hour quantitative precipitation forecast (QPF). Therefore, judgment is required when looking at long-range forecasts.

6-04. Drought Forecast. The lock and dam system operates as "run of the river". That is what ever flow enters the pool is passed on. Therefore, during low flow periods, the project pool elevation is maintained. This pool elevation is maintained provided there is sufficient inflow to meet withdrawal needs and pool evaporation. There is no drought forecasting model other than the Mississippi Basin Modeling System previously discussed.

VII - WATER CONTROL PLAN

7-01. General Objectives. The general objective of the water control plan is to maintain a minimum depth of nine feet along the navigation channel of Pool No. 4, without inducing higher stages during flood events. Project pool elevation for Lock and Dam No. 4 is 667.0 ± 0.2 feet (1912 adjustment). The control point for this elevation was established near the intersection of the ordinary high water line and the project pool elevation. For Pool No. 4, the “primary control point” is located just upstream of the Highway 25 bridge crossing the Mississippi River at Wabasha, Minnesota (see **Figure 5-1**). Maintaining project pool elevation at this location during periods of low flows ensures a minimum channel depth of nine feet, supplemented by periodic channel dredging.

The dam has minor localized impacts during flood events. The required spillway area at the dam was designed such that when all the gates are out of the water, the swellhead produced by the piers is less than one foot. Long before flood stage is reached, all the gates are raised above the water surface so that natural open river conditions exist during the flood period.

7-02. Constraints.

a. Pool Levels. For low discharges, the pool is maintained at elevation 667.0 ± 0.2 feet (1912 adjustment) at the primary control point at Wabasha, Minnesota. This is “project pool” or “normal pool” for Lock and Dam No. 4 and was mandated by the 79th Congress (1st Session, House Document No. 137, 9 December 1931). As discharges increase, there is a “drawdown” in the water surface elevation at the dam. The drawdown elevation is based on necessary navigation depths upstream of the dam. Drawdown at the dam was first established at 4.0 feet below project pool level. It was soon learned however that this drawdown impacted navigation and it was reduced to 2.5 feet in 1943. Then in 1960 it was further reduced to 1.5 feet in an effort to maintain a more stable pool elevation. Following the end over dredging

procedures in 1970, drawdown was finally reduced to 0.5 feet in 1971. Therefore, drawdown at the dam is constrained to elevation 666.5 ± 0.2 feet.

- b. Maximum Outflow Velocity.** Downstream scour protection limits outflow velocities from the roller and tainter gates. The design plan set maximum outflow velocities at 4.5 feet per second for standard operating procedures with an allowance to go to 6.0 feet per second for an emergency situation. In the 1984, additional riprap was placed upstream and downstream of the dam. Since this time, routine maximum gate openings have been computed based on a maximum outflow velocity of 6.0 feet per second. However, the design velocity of 6.0 feet per second may be exceeded for short periods of time (15 to 20 minutes) during emergency operations (e.g. barge incident, passing of debris).
- c. Open River Conditions.** The dam is “out of control” when the gates are raised clear of the water surface and “open river conditions” exist. This typically happens when the differential head is less than one foot and the discharge is around 89,000 cfs. When gates are put back in the water, the total gate openings are 78 feet on roller gates and 176 feet on tainter gates.
- d. Closure of the Lock to Navigation.** Prior to 1990, the lock would close to navigation when high water dictated the removal of the miter gate motors. This occurred when the upper pool reached elevation 669.5 feet (1912 adjustment). As part of the major rehabilitation work in 1990, the motors were raised, allowing the lock to remain open in higher water. Technically the lock could remain open to navigation provided water was not spilling over the upper miter gates or the lock wall. Since the top of the miter gates is the same as the lock wall, this elevation would be 672.0 feet. While this is the physical constraint, closure of the lock has been established at elevation 671.5 feet due to wave action over the miter gates. The Coast Guard may close the river to navigation before this elevation is achieved.

The lock is also closed when ice is too thick to permit tow traffic. As winter approaches, the lock remains open as long as towboats and barges can travel. Water temperatures are monitored to predict lock closure. When temperatures approach the low 30's, ice can form overnight and can impact the entire pool. Typically in March the ice becomes thin enough for some tow traffic and the lock is opened. The ice thickness on Lake Pepin (Pool No. 4) is monitored weekly. When the ice is down to about six inches of blue ice, tow traffic can soon be expected. The following table shows some of the recent history of opening and closing dates for Lock and Dam No. 4.

Table 7-1 Spring Opening and Fall Closing Dates					
Year	Opening Date	Closing Date	Year	Opening Date	Closing Date
1972	24 Mar	08 Dec	1987	10 Mar	01 Dec
1973	18 Mar	05 Dec	1988	20 Mar	29 Nov
1974	15 Mar	12 Dec	1989	28 Mar	23 Nov
1975	21 Mar	14 Dec	1990	13 Mar	29 Nov
1976	04 Mar	05 Dec	1991	22 Mar	24 Nov
1977	27 Mar	08 Dec	1992	09 Mar	01 Dec
1978	04 Apr	30 Nov	1993	21 Mar	27 Nov
1979	30 Mar	04 Dec	1994	25 Mar	29 Nov
1980	26 Mar	04 Dec	1995	19 Mar	28 Nov
1981	07 Mar	03 Dec	1996	20 Mar	25 Nov
1982	24 Mar	07 Dec	1997	26 Mar	25 Nov
1983	03 Mar	07 Dec	1998	10 Mar	17 Dec
1984	03 Mar	30 Nov	1999	19 Mar	09 Dec
1985	17 Mar	01 Dec	2000	03 Mar	29 Nov
1986	22 Mar	05 Dec	2001	03 Mar	05 Dec

- e. **Maximum Number of Gates Closed.** At times it is necessary to close one or more gates for maintenance purposes. All gate closures shall be coordinated with the river regulation desk at the Water Control Section. The maximum number of gates allowed to be closed will be at the discretion of Water Control based on conditions as they exist. The following table was prepared based on outlet velocities of 4.5 feet per second. The table assumes **either**

roller gates **or** tainter gates are being closed. Any mixing of roller gate and tainter gate closures would require coordination with Water Control.

**Table 7-2
Maximum Number of Gates Allowed to be Closed**

<u>Flow (cfs)</u>	<u>No. of Roller Gates Closed</u>	<u>Flow (cfs)</u>	<u>No. of Tainter Gates Closed</u>
Below 56,000	6	Below 21,000	22
45,000 – 63,000	5	21,000 – 24,000	21
52,000 – 71,000	4	24,000 – 26,000	20
59,000 – 78,000	3	26,000 – 28,000	19
66,000 – 87,000	2	28,000 – 31,000	18
87,000 – 98,000	1	31,000 – 34,000	17
Above 98,000	0	34,000 – 37,000	16
		37,000 – 40,000	15
		40,000 – 43,000	14
		43,000 – 47,000	13
		47,000 – 50,000	12
		50,000 – 54,000	11
		54,000 – 59,000	10
		59,000 – 63,000	9
		63,000 – 67,000	8
		67,000 – 71,000	7
		71,000 – 75,000	6
		75,000 – 80,000	5
		80,000 – 84,000	4
		84,000 – 89,000	3
		89,000 – 94,000	2
		94,000 – 102,000	1
		Above 102,000	0

7-03. Overall Plan for Water Control.

- a. General Plan.** The navigation channel of Pool No. 4 is 300 feet wide along the straight reaches of the river and varies from 300 feet to 550 feet in the bends. The primary purpose of Lock and Dam No. 4, combined with periodic dredging, is to maintain a minimum depth of nine feet throughout the navigation channel without inducing higher stages during flood events. During flows of less than 15,000 cfs, the pool is fairly flat. To meet depth requirements in the upper pool requires the pool elevation at Wabasha, Minnesota to be at elevation 667.0 feet (1912 adjustment). Therefore,

“project pool” elevation for Lock and Dam No. 4 is 667.0 ± 0.2 feet, and Wabasha acts as the “primary control point” for maintaining this elevation. As discharges increase, gates are opened at the dam to maintain project pool at Wabasha. This results in a drawdown in the water surface elevation at the dam. Maximum allowable drawdown is one half a foot below project pool elevation or 666.5 ± 0.2 feet. When maximum drawdown has been achieved, the lock and dam is now in “secondary control”. As discharge continues to rise to around 89,000 cfs, the differential head is reduced to less than one foot and it is no longer possible to maintain secondary control. At this time the gates are raised above the water surface and the dam is said to be “out of control” or in “open river conditions”. On the recession limb of the hydrograph, the gates are put back into the water, maintaining secondary control, and as flow continues to decrease, control passes from secondary to primary. The operating curves, shown on **Plate 7-1**, were updated for this manual based on historical data.

Table 7-3 Control Conditions at Lock and Dam No. 4			
Control Conditions	Approximate Discharge	Wabasha Gage Elevation	Lock and Dam 4 Pool Elevation
Primary	< 15,000 cfs	667.0 ft	≤ 667.0 ft
Primary to Secondary	15,000 to 27,000 cfs	>667.0 ft	< 667.0 ft >666.5 ft
Secondary	27,000 to 89,000 cfs	> 667.0 ft	666.5 ft
Open-River	> 89,000 cfs	> 667.0 ft	> 666.5 ft

- b. Computed Discharge.** Discharges are computed as part of the “River Program”. Outflows were determined on a per foot opening basis for various heads. Flows through the dam are then computed based on the differential head and the gate settings. At high discharges when the gates are out of the water, discharges are computed based on the tailwater-rating curve. To prevent a discontinuity from computed outflows to the tailwater rating curve, outflows are transitioned to the tailwater rating.

Discharge ratings for the gates were originally developed based on laboratory tests on a hydraulic model. A Gate Regulation Schedule was developed based on gate discharge, maximum outflow velocity of 4.5 feet per second, and an effort to equally distribute flow across the dam. In 1971, the US Geological Survey measured outflows in the prototype. This resulted in a new relationship in the per foot discharge for the roller and tainter gates. The analysis also showed a slight change in the tailwater rating. These changes were presented in a new Gate Regulation Schedule (revised November 1971). Included with the change in per foot discharge, was a reevaluation of the flow distribution across the dam. Flow was now to be distributed based on balancing outflow velocities. This schedule remained unchanged until 1984 when riprap was placed upstream and downstream of the dam. Based on this, the maximum outflow velocity was raised to 6.0 feet per second and hence the maximum gate openings were changed on the Gate Regulation Schedule to reflect this.

As part of the current updates to this manual, the Operating Curves (**Plate 7-1**) were updated using recent data. The data indicated a slight shift in the pool rating curve at lower flows and the tailwater rating curve at higher flows. This required the Gate Regulation Schedule to be checked and updated where necessary to provide the correct distribution of flow based on equalizing the outflow velocities. For example, consider a flow of 46,000 cfs and a respective head across the dam of 4.0 feet with a tailwater elevation of 662.5 feet. The discharge per foot opening for roller and tainter gates are 851 cfs and 563 cfs, respectively. By setting the roller gates at a total opening of 17.0 feet ($17 \times 851 = 14,470$ cfs) and the tainter gates at 56 feet ($56 \times 563 = 31,530$ cfs) gives a total discharge of 46,000 cfs. Outflow velocities are calculated based on $Q=VA$, where Q is the discharge in cfs, V is the flow velocity in fps, and A is the flow area in sq ft. Q is the discharge through one gate. Area is the gate width, plus one pier width, times the depth of flow over the end sill. Roller gates are 60-feet long with a pier width of 15 feet. Tainter gates are

35-feet long with a pier width of 7 feet. The end sill elevation for both the roller and tainter gates is 650.0 feet. Therefore, the flow velocities are;

Roller Gate

$$Q = VA$$

$$(17 \text{ ft}/6 \text{ roller gates}) 851 \text{ cfs} = V (60 \text{ ft} + 15 \text{ ft}) (662.5 \text{ ft} - 650.0 \text{ ft})$$

$$V = 2.57 \text{ ft/sec}$$

Tainter Gate

$$Q = VA$$

$$(56 \text{ ft}/22 \text{ tainter gates}) 563 \text{ cfs} = V (35 \text{ ft} + 7 \text{ ft}) (662.5 \text{ ft} - 650.0 \text{ ft})$$

$$V = 2.73 \text{ ft/sec}$$

To complete the update of the Gate Regulation Schedule the maximum allowable gate openings were checked and updated where necessary. Maximum allowable gate openings are based on flow velocity at the end sill downstream of the gates. Again, let's consider a discharge of 46,000 cfs and a differential head of 4.0 feet with a tailwater elevation of 662.5 feet. Based on $Q = VA$, where Q is the discharge per foot, times the maximum allowable gate opening, V is the maximum allowable flow velocity of 6.0 feet per second, and A is the flow area over the end sill for one gate, the following maximum allowable gate openings were determined.

Roller Gate

$$Q = VA$$

$$851 \text{ cfs (max gate opening in ft)} = 6.0 \text{ fps} (60 \text{ ft} + 15 \text{ ft}) (662.5 \text{ ft} - 650.0 \text{ ft})$$

$$\text{Max Gate Opening} = 6.6 \text{ ft}$$

Tainter Gate

$$Q = VA$$

$$563 \text{ cfs (max gate opening in ft)} = 6.0 \text{ fps} (35 \text{ ft} + 7 \text{ ft}) (662.5 \text{ ft} - 650.0 \text{ ft})$$

$$\text{Max Gate Opening} = 5.6 \text{ ft}$$

Table 7-4 shows the new Gate Regulation Schedule.

**Table 7-4
Gate Regulation Schedule
6 Roller Gates and 22 Tainter Gates**

Total Discharge cfs	Total Gate Opening in Feet		Elevation in Feet 1912 Adjustment		Head In Feet	Discharge (cfs) per Foot of Opening		Discharge (cfs)		Max Allowable Opening of a Gate	
	Rollers	Tainters	Pool	TW		Rollers	Tainters	Rollers	Tainters	Rollers	Tainters
8,000	2.0	8.0	667.00	660.16	6.84	1215	696	2,450	5,550	3.8	3.7
9,000	2.5	8.5	667.00	660.18	6.82	1213	695	3,050	5,900	3.8	3.7
10,000	3.0	9.0	667.00	660.20	6.80	1210	694	3,650	6,250	3.8	3.7
11,000	3.0	10.5	667.00	660.22	6.78	1205	693	3,600	7,300	3.8	3.7
12,000	3.5	11.5	667.00	660.24	6.76	1200	691	4,200	7,950	3.8	3.7
13,000	4.0	12.0	667.00	660.27	6.73	1194	689	4,800	8,250	3.9	3.8
14,000	4.0	13.5	667.00	660.30	6.70	1188	687	4,750	9,300	3.9	3.8
15,000	4.0	15.0	667.00	660.35	6.65	1179	683	4,700	10,250	4.0	3.8
16,000	4.5	15.5	666.98	660.38	6.60	1176	681	5,300	10,550	4.0	3.8
17,000	5.0	16.5	666.97	660.40	6.57	1169	680	5,850	11,200	4.0	3.9
18,000	5.0	18.0	666.96	660.45	6.51	1160	677	5,800	12,200	4.1	3.9
19,000	5.5	19.0	666.95	660.50	6.45	1151	674	6,350	12,800	4.1	3.9
20,000	5.5	20.5	666.90	660.55	6.35	1142	671	6,300	13,750	4.2	4.0
21,000	6.0	21.0	666.84	660.58	6.26	1135	669	6,800	14,050	4.2	4.0
22,000	6.5	22.0	666.78	660.62	6.16	1129	666	7,350	14,650	4.2	4.0
23,000	6.5	23.5	666.72	660.67	6.05	1118	663	7,250	15,600	4.3	4.1
24,000	7.0	24.5	666.66	660.72	5.94	1107	660	7,750	16,150	4.4	4.1
25,000	7.5	25.5	666.60	660.78	5.82	1098	657	8,250	16,750	4.4	4.1
26,000	7.5	27.5	666.54	660.85	5.69	1083	652	8,100	17,950	4.5	4.2
27,000	8.0	28.5	666.50	660.90	5.60	1075	649	8,600	18,500	4.6	4.2
28,000	8.5	29.5	666.50	660.95	5.55	1064	646	9,050	19,050	4.6	4.3
29,000	8.5	31.0	666.50	661.00	5.50	1055	643	8,950	19,950	4.7	4.3
30,000	9.0	32.0	666.50	661.08	5.42	1042	639	9,400	20,450	4.8	4.4

**Table 7-4 – Continued
Gate Regulation Schedule
6 Roller Gates and 22 Tainter Gates**

Total Discharge cfs	Total Gate Opening in Feet		Elevation in Feet 1912 Adjustment		Head In Feet	Discharge (cfs) per Foot of Opening		Discharge (cfs)		Max Allowable Opening of a Gate	
	Rollers	Tainters	Pool	TW		Rollers	Tainters	Rollers	Tainters	Rollers	Tainters
31,000	9.5	33.5	666.50	661.15	5.35	1032	636	9,800	21,300	4.9	4.4
32,000	10.0	34.5	666.50	661.22	5.28	1024	632	10,250	21,800	4.9	4.5
33,000	10.0	36.5	666.50	661.30	5.20	1012	629	10,100	22,950	5.0	4.5
34,000	11.0	37.0	666.50	661.40	5.10	1000	624	11,000	23,100	5.1	4.6
35,000	11.5	38.0	666.50	661.48	5.02	988	620	11,350	23,550	5.2	4.7
36,000	11.5	40.0	666.50	661.55	4.95	979	616	11,250	24,650	5.3	4.7
37,000	12.0	41.5	666.50	661.65	4.85	966	612	11,600	25,400	5.4	4.8
38,000	12.5	43.0	666.50	661.72	4.78	956	608	11,950	26,150	5.5	4.9
39,000	13.0	44.0	666.50	661.80	4.70	946	605	12,300	26,600	5.6	4.9
40,000	13.5	45.5	666.50	661.90	4.60	932	599	12,600	27,250	5.7	5.0
41,000	14.0	47.5	666.50	662.00	4.50	919	594	12,850	28,200	5.9	5.1
42,000	14.5	49.0	666.50	662.10	4.40	906	588	13,150	28,800	6.0	5.2
43,000	15.5	50.0	666.50	662.20	4.30	891	582	13,800	29,100	6.2	5.3
44,000	16.0	52.0	666.50	662.30	4.20	878	576	14,050	29,950	6.3	5.4
45,000	16.5	54.0	666.50	662.40	4.10	864	570	14,250	30,800	6.5	5.5
46,000	17.0	56.0	666.50	662.50	4.00	851	563	14,450	31,550	6.6	5.6
47,000	18.0	57.5	666.50	662.60	3.90	837	557	15,050	32,050	6.8	5.7
48,000	18.5	59.5	666.50	662.70	3.80	822	550	15,200	32,750	7.0	5.8
49,000	19.0	61.5	666.50	662.75	3.75	817	546	15,500	33,600	7.0	5.9
50,000	19.5	63.5	666.50	662.85	3.65	803	539	15,650	34,250	7.2	6.0
51,000	20.5	65.5	666.50	662.95	3.55	788	531	16,150	34,800	7.4	6.1
52,000	21.0	68.5	666.50	663.05	3.45	776	522	16,300	35,750	7.6	6.3
53,000	22.0	70.5	666.50	663.15	3.35	762	515	16,750	36,300	7.8	6.4

**Table 7-4 – Continued
Gate Regulation Schedule
6 Roller Gates and 22 Tainter Gates**

Total Discharge cfs	Total Gate Opening in Feet		Elevation in Feet 1912 Adjustment		Head In Feet	Discharge (cfs) per Foot of Opening		Discharge (cfs)		Max Allowable Opening of a Gate	
	Rollers	Tainters	Pool	TW		Rollers	Tainters	Rollers	Tainters	Rollers	Tainters
54,000	23.0	73.0	666.50	663.25	3.25	748	505	17,200	36,850	8.0	6.6
55,000	23.5	75.0	666.50	663.30	3.20	741	501	17,400	37,600	8.1	6.7
56,000	24.5	77.5	666.50	663.40	3.10	728	493	17,850	38,200	8.3	6.8
57,000	25.5	80.0	666.50	663.50	3.00	713	485	18,200	38,800	8.5	7.0
58,000	26.5	83.0	666.50	663.60	2.90	699	477	18,500	39,600	8.8	7.2
59,000	27.5	86.0	666.50	663.70	2.80	685	468	18,850	40,250	9.0	7.4
60,000	28.5	89.0	666.50	663.80	2.70	670	460	19,100	40,950	9.3	7.6
61,000	29.0	91.5	666.50	663.85	2.65	663	455	19,250	41,650	9.4	7.7
62,000	30.5	95.0	666.50	663.95	2.55	649	446	19,800	42,350	9.7	7.9
63,000	31.5	98.5	666.50	664.05	2.45	634	437	19,950	43,050	10.0	8.1
64,000	32.5	101.5	666.50	664.12	2.38	624	431	20,300	43,750	10.2	8.3
65,000	33.5	105.0	666.50	664.20	2.30	611	424	20,450	44,500	10.5	8.4
66,000	35.0	108.5	666.50	664.30	2.20	596	415	20,850	45,050	10.8	8.7
67,000	36.5	112.0	666.50	664.38	2.12	583	408	21,300	45,700	11.1	8.9
68,000	38.0	118.0	666.50	664.50	2.00	564	395	21,450	46,600	11.6	9.3
69,000	39.5	120.5	666.50	664.55	1.95	556	391	21,950	47,100	11.8	9.4
70,000	42.0	124.0	666.50	664.65	1.85	538	382	22,600	47,350	12.3	9.7
71,000	43.0	127.0	666.50	664.68	1.82	534	378	22,950	48,000	12.4	9.8
72,000	45.0	129.0	666.50	664.72	1.78	528	375	23,750	48,400	12.5	9.9
73,000	46.5	131.5	666.50	664.75	1.75	522	371	24,250	48,800	12.7	10.0
74,000	47.0	135.0	666.50	664.78	1.72	517	368	24,300	49,700	12.9	10.1
75,000	48.5	140.0	666.50	664.85	1.65	505	361	24,500	50,550	13.2	10.4
76,000	50.0	145.0	666.50	664.93	1.58	492	354	24,600	51,350	13.7	10.6

**Table 7-4 – Continued
Gate Regulation Schedule
6 Roller Gates and 22 Tainter Gates**

Total Discharge cfs	Total Gate Opening in Feet		Elevation in Feet 1912 Adjustment		Head In Feet	Discharge (cfs) per Foot of Opening		Discharge (cfs)		Max Allowable Opening of a Gate	
	Rollers	Tainters	Pool	TW		Rollers	Tainters	Rollers	Tainters	Rollers	Tainters
77,000	52.0	151.0	666.50	665.00	1.50	480	345	24,950	52,100	14.1	11.0
78,000	54.0	157.5	666.50	665.08	1.42	466	335	25,150	52,750	14.6	11.3
79,000	56.0	165.0	666.50	665.15	1.35	452	325	25,300	53,650	15.1	11.7
80,000	60.0	170.0	666.50	665.23	1.27	434	317	26,050	53,900	15.8	12.1
81,000	62.0	178.0	666.50	665.30	1.20	422	308	26,150	54,800	16.3	12.5
82,000	64.0	186.5	666.50	665.38	1.13	410	299	26,250	55,750	16.9	13.0
83,000	68.0	192.0	666.50	665.45	1.05	394	293	26,800	56,250	17.6	13.3
84,000	71.0	207.0	666.50	665.53	0.98	379	276	26,900	57,150	18.4	14.2
85,000	75.0	221.0	666.50	665.60	0.90	362	262	27,150	57,900	19.4	15.0
86,000	80.0	233.0	666.50	665.67	0.83	347	250	27,750	58,250	20.3	15.8
87,000	84.0	249.0	666.50	665.74	0.76	334	237	28,050	59,000	21.2	16.7
88,000	90.0	262.0	666.50	665.81	0.69	320	226	28,800	59,200	22.2	17.6
89,000	Out of Control – Gates raised clear of water. Put gates back in at 78 ft Roller Gates and 176 ft Tainter Gates.										

c. Regulation Procedure. Each morning at 0645-hours, the Water Control manager prints the Regulation Sheets containing all the input from the lock and dam sites. Regulation for Lock and Dam No. 4 begins at Lock and Dam No. 4. That is, gate changes at Lock and Dam No. 3 do not generally influence action needed at Dam No. 4, due to the large amount of storage provided by Lake Pepin. While this true, inflow to pool is still calculated as part of the regulation procedure. Inflow consists of outflow from Lock and Dam No. 3, inflow from the Chippewa River, and any miscellaneous inflow. Inflow from Lock and Dam 3 is computed as part of the daily regulation. Inflow from the Chippewa River will appear on the Regulation Sheet from input by site personnel (see Standing Instructions to Lockmaster). During the winter months, the Chippewa River is subject to ice jams, which gives erroneous data at the Durand gage. During this time period, the combined outflows from hydroelectric power dams at Cedar Falls, Menomonie, and Wissota, Wisconsin are used for daily regulation. This information is remotely entered by Northern States Power and appears on the regulation sheets. Miscellaneous inflow will vary seasonally but for simplicity it is assumed to be a constant 600 cfs. This may be modified if precipitation has occurred in the last 24-hours. As a general rule, for each inch of rainfall that has fallen in the past 24-hours, an additional 600 cfs is added to the miscellaneous inflow. Inflow is totaled and the 24-hour change is noted. Also noted is the change in outflow and any gate changes made in the past 24-hours. Next the rate of fall or rise of the pool is calculated. This is done at the dam, the control point, and at Lake City. Note the changes. Allow for wind at the dam. That is, adjust the pool elevation, up or down, 0.1 foot per 10 mph of wind (see Section 4-04). Determine if the pool is in primary or secondary control. Estimate the needed change in discharge to maintain the proper pool band. To aid in this assessment, it has been determined that a change in outflow of 2,000 cfs over a 24-hr period of time will result in about a one tenth of a foot change in the overall pool elevation. This value was computed based on the effective project pool area of 38,820 acres. Once the needed

change in discharge is determined, the Gate Regulation Schedule is used to distribute flow and hence set gate changes. The gate change information is e-mailed to the lock site and the St. Paul District's intranet at approximately 0800-hours each day.

The "orders" are typically one of four types; (1) no change, (2) no change at present, (3) open a given amount of flow, or (4) cut a given amount of flow. A "no change at present" order is followed by an "if statement". For example, "if the pool falls to elevation 666.8 feet, cut 2 feet on roller gates". All "open" and "cut" orders include the anticipated gate change impact on flow. All four types of orders are followed by a "pool band" to be maintained at the dam. For example, "hold 667.0 ± 0.2 feet". As a final note, the orders may also include "allow for wind on the high side" or "allow for wind on the low side", if appropriate. Sometimes it is necessary to check back with the lock site in the afternoon. If this were the case, the site would be informed, via the morning's orders, that Water Control will be contacting them at a given time (typically 1400-hours). At that time, site personnel would provide present and noon pool and tailwater elevations, and present wind conditions. Water Control would then provide any gate change verbally over the telephone or via e-mail. The following is a sample of the regulation of Lock and Dam No. 4. The portion printed in black represents the daily regulation sheet while that printed in blue represents regulation notes.

Regulation of Lock and Dam No. 4 for 23 September 2001

Orders to LD 3: Open 1 ft RG. Increase 1,500 to 12,200 cfs.
 Note: Roller Gates at LD 3 were opened 1 ft between midnight and 0400-hours.

gates in/out: 78/176 @ 89,000				6-RG	22-TG	[primary = 667.00 for flow<20,000]	
LOCK 4				Total Roller Gate	Total Tainter Gate	CP-4 Lake City Wabasha	
	sec:	Tail	Flow			TM4	TM4
	666.50						
22SEP01	0800	666.99	660.39	14300	5.0	10.0	667.35 667.18
	1200	666.99	660.39	14300	5.0	10.0	
	1600	667.01	660.38	14300	5.0	10.0	667.31 667.13
	2000	666.96	660.41	14200	5.0	10.0	
	2400	667.03	660.40	14300	5.0	10.0	667.48 667.22
23SEP01	0400	667.08	660.44	15500	6.0	10.0	← Opened 1 ft
	0630	667.10	660.46	15500	6.0	10.0	667.43 667.31
		up 0.11		up 1200			up 0.08 up 0.13
phone	HEAD	6.6		Durand:	Stage	Flow	
##027	Q/foot	1190/696			1.25	3045	Cedar Falls 1150
	temp.	52			1.29	3116	Menomonie 1200
	precip.	1.10			1.57	3609	Wissota + 1550
	wind (dir&speed)	360 @ 9				Average	(from NSP) -----
						3257	3900
	INFLOW:						
	L/D 3 -	12200					Orders:
	Chippewa	3300					Open 3 ft on TG
	2000 CFS -						Inc. Flow 2,000 to 17,500 cfs
	Misc. -	600					Hold 666.90 ± 0.2 ft, AFW HS
							16100+700=16,800
							up 2,700

The following steps walk through the regulation procedure for this particular day. This is intended only as an example.

- Step 1. Determine inflow to Pool 4.
 - a. LD 3 orders were to open up 1,500 cfs to 12,200 cfs.
 The Chippewa River is at 3,300 cfs.
 Miscellaneous inflow is 600 cfs.
 Rainfall was 1.10 inches, so add 700 cfs to inflow.
 - b. Total Inflow = 16,800 cfs (up 2,700 cfs from yesterday).
- Step 2. Note change in outflow.
 - a. Up 1,200 cfs due to gate change between 2400 and 0400-hrs.
- Step 3. Note change in pool elevations.
 - a. Pool is up 0.11 ft at the dam.
 Pool is up 0.13 ft at Wabasha.
 Pool is up 0.08 ft at Lake City.
 - b. Wind is 9 mph out of the North.
 Therefore, about 0.1 ft of increase at dam is due to wind.
- Step 4. Primary or Secondary Control?
 - a. Flow is less than 20,000 cfs; therefore, Primary Control.
 - b. For Primary Control, maintain Wabasha at 667.00 ± 0.2 ft.

- Step 5. Estimate needed change in discharge.
- a. Inflow is up 2,700 cfs from yesterday, minus the gate opening (1,200 cfs), suggests the need to increase outflow by 1,500 cfs.
 - b. Because of the large storage volume of Pool No. 4, we tend to disregard gate changes at LD 3 and base our opinion on what the needed action is to adjust the pool level.
 - c. After allowing for wind, the pool gage is fairly steady. However, Wabasha and Lake City are up about 0.1 ft. Wabasha went up 0.1 ft even after the gate opening. Wabasha is out of the band by 0.1 ft. Therefore, we need to reduce pool elevation by about 0.1 ft.
 - d. Pool elevation will decrease 0.1 feet per 2,000 cfs in 24-hr. Therefore, we need to increase outflow approximately 2,000 cfs, for a total outflow of 17,500 cfs

- Step 6. Set gate change.
- a. The Gate Regulation Schedule shows ideal gate settings for 18,000 cfs to be 5.0 ft on RG and 18 ft on TG.
 - b. We are presently at 6.0 ft on RG and 10 ft on TG. Therefore, the entire gate opening will be on the Tainter Gates.
 - c. A one-foot opening on TG's will increase outflow about 700 cfs. Therefore,
 "Open 3.0 ft on TG. Increases flow 2,000 to 17,500."

- Step 7. Set the pool band.
- a. The pool is a little high (i.e. target at Wabasha is 667.00 ft) and the pool elevation at the dam is impacted by wind.
 - b. Also, we want an opening if the pool goes up; Therefore,
 "Hold elevation 666.90 ± 0.2 feet."
 "Allow for wind on the high side."

d. Winter Regulation. Each year in early winter, the tainter gates are set at predetermined heights and are allowed to freeze in place. In late November, Water Control makes an estimate of the anticipated minimum base flow for the winter months. The estimate is based on the average flow from 1 October through 15 November and the minimum winter flow rate curve. The curve was developed using historic discharge information for the gage site at Winona, Minnesota. "Average October Flow" and "Average November Flow" were plotted against the "Minimum Winter Flow". Curves were drawn through the lowest data points. A composite curve was then developed. By entering the average flow for the period 1 October through 15 November, the anticipated minimum base flow can be selected from the curve. To determine

what to set the tainter gates at, we must first consider the roller gates. Because we are using the minimum base flow rate, we must consider minimum submerged roller gate settings. Roller gates can be submerged from 0.5 feet to 3.0 feet. Discharges for these and other gate settings are shown in **Table 7-5**. Roller gates are typically not submerged less than one foot due to ice interference. Therefore, the total discharge for all roller gates at one-foot submergence is deducted from the estimated minimum base flow. Tainter gate settings are then determined for the remainder of the flow. While four of the tainter gates can be submerged to 2.0 feet below project pool elevation, they are operated only in the raised position because of their low discharge capacity. The recommended tainter gate settings are sent to the Lockmaster for evaluation. The Lockmaster assesses the Water Control recommendations and makes the final decision on tainter gate settings before freeze up. Before ice begins to form on the pool, the roller gates are placed in a submerged position. Adjusting roller gates in the submerged position makes the needed changes in discharge. When the roller gates are at an extreme setting and additional change in outflow is needed, a tainter gate, or tainter gates, must be freed up. Usually considerable time is spent steaming and chopping before an ice bound tainter gate becomes moveable.

Throughout the winter, the tainter valves in the lock walls on the upstream are kept open four feet each and the downstream ones are just cracked open. The purpose is to maintain flow through the lock chamber to prevent the formation of ice.

During the winter, on the weekends and holidays, the shifts are limited to one person at the dam site. Two people are required to make a gate change. The first shift starts at 0800-hours. Therefore, Water Control makes an effort to get orders out by 0730-hours to prevent the third shift from hanging around on overtime, waiting to see if there is a gate change. Due to the limited staff at the site and the difficulty in moving the submerged roller gates, the tolerance for

stage deviation is increased to plus or minus three tenths of a foot. That is, the Wabasha gage is typically maintained at elevation 667.0 ± 0.3 feet. Because of the added benefit to fish habitat, Water Control operates on the high side of the band during winter months to reduce oxygen depletion in the backwater areas.

**Table 7-5
Discharge through Submerged Roller Gate – cfs**

Pool Elevation	Head (Feet)	Depth of Submerged Gate					
		0.5 ft	1.0 ft	1.5 ft	2.0 ft	2.5 ft	3.0 ft
667.2	7.0	235	485	770	1080	1380	1540
	6.0	225	465	740	1040	1340	1500
	5.0	215	445	710	1000	1290	1460
667.1	7.0	220	460	735	1040	1335	1480
	6.0	210	435	705	1000	1290	1450
	5.0	200	420	680	960	1245	1410
667.0	7.0	200	430	700	990	1290	1430
	6.0	190	410	670	950	1240	1400
	5.0	180	395	640	910	1195	1355
666.9	7.0	190	410	670	960	1240	1380
	6.0	180	390	640	920	1200	1340
	5.0	170	375	610	880	1150	1300
666.8	7.0	180	390	640	920	1200	1320
	6.0	170	370	610	880	1150	1290
	5.0	155	355	580	840	1100	1250
666.7	7.0	170	370	610	890	1150	1270
	6.0	160	350	580	850	1110	1240
	5.0	145	330	550	805	1060	1200
666.6	7.0	150	350	580	850	1110	1220
	6.0	140	330	550	820	1060	1190
	5.0	130	310	525	775	1015	1145
666.5	7.0	140	330	550	820	1060	1180
	6.0	130	310	520	780	1020	1140
	5.0	120	295	500	740	970	1100
666.4	6.5		310	520	770	1000	1110
	5.5		290	490	730	960	1070
	4.5		265	455	680	905	1030
666.3	6.0		290	490	720	950	1050
	5.0		270	450	670	900	1010
	4.0		245	420	625	850	970
666.2	6.0		280	470	690	910	1000
	5.0		260	440	640	860	960
	4.0		230	400	600	805	920

7-04. Standing Instructions to Lock and Dam No. 4 Staff. Lock and dam personnel are to update and send via computer by 0630-hours, the last 24-hour data readings needed for regulation. This data includes pool, tailwater, Lake City, Wabasha, and Alma elevations, discharges, gate settings, precipitation, air temperature, wind speed and direction, water temperature, maximum and minimum air

temperatures, and stage and discharge for the Chippewa River at Durand. Log sheets with this data are maintained at the site. Pool, tailwater, and Alma elevations, along with gate settings, are given in 4-hour intervals beginning with the previous days 0400-hour records. Pool and tailwater elevations are read within the control house. The elevation at Alma is obtained from Water Control web site (i.e. Real Time DCP readings). Discharges are calculated internally on 4-hour intervals based on pool and tailwater elevations or the tailwater rating curve when the gates are out of the water. Elevations for Lake City and Wabasha, stage and discharge on the Chippewa River at Durand, air temperature, and wind speed and direction are input on 8-hour intervals beginning at 0800-hours. The stage at Durand is obtained by calling the voice modem at the gage site. Discharge is obtained from the latest US Geological Survey rating table (**Exhibit B**). Precipitation and water temperature are input daily beginning at 0800-hours. Maximum and minimum air temperatures are measured at 1900-hours and input as 2400-hour readings. All of the morning's data are collected between 0600 and 0630-hours and are entered as 0800-hour readings. Data collected during the winter months includes percent of pool and tailwater ice coverage, ice thickness in the pool and tailwater, snow depth, and snow-water equivalent. These data are collected every Sunday.

At 0645-hours everyday, the Water Control regulator analyzes the field data and at around 0800-hours, the daily orders for gate movements are sent to the site via e-mail. On weekends and holidays during the winter operations, orders are sent by 0730-hours due to limited staffing at the dam site. Gate changes are then made as soon as possible. If Water Control has notified the site that they will contact them again later in the afternoon, site personnel will have the noon and present, pool and tailwater elevations, as well as any other pertinent information (e.g. wind speed and direction) available at that time.

Normal duty hours for Water Control are 0630 to 1500-hours during the week, and 0630 to 0930-hours on weekends and holidays. During the course of non-

duty hours site personnel may make gate changes as necessary to stay within the pool band prescribed. The site is limited however to changes up to ten percent of the 1600-hour discharge. If a gate change greater than this is necessary, site personnel should contact the river regulator at home. If the need for a gate change becomes necessary at 0400-hours, no gate change will be made. Water Control will provide the necessary gate change and band limit with the morning's orders. The following is a list of Water Control personnel with river responsibilities. The first contact should be the person who issued the last orders. If that person is not available, contact should be made in the order listed below. The weekend pager number is 612-660-8053.

Table 7-6 Water Control Personnel Telephone Numbers		
Name	Non-Duty	Office
Scott Bratten	651-436-6135	651-290-5624
Dennis Holme	651-483-4003	651-290-5614
Ted Pedersen	715-639-2625	651-290-5253
Ferris Chamberlin	651-653-7981	651-290-5619
Bob Engelstad	651-459-6343	651-290-5610

Lock personnel contacting Water Control personnel at home should have pool and tailwater readings, wind speed and direction, amount of precipitation since last report, latest discharge calculations, and all gate changes made since the morning gate change.

If lock personnel have any questions regarding the Water Control order, they are to contact the regulator via telephone (651-290-5624) and the question will be resolved. During computer outages, log sheets will be faxed to Water Control Section (651-290-5841) and orders will be given via telephone or FM radio.

In the event of a gate failure or any occurrence that will require the installation of the bulkheads, communications must be established as quickly as possible with Water Control Section and Construction and Operations (Con-Ops) Division.

Under full head conditions at the dam, the force is too great to allow the installation of the bulkheads. Therefore, the operating head must be reduced. Water Control will coordinate gate movements with site personnel in preparation for installation and removal of the bulkheads.

While not part of the lock and dam operation, site personnel are also responsible for operation the aeration culvert to Lower Peterson Lake. Gate settings prescribed by the US Fish and Wildlife Services (USFWS) are such that winter flows are set at 5 cfs and summer flows are set at 40 cfs. All other culverts through the dike are regulated by the USFWS.

7-05. Flood Control. Lock and Dam No. 4 has no flood control benefits. It is operated strictly for navigation. While it may seem possible that the pools be drawdown over the winter months to provide storage for spring runoff, this plan has no merit for two reasons. First, the Anti-Drawdown Act of 1934 as amended in 1948, prevents any drawdown of the pools. Secondly, the storage volume that would be made available in the pool is insignificant in comparison to the flood flow volume. The pool would be filled in a matter of hours and would have no impact on the peak flood stage.

7-06. Recreation. The major recreation features for Lock and Dam No. 4 are fishing, hunting, and boating. Construction of the lock and dam inundated the numerous wing dams that were constructed as part of the six-foot channel project. The wing dams as well as some of the backwater areas provide excellent fish and waterfowl habitat. As for recreational boating, there were over 12,000 recreation boat lockages in the year 2000. **Table 7-7** shows a comparison of recreational to towboat lockages.

Table 7-7 Commercial & Recreational Lockages at Lock No. 4					
Year	Towboats & Barges	Recreation Boaters	Other Lockages	Total Lockages	Percent Recreation
1991	1,385	13,630	73	15,088	90%
1992	1,309	13,352	85	14,746	91%
1993	872	7,115	107	8,094	88%
1994	1,004	14,576	133	15,713	93%
1995	1,148	15,168	186	16,502	92%
1996	1,250	13,253	183	14,686	90%
1997	1,144	13,231	101	14,476	91%
1998	1,286	12,884	85	14,255	90%
1999	1,375	12,942	203	14,520	89%
2000	1,294	12,623	123	14,040	90%

7-07. Water Quality. The Corps of Engineers does not perform any water quality analysis in Pool No. 4. However, as an element of the Environmental Management Program (EMP), the Corps of Engineers oversees the Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System. The LTRMP was implemented to provide decision makers with the information needed to maintain the Upper Mississippi River System as a viable multiple-use large river ecosystem. The LTRMP is being implemented by the US Geological Survey (USGS) in cooperation with the states of Illinois, Iowa, Minnesota, Missouri and Wisconsin with guidance and overall program responsibility by the Corps of Engineers.

7-08. Fish and Wildlife. Until 1967, during low to moderate flows, the only water flowing into Pool No. 5 was passed through the dam. In September 1967, a 48-inch corrugated metal culvert was installed through the earthen dike portion of the dam. The culvert provided a constant flow of 100 cfs to Lower Peterson Lake when the pool was at project level. In 1994, a slide gate was added to the culvert to regulate the flow. Along with the modification to the older culvert, three additional gated culverts were installed in the earthen dike to provide flow to the remaining Finger Lakes including 1st Lake, 2nd Lake, 3rd Lake and Clear Lake.

Culvert specifications and flow regulation are provided in **Table 3-1**. The flow from these culverts aids fish habitat by aerating the water in the Finger Lakes. The culverts provide minimum dissolved oxygen levels of 5 mg/l to the Finger Lakes on a year-round basis, leading to increased use of the area by fish. The total project, constructed as part of the Upper Mississippi River Environmental Management Program (EMP), has improved fish habitat conditions in approximately 113 acres of backwater habitat.

Because the lock and dam was constructed for the purpose of navigation, the pool would sometimes be drawn down in non-navigation season. The 1934 Anti-Drawdown Act, as amended in 1948, prevented any winter drawdown of the pool. The pool is to be regulated the same as during navigation season. A higher stage in the backwater areas reduces the oxygen depletion. Because of this, Water Control typically operates on the high side of the band during the winter months.

7-09. Water Supply. The cities of Red Wing, Lake City, and Wabasha Minnesota and the village of Pepin, Wisconsin obtain their water from wells. Pool No. 4 does not provide water supply.

7-10. Hydroelectric Power. There is no hydroelectric power at Lock and Dam No. 4.

7-11. Navigation. The primary purpose of Lock and Dam No. 4 is to provide navigation. The lock is 110 feet wide and 600 feet long. Barges are typically 35 feet wide and 195 feet long. Towboats are of similar size. There are many ways in which the barges and towboat may be configured. Tows oriented such that the overall length exceeds the lock chamber require a double lockage. The maximum number of barges allowed in a double lockage is 17. This orientation, while rare, consists of five rows of three barges with two empty “hip” barges straddled along the side of the towboat. The first nine barges enter the lock chamber and are broken free of the remainder. The tow haulage unit moves these through the lock and they are then tied to the guidewall. The towboat with the remaining eight

barges passes through the lock and is rejoined with the nine other barges. Filling and emptying time for the lock under normal conditions is seven minutes. Lockage time for a double lockage depends on the experience of the deck hands breaking and making couplings, number of loaded and empty barges, wind speed and direction, flow conditions, and whether it is an up bound or down bound tow. A down bound tow will take longer due to outdraft conditions at the dam. On average, a double lockage takes about 1.5 to 2 hours.

7-12. Emergency Action Plans. The Emergency Action Plan is a stand-alone document entitled *Emergency Plan for Lock and Dam 4, Alma, Wisconsin*, July 1985. The plan addresses emergencies related to above normal reservoir water levels and/or rapid release of large volumes of water past the dam. It covers identification of impending or existing emergencies and notification of other parties concerning impending or existing emergencies, and emergency operations and repairs. Potential causes of an emergency affecting the operation or safety of Lock and Dam No. 4 include excess seepage, sabotage, mechanical and/or electrical system failure, extreme storm, and failure of the earthen dike.

There are several protective measures taken at Lock and Dam No. 4 when a flood occurs. When the tailwater level is forecasted to go above elevation 666.5 feet (1912 adjustment) plugs are installed in the miter gate curtain walls and the gage house lights are removed. As the pool rises other actions are required. The following gives a brief summary of the steps to be taken as water levels go higher.

**Table 7-8
Flood Emergency Actions at the Dam**

<u>Pool Elevation</u>	<u>Action Taken</u>
668.0 feet	Begin earth dike patrol.
671.5 feet	Lock goes out of operation. Lower miter gates are opened. Remove tainter valve motors and limit switches if forecast elevation is above 674.0 ft.
673.0 feet	Miter gate handrails are removed.
674.0 feet	Remove tainter gate motors and limit switches

7-13 Other. During a flood event, debris is passed beneath the gates as they are typically raised clear of the water. During ice breakup, ice is passed over the submerged roller gates.

7-14 Deviation from Normal Regulation. Project pool elevation is mandated by congress. While in primary control, the pool is to be maintained at elevation 667.0 ± 0.2 feet at the primary control point (Wabasha) as best as possible. During low flows, the pool is not to be intentionally raised above or lowered below this elevation; however, temporary deviations are permitted. Because these deviations are unplanned and are only temporary, while actions are being taken to correct the situation, these exceptions do not require notification of the Division Office. The Division Office (MVD) must be notified when deviation outside the limits set by primary and secondary control is intentional and for a prolonged period of time. A written request describing cause and effect will be sent to the Division Water Control Manager for approval. The District Commander or Chief of Engineering Division may deviate from the approved plan in an emergency situation. The District will inform MVD as soon as possible. This will include a written confirmation of the deviation and description of the cause.

7-15 Rate of Release Change. The only guideline for rate of release change is the “ten percent rule” (**Section 7-04**). During Water Control’s non-duty hours, lock and dam personnel may only make a gate change to remain within the band such that it does not exceed ten percent of the total flow. There are no other guidelines for rate of release change. Operation of the dam is basically run-of-the-river. Therefore, rate of release change is typically nature driven.

VIII – EFFECT OF WATER CONTROL PLAN

- 8-01. General.** The effect of the water control plan for Lock and Dam No. 4 is to maintain a nine-foot depth in the navigation channel of Pool No. 4. Lock and Dam No. 4 is just one piece of the lock and dam system that provides navigation from St. Louis, Missouri to Minneapolis, Minnesota. Navigation on the Upper Mississippi River progressed from a four-foot deep channel in 1866, to a four and one-half foot channel in 1878, to a six-foot channel in 1907, and finally, to a nine-foot channel in the 1930's. A more complete description of this development is available in the Master Water Control Manual for the Locks and Dams.
- 8-02. Flood Control.** The locks and dams provide no flood control benefits. They were constructed strictly for navigation purposes. The dam operates on a run-of-the-river principal. As discharge increases, the gates are opened. At around 89,000 cfs the gates are raised clear of the water surface. Therefore, for flood events, the only impact on the flow line is the swellhead at the dam, which is less than one foot.
- 8-03. Recreation.** The project is not regulated for recreation purposes; however, it does provide recreational benefits. The three recreation qualities associated with Pool No. 4 are fishing, hunting, and boating. Project pool inundated the wing dams, constructed as part of the six-foot navigation project, and created backwater areas, which provide good fish and waterfowl habitat. While Lock and Dam No. 4 provides the necessary depths for the towing industry, it also is a benefit to recreational boating. The more stable water surface provides a more suitable environment for docks and marinas. There were over 12,000 recreation boat lockages in the year 2000.
- 8-04. Fish and Wildlife.** Part of the Upper Mississippi River Wildlife and Fish Refuge is located in Pool No. 4. The Refuge was established in 1924 to preserve the Upper Mississippi River for fish, migratory birds, other wildlife and people. The Refuge includes acreage acquired by the US Fish and Wildlife Service and land

acquired during the 1930's by the US Army Corps of Engineers for the construction of the nine-foot navigation channel. Today, the refuge consists of about 200,000 acres of wooded islands, forest, prairie, marsh, and water extending 261 miles southward from Wabasha, Minnesota to just above Rock Island, Illinois. The refuge still remains relatively untouched by modern civilization.

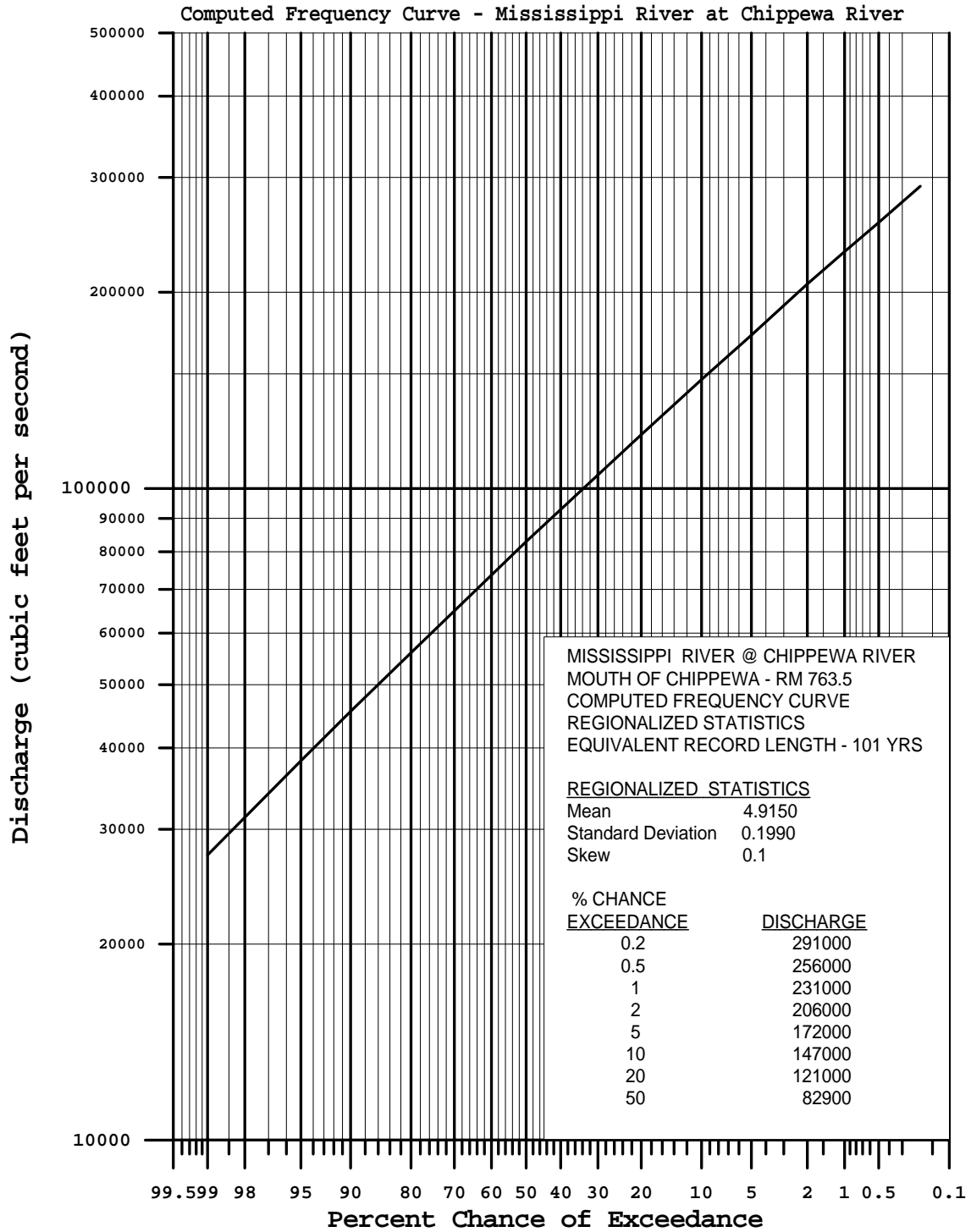
8-05. Navigation. The Upper Mississippi River Nine-Foot Channel Project originated in the 1920's when it was promoted as a way to alleviate the Nation's worsening farm crisis. It was also aimed at allaying the inequities in commercial rail and water freight rates. The project was authorized by the Rivers and Harbors Act of 1930, with most of the locks and dams, including Lock No. 4, being constructed in the 1930's. The project was not without its controversy. For example, railroads claiming damage to their right-of-ways and conservationists fearing its effects on the environment. Ultimately, the economic benefits overrode all other concerns. After completion of the project, river traffic increased from 2,400,000 tons in 1939 to 68,400,000 in 1976. **Table 8-1** shows the recent history of tonnage commodities at Lock and Dam No. 4. For more historical information concerning the Nine-Foot Channel Project, see the Master Water Control Manual for the Locks and Dams.

8-06. Frequencies. The Corps of Engineers developed a discharge-frequency relationship in 2002 for the Mississippi River at the confluence with the Chippewa River. The Chippewa River confluence is just downstream of Lake Pepin and is about ten miles upstream of Lock and Dam No. 4. The frequency curve displayed in **Figure 8-1** represents peak flow relationships near the confluence of the Chippewa River at Mississippi River mile 763.5. The frequency curve is derived from regionalized statistics for the mean and standard deviation, based on the drainage area relationships of the Mississippi River at the mouth of the Chippewa River.

**Table 8-1
Lock and Dam No. 4 Tonnage – Commodities**

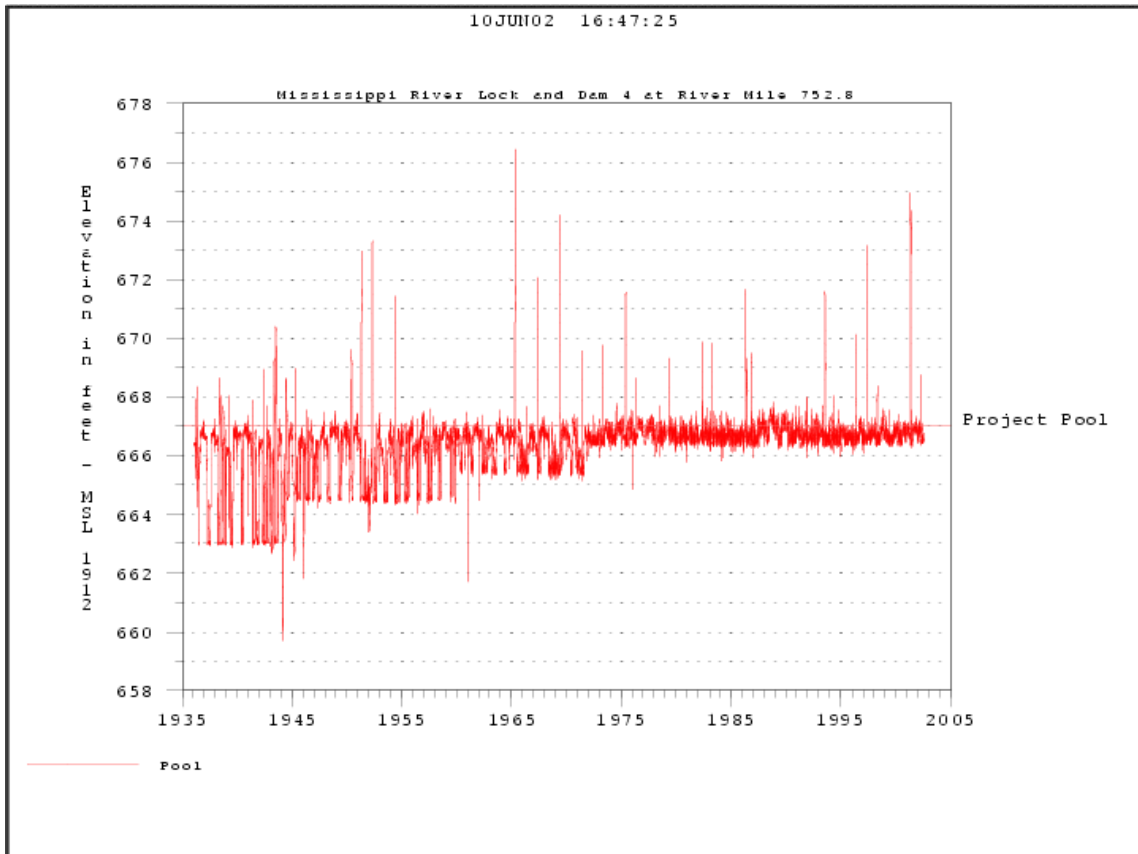
Year	Coal	Petrol Product	Chemical Products	Crude Material	Manu Goods	Farm Products	Equip Mach	Misc Product	Total Tonnage
1991	1,008,000	622,400	1,257,200	724,500	448,600	8,453,500	7,500	0	12,521,700
1992	806,900	285,900	1,690,600	798,100	434,900	9,227,700	23,800	20,000	13,287,900
1993	675,500	186,000	1,620,700	701,900	277,900	4,417,600	73,500	24,600	7,947,700
1994	736,200	262,000	2,053,300	838,200	390,700	5,542,800	12,400	37,100	9,874,500
1995	500,200	537,200	1,642,100	917,800	366,700	6,248,800	14,700	128,900	10,356,400
1996	585,500	435,800	1,845,700	924,900	230,700	7,208,900	21,900	68,500	11,121,900
1997	485,700	547,000	1,442,900	1,134,200	304,500	6,251,100	26,100	121,200	10,312,700
1998	571,200	898,900	1,598,200	1,006,600	509,800	6,694,900	16,000	56,400	11,352,000
1999	597,300	641,300	1,422,200	964,700	657,800	7,975,000	2,200	90,200	12,350,700
2000	563,583	605,554	1,671,485	989,105	561,771	7,166,948	27,112	211,270	11,796,828

Figure 8-1



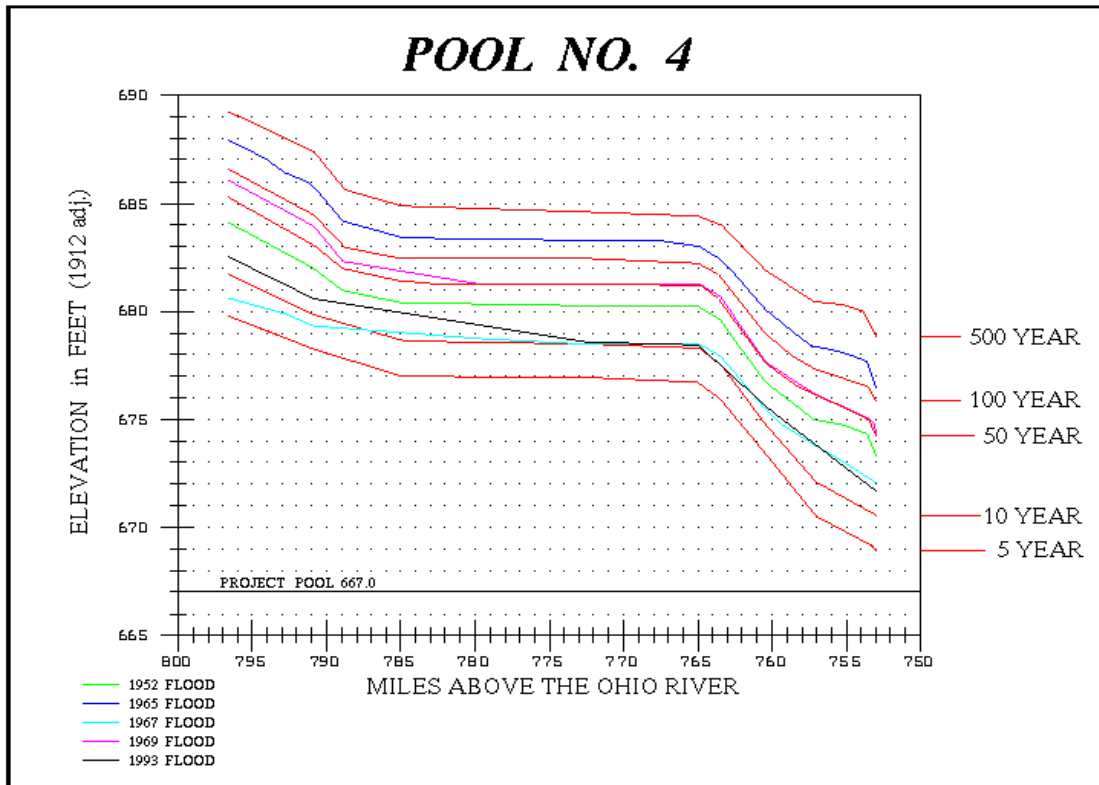
Construction of the dam was completed in June 1935. By March 1936, project pool elevation was achieved. The following shows a history of the pool elevation. The high elevations represent flood events and the lows represent drawdown at the dam (typically secondary control). When in secondary control, the pool elevation at the dam was originally allowed to be drawn down 4.0-feet below project pool level to elevation 663.0 feet (1912 adjustment). This was reduced to 2.5 feet in 1943, then 1.5 feet in 1960, and finally by 1971, drawdown of the pool had been reduced to one half a foot, thus making the secondary control elevation 666.5 feet. Prior to the Anti-Drawdown Law, passed by Congress in 1948, the pools were sometimes drawn down below primary and secondary elevations during the winter months. The greatest drawdown occurred in January 1944 when the pool was draw down to elevation 659.68 feet.

Figure 8-2. History of Pool Elevations



Water surface profile frequencies were developed in 1979 for Pool No. 4. The following figure shows how these profiles compare with historic floods. Note that the flood of 2001 was not documented at the time of this report.

**Figure 8-3. Water Surface Profiles
Flood Frequencies and Historic Floods**



9-02. Interagency Coordination.

- a. **Local Press and Corps Bulletins.** Information concerning regulation of Lock and Dam No. 4 is provided by the St. Paul District's Public Affairs Office (PAO) to the local news media in response to their requests. In addition, Construction and Operations Division coordinates with PAO to provide News Releases regarding the opening or closing of the lock to navigation.

- b. **National Weather Service.** The National Weather Service (NWS) provides the St. Paul District a "Work 10" file daily by 0830-hours. The file contains the five-day forecast for tributaries to the Mississippi River lock and dam system. The five-day forecast includes the 24-hour quantitative precipitation forecast. These hydrographs are input to Mississippi Basin Modeling System which is an unsteady flow model utilizing the computer program UNET. After the model is run, the output is sent electronically to the NWS by 0930-hours. The NWS uses this information to forecast stages along the Mississippi River, which includes Lake City and Wabasha, Minnesota in Pool No. 4.

- c. **US Geological Survey.** To maintain the vast network of stream gages for operation of the locks and dams in the St. Paul District by in-house staff would be a costly undertaking. Because of the existing infrastructure of the US Geological Survey (USGS), the St Paul District enters into a cooperative agreement each year with the USGS to maintain many of the gages on the Mississippi River and its tributaries. As for Pool No.4, this includes the Chippewa River at Durand, Wisconsin gage. St. Paul District owns all the gage equipment. The USGS publishes the daily discharges for this site annually as part of their *Water Resources Data – Wisconsin*. Data are also available from their web site (agency links on www.mvp-wc.usace.army.mil).

- d. US Fish and Wildlife Service.** The St. Paul District coordinates with the US Fish and Wildlife, and other Federal, State, and local agencies to evaluate ways to reduce dredging, increase river safety, develop long-term plans for managing dredge material, enhance fish and wildlife habitat and enhance recreation in Pool No. 4 between the Chippewa River confluence and Lock and Dam No. 4.

The US Fish and Wildlife Service (USFWS) is responsible for the operation and maintenance of several habitat improvement projects constructed in Pool No. 4, including Indian Slough and Peterson Lake habitat enhancement projects. While the aeration culverts to the Finger Lakes are operated and maintained by the St. Paul District, the USFWS establishes the gate settings for the enhancement of fish habitat.

- e. River Resources Forum.** The River Resources Forum and the subcommittee, Water Level Management Task Force, shares information and provides recommendations to the Corps of Engineers on river management. Participants include the US Fish and Wildlife Service, US Geological Survey, US Environmental Protection Agency, National Park Service, US Coast Guard, US Department of Transportation, Departments of Natural resources for Minnesota and Wisconsin, Departments of Transportation for Minnesota and Wisconsin, and representatives of the commercial navigation industry.

9-03. Reports. “Water Log Sheet” is the name for the daily log of river and dam conditions. These are kept at the site. Nation Weather Service (NWS) Form B-91 contains pertinent weather information at the lock site. This is mailed to the NWS on the first of each month. The “Stevens Strip Charts” are sent to Water Control section at a minimum of once a year.

EXHIBIT A
SUPPLEMENTARY PERTINENT DATA

General Information

Location: Mississippi River Mile 752.8
Lat 44° 19' 30" N Long 91° 55' 24" W
Alma, Wisconsin
44.2 miles below Lock and Dam No. 3
14.7 miles above Lock and Dam No. 5

Type of Project: Lock and Dam for Navigation Purposes

Project Owner: Corps of Engineers

Operating Agency: St. Paul District; Construction-Operations Division

Regulating Agency: St. Paul District; Water Control Section

Completion Dates: **Lock:** 5 January 1934
Dam: 26 June 1935 (operational 25 May 1935)

Hydrology

Drainage Areas:

Lock and Dam No. 4:	57,100 square miles
Chippewa River:	9,480 square miles
Cannon River:	1,440 square miles

Design Flood: Flood of 1880
Design High Water: Elevation 673.3 ft
Design Discharge: 175,000 cfs

Minimum Flow: Pre Const: Aug 1934 Discharge 2,200 cfs
Post Const: Aug 1988 Discharge 5,600 cfs

Maximum Flow: 19 Apr 1965: Discharge 269,000 cfs

Average Annual Flow: Years 1959-1993: Discharge 30,700 cfs

Maximum Monthly Flow: April 2001: Discharge 157,700 cfs

Maximum Daily Flow: 19 April 1965: Discharge 254,500 cfs

Key Stream Flow Locations: Mississippi River @ Lake City, Minnesota
Mississippi River @ Wabasha, Minnesota
Chippewa River @ Durand, Wisconsin

Data Recorded at Dam: Pool & Tailwater Elevations (4-hour)
 Roller Gate Discharge (4-hour)
 Tainter Gate Discharge (4-hour)
 Tainter Valve Discharge (4-hour, winter only)
 Total Discharge (4-hour)
 Gate Positions (4-hour)
 Alma, WI (CP 5) Elevation (4-hour)
 Wind Speed & Direction (8-hour)
 Air Temperature (8-hour)
 Control Pt Elevation at Wabasha (8-hour)
 Lake City Elevation (8-hour)
 Chippewa River Stage & Discharge (8-hour)
 Max and Min Air Temperature (daily)
 Water Temperature (daily)
 Precipitation (daily)
 Snow Depth & Snow-Water Equivalent (weekly)
 Percent of Pool & Tailwater Ice Coverage (weekly)
 Pool & Tailwater Ice Thickness (weekly)

Precipitation Gages: Lock & Dam No. 3 and 4
 Chippewa River @ Durand, Wisconsin
 Mississippi River at Lake City, Minnesota

Snow Survey: At Lock and Dam No. 4 (weekly by site personnel)
 Chippewa Basin (late Feb by Gage Crew)
 Mondovi, Osseo, Spring Valley, Menomonie,
 Chippewa Falls, Gilman, Stanley, Hawkins, Ladysmith,
 Cameron, Turtle River, Connersville, Stone Lake,
 Winter, Clam Lake, Couderay, Park Falls, Prentice,
 Bloomer, and Cornell, Wisconsin
 Cannon River Basin (late Feb by Gage Crew)
 Cannon Falls and Elko, Minnesota

Physical Features

Moveable Dam:

Roller Gates:	6 Gates	60 feet by 20 feet
Tainter Gates:	22 Gates	35 feet by 15 feet
Roller Gate Sill:		Elevation 647.0 ft
Tainter Gate Sill:		Elevation 652.0 ft
Roller Gate End Sill:		Elevation 650.0 ft
Tainter Gate End Sill:		Elevation 650.0 ft
Roller Gate Submergence:		3 feet below PP
Tainter Gate Submergence (4 gates):		2 feet below PP
Bulkheads:	Roller Gates: 5 @	4'-2" by 62'-6"
	Tainter Gates: 4 @	4'-2" by 36'-6"
Top of Bridge Deck:		Elevation 695.0 ft

Lock:	Main Lock Chamber:	110 ft by 600 ft
	Top of Lock Walls:	Elevation 672.0 ft
	Top of Upper Gate Sill (main):	Elevation 650.0 ft
	Top of Upper Gate Sill (aux):	Elevation 650.0 ft
	Top of Lower Gate Sill:	Elevation 647.0 ft
	Lock Chamber Floor:	Elevation 646.0 ft
	Height of Upper Miter Gates (main):	20.0 feet
	Height of Splash Guard:	2.0 feet
	Total Miter Gate Height:	22.0 feet
	Top of Miter Gate:	Elevation 672.0 ft
	Height of Upper Miter Gates (aux):	20.0 feet
	Height of Lower Miter Gates:	23.0 feet
	Height of Splash Guard:	2.0 feet
	Total Miter Gate Height:	25.0 feet
	Top of Miter Gate:	Elevation 672.0 ft
	Lift:	7.0 feet
	Upper Guidewall Length:	521 feet
	Lower Guidewall Length:	504 feet
	Freeboard @ Project Pool:	5 feet
	Average Filling/Emptying Time:	7 minutes
	Average Double Lockage Time:	1.5 to 2.0 hours

Pool:	Normal (Project) Upper Pool:	Elevation 667.0 ft
	Normal (Project) Lower Pool:	Elevation 660.0 ft
	Pool Area (at Project Pool):	38,820 acres
	Primary Control Point (Wabasha):	Elevation 667.0 ft
	Secondary Control Point:	Elevation 666.5 ft
	Length in River Miles:	44.2 miles
	Navigation Channel Width;	
	Straight Reaches:	300 feet
	Curved Reaches:	300-550 feet
	Most Frequent Dredge Site:	Crats Island

Aeration Culverts:

Lake Name	Pipe	Discharge (cfs)	
		Summer	Winter
Clear Lake	36-inch RCP	40	5
Lower Peterson Lake	48-inch CMP	40	5
3 rd Lake	36-inch RCP	40	3
2 nd and 1 st Lake Single Intake	48-inch RCP		
2 nd Lake Outlet	48-inch RCP	20	1
1 st Lake Outlet	48-inch RCP	20	2

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

EXPANDED RATING TABLE

TYPE: LOG

05369500

DATE PROCESSED: 04-05-2002 @ 16:41 BY rjwaschb

CHIPPEWA RIVER AT DURAND, WI

DD: 6 TYPE: 001 RATING NO: 27.0

NO OFFSETS USED

START DATE/TIME: 06-20-1993 (0100)

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.30	1375*	1394	1412	1431	1449	1466	1483	1500	1517	1534
.40	1550*	1568	1587	1605	1622	1640	1657	1675	1692	1708
.50	1725*	1743	1761	1779	1797	1814	1832	1849	1866	1883
.60	1900*	1918	1936	1954	1971	1989	2006	2024	2041	2058
.70	2075*	2093	2111	2128	2146	2164	2181	2198	2216	2233
.80	2250*	2268	2286	2303	2321	2338	2356	2373	2391	2408
.90	2425*	2443	2461	2478	2496	2513	2531	2548	2565	2583
1.00	2600*	2618	2635	2653	2671	2688	2706	2723	2740	2758
1.10	2775*	2793	2811	2829	2846	2864	2882	2899	2917	2935
1.20	2952	2970	2987	3004	3022	3039	3056	3074	3091	3108
1.30	3125*	3143	3162	3180	3198	3216	3234	3253	3271	3289
1.40	3307	3325	3343	3361	3378	3396	3414	3432	3450	3468
1.50	3485	3503	3521	3538	3556	3574	3591	3609	3626	3644
1.60	3661	3679	3696	3713	3731	3748	3765	3783	3800	3817
1.70	3834	3851	3869	3886	3903	3920*	3945	3970	3995	4020
1.80	4045	4070	4094	4119	4144	4169	4195	4220	4245	4270
1.90	4295	4320	4345	4370	4395	4420	4446	4471	4496	4521

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
2.00	4547	4572	4597	4622	4648	4673	4698	4724	4749	4774
2.10	4800	4825	4850	4876	4901	4927	4952	4978	5003	5029
2.20	5054	5080	5105	5131	5156	5182	5207	5233	5259	5284
2.30	5310	5335	5361	5387	5412	5438	5464	5489	5515	5541
2.40	5567	5592	5618	5644	5670	5696	5721	5747	5773	5799
2.50	5825	5851	5877	5902	5928	5954	5980	6006	6032	6058
2.60	6084	6110	6136	6162	6188	6214	6240	6266	6292	6318
2.70	6344	6371	6397	6423	6449	6475	6501	6527	6554	6580
2.80	6606	6632	6658	6685	6711	6737	6763	6790	6816	6842
2.90	6868	6895	6921	6947	6974	7000*	7027	7055	7082	7110
3.00	7137	7164	7192	7219	7247	7274	7302	7329	7357	7385
3.10	7412	7440	7467	7495	7523	7550	7578	7606	7633	7661
3.20	7689	7716	7744	7772	7800	7827	7855	7883	7911	7939
3.30	7966	7994	8022	8050	8078	8106	8134	8162	8190	8218
3.40	8246	8274	8302	8330	8358	8386	8414	8442	8470	8498
3.50	8526	8554	8582	8610	8638	8667	8695	8723	8751	8779
3.60	8808	8836	8864	8892	8921	8949	8977	9005	9034	9062
3.70	9090	9119	9147	9175	9204	9232	9261	9289	9317	9346
3.80	9374	9403	9431	9460	9488	9517	9545	9574	9602	9631
3.90	9659	9688	9717	9745	9774	9802	9831	9860	9888	9917
4.00	9946	9974	10000	10030	10060	10090	10120	10150	10180	10200
4.10	10230	10260	10290	10320	10350	10380	10410	10430	10460	10490
4.20	10520	10550	10580	10610	10640	10670	10700	10720	10750	10780
4.30	10810	10840	10870	10900	10930	10960	10990	11010	11040	11070
4.40	11100	11130	11160	11190	11220	11250	11280	11310	11330	11360

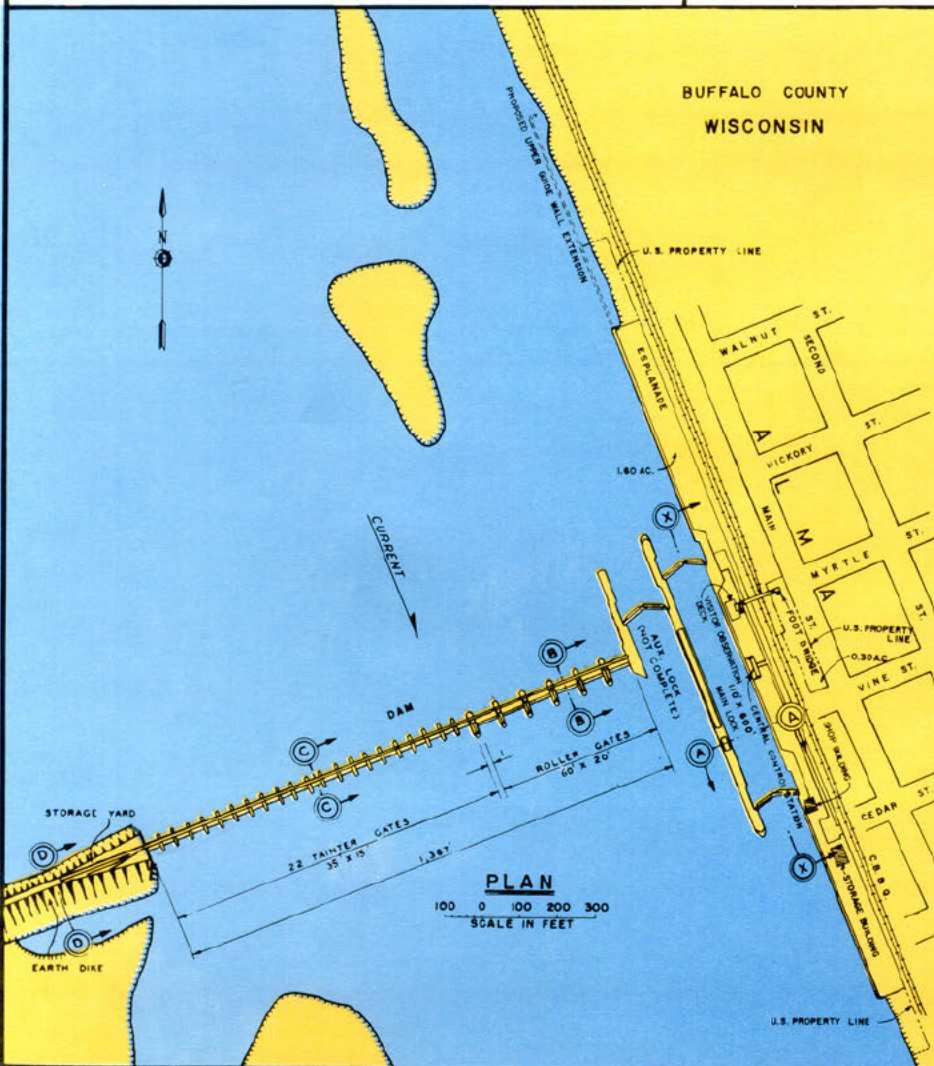
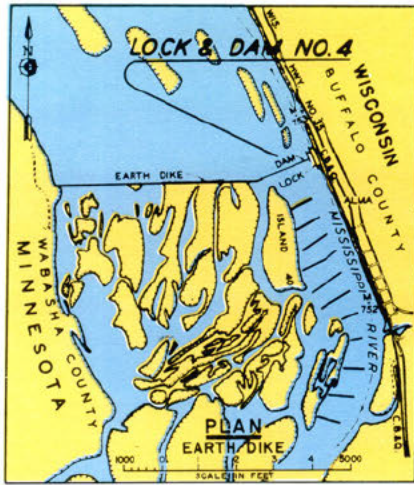
GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
4.50	11390	11420	11450	11480	11510	11540	11570	11600	11630	11660
4.60	11690	11710	11740	11770	11800	11830	11860	11890	11920	11950
4.70	11980	12010	12040	12070	12100	12130	12160	12190	12210	12240
4.80	12270	12300	12330	12360	12390	12420	12450	12480	12510	12540
4.90	12570	12600	12630	12660	12690	12720	12750	12780	12810	12840
5.00	12870	12900	12920	12950	12980	13010	13040	13070	13100	13130
5.10	13160	13190	13220	13250	13280	13310	13340	13370	13400	13430
5.20	13460	13490	13520	13550	13580	13610	13640	13670	13700*	13730
5.30	13760	13790	13820	13860	13890	13920	13950	13980	14010	14040
5.40	14070	14100	14140	14170	14200	14230	14260	14290	14320	14350
5.50	14390	14420	14450	14480	14510	14540	14570	14610	14640	14670
5.60	14700	14730	14760	14790	14830	14860	14890	14920	14950	14980
5.70	15010	15050	15080	15110	15140	15170	15200	15240	15270	15300
5.80	15330	15360	15390	15430	15460	15490	15520	15550	15580	15620
5.90	15650	15680	15710	15740	15770	15810	15840	15870	15900	15930
6.00	15970	16000	16030	16060	16090	16120	16160	16190	16220	16250
6.10	16280	16320	16350	16380	16410	16440	16480	16510	16540	16570
6.20	16600	16640	16670	16700	16730	16760	16800	16830	16860	16890
6.30	16930	16960	16990	17020	17050	17090	17120	17150	17180	17210
6.40	17250	17280	17310	17340	17380	17410	17440	17470	17510	17540
6.50	17570	17600	17630	17670	17700	17730	17760	17800	17830	17860
6.60	17890	17930	17960	17990	18020	18060	18090	18120	18150	18190
6.70	18220	18250	18280	18320	18350	18380	18410	18450	18480	18510
6.80	18550	18580	18610	18640	18680	18710	18740	18770	18810	18840
6.90	18870	18900	18940	18970	19000	19040	19070	19100	19130	19170

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
7.00	19200*	19240	19270	19310	19350	19380	19420	19460	19490	19530
7.10	19560	19600	19640	19670	19710	19750	19780	19820	19860	19890
7.20	19930	19970	20000	20040	20080	20120	20150	20190	20230	20260
7.30	20300	20340	20370	20410	20450	20480	20520	20560	20600	20630
7.40	20670	20710	20740	20780	20820	20850	20890	20930	20970	21000
7.50	21040	21080	21120	21150	21190	21230	21260	21300	21340	21380
7.60	21410	21450	21490	21530	21560	21600	21640	21680	21710	21750
7.70	21790	21830	21860	21900	21940	21980	22010	22050	22090	22130
7.80	22160	22200	22240	22280	22320	22350	22390	22430	22470	22500
7.90	22540	22580	22620	22660	22690	22730	22770	22810	22850	22880
8.00	22920	22960	23000	23040	23070	23110	23150	23190	23230	23270
8.10	23300	23340	23380	23420	23460	23490	23530	23570	23610	23650
8.20	23690	23720	23760	23800	23840	23880	23920	23950	23990	24030
8.30	24070	24110	24150	24190	24220	24260	24300	24340	24380	24420
8.40	24460	24490	24530	24570	24610	24650	24690	24730	24760	24800
8.50	24840	24880	24920	24960	25000	25040	25080	25110	25150	25190
8.60	25230	25270	25310	25350	25390	25430	25460	25500	25540	25580
8.70	25620	25660	25700	25740	25780	25820	25860	25890	25930	25970
8.80	26010	26050	26090	26130	26170	26210	26250	26290	26330	26370
8.90	26410	26440	26480	26520	26560	26600	26640	26680	26720	26760
9.00	26800*	26840	26880	26920	26960	27000	27040	27080	27110	27150
9.10	27190	27230	27270	27310	27350	27390	27430	27470	27510	27550
9.20	27590	27630	27670	27710	27750	27790	27830	27870	27910	27950
9.30	27990	28030	28070	28110	28140	28180	28220	28260	28300	28340
9.40	28380	28420	28460	28500	28540	28580	28620	28660	28700	28740

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
9.50	28780	28820	28860	28900	28940	28980	29020	29060	29100	29140
9.60	29180	29220	29260	29300	29340	29380	29420	29470	29510	29550
9.70	29590	29630	29670	29710	29750	29790	29830	29870	29910	29950
9.80	29990	30030	30070	30110	30150	30190	30230	30270	30310	30350
9.90	30390	30430	30480	30520	30560	30600	30640	30680	30720	30760
10.00	30800*	30860	30930	30990	31050	31120	31180	31250	31310	31380
10.10	31440	31500	31570	31630	31700	31760	31830	31890	31960	32020
10.20	32090	32150	32220	32280	32350	32410	32480	32540	32610	32670
10.30	32740	32800	32870	32940	33000	33070	33130	33200	33270	33330
10.40	33400	33460	33530	33600	33660	33730	33800	33860	33930	34000
10.50	34070	34130	34200	34270	34330	34400	34470	34540	34600	34670
10.60	34740	34810	34870	34940	35010	35080	35150	35210	35280	35350
10.70	35420	35490	35560	35620	35690	35760	35830	35900	35970	36040
10.80	36110	36170	36240	36310	36380	36450	36520	36590	36660	36730
10.90	36800	36870	36940	37010	37080	37150	37220	37290	37360	37430
11.00	37500*	37570	37640	37710	37790	37860	37930	38000	38070	38150
11.10	38220	38290	38360	38430	38510	38580	38650	38720	38800	38870
11.20	38940	39020	39090	39160	39230	39310	39380	39450	39530	39600
11.30	39680	39750	39820	39900	39970	40040	40120	40190	40270	40340
11.40	40410	40490	40560	40640	40710	40790	40860	40940	41010	41090
11.50	41160	41240	41310	41390	41460	41540	41610	41690	41760	41840
11.60	41910	41990	42070	42140	42220	42290	42370	42450	42520	42600
11.70	42670	42750	42830	42900	42980	43060	43130	43210	43290	43370
11.80	43440	43520	43600	43670	43750	43830	43910	43980	44060	44140
11.90	44220	44300	44370	44450	44530	44610	44690	44760	44840	44920

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
12.00	45000*	45090	45190	45280	45370	45470	45560	45650	45750	45840
12.10	45940	46030	46130	46220	46310	46410	46500	46600	46690	46790
12.20	46890	46980	47080	47170	47270	47360	47460	47560	47650	47750
12.30	47850	47940	48040	48140	48230	48330	48430	48520	48620	48720
12.40	48820	48910	49010	49110	49210	49310	49410	49500	49600	49700
12.50	49800*	49900	50010	50110	50220	50320	50430	50540	50640	50750
12.60	50850	50960	51060	51170	51280	51380	51490	51600	51700	51810
12.70	51920	52030	52130	52240	52350	52460	52570	52670	52780	52890
12.80	53000	53110	53220	53330	53430	53540	53650	53760	53870	53980
12.90	54090	54200	54310	54420	54530	54640	54760	54870	54980	55090
13.00	55200*	55310	55430	55540	55650	55760	55880	55990	56100	56220
13.10	56330	56450	56560	56670	56790	56900	57020	57130	57250	57360
13.20	57480	57590	57710	57820	57940	58050	58170	58290	58400	58520
13.30	58640	58750	58870	58990	59100	59220	59340	59460	59580	59690
13.40	59810	59930	60050	60170	60280	60400	60520	60640	60760	60880
13.50	61000*	61120	61230	61350	61470	61580	61700	61820	61940	62050
13.60	62170	62290	62410	62530	62650	62760	62880	63000	63120	63240
13.70	63360	63480	63600	63720	63840	63960	64080	64200	64320	64440
13.80	64560	64680	64800	64920	65040	65160	65290	65410	65530	65650
13.90	65770	65890	66020	66140	66260	66380	66510	66630	66750	66880
14.00	67000*	67120	67230	67350	67470	67590	67700	67820	67940	68060
14.10	68180	68290	68410	68530	68650	68770	68890	69010	69130	69240
14.20	69360	69480	69600	69720	69840	69960	70080	70200	70320	70440
14.30	70560	70680	70800	70930	71050	71170	71290	71410	71530	71650
14.40	71780	71900	72020	72140	72260	72390	72510	72630	72750	72880

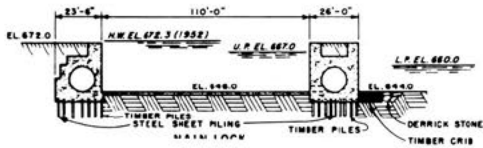
GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)									
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
14.50	73000*	73120	73230	73350	73470	73590	73710	73820	73940	74060
14.60	74180	74300	74420	74530	74650	74770	74890	75010	75130	75250
14.70	75370	75490	75610	75730	75850	75970	76090	76210	76330	76450
14.80	76570	76690	76810	76930	77050	77170	77290	77410	77540	77660
14.90	77780	77900	78020	78140	78270	78390	78510	78630	78750	78880
15.00	79000*	79140	79270	79410	79550	79680	79820	79960	80100	80230
15.10	80370	80510	80650	80780	80920	81060	81200	81340	81480	81620
15.20	81760	81900	82040	82170	82310	82450	82590	82730	82880	83020
15.30	83160	83300	83440	83580	83720	83860	84000	84140	84290	84430
15.40	84570	84710	84860	85000	85140	85280	85430	85570	85710	85860
15.50	86000*	86160	86310	86470	86620	86780	86940	87090	87250	87410
15.60	87560	87720	87880	88040	88190	88350	88510	88670	88830	88990
15.70	89150	89300	89460	89620	89780	89940	90100	90260	90420	90580
15.80	90750	90910	91070	91230	91390	91550	91710	91880	92040	92200
15.90	92360	92530	92690	92850	93020	93180	93340	93510	93670	93840
16.00	94000*									



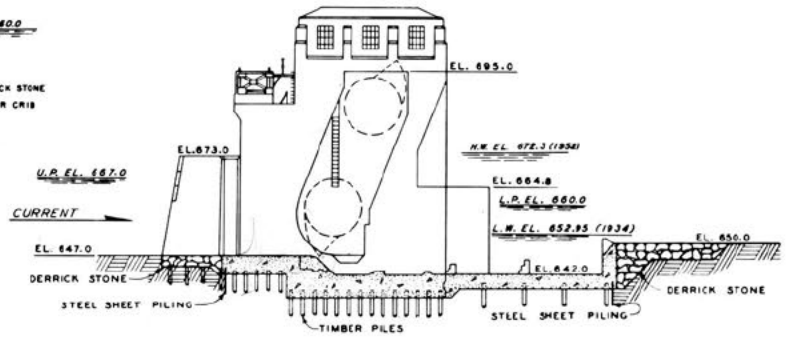
TOTAL LENGTH OF EARTH DIKE 5496.0 FT
 DEPTH ON UPPER GATE SILL - 17.0 FT. (U.P. EL. 667.0)
 DEPTH ON LOWER GATE SILL - 13.0 FT. (L.P. EL. 660.0)
 ELEVATION UPPER GATE SILL - 650.0
 ELEVATION LOWER GATE SILL - 647.0

ELEVATIONS ARE REFERRED TO M.S.L. (1912 ADJ.)

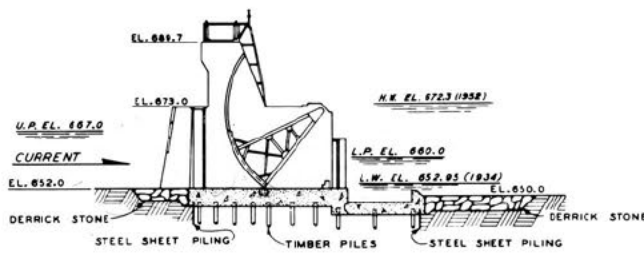
Upper Mississippi River
 Nine-Foot Navigation Project
Lock and Dam No. 4
Project Location Map
 US Army Corps of Engineers
 St. Paul District - 30 Sept 1977



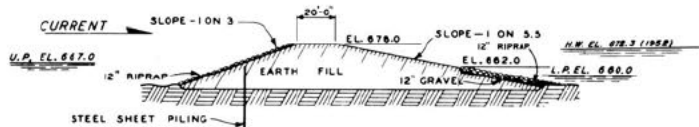
SECTION A-A
LOCK
SCALE IN FEET
0 20 40 60



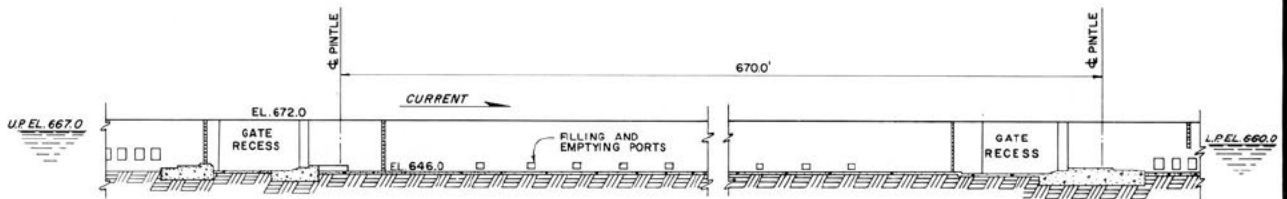
SECTION B-B
ROLLER GATE
SCALE IN FEET
0 10 20 30



SECTION C-C
TAITNER GATE
SCALE IN FEET
0 10 20 30



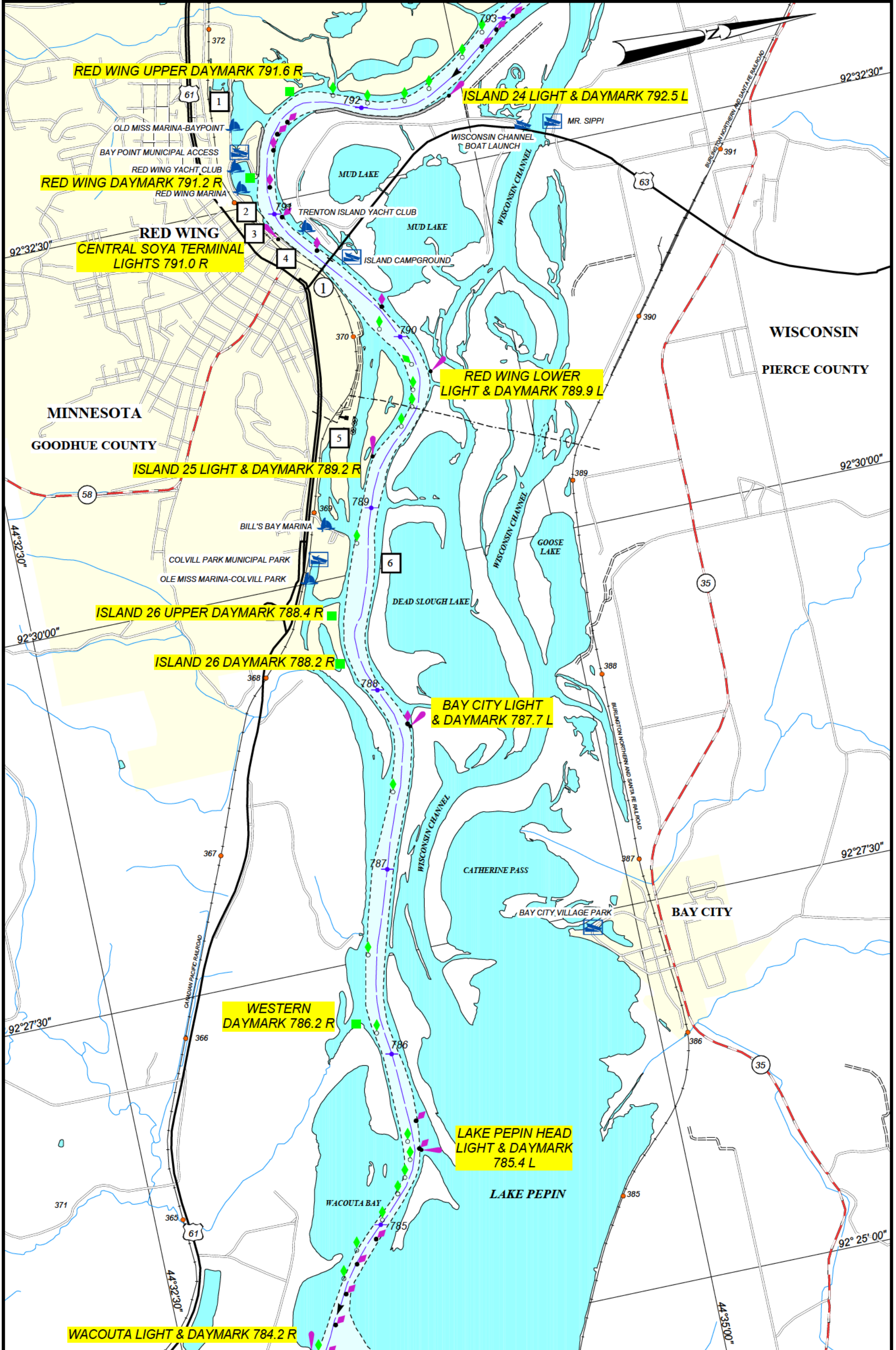
SECTION D-D
EARTH DIKE
SCALE IN FEET
0 20 40 60



SECTION X-X
MAIN LOCK
SCALE IN FEET
0 20 40 60

ELEVATIONS ARE REFERRED TO M.S.L. (1912 ADJ.)

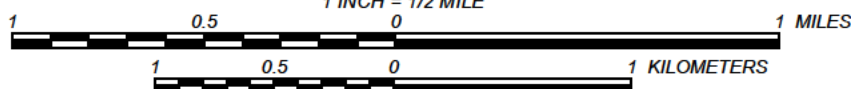
Upper Mississippi River
Nine-Foot Navigation Project
Lock and Dam No. 4
Cross-Sections
US Army Corps of Engineers
St. Paul District - 30 Sept 1977



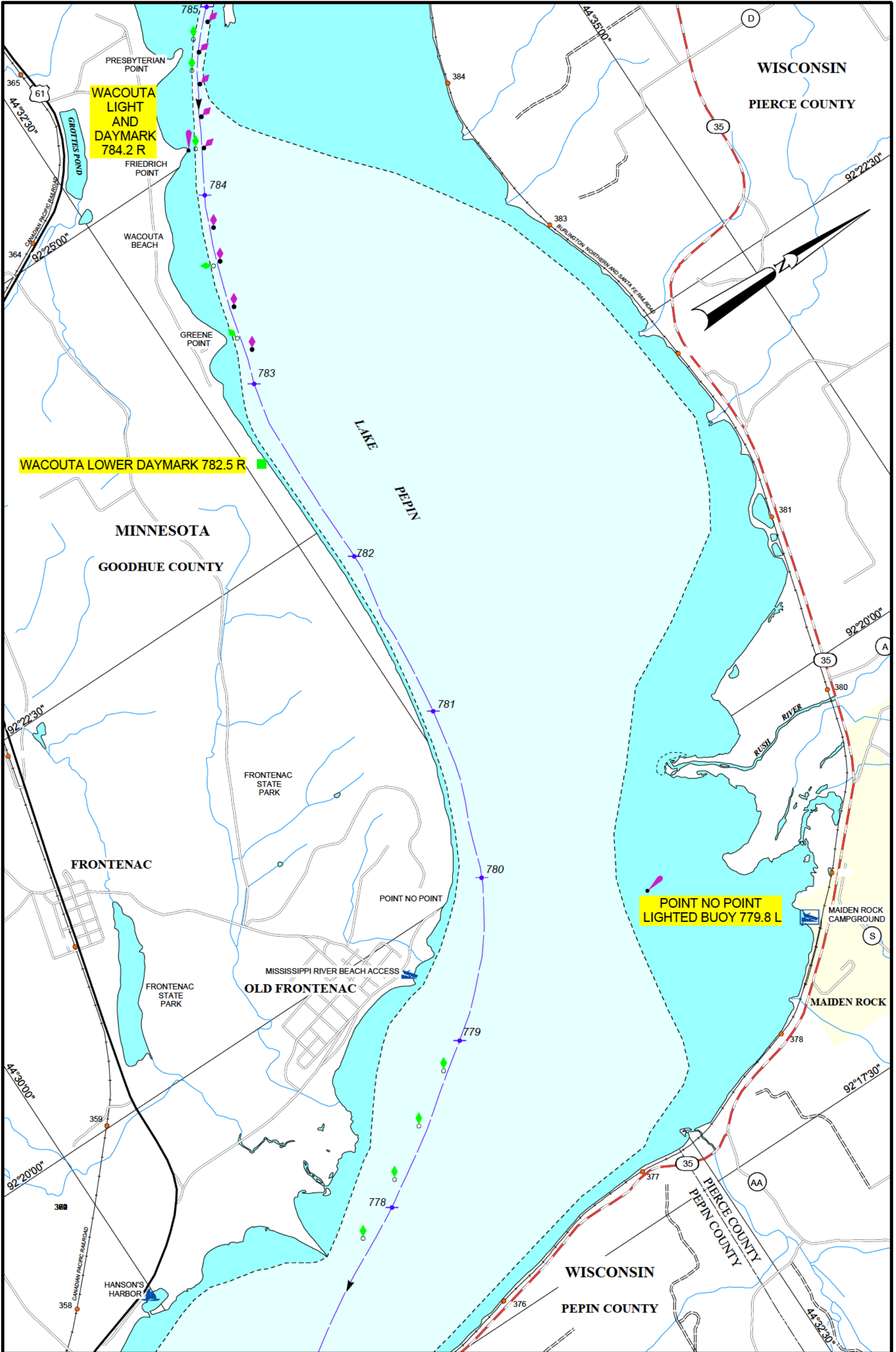
2001

BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO. 1

SCALE 1:31,680
1 INCH = 1/2 MILE



Upper Mississippi River
 Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 785 to 793
 U.S. Army Corps of Engineers
 St. Paul District - St. Paul, MN

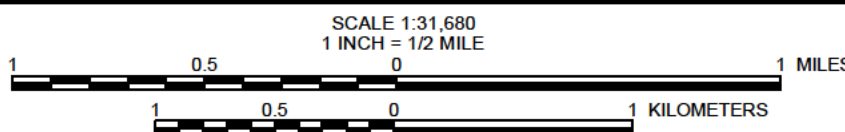


WACOUTA LIGHT AND DAYMARK 784.2 R

WACOUTA LOWER DAYMARK 782.5 R

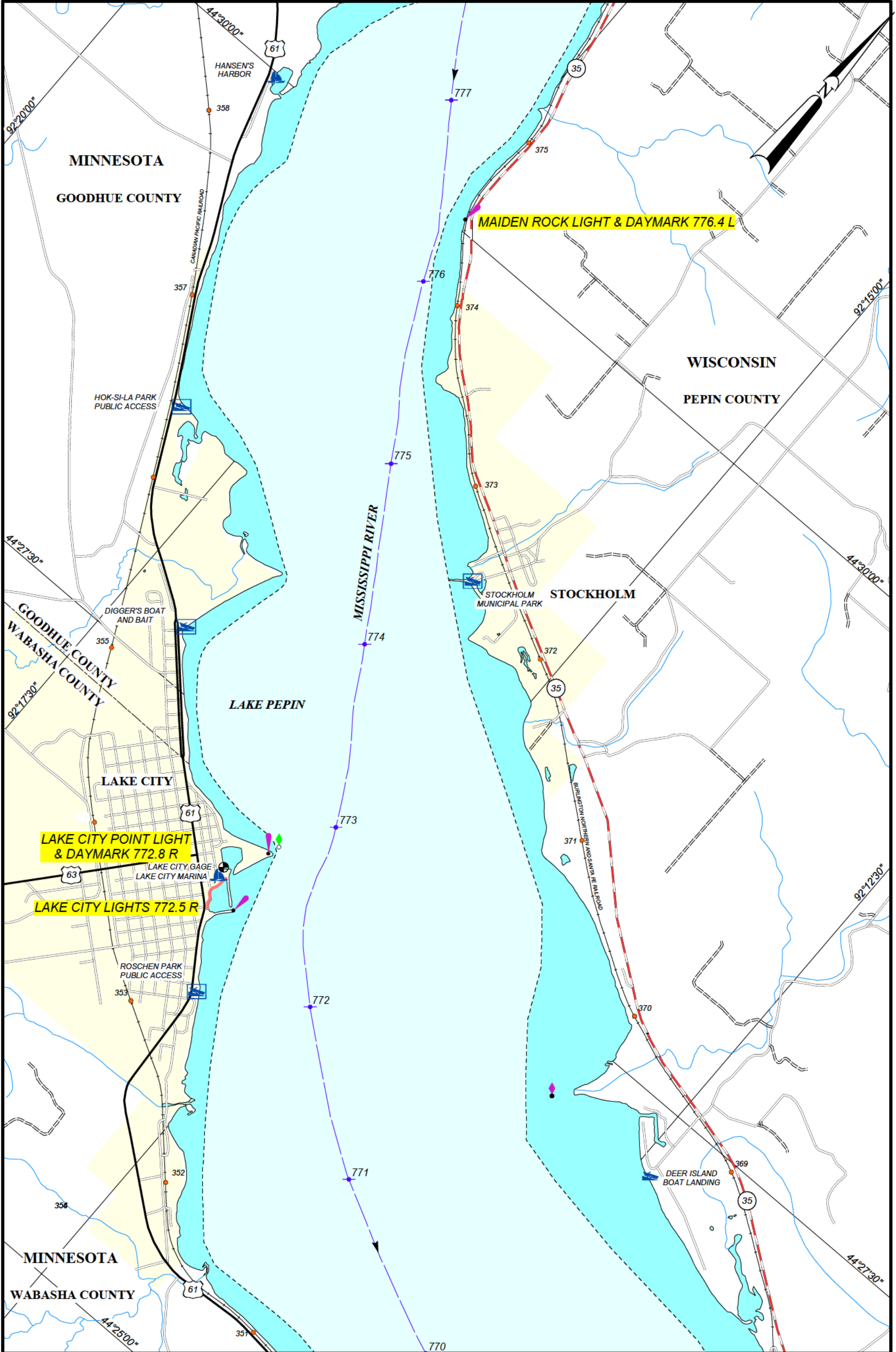
POINT NO POINT LIGHTED BUOY 779.8 L

2001 BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO. 1

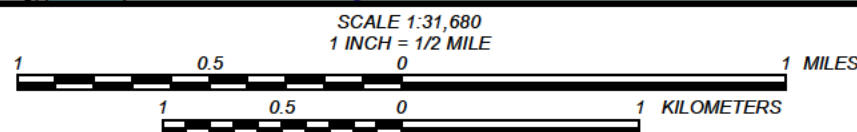


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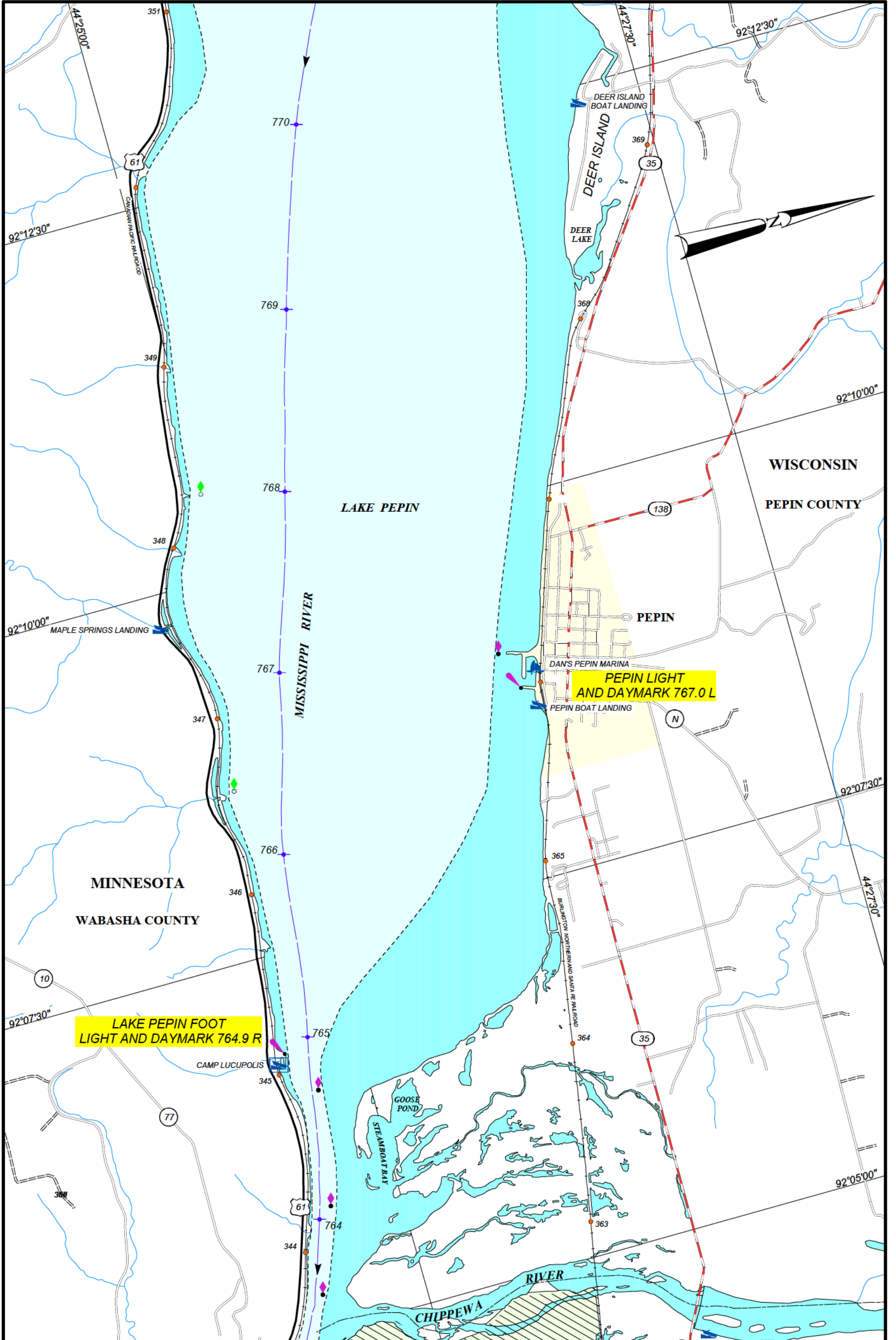
Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 778 to 785
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN



2001 BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO. 1



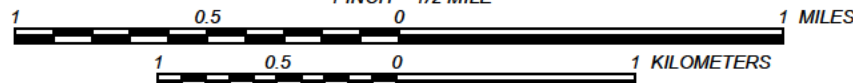
Upper Mississippi River
 Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 770 to 777
 U.S. Army Corps of Engineers
 St. Paul District - St. Paul, MN



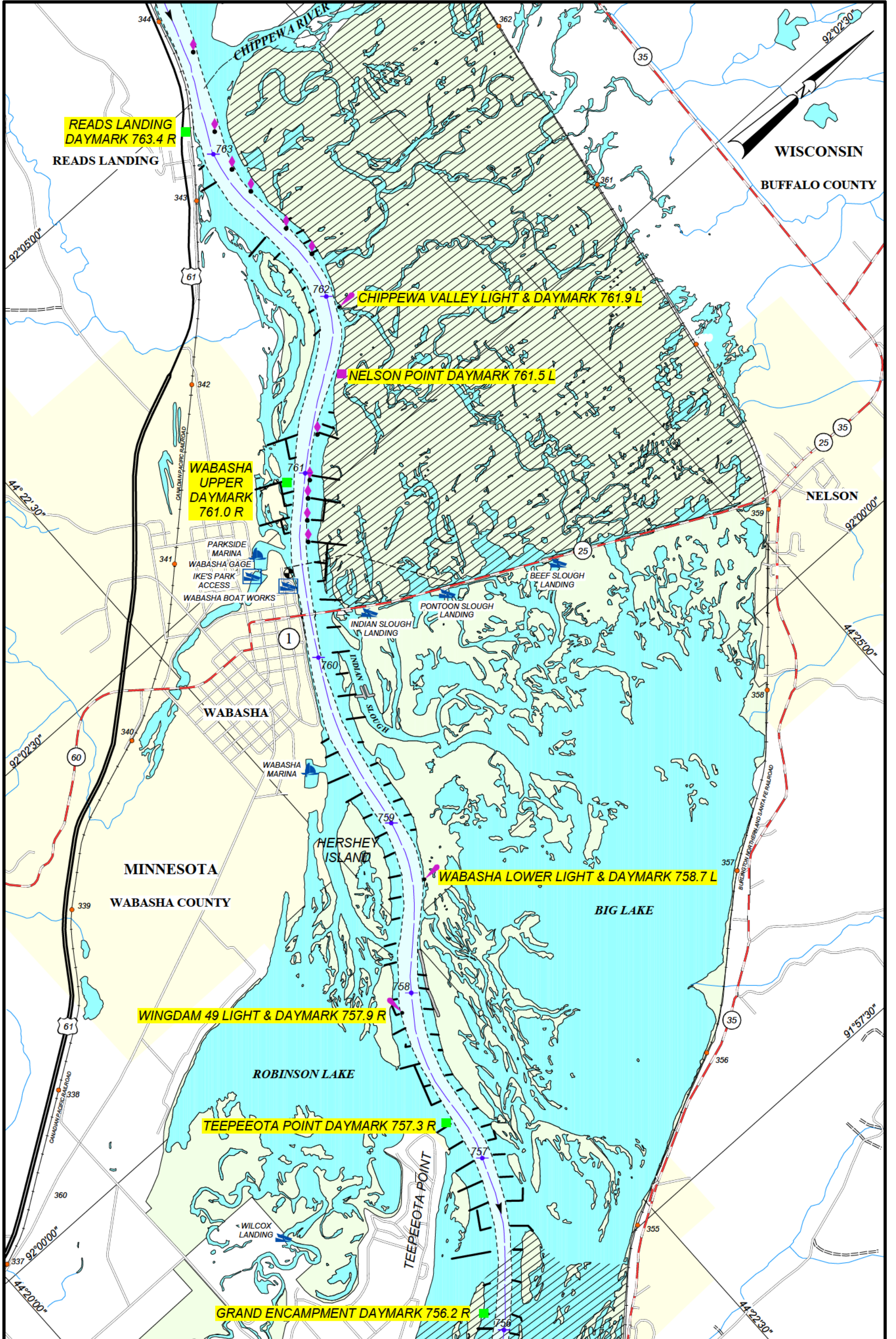
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BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO. 1

SCALE 1:31,680
1 INCH = 1/2 MILE



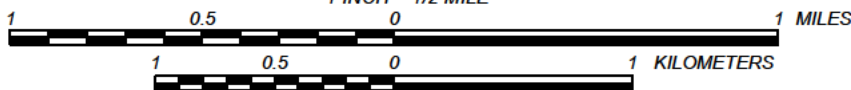
Upper Mississippi River
 Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 764 to 770
 U.S. Army Corps of Engineers
 St. Paul District - St. Paul, MN



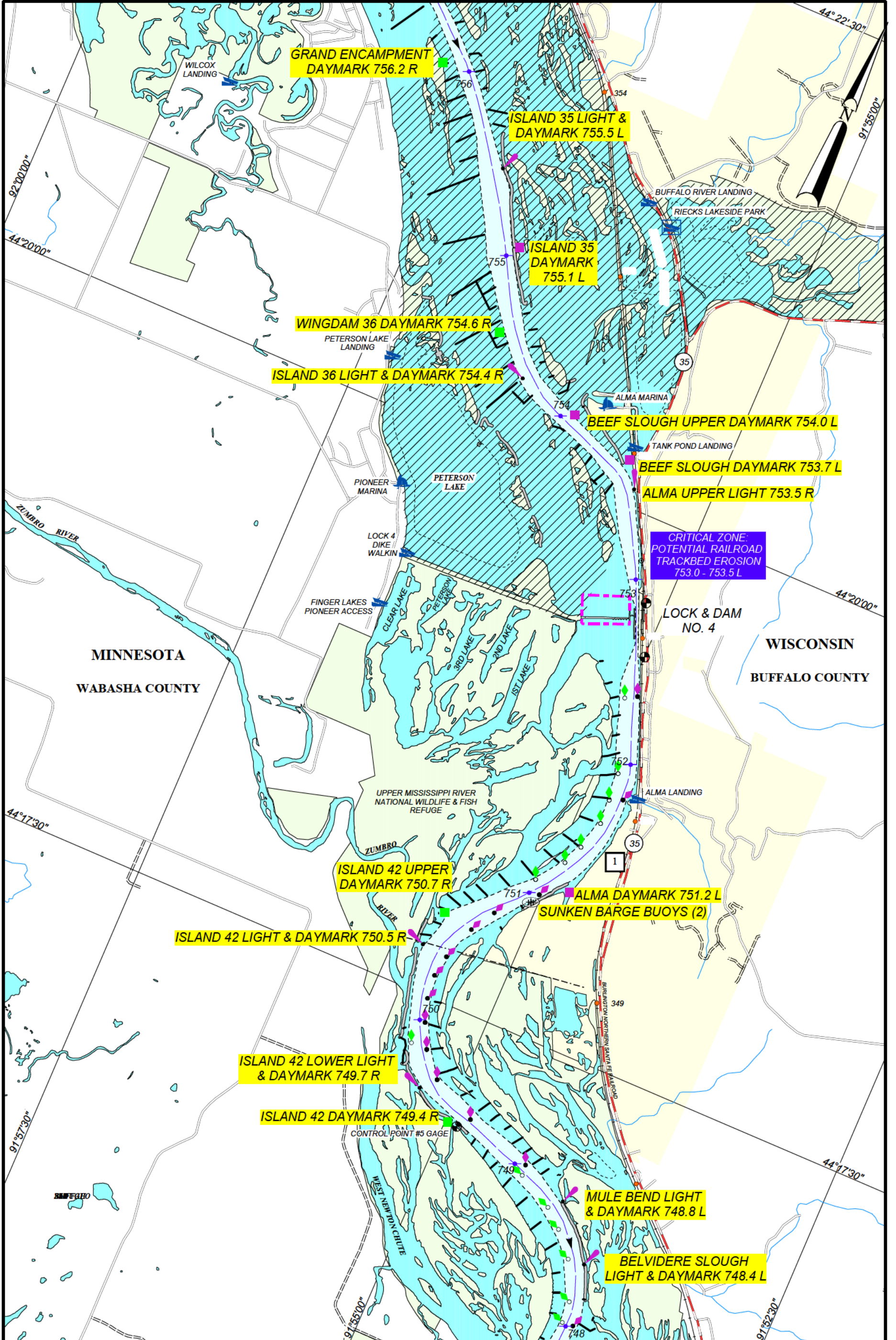
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BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO.1

SCALE 1:31,680
1 INCH = 1/2 MILE



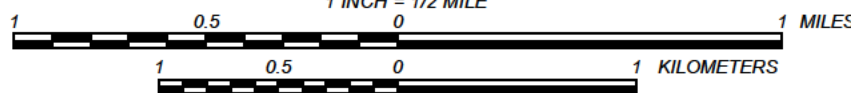
Upper Mississippi River
 Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 756 to 763
 U.S. Army Corps of Engineers
 St. Paul District - St. Paul, MN



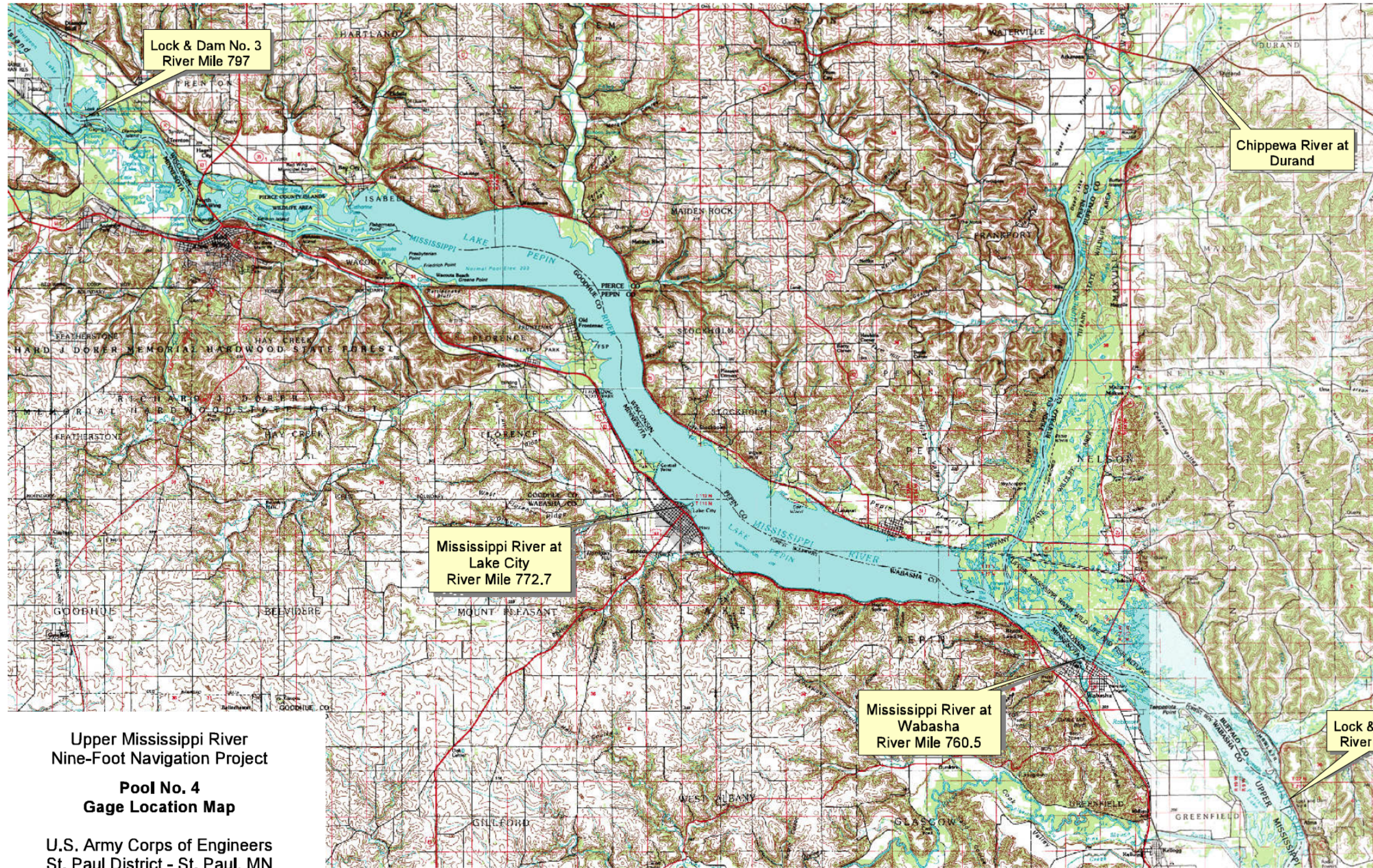
2001

BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO.1

SCALE 1:31,680
1 INCH = 1/2 MILE



Upper Mississippi River
 Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 748 to 756
 U.S. Army Corps of Engineers
 St. Paul District - St. Paul, MN



Upper Mississippi River
Nine-Foot Navigation Project

Pool No. 4
Gage Location Map

U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN

