US Army Corps
of Engineers®
St. Paul District

WATER CONTROL MANUAL

MISSISSIPPI RIVER NINE FOOT CHANNEL
NAVIGATION PROJECT

LOCK AND DAM NO. 5

MINNEISKA, MINNESOTA

APPENDIX 5 OF THE MASTER WATER CONTROL MANUAL

UPDATED SEPTEMBER 2002

WATER CONTROL MANUAL

LOCK AND DAM No. 5
MINNEISKA, MINNESOTA

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

APPENDIX No. 5
Of The
MASTER WATER CONTROL MANUAL

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

SEPTEMBER 2002

Updated from
Reservoir Regulation Manual, July 1970
Operation of Navigation Pools, February 1943

LOCK AND DAM No. 5

MINNEISKA, MINNESOTA

Aerial View Looking Upstream – October 1995

6 Roller Gates and 28 Tainter Gates
Project Pool 660.0 feet (1912 Adjustment)

LOCK AND DAM No. 5

MINNEISKA, MINNESOTA

Lock and Dam No. 5 Control House
Dedicated June 1998

Lock Chamber and Miter Gates in 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 Dams 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. 5 being completed in July 1970. This manual is an update of Appendix No. 5. 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 [redacted]
Duty Regulator	Mississippi River Duty Regulator; Pager and Fax	Pager: 612-660-8053 Fax: 651-290-5841
Farley R. Haase	Hydraulic Technician fraley.r.haase@usace.army.mil	Duty: 651-290-5633 [redacted]
Ferris W. Chamberlin	Hydraulic Engineer ferris.w.chamberlin@usace.army.mil	Duty: 651-290-5619 [redacted]
Robert G. Engelstad	Chief, Water Control Section robert.g.engelstad@usace.army.mil	Duty: 651-290-5610 [redacted]
Michael R. Knoff	Chief, Hydraulics & Hydrology Br michael.r.knoff@usace.army.mil	Duty: 651-290-5600 [redacted]
John J. Bailen	Chief, Engineering Division john.j.bailen@usace.army.mil	Duty: 651-290-5303

Lock and Dam No. 5
Minneiska, Minnesota

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

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Location: Lock and Dam No. 5 is located on the Mississippi River, 738.1 river miles above the mouth of the Ohio River, 14.7 river miles below Lock and Dam No. 4, and 9.6 river miles above Lock and Dam No. 5A. The lock is on the right bank of the river at approximate latitude 44° 9' 42" N and longitude 91° 48' 42" W.

Drainage Area: 58,845 square miles

Datum: MSL - 1912 adjustment

Fixed Height Dam:

Type:	Earth Dike
Total Length	18,219 feet
Crest of Earth Dam	Elevation 670.0 to 672.0 feet
Top Width of Earth Dam	20 feet
Maximum Height of Earth Dam	30 feet

Moveable Dam:

Roller Gates	6 Gates	60 feet by 20 feet
Tainter Gates	28 Gates	35 feet by 15 feet
Roller Gate Sill	Elevation 640.0 feet	
Tainter Gate Sill	Elevation 645.0 feet	
Roller and Tainter Gate End Sill:	Elevation 643.0 feet	
Top of Bridge Deck:	Elevation 688.0 feet	

Lock:

Main Lock Chamber	110 feet by 600 feet
Top of Lock Walls	Elevation 665.0 feet
Top of Upper Gate Sill (Main)	Elevation 642.0 feet
Top of Upper Gate Sill (Auxiliary)	Elevation 639.0 feet
Top of Lower Gate Sill	Elevation 639.0 feet
Lock Floor	Elevation 637.0 feet
Height of Upper Miter Gates (Main)	20.0 feet
Height of Upper Miter Gates (Aux.)	23.0 feet
Height of Lower Miter Gates	23.0 feet

Pool:

Normal (Project) Upper Pool	Elevation 660.0 feet
Normal (Project) Lower Pool	Elevation 651.0 feet
Total Pool Area (at Project Pool)	12,580 acres
Length in River Miles:	14.7 miles
Primary Control Point	Alma, Wisconsin, Elevation 660.0 ft
Secondary Control Point	Lock & Dam 5, Elevation 659.5 ft

Notes:
1. Roller gates are submergible to 3.0 feet below Normal Pool (657.0 feet).
2. Four tainter gates are submergible to 2.0 feet below Normal Pool (658.0 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 the 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 5 Regulation Manual dated July 1970 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. Lock and Dam No. 5 was completed on 9 December 1935. A general scheme of operation was developed on 28 March 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*, Department of the Army, St. Paul District, Corps of Engineers, September 1969.
e. *Mississippi River Nine-Foot Channel Navigation Project, Reservoir Regulation Manual, Appendix 5, Lock and Dam No. 5, Minneiska, Minnesota,* Department of the Army, St. Paul District, Corps of Engineers, July 1970.
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, US Army Corps of Engineers, St. Paul District, September 1983.
h. *Emergency Plan for Lock and Dam No. 5, Minnesota City, Minnesota,* US Army Corps of Engineers, St. Paul District, May 1997.
i. *Scour Protection for Locks and Dams 2-10, Upper Mississippi River*, Technical Report HL-87-4, Department of the Army, Waterways Experiment Station, 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, St. Paul Minnesota, 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*, Department of the Army, 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, St. Paul District, November, 1997.
o. *The Weaver Bottoms Rehabilitation Project, Resource Analysis Program, 1985-1997, Final Report*, US Army Corps of Engineers, US Fish and Wildlife Service, Minnesota and Wisconsin Departments of Natural Resources, September 1998.

p. *Locks and Dams Sounding Reports, Volume 2*, U.S. Army Corps of Engineers, St. Paul District, 1999.

q. 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. 5. The U.S. Army Corps of Engineers, St. Paul District, St. Paul Minnesota, is responsible for regulation of Lock and Dam No. 5.

1-05. Operating Agency. Lock and Dam No. 5 is regulated, operated, and maintained by the U.S. Army Corps of Engineers, St. Paul District. 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. 5.

St. Paul District Office
← ← ← **District Engineer** → → →

↓	↓
Chief Engineering Division	**Chief Con-Ops Division**
↓	↓
Chief H&H Branch	**Chief Lock & Dam Project Office**
↓	↓
Chief Water Control Section	**Area Lockmaster**
↓	↓
Water Control Manager	**Lockmaster**
651-290-5624 → → → → → →	507-689-2101
fax 651-290-5841	fax 507-689-4291

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. 5 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. 5 is located on the Mississippi River, 738.1 river miles above the mouth of the Ohio River, 14.7 river miles below Lock and Dam No. 4, and 9.6 river miles above Lock and Dam No. 5A. The lock is on the right bank of the river 4.3 river miles below Minneiska, Minnesota and 12.4 river miles above Winona, Minnesota at approximate latitude 44° 9' 42" N and longitude 91° 48' 42" W. The project is bordered by Buffalo County on the Wisconsin side and Winona County on the Minnesota side. See **Plate 2-1** for project location.

2-02. Purpose. Lock and Dam No. 5 is a unit of the Inland Waterway Navigation System of the Upper Mississippi River Basin. The system includes 29 locks and dams, which provide 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. 5 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.

2-03. Physical Components. Lock and Dam No. 5 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 following describes the hydraulic feature of each component in detail.

a. Lock. Lock and Dam No. 5 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 642.0 feet and 639.0 feet (1912 adjustment). A walkway is located atop the miter gates. It extends three feet above the top of miter gates (elevation 662.0 feet) to meet the top of lock walls (elevation 665.0 feet). 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 23.0 feet high with a sill elevation of 639.0 feet. The gates of the auxiliary lock have no machinery and therefore are inoperable. However, should a lower 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 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 ten 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.

Figure 2-1. Lock and Dam No. 5 - Looking Upstream

b. Moveable Dam. The moveable dam section extends from the auxiliary lock to the left 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 28 tainter gates, 35-feet wide by 15-feet high (**Figure 2-1**). The sill elevation of the roller gates is 640.0 feet (1912 adjustment), while the tainter gates sill elevation is 645.0 feet. The end sill elevation for both the roller and tainter gates is 644.5. The roller gates can be submerged up to three feet below normal pool (elevation 660.0 feet). Four of the 28 tainter gates can be submerged up to two feet below normal pool.

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 64 feet – 2 inches. The sill elevation is 640.0 feet; therefore, the top of the bulkheads, with five in place, would be at elevation 660.83 feet (i.e. 660 feet – 10 inches).

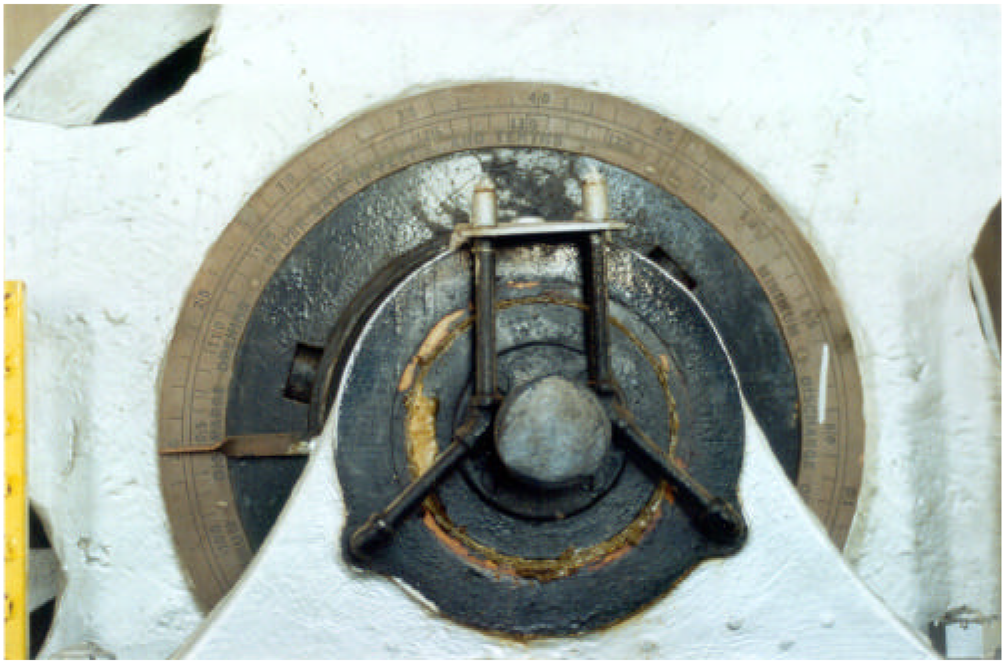

Figure 2-2. Roller Gate Position Indicator

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 37 feet-6 inches. The sill is at elevation 645.0 feet; therefore, with four bulkheads in place, the top elevation would be 661.7 feet (i.e. 661 feet-8 inches).

Figure 2-3. Tainter Gate Position Indicator

A service bridge, at elevation 688.0 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. Sections B-B and C-C of **Plate 2-2** show the original derrick stone protection. Over the years, scour upstream and downstream of the derrick stone caused some unraveling of the derrick stone. In 1983 and 1984, riprap protection was extended upstream and downstream in the form of capstone and rockfill. **Plate 2-3** shows two 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 643.0 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 640.0 feet. The scour holes that formed upstream and downstream of the derrick stone were filled in 1983 and 1984 by a horizontal capstone section, underlain by a rockfill section a minimum of 30-inches thick. Upstream, a 42-inch thick layer of capstone extends 45 feet upstream from the dam. The rockfill section extends upstream about 230 feet for the two roller gates closest to the locks and a minimum of 65 feet upstream for the remaining roller gates. Downstream, a 54-inch thick layer of capstone extends 95 feet downstream of the end sill. The rockfill section extends downstream of the end sill a minimum of 150 feet. The rock surface downstream of the horizontal capstone section slopes down at a rate of 1V:3H. The horizontal capstone was placed to the same elevation as the original derrick stone (elevation 643.0 feet downstream and 640.0 feet upstream).

(2) **Tainter Gates.** Downstream protection originally consisted of derrick stone 4-feet thick with a top of rock elevation of 643.0 feet (1912 adjustment). It extends either 25 or 40 feet downstream of the tainter gates, depending on the location. Upstream, the derrick stone section was 12-feet wide and 3-feet thick with a top of rock elevation of 645.0 feet. The scour holes that formed upstream and downstream of the derrick stone were filled in 1983 and 1984 by a horizontal capstone, underlain by a rockfill section a minimum of 30-inches thick. Upstream, a 42-inch thick layer of horizontal capstone extends 45 feet upstream of the dam and the rockfill extends 65 feet upstream of the dam. Downstream, the horizontal capstone extends 45 to 55 feet from the end sill. The capstone is 10-feet thick where it extends 45 feet downstream and 54-inches thick where it extends 55 feet downstream. The rockfill section extends downstream a minimum of 125 feet of the end sill. The rock surface downstream of the horizontal capstone section slopes down at a rate of 1V:3H. The

horizontal capstone was placed to the same elevation as the original derrick stone (elevation 643.0 feet downstream and 645.0 feet upstream).

(3) **Lock and Guidewalls.** The original scour protection downstream of the lock and along the guidewall was a combination of rock filled cribs and derrick stone. A 20-foot wide, 440-foot long section of rock filled cribs was placed on the riverward side of the intermediate lock wall. Derrick stone 3-feet thick extends from the auxiliary lock to a point 100 feet downstream on the lower guidewall. The top of rock elevation varies from 635.0 feet (1912 adjustment) at the auxiliary lock to 637.0 feet downstream of the main lock. No scour protection was originally placed upstream of the locks.

Additional scour protection was placed along the upper guide wall, upstream of the upper sill, and downstream of the lower apron in the early 1980's. Upstream rock protection was placed along the upper sill and almost the entire length of the upper guide wall. Filling and shaping of the channel bed was required to bring the existing channel bed adjacent to the structure up to the base of concrete elevation of 637.0 feet. Along the upper guide wall, scour protection consists of a 30-inch riprap section with a top of rock elevation of 640.5 feet, which extends horizontally for a distance of 20 feet out from the wall. At that point the riprap slopes at 1V:2H until it intersects the channel bed. The riprap was underlain by a 12-inch thick bedding layer. The scour protection upstream of the upper sill is similar to the upper guide wall protection except that the top of rock elevation was 640.0 feet and the end of the horizontal section it sloped down at 1V:3H to meet the channel bed.

Scour protection downstream was placed along the lock apron between the landward and intermediate lock walls. Scour protection for the lock apron consists of a 30-inch thick layer of riprap underlain by a 12-inch thick bedding layer with a top of rock elevation the same as the apron elevation. Scour protection extends horizontally for a distance of 20 feet after which it slopes down to meet the channel at a slope of 1V:3H.

(4) Storage Yard. Original scour protection upstream of the storage yard consisted of a 12-inch thick layer of riprap placed on a 1V:3H slope from the top of the earth dike at elevation 670.0 feet down to elevation 645.0 feet. Original protection downstream of the storage yard consisted of a 12-inch thick layer of riprap placed on a 1V:3H slope from the top of the berm at elevation 658.0 feet down to intersect the channel bed. Surface riprap was placed between the downstream riprap and the derrick stone protection below the tainter gates to merge the protective layers.

In 1983 and 1984, a 30-inch thick rockfill section was placed along the downstream bank of the storage yard for a distance of 125 feet downstream of the end sill.

d. Earthen Dam. An earthen dam, 18,219 feet in length, extends northwest from the end of the moveable dam section to the high ground on the Wisconsin side of the river (**Plate 2-1**). The dam has a crest elevation that varies from 670.0 feet at the dam to 672.0 feet at the end of the dike, a top width of 20 feet, and a maximum height of 30 feet (**Plate 2-2**). The pool side slope is 1V:3H, while the tailwater slope is 1V:5.5 H. 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 (i.e. 651.0 + 2.0 = 653.0 ft). Within the earthen dam are four aeration culverts. In 1956, a 36-inch corrugated metal culvert was constructed through the earthen dam to provide flow to Indian Creek. At project pool, elevation 660.0 feet, a continuous flow of 70 cfs is maintained through the culvert. Stop logs are stored on site to control the 36-inch culvert when needed. In 1977, three 48-inch corrugated metal culverts were constructed through the upper end of the earthen dam to provide additional flow to downstream areas. At project pool, a combined continuous flow of 320 cfs is maintained through the three culverts. The culverts are sluice gate controlled; however, they are typically left open and closed only when needed, such as during flood events.

2-04. Related Control Facilities. There are no related control facilities to Lock and Dam No. 5; however, several habitat restoration projects have been constructed or are scheduled to be constructed in Pool No. 5. In 1986-87, Mallard Island and Swan Island were constructed in a 4,000-acre backwater marsh called Weaver Bottoms (**Plate 2-5**). The purpose of the islands is to reduce wind and wave action that causes sediment resuspension. For more information see *reference o*.

Figure 2-4. Mallard Island (top-left) and Swan Island – 1987

In 1995, the breach in the Spring Lake peninsula was closed and the entire peninsula was stabilized (**Figure 2-6**). Spring Lake is a 300-acre backwater area located at the south end of Buffalo City, Wisconsin (**Plate 2-5**).

Figure 2-5. Breach Closure of Spring Lake Peninsula

Also in 1995, a general design to construct islands along the west side of Spring Lake was initiated. The new islands will permit over 200 acres of Spring Lake to be maintained as a protected, shallow backwater area for fish and wildlife habitat.

For more information concerning habitat restoration projects in Pool No. 5, see **Chapter IV** section **4-07. Water Quality**.

2-05. Real Estate Acquisition. The Corps of Engineers acquired 7,565 acres of land and water area in fee for the Lock and Dam No. 5 project. Of the Corps of Engineers lands, all but the 2 acres at the Lock and Dam site are under permit to the US Fish and Wildlife Service (USFWS) as part of the Upper Mississippi River Wildlife and Fish Refuge. In addition, the Corps of Engineers holds special rights to 1,363 acres, which is also administered by the USFWS.

2-06. Public Facilities. Lock and Dam No. 5 has one observation platform, picnic tables, and a comfort station with restrooms available for public use. The observation platform is located near the middle of the lock and is handicap accessible. Picnic tables are located at the observation platform and at the upper end of the lock near the restrooms. 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
Pool No. 5 Recreation Facilities

River Mile	Name	Manager	Fee	Slips	Parking	Camp Sites	Toilets	Picnic Tables
752.8 L	Alma Fishing Float				20		Yes	Yes
752.7 L	Alma Public Dock	Alma			10			
752.7 R	Pioneer Landing	MDNR			3			
751.6 L	Alma Landing	WDNR			30		Yes	
747.9 L	Great River Harbor	Private	Yes	30	10	Yes	Yes	Yes
747.5 R	Half Moon Landing	FWS			25		Yes	Yes
746.9 L	Belvedere Slough	WDNR			20			
746.8 R	Good Lake Public Access	MDNR			20			
744.6 R	Weaver Landing	FWS			20		Yes	
744.3 L	Buffalo City Landing	Buffalo City			10			
742.2 L	Upper Spring Lake	Buffalo City			5			
741.2 L	Lower Spring Lake	WDNR			50			
741.8 R	Minneiska Public Access	MDNR			15			

III – HISTORY OF PROJECT

3-01. Authorization. The Lock and Dam No. 5 project was authorized on 3 July 1930 when the 71st Congress, second session, passed an act that modified the existing 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. Typically the water surface is 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.

Congress established a project pool elevation of 660.0 feet (1912 adjustment) for Pool No. 5. In 1935 the primary control point for Lock and Dam No. 5 was determined to be at river mile 751.25. By 1941, the primary control point had been official relocated to river mile 748.5, approximately 3.5 miles downstream of Alma, Wisconsin. Operation of the gage at this location proved to be difficult. It was located off the main channel in a backwater area where sedimentation was a problem in the summer months and icing was a problem during the winter. In 1996, the gage was moved to the right bank of the main channel, 0.8 miles upstream of the old location, at river mile 749.3. While the gage moved upstream, the regulated water surface elevation of 660.0 feet remained unchanged. Therefore, when the pool is in primary condition, the water surface profile is slightly lower than it was prior to 1996. This change has had no impact on navigation. Elevation 660.0 feet is maintained at the primary control point until discharge at the dam is sufficient to allow for a drawdown at the dam. As originally designed, maximum drawdown was 2.5-feet, or elevation 657.5 feet. To maintain a more stable water surface elevation, maximum drawdown was reduced to 1.5-feet in 1960. With the reduced dredging in 1970, maximum drawdown was reduced to 0.5-feet, or elevation 659.5 feet. As discharge increases, the gates are raised to maintain elevation 660.0 feet at the primary control point while a draw down at the dam occurs. After maximum drawdown is achieved, and discharge continues to increase, gates are opened to maintain maximum drawdown. 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 am No. 5 was the flood of 1880. The design high water was elevation 665.5 feet with a flow rate of 178,000 cfs. For Lock and Dam No. 5 the swellhead 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 significant portion of the main channel but still allowed for six roller gates and 28 tainter gates. An earth-fill dike was constructed from the abutment on the Wisconsin side upstream 3.5-miles to high ground. 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.

In 1956, a 36-inch corrugated metal culvert was installed through the earthen dike to provide flow to Indian Creek thereby aerating the water for fish habitat (see **Plate 2-1**). In 1978, three 48-inch corrugated metal culverts were installed through the upper end of the earth dike to provide additional flow to backwater areas (see **Plate 2-1**).

3-03. Construction. Construction of the lock began on 19 December 1932 and was completed on 16 June 1934. Construction of the dam began on 9 October 1933 and was completed on 9 December 1935. The cost of constructing Lock and Dam No. 5 was $3,231,000. The project was placed in operation on 29 May 1935. At an additional cost, the earth dike was completed on 22 April 1935. Other structures (at additional costs) related to the lock and dam are a tainter gate hoist (24 April 1935), power control and lighting system (25 October 1935), and access road on the Minnesota side (22 November 1935).

3-04. Related Projects. Lock and Dam No. 5 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. 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."

b. 1956 Modification. In November 1956, a 36-inch corrugated metal culvert was installed through the earth dike to provide flow to Indian Creek below the dike. It is stop log controlled, but it is primarily left open. The stop logs are stored on site if needed. At project pool, elevation 660.0 feet (1912 adjustment), a continuous flow of 70 cfs is maintained through the culvert to help reduce harmful effects of stagnant water on fish and wildlife in Indian Creek and adjacent downstream backwater areas.

c. 1960 Modification. The original maximum allowable drawdown for Lock and Dam No. 5 was established in 1936 at 2.5-feet. This was based on the concept that further drawdown would result in jeopardizing navigation depths upstream of the dam but would have very little effect on the water surface elevation at the primary control point. To reduce the adverse effects of the drawdown on navigation, riverfront property, and conservation interests, the maximum allowable drawdown was reduced to 1.5-feet (i.e. elevation 658.5 feet). This remained as the secondary control elevation until 1970.

d. 1970 Modification. Maximum allowable drawdown was again reduced in 1970. This was done to maintain amore stable water surface elevation and to account for the reduced dredging effort that began in 1970. Maximum drawdown was reduced to 0.5-feet (i.e. elevation 659.5 feet). This remains today as the secondary control elevation.

e. 1974 Modification. Discharge through the dam was reevaluated in 1974. 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.

f. 1978 Modification. In 1978, three 48-inch corrugated metal culverts were installed in the upper end of the earth dike to provide additional flow to backwater areas below the dike. At project pool, elevation 660.0 feet, a combined continuous flow of 320 cfs is maintained through the three culverts. The culverts are sluice gate controlled, but are primarily left open and only closed during extreme flood events. Along with the single 36-inch culvert constructed in 1956, these three culverts aid in reducing harmful effects of stagnant water on fish and wildlife in downstream backwater areas.

g. 1983 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 1983 and 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, and under emergency situations, this velocity may be exceeded for brief periods (e.g. 15 minutes). Therefore, a new Gate Regulation Schedule was developed showing the new maximum allowable gate openings.

h. **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 662.5 feet. Since the motors were raised, the lock does not go out of operation until the pool is one-half a foot below the top of the lock wall or elevation 664.5 feet.

i. **1995 Modification.** Historically, winter regulation allowed a 0.3-foot drawdown at the primary control point. That is, the target value for primary control was 660.0 ± 0.3 feet. The additional 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 drawdown be abandoned on a trial basis. Further more, they requested Water Control to operate on the high side of the band during winter regulation. The purpose being to keep as much volume of water as possible in the backwater areas to avoid or delay dissolved oxygen depletion. The plan was so successful, the committee officially requested in the year 2000 that this be incorporated as a routine part of the operating plan.

j. **1996 Modification.** The primary control point near Alma, Wisconsin was originally located on the left bank at river mile 748.5, approximately 3.5 miles downstream of Alma. The original location of the control point was effected by backwater and did not always reflect the actual water surface elevation in the main channel. Also, the gage would sometimes freeze up during the winter months. In the summer of 1996, the gage was moved to the main channel, 0.8 miles upstream. The primary control point is now located at river mile 749.3 on the right bank, approximately three miles downstream of Alma.

k. 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. A new Gate Regulation Schedule is presented in (**Table 7-2**).

3-06. Principal Regulation Problems.

a. Outdraft. An outdraft problem exists at Lock and Dam 5 for down bound tows. A permanently mounted sign is displayed at the end of the guidewall when flows are above 70,000 cfs to alert down bound tows.

b. Aeration Culverts. The single 36-inch culvert constructed through the earth dike in 1956 and the three 48-inch culverts constructed in 1978 require periodic removal of debris.

c. Zebra Mussels. The infestation of zebra mussels could have significant impact on 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 1989-1990, it was noted that zebra mussels had attached themselves in sporadic fashion along the lock culverts and other areas. 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 3-1 Zebra Mussel Control Techniques		
Code	**Method**	**Description**
A	Physical Removal	Removed by scraping, brushing, or high-pressure water or steam spraying.
B	Mollusicides	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 3-2 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. 5 totals 58,845 square miles in Minnesota and Wisconsin. At project pool elevation of 660.0 feet (1912 adjustment), the pool has a total surface area of 12,580 acres. Except for several small creeks, the only major tributary that flows into Pool No. 5 is the Zumbro River, with a total drainage area of 1,380 square miles. The Zumbro River enters the pool from the Minnesota side of the Mississippi River about three miles below Lock and Dam No. 4.

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. Presented here is a description of the topography for the Zumbro River, the only major tributary to Pool No. 5. The Zumbro River basin covers an area of about 1,380 square miles located in south eastern Minnesota, just downstream of Lock and Dam No. 4. The basin encompasses all or portions of Steele, Goodhue, Olmsted, Rice, Wabasha, and Dodge counties. The drainage basin in the upper reaches of the Zumbro River is gently undulating agricultural land. East of Rochester the watershed area is a plateau-like surface dissected by narrow, steep-walled gorges and by tributary coulees, hollows, or ravines. Rochester is located in a bowl-shaped valley about two miles in diameter surrounded by bluffs cut by the valleys of the South Fork and its tributaries at that point. Beginning in the Rochester area and extending downstream, the river valleys become sharply defined and the adjacent rock walled bluffs rise on steep gradients to heights of 100 to 200 feet above the valley floor. At Zumbro Falls, Minnesota, about 24 miles west of the mouth of the river, the valley floor is about 160 feet below the uplands and approximately one-eight of a mile wide. Between Zumbro Falls and Kellogg, the upland areas are as much as 500 feet above the valley floor, which in several places is a mile wide. Near Kellogg, the Zumbro River leaves a well-defined valley and crosses a wide, gently sloping area before entering the Mississippi River. Average elevations vary from about 1,300 feet in the upland areas south of Rochester to about 1,000 feet at Rochester and 680 feet near the junction of the Zumbro and the Mississippi Rivers. Other than some small marsh-type impoundments, there are no natural lakes in the basin.

4-03. Sediment. Part of the nine-foot navigation plan authorized by Congress included periodic dredging of sediment. There are eight sites within the Pool No. 5 navigation channel that require periodic dredging. 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. 5. Pan evaporation data was collected at Lock and Dam No. 6, but stopped after 1997. The data shown in the following tables is from the National Oceanic and Atmospheric Administration's *Climatological Data Annual Summaries*. The nearest climate data station to Lock and Dam No. 5 is Minnesota City, Minnesota. Temperature data shown in **Table 4-1** was taken from Winona, Minnesota as it was unavailable for Minnesota City. Precipitation data shown in **Table 4-2** is from Minnesota City, Minnesota except where noted. 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
14.1	19.5	32.0	46.6	58.5	68.0	73.2	69.7	60.8	49.7	35.3	19.8	45.6

Table 4-2
30-Year Normal Monthly Precipitation in Inches

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
0.96**	0.72	1.87*	3.01	3.74	3.77	4.45	3.84	3.84	2.45	1.70*	1.12	31.47

*values from Winona, Minnesota
**values from divisional data

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. 5. While this information is valuable for the regulation of the dam, it is of little value for representing 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												
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 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, assume 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 Zumbro River basin can have a significant impact on water levels in Pool No. 5 during low flows, it is high inflows from upstream that produce flooding of the pool. After construction of the Lock and Dam in 1935, the first significant flood events didn’t occur until spring of 1951. On the 18th of April, the Mississippi River at Pool No. 5 crested at elevation 664.24 (1912 adjustment). This stage was exceeded the following year. On 20 April 1952, Pool No. 5 peaked with a pool gage elevation of 664.59 feet. Estimated discharge was 190,500 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**						
Dam No. 4 Tailwater			**Lock and Dam No. 5**			
Date	Stage Ft	Elev. ft (1912)	Date	Pool ft (1912)	Tailwater ft (1912)	Discharge cfs
17-Apr-51	16.20	672.20	18-Apr-51	664.24	663.30	-
19-Apr-52	16.30	672.30	20-Apr-52	664.59	663.84	~190,500
19-Apr-65	**19.78**	**675.78**	**19-Apr-65**	**668.73**	**667.85**	**270,000**
6-Apr-67	15.35	671.35	6-Apr-67	663.25	662.56	168,000
18-Apr-69	17.53	673.53	19-Apr-69	665.84	665.10	218,000
25-Jun-93	14.93	670.93	26-Jun-93	662.77	662.18	168,600
11-Apr-97	16.40	672.40	12-Apr-97	664.28	663.58	189,100
17-Apr-01	18.15	674.15	17-Apr-01	666.55	665.70	228,300

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 on 19 March 1965. Forecast for the Lock and Dam No. 5 pool are translated from the forecast for Winona. The forecast for Winona indicated that the flow in the Mississippi River would peak at 127,000 cfs. The operating curves in use in 1965 at Lock and Dam No. 5 showed that for this flow, Pool No. 5 would reach elevation 660.7 feet (1912 adjustment). The forecast also cautioned that if rainfall of one inch should occur before or during the crest, the resulting peak stages would be near the 1952 level. This would result in Pool No. 5 peaking at elevation 664.6 feet with an outflow of 190,500 cfs. Moderate to heavy rains early in April increased the water content of the snow on the ground. On the 9th of April, the Weather Bureau revised the forecast for Pool No. 5 to elevation 667.4 feet with a discharge of 240,000 cfs. Based on this, the lock gate operating motors had to be removed, and the central control station, dwellings, and esplanade had to be protected by sandbags. Additional rainfall in the period between the 8th and 12th of April caused another upward revision in the forecast for Pool No. 5. On the 16th of April, the forecast for Pool No. 5 was raised to elevation 668.5 feet with a discharge of 255,000 cfs. The rapid increase of inflow began on the 1st of April when the discharge rose from 13,800 cfs on this date to 78,500 cfs on the 8th of April. By this time the head at the dam had been reduced to less than one-foot and the gates were removed from the water. The motors that operate the lock miter gates were pulled on the 13th of April when the pool reached an elevation 662.5 feet, thus shutting the lock down to navigation. The pool at Lock and Dam No. 5 crested on the 19th of April at elevation 668.73 feet with a peak flow 270,000 cfs. The pool fell below elevation 662.5 feet on the 29th of April. The pool returned to secondary control (elevation 658.5 feet) and the lock reopened to navigation on the 6th of May.

The South Fork of the Zumbro River at Rochester, Minnesota had record flooding in March 1965, but only had minor flooding in April 1965. A crest of 13.55 feet (flood stage is 12.0 feet) was reached on the 6th of April. Flooding on the main stem of the Zumbro River was more severe. On the 7th of April, a stage of 44.51 feet was recorded at Theilman, Minnesota (flood stage is 38.0 feet). This stage was within 1.25 feet of the record March 1965 flood, where a stage of 45.75 feet was reached. The previous flood of record was 43.43 feet in July 1951.

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 an elevation of 673.0 feet (1912 adjustment) for the tailwater of Lock and Dam 4 and 659.1 feet for Winona, Minnesota. On the 11th of April, Lock and Dam No. 4 tailwater crested at elevation 672.40 feet and Alma crested at 669.39 feet. On the 12th of April, Winona crested at elevation 658.42 feet. The pool at the dam crested on the 12th of April at elevation 664.28 feet and the peak discharge was 189,100 cfs. The lock was closed to navigation for 7 days from the 8th to the 15th of April.

c. **April 2001.** The National Weather Service's 2001 Spring Snowmelt Flood Outlook predicted minor to moderate flooding for Pool No. 5. 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. 5. In the early morning of 16 April, the tailwater stage at Lock and Dam No. 4 peaked at 674.10 feet (1912 adjustment) and Alma crested at 672.03 feet. On the 17th of April, the pool at Lock and Dam No. 5 peaked at elevation 666.55 feet with a discharge of 228,300 cfs. The pool reached the closure elevation of 664.5 feet on the 14th of April and did not fall below elevation 664.5 feet until the 23rd of April. However, additional rainfall runoff resulted in a second crest of elevation 665.85 feet on the 29th of April. The pool fell below elevation 664.5 feet on the 3rd of May, but the lock did not reopen to navigation until the 9th of May. While the lock may have been in operation before the 14th of April, the Coast Guard closed the river to navigation from the 9th of April to the 9th of May. By this time the pool had fallen to elevation 661.1 feet.

4-06. Runoff Characteristics. The mean annual discharge at Lock and Dam No. 5 is 31,600 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
16,200	16,400	33,100	66,300	53,200	40,900	32,700	22,300	24,500	26,500	26,800	20,300

The maximum discharge of 270,000 cfs occurred, at the dam, on 19 April 1965 (**Table 4-5**). The minimum discharge of 2,400 cfs occurred on 13 December 1980. A discharge frequency curve for the Mississippi River at the confluence with the Chippewa River in Pool No. 4 is shown on **Figure 8-1**. The following table shows the discharge-duration at the dam.

Table 4-7
Discharge-Duration at Lock and Dam No. 5
Percent Time At or Above Indicated Discharge (Years 1972-2000)

Discharge	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
175,000				0.8									
170,000				0.9									
165,000				1.3	0.3	0.5							0.2
160,000				1.6	0.4	0.7							0.2
155,000				2.0	0.4	0.7	0.2						0.3
150,000				2.2	0.6	0.7	0.3						0.3
145,000				2.5	0.7	0.8	0.4						0.4
140,000				3.0	0.9	0.8	0.7						0.4
135,000			0.1	3.3	0.9	0.8	0.8		0.3				0.5
130,000			0.2	4.0	1.0	0.8	0.9		0.5	0.2			0.6
125,000			0.7	5.4	1.5	0.9	1.8		0.6	0.3			0.9
120,000			1.0	6.3	2.1	0.9	1.9		0.6	0.4			1.1
115,000			1.1	7.1	2.9	1.0	2.1		0.7	0.4			1.3
110,000			1.6	8.3	3.9	1.0	2.1		0.7	0.6			1.5
105,000			1.8	10.9	5.0	1.0	2.1		0.8	0.7			1.9
100,000			2.3	15.3	6.8	1.7	2.1		0.8	0.7			2.5
95,000			2.9	19.4	8.6	2.8	2.8	0.1	0.8	1.1			3.2
90,000			4.2	24.4	11.7	3.7	3.2	0.2	0.9	1.9			4.2
85,000			5.7	29.3	15.6	4.4	3.9	0.3	0.9	2.2			5.2
80,000			7.9	33.9	19.5	4.9	4.3	0.4	0.9	2.9	0.1		6.3
75,000			9.9	40.1	26.6	6.6	5.0	0.6	1.2	3.6	0.2		7.8
70,000			11.8	45.6	32.4	9.7	7.3	1.7	1.4	4.0	0.5		9.6
65,000		0.2	14.0	52.8	40.5	12.1	10.5	3.8	1.7	5.1	1.2		11.9
60,000		0.6	17.1	59.7	45.7	16.6	14.0	5.1	2.5	6.6	3.8		14.4
55,000		0.7	20.1	65.6	50.6	23.3	20.5	6.3	5.3	9.9	6.0	0.1	17.4
50,000		0.9	24.9	71.5	54.6	32.2	27.7	8.3	8.1	13.5	8.6	1.2	21.0
45,000		1.5	29.5	76.2	60.5	40.3	33.9	12.5	12.9	15.8	12.9	2.1	24.9
40,000	0.1	2.0	35.0	80.0	66.7	51.4	43.3	17.6	19.0	20.6	18.2	4.5	30.0
35,000	0.6	3.7	43.8	82.8	72.8	64.3	50.6	26.5	27.5	27.1	31.5	10.9	36.9
30,000	4.78	5.2	54.3	87.8	78.1	74.1	61.5	36.5	36.8	36.8	46.7	21.0	45.4
25,000	17.6	13.9	65.1	93.5	83.8	79.2	70.0	49.5	47.8	48.1	61.3	39.0	55.9
20,000	36.0	33.5	77.1	98.2	91.0	84.3	76.8	65.5	61.8	63.3	76.4	57.3	68.6
15,000	67.7	70.2	90.6	99.5	95.1	92.0	84.5	80.5	78.2	76.1	91.2	74.7	83.4
10,000	93.1	91.1	98.1	100.0	100.0	97.6	93.7	91.2	95.1	94.8	95.9	89.1	95.0
5,000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.77	99.2	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 three elevation-duration tables were developed for the pool, the control point near Alma, Wisconsin, and the tailwater. The tables indicate the percent of time the water surface is at or above the indicated elevation (1912 adjustment). Gage zero for the pool and tailwater is elevation 648.65 feet, while gage zero for the control point near Alma is elevation 600.00 feet.

Table 4-8
Elevation-Duration, Lock and Dam No. 5 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
663.0				1.0									
662.8				1.0									
662.6				1.4	0.2	0.3							0.2
662.4				1.5	0.3	0.6							0.2
662.2				2.0	0.3	0.7							0.3
662.0				2.0	0.4	0.7	0.1						0.3
661.8				2.3	0.4	0.7	0.2						0.3
661.6				2.4	0.6	0.7	0.3						0.3
661.4				2.4	0.6	0.8	0.4						0.4
661.2				2.8	0.7	0.8	0.4						0.4
661.0				2.9	0.8	0.8	0.6		0.1				0.4
660.8				3.3	0.8	0.8	0.7		0.5				0.5
660.6			0.3	3.7	0.9	0.8	0.7		0.8				0.6
660.4		0.1	0.4	3.9	0.9	1.0	1.1	0.1	0.9	0.2	0.2		0.8
660.2	1.0	0.7	2.5	4.9	1.9	1.8	4.3	3.2	5.3	4.8	3.0	2.1	3.0
660.0	10.6	9.0	7.9	8.4	5.2	8.6	13.9	19.8	21.3	23.6	17.4	17.3	13.6
659.8	27.8	33.7	24.4	18.7	18.4	29.8	32.4	45.9	48.3	49.5	43.5	51.6	35.3
659.6	61.0	67.8	56.6	50.6	52.4	64.1	63.2	75.0	76.2	80.8	75.5	77.0	66.7
659.4	90.2	90.6	89.0	88.7	92.2	93.6	94.2	95.8	95.5	95.8	95.9	93.6	92.9
659.2	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 the Control Point near Alma, WI
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
668.50				1.2	0.4								0.1
668.00				1.7	0.6	0.6							0.3
667.50				2.5	1.0	0.9	0.3						0.4
667.00				3.2	1.0	1.0	0.6						0.5
666.50				4.1	1.0	1.0	0.9		0.3				0.6
666.00			0.4	5.6	1.1	1.2	2.1		0.7	0.1			0.9
665.50			1.0	8.1	2.5	1.3	2.4		0.7	0.5			1.4
665.00			2.5	11.8	5.0	1.4	2.6		0.9	0.5			2.1
664.50			3.6	15.9	6.8	2.2	2.9		0.9	0.7			2.8
664.00			5.0	21.8	11.4	3.3	3.6	0.2	1.0	1.5			4.0
663.50			7.3	27.9	18.1	4.6	4.6	0.4	1.0	2.2		0.4	5.6
663.00			10.7	35.9	24.4	7.6	5.3	0.7	1.2	3.5	0.3	0.9	7.6
662.50			13.2	44.6	30.5	9.2	8.7	4.0	1.9	4.5	0.6	1.3	10.0
662.00			15.3	52.8	37.7	14.9	15.8	5.2	3.6	6.8	3.2	2.1	13.3
661.50		1.1	21.2	63.1	47.6	23.3	26.2	6.6	9.1	10.3	6.3	3.9	18.6
661.00	4.1	3.6	29.6	71.4	57.4	41.9	38.7	13.4	15.9	14.1	13.5	12.5	26.8
660.50	20.5	17.6	49.0	82.9	72.0	65.0	53.5	24.7	30.7	30.3	35.6	29.8	43.0
660.00	82.3	85.8	88.3	97.0	95.7	93.3	91.3	89.0	88.3	90.1	91.7	82.7	89.8
659.50	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. 5 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
662.5				0.9									
662.0				1.2	0.2	0.3							0.1
661.5				1.8	0.4	0.7	0.1						0.3
661.0				2.4	0.6	0.7	0.3						0.3
660.5				2.8	0.7	0.8	0.5						0.4
660.0			0.4	3.8	0.9	0.8	0.8		0.2				0.6
659.5			0.8	4.5	1.1	0.9	1.2		0.6	0.2			0.8
659.0			1.2	6.1	1.6	0.9	1.9		0.6	0.3			1.1
658.5			1.5	7.5	2.9	1.0	2.1		0.7	0.5			1.4
658.0			2.1	10.8	4.1	1.3	2.2		0.8	0.6			1.8
657.5			2.5	15.5	6.1	2.4	2.6	0.2	0.8	0.8			2.6
657.0			3.1	22.1	9.1	2.8	3.1	0.3	0.8	1.3			3.6
656.5			5.1	26.3	14.1	3.9	3.8	0.4	0.9	2.1			5.0
656.0			7.2	32.8	20.2	4.6	4.6	0.6	0.9	3.0			6.2
655.5			9.5	38.4	27.8	6.4	6.5	0.7	1.1	3.7	0.1		7.9
655.0			11.2	45.8	34.9	10.1	9.2	2.1	1.5	4.3	0.3		10.0
654.5			13.3	52.4	41.2	13.7	11.9	4.1	1.7	5.7	1.3	0.2	12.2
654.0		0.5	16.2	60.9	47.6	20.0	16.7	5.6	3.3	8.3	3.7	0.6	15.3
653.5	0.1	0.9	20.8	67.8	53.3	26.6	23.7	8.3	6.7	11.1	6.7	1.2	19.0
653.0	0.3	1.2	26.5	74.6	58.8	36.9	31.0	11.9	11.7	14.6	10.7	4.2	23.6
652.5	2.6	2.4	32.0	78.1	63.5	50.3	37.4	14.9	18.5	19.5	16.2	10.8	28.9
652.0	11.8	11.1	41.1	82.9	69.9	63.0	48.3	22.4	26.9	26.7	25.9	21.4	37.7
651.5	35.7	31.8	59.3	88.2	78.0	73.5	63.0	37.6	38.4	40.8	49.4	40.1	53.0
651.0	89.1	85.6	91.6	98.6	95.3	95.5	93.7	89.4	89.5	92.1	93.1	88.9	91.9
650.5	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 660.0 feet (project pool), the storage volume in Pool No. 5 is 59,300 acre-feet. At moderate flows, there is a 0.5-foot drawdown at the dam. That is, while the elevation at the dam is 659.5 feet, the elevation at the control point near Alma is a minimum of 660.0 feet. For the purpose of computing the storage volume in Pool No. 5, the pool was divided into two reaches; namely, the control point near Alma upstream to the tailwater of Lock and Dam No. 4 (**Table 4-11**) and the control point near Alma downstream to the pool of Lock and Dam No. 5 (**Table 4-12**). The total storage is the sum of the storage in the two reaches. Assuming an elevation of 659.5 ft at the dam, elevation 661.0 at the control point, and elevation 662.0 at the tailwater of Lock and Dam No. 4, the approximate volume of Pool No. 5 would be 64,500 acre-feet (55,500 + 9,000 ac-ft). A flow rate of approximately 32,500 cfs would result in a daily exchange in storage. A relationship of storage to discharge is shown on **Plate 4-1**.

Table 4-11
Storage Volume of Pool No. 5 in 1,000 Ac-Ft
Between the Control Point near Alma, Wisconsin and Tailwater of Lock and Dam No. 4

TW Elev. Dam 4	Elevation at the Control Point near Alma, WI																				
	670	669	668	667	666	665	664	663	662	661	660	659	658	657	656	655	654	653	652	651	650
673	51	48	45																		
672	48	45	42	39																	
671	46	43	40	37	34																
670	44	41	38	35	33	30															
669		38	36	33	31	28	26														
668			33	31	29	26	24	22													
667				29	26	24	22	20	18												
666					24	22	20	18	16	15											
665						20	18	16	15	13	12										
664							16	14	13	12	11	9									
663								13	12	10	9	9	8								
662									10	9	8	8	7	6							
661										8	7	7	6	6	5						
660											6	6	6	5	5	4					
659												5	5	5	4	4	3				
658													4	4	4	3	3				
657														4	3	3	3	2			
656															3	3	2	2	2		
655																2	2	2	2	1	
654																	2	2	1	1	
653																		1	1	1	1
652																			1	1	1
651																				1	1

Table 4-12
Storage Volume of Pool No. 5 in 1,000 Ac-Ft
Between the Control Point near Alma, Wisconsin and Lock and Dam No. 5

Pool Elev Dam 5	**Elevation at the Control Point near Alma, WI**																				
	670	669	668	667	666	665	664	663	662	661	660	659	658	657	656	655	654	653	652	651	650
664	142	134	127	119	112																
663	136	129	121	114	107	100															
662		123	115	108	102	95	88														
661		117	110	103	96	89	82	75													
660			103	96	89	83	76	70	64	58	53										
659				91	84	77	71	64	58	53	47	43									
658					79	72	65	59	53	47	42	37	33								
657					74	68	62	55	49	43	38	33	29	25							
656						62	56	50	44	39	34	29	25	21							
655							50	44	39	34	30	26	22	19							
654								39	34	29	26	22	19	16							
653									30	26	22	19	16	14							
652										22	19	17	15	13	11						
651											16	14	13	11	10	9					
650												13	11	10	9	8	7				
649													9	8	7	6	6	5			
648														7	6	6	5	4	3		
647															6	5	4	3	3		
646																4	3	3	2	2	2
645																	3	2	2	2	1

4-07. Water Quality. In 1986-87, Mallard Island and Swan Island (**Figure 2-4**) were constructed in a 4,000-acre backwater area called Weaver Bottoms (**Plate 2-5**). The purpose of the islands was to reduce wave action and thereby reduce the resuspension of sediments. As part of the Weaver Bottoms Rehabilitation Project (**Chapter** I, *reference o*), water quality was assessed at Weaver Bottoms and Belvidere Slough (**Plate 2-5**). There were 22 water quality sampling stations (see **Figure 4-1**). Water quality was assessed by three methods and summarized in terms of pre-project (1985-1986) and post project (1988-1995) conditions. The results are presented in the *Weaver Bottoms Rehabilitation Project, Resource Analysis Program, 1985-1997, Final Report.*

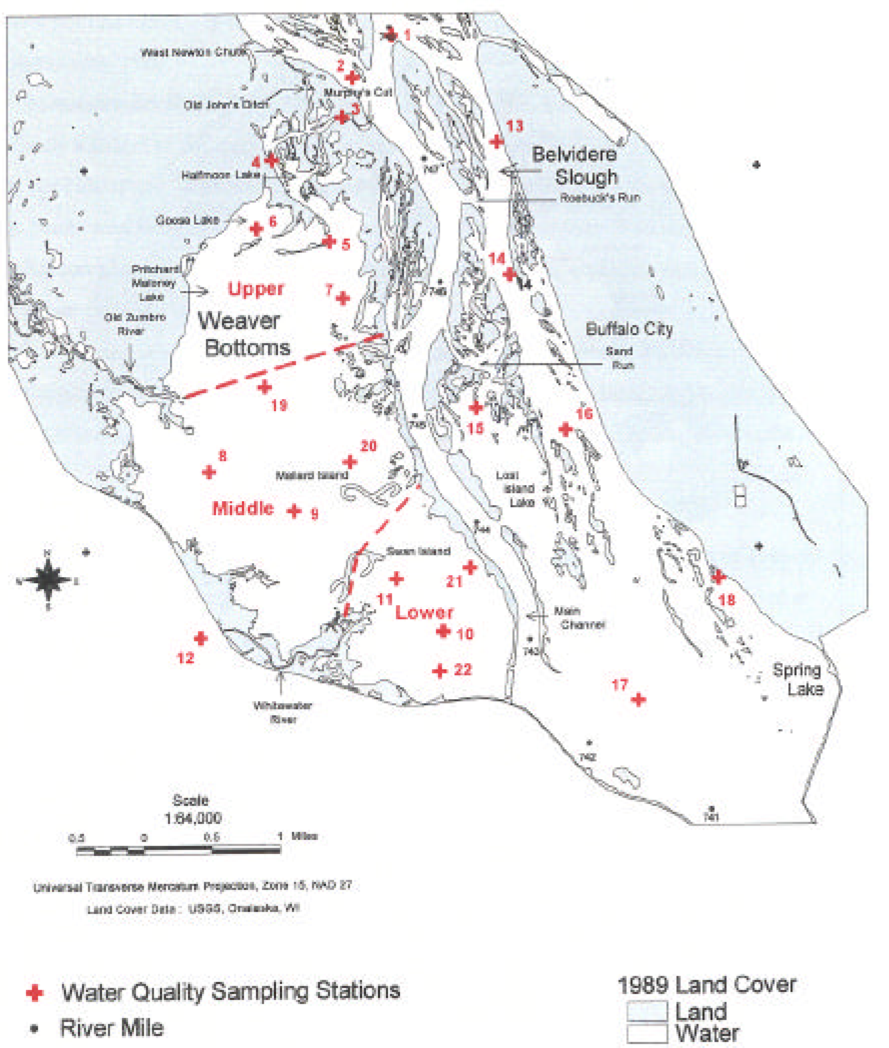

Figure 4-1. Weaver Bottoms/Belvidere Slough, Water Quality Stations

Island 42 is located on the right bank of the Mississippi River at river mile 749.0. Backwater sloughs at Island 42 did not receive adequate water flows from the Mississippi River at normal pool levels. This resulted in stagnation and dissolved oxygen depletion in these waters during late summer and winter. In 1987, seven acres of backwater area was deepened from 2-feet to 5-feet by dredging 36,000 cubic yards. In addition, an 80-foot long culvert in conjunction with a channel, 900-feet long and 50-feet wide, was constructed to provide flows to a semi-isolated backwater area. The project provides sufficient fresh flows of water to the backwaters to alleviate the dissolved oxygen problems. The project improved 95 acres of fish habitat. Generally, dissolved oxygen levels have been maintained above the desired 5 mg/l level.

Spring Lake is a 300-acre backwater area at the south end of Buffalo City, Wisconsin (**Plate 2-5**). Many of the natural islands along the west side of Spring Lake used to protect the shallow water fish and wildlife habitat in the lake by reducing wind fetch and associated wind action. The islands have either eroded or disappeared since the creation of Pool No. 5. In 1995, a general design to construct new islands was initiated. In addition, spring floods breached the natural peninsula at the upper end of Spring Lake that protected it from high river flows. The shallow water habitat was being degraded by high flows and sediments entering the lake. In 1995, the breached area of the peninsula was closed and the peninsula was stabilized (see **Figure 2-6**).

A small scale drawdown of Lizzy Pauls Pond near Buffalo City, Wisconsin was conducted in 1997 to reestablish aquatic species plants in the bottom sediments. Although the desired level of drawdown was not reached, the vegetative response was still positive.

4-08. Channel and Floodway Characteristics. The top of the lower lock sill elevation at Lock and Dam No. 4 is elevation 647.0 feet and the top of the upper lock sill elevation at Lock and Dam No. 5 is elevation 642.0 feet. Therefore, there is a

5.0-foot drop in sill elevation along the pool, which has a length of 14.7 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 2-4, 2-5, and 2-6**.

4-09. Upstream Structures. Lock and Dam No. 4 is located 14.7 miles upstream of Lock and Dam No. 5. The drainage area above Lock 4 is 57,100 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. 5A is located 9.6 river miles downstream of Lock and Dam No. 5. The drainage area above Lock 5A is 59,105 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 and Dam No. 10.

4-11. Economic Data. Pool No. 5 lies on the Minnesota-Wisconsin border. Winona and Wabasha Counties lie on the western side and Buffalo County lies on the eastern side. Based on the US Census Bureau, county populations have increased slightly.

Table 4-13
County and City Populations Near Pool No. 5

	1990	2000	Difference	Change
County				
Winona, MN	47,828	49,985	2,157	4.5%
Wabasha, MN	19,744	21,610	1,866	9.5%
Buffalo, WI	13,584	13,804	220	1.6 %
City				
Minneiska, MN	127	116	-11	-8.7%
Alma, WI	790	942	152	19.2%
Buffalo, WI	915	1,040	125	13.7%

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 4-14
Employment by Industry – Counties on Pool No. 5 (1997)

Industry	Winona	Wabasha	Buffalo
Manufacturing	7,115	1,934	
Wholesale Trade	682	199	180
Retail Trade	2,506	882	305
Real Estate, Rental, Leasing	129	28	7
Professional, Scientific, Tech Services	569	71	39
Admin & Support, Waste Management	567	45	77
Education Services	10		
Health Care & Social Services	705	316	169
Arts, Entertainment & Recreation	134	35	28
Accommodations & Food Services	1,725	375	350
Other Services	296	90	38
Totals	15,038	3,975	1,403

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. About three miles downstream of Lock No. 4 is the Pool No. 5 primary control point gage. It is located on the right bank of the Mississippi River at river mile 749.3 near Alma, Wisconsin (**Figure 5-1**).

Figure 5-1. Control Point near Alma, Wisconsin Stream Gage

The Alma gage was originally located on the left bank in a backwater area at river mile 748.5. Because it was in a backwater area, the gage did not always reflect the water surface on the main channel. Also, the gage was impacted by sedimentation in the summer and icing problems in the winter. In 1996 the gage was moved to its present location, 0.8 miles upstream. The regulated elevation for primary control did not change with movement of the gage. Therefore, the water surface elevation maintained at the original primary control point (RM 748.5) is slightly lower than it was prior to 1996; however, it has not had an impact on navigation. The Alma gage is owned and maintained by the COE. While its present location is on the main channel, it is so remote that there is no power or telephone service. Therefore, the only available data at this site is that sent by the Data Collection Platform (DCP), which is solar powered. The DCP transmits hourly data to Water Control via a satellite system. In addition to water surface elevations, the DCP also transmits cumulative precipitation and water temperature. The type of equipment at the site is listed in **Table 5-1**.

The COE operates and maintains the pool and tailwater gages at the lock. The gage houses are located on the upper and lower guidewalls about 500 feet from the lock chamber (**Figure 5-2**). Each gage house has a well with a float and tape system that reports elevation to the Stevens PAV-C Recorder located in the lock house (**Figure 5-3**). Staff gages are mounted inside the downstream gage house and outside the upstream gage house 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 5-2. Pool (left) and Tailwater (right) Gage Houses

Figure 5-3. Stevens PAV-C Strip Chart Recorders

The main tributary to the pool is the Zumbro River, which enters the Mississippi River about two miles downstream of Lock and Dam No. 4. A gage is located on the south side of Highway 60 on the left bank, approximately 0.7 miles west of Zumbro Falls, Minnesota. The gage is a DCP with a stilling well. A staff gage is located within the well for verifying the stilling well tape. There is no power service; therefore, it is solar powered. Discharges are obtained by translating stage to flow using the latest USGS rating table. A copy of the table is shown in **Exhibit B**. The equipment for this site is listed in **Table 5-1**. The equipment is owned by the COE; however, it is maintained by the USGS through a cooperative agreement.

A water temperature sensor, reading in degrees Fahrenheit, is located in the upper ladder recess of the lock chamber. A standard 8-inch precipitation gage is mounted on the chain-link fence just south of the Control Station. 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 the control house. Data types and equipment are listed in **Table 5-1**.

Table 5-1 Hydrometeorological Stations			
Location	**Data Type**	**Equipment**	**Notes**
Mississippi River near Alma, Wisconsin (control point)	Water Surface Elevation, Precipitation, Water Temperature	Sutron 8200 Data Recorder, Design Analysis Pressure Transducer w/Temp, GOES Telemetry, Tipping Bucket Staff Gage	Gage Zero: 600.00 (1912) NWS ID: AMAW3 Maintained by COE Solar Powered
Zumbro River at Zumbro Falls, Minnesota	Water Surface Stage, Elevation	Sutron 8200 Data Recorder, Stilling Well, GOES Telemetry, Staff Gage	Gage Zero: 811.26 (1929) Flood Stage: 18.0 ft (NWS) NWS ID: ZUMM5 Co-Op Gage Solar Powered
Lock & Dam No. 5 Upper Guide Wall	Pool Elevation	Stilling Well, Stevens PAV-C Recorder, Staff Gage	Continuous Strip Chart record of pool elevations.
Lock & Dam No. 5 Lower Guide Wall	Tailwater Elevation	Stilling Well, Stevens PAV-C Recorder Staff Gage	Gage Zero: 656.00 (1912) Continuous Strip Chart record of TW elevations.
Lock & Dam No. 5	Snow Depth & Water Content	Snow Rod , Snow Tube, Scale	Maintained by Corps Gage Crew.
Lock & Dam No. 5 Top of Control House	Wind Speed & Direction	Anemometer	Maintained by site personnel.
Lock & Dam No. 5 Upper Ladder Recess	Water Temperature	Water Temperature Sensor	Electronically transmitted to Central Control Station.
Lock & Dam No. 5 Fence South of CCS	Precipitation	Standard 8-inch Precipitation Gage	Recorded daily.

b. Reporting. Daily log sheets of data are kept at the lock and dam site. The log sheet begins at 0400-hours. The data entry interval varies from once a day to every four hours. Four-hour interval data include pool and tailwater elevation, gate openings, and the elevation at Alma. Air temperature is entered every eight hours. Daily records include wind speed and direction, maximum and minimum air temperature, water temperature, and precipitation. The information needed to regulate the lock and dam is provided to Water Control, via computer by dam personnel, daily at 0630-hours. While morning data is collected between 0600 and 0630-hours, it is archived as being taken at hour 0800, thereby maintaining the four-hour data interval. Each morning, Water Control is provided data for the last 24-hours beginning at 0800-hours. These data include the four-hour pool and tailwater elevations, gate openings, and Alma elevations; the morning stage on the Zumbro River at Zumbro Falls, the wind speed and direction, and the 24-hour precipitation. Gage readings from Zumbro Falls and the control point near Alma are transmitted hourly via satellite and obtained from the Water Control web site at www.mvp-wc.uasace.army.mil. The Zumbro Falls stage is converted to discharge using the latest US Geological Survey rating table (**Exhibit B**). These data are transferred to Water Control's "river program" via a remote computer using "sig-na-term". The Stevens PAV-C strip charts containing the continuous record of pool and tailwater elevations are mailed to Water Control at least once a year where they are then periodically micro filmed.

During the winter months, percent of ice coverage over the lower pool and upper tailwater, ice thickness (observed), snow depth, and snow-water content (all in inches) are reported to Water Control once a week on Sundays. The snow-water content is determined by instructions contained in the National Weather Service Observing Handbook No. 2.

c. Maintenance. The equipment at the gages located at the control point near Alma, Wisconsin and Zumbro Falls, Minnesota are property of the Corps of Engineers; however, the Zumbro Falls gage is maintained by the US Geological Survey as part of the cooperative stream gaging network. Operation and maintenance of the pool and tailwater gages are the responsibility of the Water Control Gage Crew. Dam personnel maintain the Stevens PAV-C strip chart recorders. The anemometer, water temperature sensor, and precipitation gage are maintained by site personnel; however should the precipitation gage become damaged, a new one would be mailed to the site from Water Control. Repair of the snow survey equipment is the responsibility of the Water Control Gage Crew. In all cases, the Water Control Gage Crew provides emergency backup.

5-02. Water Quality Stations. There are no Corps of Engineers' water quality stations in Pool No. 5; however, site personnel may be asked to assist district office personnel or contractors to collect water samples in the project area.

5-03. Sediment Stations. No suspended sediment data has been collected in Pool No. 5; however, discrete sediment samples were taken at the Zumbro River gage at Zumbro Falls between March 1973 and April 1975. Routine dredging of sediment is part of the nine-foot navigation plan. There are several sites in Pool No. 5 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. Prior to 1970, the Corps of Engineers engage in over-dredging operations in an attempt to reduce the frequency of needed dredging. This stopped in 1970. **Table 5-2** gives a summary of dredging in Pool No. 5 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
Lower Approach LD 4	753.0	509 yd	5,264 yd	10%	1976
Mule Bend	748.6 to 749.6	11,914 yd	33,576 yd	35%	1998
West Newton	747.2 to 748.2	6,096 yd	20,999 yd	29%	1998
Below West Newton	746.0 to 746.8	16,162 yd	27,834 yd	58%	2000
Fisher Island	744.8 to 746.0	31,522 yd	44,417 yd	71%	2000
Lower Zumbro	744.0 to 744.6	18,865 yd	36,551 yd	52%	2000
Minneiska	742.7 to 743.0	8,154 yd	22,980 yd	35%	2000
Above Mt. Vernon Light	741.2 to 741.5	2,584 yd	40,054 yd	6%	1996

5-04. Recording Hydrologic Data. Daily log sheets containing the pool and tailwater elevations, roller and tainter gate settings, Alma elevation, precipitation, air temperature, maximum and minimum air temperature, wind speed and direction, and water temperature are kept at the lock and dam. Up until 2001, log sheets were mailed to Water Control where they were periodically micro filmed. Beginning in 2001, log sheets were stored electronically and are available on the Water Control web site at *www.mvp-wc.usace.army.mil*. The log sheets were back entered such that they are now available beginning in January 1993. All daily data received by Water Control from the dam site is now compiled and archived using Hydraulic Engineering Center's Data Storage System (HEC-DSS) and is accessible from the Water Control web site. Water Control also maintains electronic files of hourly stage/elevation data for the gages located at the control point near Alma, Wisconsin and the Zumbro River at Zumbro Falls, Minnesota beginning 1 December 1997. The US Geological Survey (USGS) is responsible for maintaining a discharge record for Zumbro Falls. 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, Minnesota. 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 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, 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 Zumbro Falls, Minnesota and Alma, Wisconsin send stage/elevation data hourly via satellite to Water Control. In addition, the Alma gage sends hourly cumulative precipitation. This information is made available to the dam site from the Water Control web site; *www.mvp-wc.usace.army.mil*. 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. 5 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 ten percent of the total river 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) 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. 5 personnel should notify Lock No. 5A of the cut or opening that was made. In the event of a gate failure, communications must be established as quickly as possible with Water Control Section and 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 and the embankment, 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 of the dam to control floods is not possible. The lock goes out of operation at elevation 664.5 feet (1912 adjustment) at which time water is within half a foot of the top of the lock wall. The timing and elevation of the crest is important for planning sand bagging operations and forecasting when the lock would go out of operation. Additionally, the timing of the receding limb of the hydrograph aids in estimating when the lock will go back into service. In 1997, the St. Paul District developed an unsteady-flow model of the Mississippi River.

a. **Role of the Corps.** The St. Paul District previously relied solely on the National Weather Service (NWS) for Mississippi River forecasts. However, the NWS only forecasts for designated sites along the Mississippi River. The nearest forecast site to Lock and Dam No. 5 is the Dam No. 4 tailwater gage at Alma, Wisconsin. Also, the NWS forecast typically is only 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 for planning sand bag operations, but also the receding limb for forecasting when the lock may go back into operation. In 1997, the District developed such a model. It is called the Mississippi Basin Model System (MBMS) and 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 Water Control forecasted five-day flow hydrographs of the major tributaries to the Mississippi River by 0830-hours daily. The hydrographs typically include the 24-hour quantitative precipitation forecast. 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 model results and the results from their Mississippi River forecast model to provide stage forecasts at various points along the Mississippi River. The NWS forecast site for Pool No. 5 is at Dam No. 4 tailwater (Alma, Wisconsin).

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. 5. 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 (NWS) 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 5-7 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; *www.mvp-wc.usace.army.mil*.

Modeling efforts as part of the Corps of Engineers Water Management System (CWMS) began in 2001. In the future, CWMS will contain 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-rang 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 MBMS model 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. 5, without inducing higher stages during flood events. Project pool elevation for Lock and Dam No. 5 is 660.0 ± 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. 5, the "primary control point" is located at river mile 749.2 near Alma, Wisconsin (see **Figure 5-1**). Maintaining project pool elevation at this location during periods of low flows ensures a minimum channel depth of nine feet; however, periodic dredging is required.

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 660.0 ± 0.2 feet (1912 adjustment) at the primary control point near Alma, Wisconsin. This is "project pool" or "normal pool" for Lock and Dam No. 5 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 2.5-feet below project pool level. This was reduced to 1.5-feet in 1960 to ensure more stable water surface elevations for riverfront property owners and conservation interests. Because of adverse effects on navigation due to the reduced dredging effort by the Corps of Engineers in 1970, it was further reduced to 0.5-feet. Therefore, drawdown at the dam is constrained to elevation 659.5 ± 0.2 feet.

b. Maximum Outflow Velocity. Downstream scour protection limits outflow velocities from the roller and tainter gates. The original design plan set maximum outflow velocities at 4.5 feet per second (fps) for standard operating procedures with an allowance to go to 6.0 fps for an emergency situation. In 1983 and 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 fps. Flow velocities are allowed to exceed 6.0 fps 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 116,000 cfs. When gates are put back in the water, the total gate openings are 96 feet on roller gates and 280 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 662.5 feet (1912 adjustment). As part of the major rehabilitation work in 1990, the motors were raised; therefore, the lock can now technically remain open to navigation provided water is not spilling over the upper miter gates of the main lock at elevation 665.0 feet. While this is the physical constraint, closure will often happen before the water level gets this high due to wave action over the miter gates. For this reason, the lock closes when the pool elevation is half a foot from the top of the lock wall or elevation 664.5 feet. However, it is not unusual for the Coast Guard to close the river to navigation before this elevation is reached.

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. **Table 7-1** shows some of the recent history of opening and closing dates for Lock and Dam No. 5.

Table 7-1
Spring Opening and Fall Closing Dates

Year	Opening Date	Closing Date	Year	Opening Date	Closing Date
1972	23 Mar	09 Dec	**1987**	10 Mar	01 Dec
1973	17 Mar	05 Dec	**1988**	20 Mar	30 Nov
1974	14 Mar	12 Dec	**1989**	27 Mar	23 Nov
1975	20 Mar	14 Dec	**1990**	13 Mar	29 Nov
1976	04 Mar	05 Dec	**1991**	21 Mar	24 Nov
1977	27 Mar	09 Dec	**1992**	08 Mar	01 Dec
1978	05 Apr	30 Nov	**1993**	21 Mar	27 Nov
1979	30 Mar	04 Dec	**1994**	24 Mar	29 Nov
1980	26 Mar	04 Dec	**1995**	17 Mar	28 Nov
1981	07 Mar	04 Dec	**1996**	20 Mar	25 Nov
1982	24 Mar	07 Dec	**1997**	26 Mar	25 Nov
1983	03 Mar	09 Dec	**1998**	10 Mar	17 Dec
1984	03 Mar	30 Nov	**1999**	19 Mar	10 Dec
1985	17 Mar	01 Dec	**2000**	03 Mar	29 Nov
1986	21 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 Water Control. 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 additional evaluation by Water Control.

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

Flow (cfs)	No. of Roller Gates Closed	Flow (cfs)	No. of Tainter Gates Closed
Below 54,000	6	Below 16,000	28
54,000 – 62,000	5	16,000 – 18,000	27
62,000 – 70,000	4	18,000 – 19,000	26
70,000 – 78,000	3	19,000 – 21,000	25
78,000 – 89,000	2	21,000 – 22,000	24
89,000 –103,000	1	22,000 – 24,000	23
Above 103,000	0	24,000 – 26,000	22
		26,000 – 28,000	21
		28,000 – 30,000	20
		30,000 – 32,000	19
		32,000 – 34,000	18
		34,000 – 36,000	17
		36,000 – 39,000	16
		39,000 – 41,000	15
		41,000 – 44,000	14
		44,000 – 47,000	13
		47,000 – 50,000	12
		50,000 – 54,000	11
		54,000 – 57,000	10
		57,000 – 61,000	9
		61,000 – 66,000	8
		66,000 – 70,000	7
		70,000 – 75,000	6
		75,000 – 79,000	5
		79,000 – 86,000	4
		86,000 – 94,000	3
		94,000 –101,000	2
		101,000 –107,000	1
		Above 107,000	0

7-03. Overall Plan for Water Control.

a. General Plan. The navigation channel of Pool No. 5 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. 5, 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 20,000 cfs, the pool is fairly flat. To meet depth requirements in the upper pool requires the pool elevation at the control point near Alma, Wisconsin to be at elevation 660.0 feet (1912 adjustment). Therefore, "project pool" elevation for Lock and Dam No. 5 is 660.0 ± 0.2 feet, and Alma acts as the "primary control point" for maintaining this elevation. As discharges increase, gates are opened at the dam to maintain project pool at the control point near Alma. This results in a draw down in the water surface elevation at the dam. Maximum allowable drawdown is 0.5 feet below project pool elevation or 659.5 ± 0.2 feet. When this elevation is reached, the lock and dam is now in "secondary control". As discharges continue to rise to around 116,000 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 following table summarizes the control conditions at the lock and dam.

Table 7-3
Control Conditions at Lock and Dam No. 5

Control Conditions	Approximate Discharge	Control Point Gage Elevation	Lock and Dam 5 Pool Elevation
Primary	< 20,000 cfs	660.0 ft	≤ 660.0 ft
Primary to Secondary	20,000 to 28,000 cfs	> 660.0 ft	< 660.0 ft > 659.5 ft
Secondary	28,000 to 116,000 cfs	> 660.0 ft	659.5 ft
Open-River	> 116,000 cfs	> 660.0 ft	> 659.5 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 and the tailwater rating curve, computed 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 1974, 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 June 1974). 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 1983 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. The Gate Regulation Schedule was again changed as part of this update to the Water Control Manual based on a review of the Operating Curves.

As part of the current updates to this manual, the Operating Curves (**Plate 7-1**) were updated using recent data. The data indicate a slight shift in the pool and tailwater rating curves 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 45,000 cfs and a respective head across the dam of 7.0 feet with a tailwater elevation of 652.5 feet. The discharge per foot opening for roller and tainter gates are 1,240 cfs and 805 cfs respectively. By setting the roller gates at a total opening of 10.0 feet (10.0 x 1,240 = 12,400 cfs) and the tainter gates at 40.5 feet (40.5 x 805 = 32,600 cfs) gives a total discharge of 45,000 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 644.5 feet. Therefore, the flow velocities are;

<u>Roller Gate</u>
$Q = VA$
(10.0 ft/6 roller gates) 1,240 cfs = V (60 ft + 15 ft) (652.5 ft – 643.0 ft)
V = 2.90 ft/sec

<u>Tainter Gate</u>
$Q = VA$
(40.5 ft/28 tainter gates) 805 cfs = V (35 ft + 7 ft) (652.5 ft – 643.0 ft)
V = 2.92 ft/sec

To complete the update of the Gate Regulation Schedule to reflect the change in per foot discharge, the maximum allowable gate openings were re-calculated. Maximum allowable gate openings are based on flow velocity at the end sill downstream of the gates. Again, let's consider a discharge of 45,000 cfs and a differential head of 7.0 feet with a tailwater elevation of 652.5 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
$Q = VA$
1,240 cfs (max gate opening in ft) = 6.0 fps (60 ft + 15 ft) (652.5 ft – 643.0 ft)
Max Gate Opening = 3.4 ft

Tainter Gate
$Q = VA$
805 cfs (max gate opening in ft) = 6.0 fps (35 ft + 7 ft) (652.5 ft – 643.0 ft)
Max Gate Opening = 3.0 ft

Table 7-4 shows the new Gate Regulation Schedule.

Table 7-4
Gate Regulation Schedule
6 Roller Gates and 28 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	1.5	6.5	659.92	651.00	8.92	1474	928	2,200	6,000	2.4	2.2
9,000	2.0	6.5	659.91	651.00	8.91	1473	927	2,950	6,050	2.4	2.2
10,000	2.0	7.5	659.90	651.00	8.90	1472	926	2,950	6,950	2.4	2.2
11,000	2.0	8.5	659.88	651.00	8.88	1470	924	2,950	7,850	2.4	2.2
12,000	2.5	9.0	659.86	651.00	8.86	1468	922	3,650	8,300	2.5	2.2
13,000	2.5	10.0	659.84	651.00	8.84	1466	920	3,650	9,200	2.5	2.2
14,000	3.0	10.5	659.82	651.00	8.82	1463	919	4,400	9,650	2.5	2.2
15,000	3.0	11.5	659.80	651.00	8.80	1461	918	4,400	10,550	2.5	2.2
16,000	3.0	12.5	659.78	651.00	8.78	1459	917	4,400	11,450	2.5	2.2
17,000	3.5	13.0	659.76	651.00	8.76	1456	916	5,100	11,900	2.5	2.2
18,000	3.5	14.0	659.74	651.00	8.74	1454	914	5,100	12,800	2.5	2.2
19,000	3.5	15.0	659.72	651.00	8.72	1452	913	5,100	13,700	2.5	2.2
20,000	4.0	15.5	659.70	651.00	8.70	1449	912	5,800	14,150	2.5	2.2
21,000	4.0	17.0	659.68	651.03	8.65	1443	909	5,750	15,450	2.5	2.2
22,000	4.0	18.0	659.66	651.06	8.60	1437	906	5,750	16,300	2.5	2.2
23,000	4.5	18.5	659.64	651.09	8.55	1431	903	6,450	16,700	2.5	2.3
24,000	4.5	19.5	659.62	651.12	8.50	1425	900	6,400	17,550	2.6	2.3
25,000	5.0	20.0	659.60	651.15	8.45	1419	897	7,100	17,950	2.6	2.3
26,000	5.5	20.5	659.57	651.20	8.37	1409	892	7,750	18,300	2.6	2.3
27,000	5.5	22.0	659.53	651.25	8.28	1399	887	7,700	19,500	2.7	2.3
28,000	5.5	23.0	659.50	651.30	8.20	1389	882	7,650	20,300	2.7	2.4
29,000	6.0	23.5	659.50	651.35	8.15	1383	879	8,300	20,650	2.7	2.4
30,000	6.0	25.0	659.50	651.40	8.10	1377	876	8,250	21,900	2.7	2.4

Table 7-4
Gate Regulation Schedule
6 Roller Gates and 28 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	6.0	26.0	659.50	651.46	8.04	1370	872	8,200	22,650	2.8	2.4
32,000	6.0	27.5	659.50	651.52	7.98	1363	869	8,200	23,900	2.8	2.5
33,000	6.5	28.0	659.50	651.58	7.92	1355	864	8,800	24,200	2.8	2.5
34,000	7.0	28.5	659.50	651.64	7.86	1348	861	9,450	24,550	2.9	2.5
35,000	7.0	30.0	659.50	651.70	7.80	1340	857	9,400	25,700	2.9	2.6
36,000	7.5	30.5	659.50	651.78	7.72	1330	852	10,000	26,000	3.0	2.6
37,000	8.0	31.0	659.50	651.86	7.64	1320	847	10,550	26,250	3.0	2.6
38,000	8.5	32.0	659.50	651.94	7.56	1310	842	11,150	26,950	3.1	2.7
39,000	8.5	33.5	659.50	652.02	7.48	1300	837	11,050	28,050	3.1	2.7
40,000	8.5	35.0	659.50	652.10	7.40	1290	831	10,950	29,100	3.2	2.8
41,000	9.0	35.5	659.50	652.18	7.32	1280	826	11,500	29,300	3.2	2.8
42,000	9.5	36.5	659.50	652.26	7.24	1270	821	12,050	29,950	3.3	2.8
43,000	9.5	38.0	659.50	652.34	7.16	1260	816	12,000	31,000	3.3	2.9
44,000	9.5	39.5	659.50	652.42	7.08	1250	811	11,900	32,050	3.4	2.9
45,000	10.0	40.5	659.50	652.50	7.00	1240	805	12,400	32,600	3.4	3.0
46,000	10.5	41.5	659.50	652.58	6.92	1230	800	12,900	33,200	3.5	3.0
47,000	10.5	43.0	659.50	652.66	6.84	1219	795	12,800	34,200	3.6	3.1
48,000	11.0	44.0	659.50	652.74	6.76	1209	790	13,300	34,750	3.6	3.1
49,000	11.5	45.0	659.50	652.82	6.68	1199	784	13,800	35,300	3.7	3.2
50,000	12.0	46.0	659.50	652.90	6.60	1188	779	14,250	35,850	3.7	3.2
51,000	12.0	47.5	659.50	652.99	6.51	1177	773	14,100	36,700	3.8	3.3
52,000	12.0	49.5	659.50	653.08	6.42	1165	767	14,000	37,950	3.9	3.3
53,000	13.0	50.0	659.50	653.17	6.33	1153	762	15,000	38,100	4.0	3.4

Table 7-4
Gate Regulation Schedule
6 Roller Gates and 28 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	13.0	52.0	659.50	653.26	6.24	1142	755	14,850	39,250	4.0	3.4
55,000	13.5	53.0	659.50	653.35	6.15	1130	750	15,250	39,750	4.1	3.5
56,000	13.5	55.0	659.50	653.44	6.06	1118	744	15,100	40,900	4.2	3.5
57,000	14.5	55.5	659.50	653.53	5.97	1106	738	16,050	40,950	4.3	3.6
58,000	14.5	57.5	659.50	653.62	5.88	1094	732	15,850	42,100	4.4	3.7
59,000	15.0	59.0	659.50	653.71	5.79	1083	725	16,250	42,750	4.5	3.7
60,000	15.5	60.5	659.50	653.80	5.70	1071	719	16,600	43,500	4.5	3.8
61,000	15.5	62.5	659.50	653.89	5.61	1059	713	16,400	44,550	4.6	3.9
62,000	16.0	64.0	659.50	653.98	5.52	1048	707	16,750	45,250	4.7	3.9
63,000	16.5	65.5	659.50	654.07	5.43	1036	701	17,100	45,900	4.8	4.0
64,000	17.0	67.0	659.50	654.16	5.34	1025	694	17,450	46,500	4.9	4.1
65,000	18.0	68.0	659.50	654.25	5.25	1013	688	18,250	46,800	5.0	4.1
66,000	18.0	70.5	659.50	654.34	5.16	1001	681	18,000	48,000	5.1	4.2
67,000	19.0	71.5	659.50	654.43	5.07	989	675	18,800	48,250	5.2	4.3
68,000	19.0	74.0	659.50	654.52	4.98	977	669	18,550	49,500	5.3	4.3
69,000	20.0	75.0	659.50	654.61	4.89	966	662	19,300	49,650	5.4	4.4
70,000	20.5	77.0	659.50	654.70	4.80	953	657	19,550	50,600	5.5	4.5
71,000	20.5	79.5	659.50	654.78	4.72	942	651	19,300	51,750	5.6	4.6
72,000	21.5	80.5	659.50	654.86	4.64	932	645	20,050	51,900	5.7	4.6
73,000	22.0	82.5	659.50	654.94	4.56	921	639	20,250	52,700	5.8	4.7
74,000	22.5	84.5	659.50	655.02	4.48	910	634	20,450	53,550	5.9	4.8
75,000	23.0	86.5	659.50	655.10	4.40	899	628	20,700	54,300	6.1	4.9
76,000	23.5	88.5	659.50	655.18	4.32	888	623	20,850	55,150	6.2	4.9

Table 7-4
Gate Regulation Schedule
6 Roller Gates and 28 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	24.5	90.0	659.50	655.26	4.24	878	617	21,500	55,550	6.3	5.0
78,000	25.0	92.0	659.50	655.34	4.16	866	612	21,650	56,300	6.4	5.1
79,000	25.5	94.5	659.50	655.42	4.08	856	606	21,850	57,250	6.5	5.2
80,000	26.5	96.0	659.50	655.50	4.00	845	600	22,400	57,600	6.7	5.3
81,000	27.0	99.0	659.50	655.60	3.90	831	592	22,450	58,600	6.8	5.4
82,000	27.5	102.0	659.50	655.70	3.80	816	584	22,450	59,550	7.0	5.5
83,000	28.5	104.5	659.50	655.80	3.70	802	576	22,850	60,200	7.2	5.6
84,000	29.5	107.0	659.50	655.90	3.60	787	568	23,200	60,800	7.4	5.7
85,000	31.0	109.0	659.50	656.00	3.50	773	560	23,950	61,050	7.6	5.9
86,000	31.5	112.5	659.50	656.10	3.40	758	552	23,900	62,100	7.8	6.0
87,000	32.5	115.5	659.50	656.20	3.30	744	544	24,200	62,850	8.0	6.1
88,000	33.5	118.5	659.50	656.30	3.20	729	536	24,400	63,500	8.2	6.3
89,000	34.5	122.0	659.50	656.40	3.10	715	528	24,650	64,400	8.4	6.4
90,000	35.5	125.5	659.50	656.50	3.00	699	520	24,800	65,250	8.7	6.5
91,000	37.0	129.0	659.50	656.60	2.90	682	510	25,250	65,800	9.0	6.7
92,000	38.5	133.0	659.50	656.70	2.80	663	500	25,500	66,500	9.3	6.9
93,000	40.0	137.5	659.50	656.80	2.70	645	489	25,800	67,250	9.6	7.1
94,000	41.5	142.0	659.50	656.90	2.60	626	479	26,000	68,000	10.0	7.3
95,000	43.0	147.0	659.50	657.00	2.50	608	469	26,150	68,950	10.4	7.5
96,000	45.0	151.5	659.50	657.10	2.40	589	459	26,500	69,550	10.8	7.7
97,000	47.0	156.5	659.50	657.20	2.30	570	449	26,800	70,250	11.2	8.0
98,000	49.0	162.0	659.50	657.30	2.20	552	438	27,050	70,950	11.7	8.2
99,000	51.5	167.0	659.50	657.40	2.10	533	428	27,450	71,500	12.2	8.5

Table 7-4
Gate Regulation Schedule
6 Roller Gates and 28 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
100,000	54.0	172.5	659.50	657.50	2.00	515	418	27,800	72,100	12.7	8.7
101,000	56.5	181.0	659.50	657.60	1.90	493	404	27,850	73,100	13.3	9.1
102,000	58.5	185.5	659.50	657.65	1.85	482	398	28,200	73,850	13.7	9.3
103,000	60.5	190.5	659.50	657.70	1.80	471	391	28,500	74,500	14.0	9.5
104,000	64.0	199.5	659.50	657.80	1.70	449	377	28,750	75,200	14.8	9.9
105,000	68.0	208.5	659.50	657.90	1.60	427	364	29,050	75,900	15.7	10.3
106,000	71.0	214.0	659.50	657.95	1.55	416	357	29,550	76,400	16.2	10.6
107,000	73.5	220.5	659.50	658.00	1.50	405	350	29,750	77,250	16.7	10.8
108,000	79.0	234.0	659.50	658.10	1.40	381	333	30,100	77,900	17.8	11.4
109,000	82.0	242.0	659.50	658.15	1.35	369	325	30,250	78,650	18.5	11.7
110,000	88.5	258.0	659.50	658.25	1.25	345	308	30,550	79,450	19.9	12.5
111,000	92.5	268.0	659.50	658.30	1.20	333	299	30,800	80,150	20.7	12.9
112,000	100.0	287.5	659.50	658.40	1.10	309	282	30,900	81,100	22.4	13.8
113,000	105.0	298.5	659.50	658.45	1.05	297	274	31,200	81,800	23.4	14.2
114,000	116.0	324.0	659.50	658.55	0.95	270	255	31,300	82,600	25.9	15.4
115,000	124.0	346.0	659.50	658.60	0.90	258	240	32,000	83,050	27.2	16.4
116,000	Out of Control – Gates raised clear of water. Put gates back in at 96 ft Roller Gates and 280 ft Tainter Gates.										

c. Regulation Procedure. Each morning at 0645-hours, the Water Control river manager prints the Regulation Sheets containing all the input from the lock and dam sites. Regulation for Lock and Dam No. 5 begins at Lock and Dam No. 4. Gate changes at Lock and Dam No. 4 directly influence action needed at Dam No. 5. After regulating Lock and Dam 4, inflow to Pool No. 5 is determined. Inflow consists of outflow from Lock and Dam No. 4, inflow from the Zumbro River, and any miscellaneous inflow. Inflow from Lock and Dam 4 is computed as part of the "river program" based on gate settings or the tailwater rating curve. Inflow from the Zumbro River will appear on the Regulation Sheet from input by site personnel (see Standing Instructions to Lockmaster). Miscellaneous inflow will vary seasonally but for simplicity it is assumed to be a constant 400 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 past 24-hours, an additional 700 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 change made in the past 24-hours. Next the rate of fall or rise of the pool is calculated. This is done at the dam and at the control point. 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 600 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 12,580 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 659.8 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 660.0 ± 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. 5. The portion printed in black represents the daily regulation sheet while that printed in blue represents regulation notes.

Regulation of Lock and Dam No. 5 for 23 September 2001

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Orders to LD 4:  Open 3 ft TG. Increase 2,000 to 17,500 cfs.
Note:   Roller gates at LD4 were opened 1-ft between midnight
        and 0400 hours.

                                              6-RG   28-TG  [primary = 660.00
gates in/out:  96/280 @ 116,000              Total  Total   for flow<30,000]
                | sec: |                      Roller Tainter     CP-5
LOCK 5          |659.50|  Tail    Flow       Gate   Gate      Alma DCP
          ------------------------------------------
22SEP01 0800  659.89  651.16  18300  5.0   12.0       660.33
        1200  659.87  651.18  18200  5.0   12.0       660.32
        1600  659.86  651.16  18200  5.0   12.0       660.29
        2000  659.89  651.21  18200  5.0   12.0       660.46
        2400  659.92  651.19  18300  5.0   12.0       660.34
23SEP01 0400  659.99  651.23  18300  5.0   12.0       660.37
        0630  660.01  651.21  18400  5.0   12.0
              up 0.12         up 100                  up 0.04
phone   HEAD    8.8                          Zumbro Falls:   7.44
##028   Q/foot   1461/921                    DCP
        temp.        55                      Flow:           531
        precip.    0.87
        wind (dir&speed)     360    @    10
        INFLOW:
          L/D 4   -    17500               Orders:
          Zumbro R.     500                Open 3 ft on TG
          600 CFS -                        Inc. Flow 2,600 to 21,000 cfs
          Misc. -       400                Hold 659.80 ± 0.2 ft
                     ------                     AFW HS
                     18400+600=19,000
                               up 2,000
```

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 5.
- Computed inflow from LD 4 was 15,500 cfs.
- LD 4 orders were to open up 2,000 cfs to 17,500 cfs.
- The Zumbro River is at 500 cfs.
- Miscellaneous inflow is 400 cfs.
- Rainfall was 0.87 inches, so add 600 cfs to inflow.
- Total Inflow = 19,000 cfs (up 2,000 cfs from yesterday).
- Note that this increase includes the earlier 1-ft opening at LD 4.

Step 2. Note change in outflow.
- Up 100 cfs due to pool elevation change.

Step 3. Note 24-hour change in pool elevation.
- Pool is up 0.04 feet at Alma.
- Pool is up 0.12 feet at the dam.
- Wind is 10 mph out of the north, therefore there is a 0.1 ft of increase at dam is due to wind.

Step 4. Primary or Secondary Control?
- Flow is less than 20,000 cfs; therefore, Primary Control.
- For Primary Control, maintain Alma at 660.00 ± 0.2 ft.

Step 5. Estimate needed change in discharge.
- Inflow is up 2,000 cfs from yesterday.
- The pool has increased 0.12 ft – 0.1 ft (due to wind) = 0.02 ft and is fairly steady but a little on the high side.
- Need to increase outflow, as a minimum, the opening made at LD 4 (2,000 cfs). Also, need to reduce pool elevation 0.1 ft.
- Pool will decrease 0.1 ft per 600 cfs in 24 hours; therefore need to increase outflow 2,000 + 600 = 2,600 cfs for a total outflow of 21,000 cfs.

Step 6. Set gate change.
- The Gate Regulation Schedule shows ideal gate settings for 21,000 cfs to be 4.0 ft on RG and 17.0 ft on TG.
- Therefore, the gate opening will be on the Tainter Gates.
- A 1-foot opening on TG’s would increase outflow about 900 cfs.
- Because the pool is on the high side,
  - “Open 3.0 ft on TG. Increases flow 2,600 to 21,000.”

Step 7. Set the pool band.
- The pool is a little high (i.e. target at Alma is 660.0 ft).
- The pool is being affected by wind.
- We want an opening if the pool goes up; therefore,
  - “Hold elevation 659.80 ± 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" was 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, 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, a submergence of one foot is assumed. These discharges are deducted from the estimated minimum base flow. This flow is then used to determine tainter gate settings. While four of the tainter gates can be submerged up to 2 feet below project pool elevation, they are operated in the raised position due to ice problems. The recommended 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.

Table 7-5 Discharge Through One 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
660.0	9.0	280	460	790	1100	1410	1440
	8.0	190	440	750	1060	1370	1410
659.9	9.0	190	430	750	1070	1360	1390
	8.0	170	410	720	1030	1320	1360
659.8	9.0	180	410	720	1030	1310	1330
	8.0	160	390	690	1030	1270	1300
659.7	9.0	160	390	690	990	1260	1280
	8.0	150	370	660	960	1220	1250
659.6	9.0	150	370	660	960	1220	1240
	8.0	140	350	630	930	1180	1210
659.5	9.0	140	350	640	930	1180	1190
	8.0	130	340	610	890	1140	1160
659.4	8.0	120	320	590	860	1100	1120
	7.0	110	310	560	820	1060	1080
659.3	8.0	-	310	570	830	1070	1060
	7.0	-	300	540	790	1020	1030
659.2	8.0	-	300	550	800	1030	1020
	7.0	-	280	520	760	980	980
659.1	7.0	-	270	500	730	950	950
	6.0	-	260	470	690	900	920
659.0	7.0	-	260	480	710	920	900
	6.0	-	240	450	670	870	870

Throughout the winter, the tainter valves in the lock walls are kept open one or two feet so that the lock chamber will remain ice free. In addition, the flow through the lock chamber reduces deposition of sediment.

On the weekends and holidays, the third and first shifts are limited to one person at the dam site. Therefore, overtime or compensatory time is used when a gate change is necessary. 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 control point gage near Alma is typically maintained at elevation 660.0 ± 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.

7-04. Standing Instructions to Lock and Dam No. 5 Staff. Lock and dam personnel are to maintain daily log sheets. Pool and tailwater elevations, gate openings, and elevations at Alma are recorded in four hour intervals beginning at 0400-hours. Air temperature and wind speed and direction are recorded every 8-hours beginning at 0800-hours. Maximum and minimum air temperature, water temperature, and precipitation are recorded once a day. In addition, lock and dam personnel are to send via computer, by 0630-hours, the last 24-hour data readings needed for regulation. The data set includes pool and tailwater elevations, discharges at the dam (computed internally), stage and discharge at Zumbro Falls, gate openings, precipitation, air temperature, and wind speed and direction. Gage readings from the Zumbro River at Zumbro Falls and the control point near Alma are obtained from the Water Control web site. Discharge for the Zumbro River is obtained from the latest rating curve provided by the US Geological Survey. All of the morning's readings are taken between 0600 and 0630-hours but are entered as being taken at 0800-hours to maintain the four-hour interval. Maximum and minimum air temperatures are taken daily at 1900-hours and entered as 2400-hour readings. During the winter months, every Sunday the snow depth is measured and a snow-water equivalent is determined. Also an estimate is made as to the percent the pool and tailwater are covered with ice and the ice thickness. Winter data are sent to Water Control via computer.

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 typically sent by 0730-hours. Gate changes are then made as soon as possible. If Water Control has notified the site that they will contact them again at 1400-hours, 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	Home Telephone No.	Office Telephone No.
Scott Bratten	651-436-6135	651-290-5624
Farley Haase	715-235-1928	651-290-5633
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 at 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.

7-05. Flood Control. Lock and Dam No. 5 has no flood control benefits. It is operated strictly for navigation. While it may seem possible that the pools be drawn down 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, which was amended in 1948 to prevent 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. 5 is 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 8,000 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. 5

Year	Towboats & Barges	Recreation Boaters	Other Lockages	Total Lockages	Percent Recreation
1991	1,368	9,654	145	11,167	86.5
1992	1,296	9,584	115	10,995	87.2
1993	869	5,315	106	6,290	84.5
1994	1,029	9,914	119	11,062	89.6
1995	1,185	10,108	124	11,417	88.5
1996	1,284	9,817	272	11,373	86.3
1997	1,194	9,624	214	11,032	87.2
1998	1,325	9,126	136	10,587	86.2
1999	1,298	9,118	105	10,521	86.7
2000	1,278	8,869	91	10,238	86.6

7-07. Water Quality. The Corps of Engineers does not currently perform any water quality analysis in Pool No. 5; however, water quality assessments were made in Weaver Bottoms and Belvidere Slough between the years 1985 and 1995. The work was performed as part of an assessment of the rehabilitation project for that area. There were 22 sampling stations (see **Figure 4-1.**) For more information see section **4-07. Water Quality** or the *Weaver Bottoms Rehabilitation Project, Resource Analysis Program, 1985-1997, Final Report*.

Also, 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 1956, during low to moderate flows, the only water flowing into Pool No. 5A was passed through the dam. In November 1956, a 36-inch corrugated metal culvert was installed through the earth dike portion of the dam to provide flow to Indian Creek below the dike. At project pool, elevation 660.0 feet, a continuous flow of 70 cfs is maintained through this culvert. In 1978, three 48-inch corrugated metal culverts were installed through the upper end of the earth dike to provide additional flow to backwater areas below the earth dike. At project pool, a combined continuous flow of 320 cfs is maintained through the three culverts. This flow aids fish habitat by aerating the water downstream. While all four culverts are capable of being regulated (stop logs for the single culvert and sluice gates for the set of three culverts), they are primarily left open and are closed only when needed, such as during flood events.

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. Therefore, Water Control typically operates on the high side of the band (i.e. 660.3 ft) during the winter months.

7-09. Water Supply. The cities of Alma and Buffalo, Wisconsin obtain their water from wells. Pool No. 5 does not provide water supply.

7-10. Hydroelectric Power. There is no hydroelectric power at Lock and Dam No. 5.

7-11. Navigation. The primary purpose of Lock and Dam No. 5 is to provide navigation. The lock is 110 feet wide and 600 feet long. In a single lockage, this will accommodate a towboat (about the same length as a barge) and two rows of three barges (typically 35 ft by 195 ft). On a double lockage, a maximum of 15 barges can be locked through. The first nine barges (three rows of three) enter the lock chamber and are broken free of the remainder. The haulage unit moves these through the lock and they are then tied to the guidewall. The towboat with the remaining six barges (two rows of three) passes through the lock and is rejoined with the nine other barges. Filling and emptying time for the lock under normal conditions is ten 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 hour and 30 minutes to 2 hours.

7-12. Emergency Action Plans. The Emergency Action Plan is a stand-alone document entitled *Emergency Plan for Lock and Dam 5 at Minnesota City, Minnesota*, May 1997. 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. Potential causes of an emergency affecting the operation or safety of Lock and Dam No. 5 include earthquake, landslide (reservoir), operation error, excessive seepage, sabotage, foundation failure, abutment failure, equipment failure, extreme storm, upstream dam failure, overtopping, blockage of spillway, and slope failure (embankment).

There are several protective measures taken at Lock and Dam No. 5 when a flood occurs. When the pool level is forecasted to go above elevation 661.9 feet (1912 adjustment), staff monitoring is initiated in the miter gate machinery pits during operations to check for debris. Also, over-travel limit switches are disconnected. As the pool continues to rise other actions are required. The following table gives a brief summary of the steps to be taken for high water levels:

Table 7-8
Emergency Action for Flood Conditions

Water Elevation	Action Taken
657.0 feet (TW)	Control seepage in control building and transformer vault. Pump crossover. Install plugs in miter gage machinery pits.
664.5 feet (pool)	Lock is closed to navigation.
665.0 feet (pool)	Remove miter gate handrails. Fill septic tank for control building. Fill fuel storage tanks. Construct a dike from levee on upstream end of esplanade to lock wall. Sandbag the control building and manholes on lock walls. Construct dike along south edge of esplanade from the control building to higher ground. Protect lower tow haulage motor and upper tow haulage unit.
669.0 feet (pool)	Construct sandbag levee across storage yard. (There is a plan for raising the 3.5 miles of earth dike.)

7-13. Other. During a flood event, debris is passed beneath the gates as they are typically raised clear of the water. Debris that hangs up around the tainter gates may require assistance. This is handled after the peak has passed. 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 660.0 ± 0.2 feet at the primary control point near Alma 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, 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. Planned deviations will be coordinated with MVD. 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 prescribed 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. 5 is to maintain a nine-foot depth in the navigation channel of Pool No. 5. Lock and Dam No. 5 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 principle. As discharge increases, the gates are opened. At around 116,000 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. 5 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. 5 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 8,000 recreation boat lockages in the year 2000 (**Table 7-7**).

8-04. Fish and Wildlife. Part of the Upper Mississippi River Wildlife and Fish Refuge is located in Pool No. 5. The Refuge was established in 1924 to preserve the Upper Mississippi River for fish, migratory birds, and other wildlife. The Refuge includes acreage acquired by the U.S 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. 5, 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 tons in 1976. **Table 8-1** shows the recent history of tonnage commodities at Lock and Dam No. 5. 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 about ten miles upstream of Lock and Dam No. 4, and about 25 miles upstream of Lock and Dam No. 5. 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. 5 Tonnage – Commodities

Year	Coal	Petrol Product	Chemical Products	Crude Material	Manu Goods	Farm Products	Equip Mach	Misc Product	Total Tonnage
1991	1,116,000	746,100	1,336,000	775,500	421,600	8,344,600	4,500	0	12,744,300
1992	887,000	331,900	1,710,500	819,100	456,900	9,281,600	17,400	12,500	13,516,900
1993	932,000	186,000	1,597,100	713,500	295,900	4,380,400	28,500	17,000	8,150,400
1994	1,107,600	253,000	2,039,300	838,600	405,700	5,571,600	3,800	35,900	10,255,500
1995	660,700	513,600	1,598,200	897,200	382,000	6,329,700	16,400	130,400	10,528,200
1996	780,000	449,400	1,640,900	1,066,500	238,200	7,215,300	21,100	68,600	11,480,000
1997	804,500	548,500	1,429,400	1,206,300	304,500	6,284,300	24,900	122,700	10,725,100
1998	975,800	897,900	1,561,800	986,300	515,000	6,677,100	10,900	55,000	11,699,800
1999	1,022,400	641,300	1,383,700	958,700	656,300	8,015,500	1,600	91,700	12,771,200
2000	842,125	605,554	1,663,985	988,138	567,871	7,138,448	28,362	212,870	12,047,353

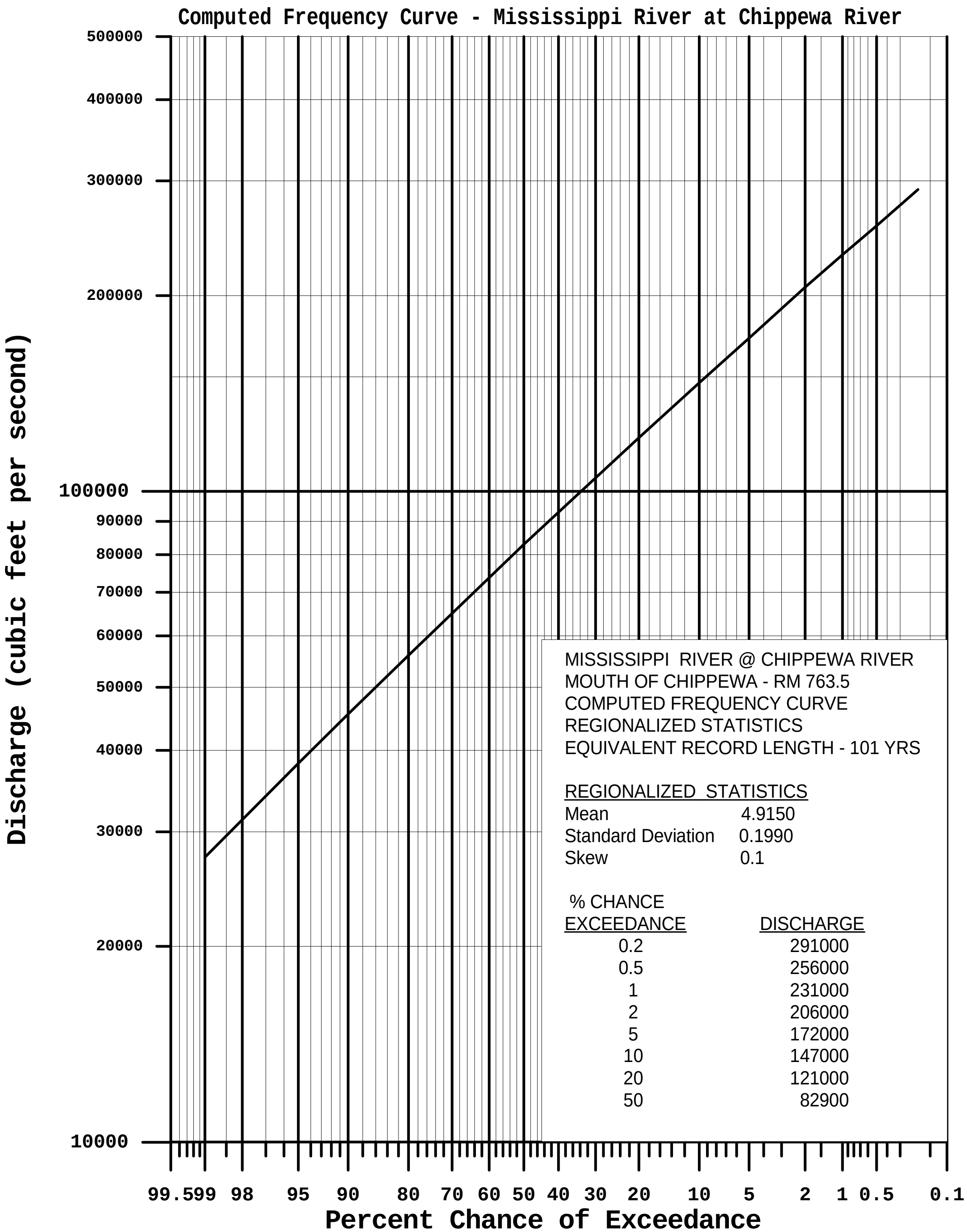


Figure 8-1. Mississippi River at Chippewa River Discharge-Frequency

Construction of the dam was completed in December 1935. By August 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 allowed to be drawn down 2.5-foot below project pool level to elevation 657.5 feet (1912 adjustment). In 1960, drawdown of the pool was reduced to 1.5-foot and was reduced again in 1970 to only 0.5-foot, thus making the secondary control elevation 659.5 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 February 1944 when the pool was draw down to elevation 648.32 feet.

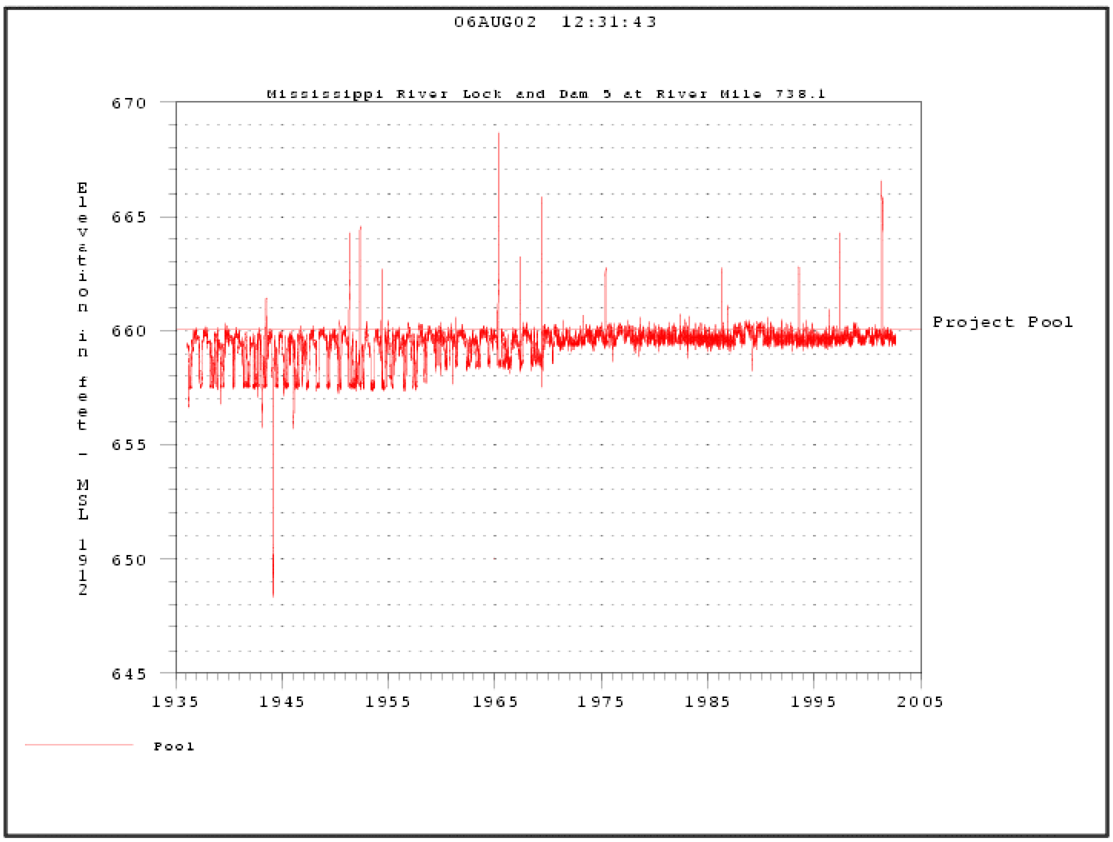


Figure 8-2. History of Pool Elevation

Water surface profile frequencies were developed in 1979 for Pool No. 5. 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.

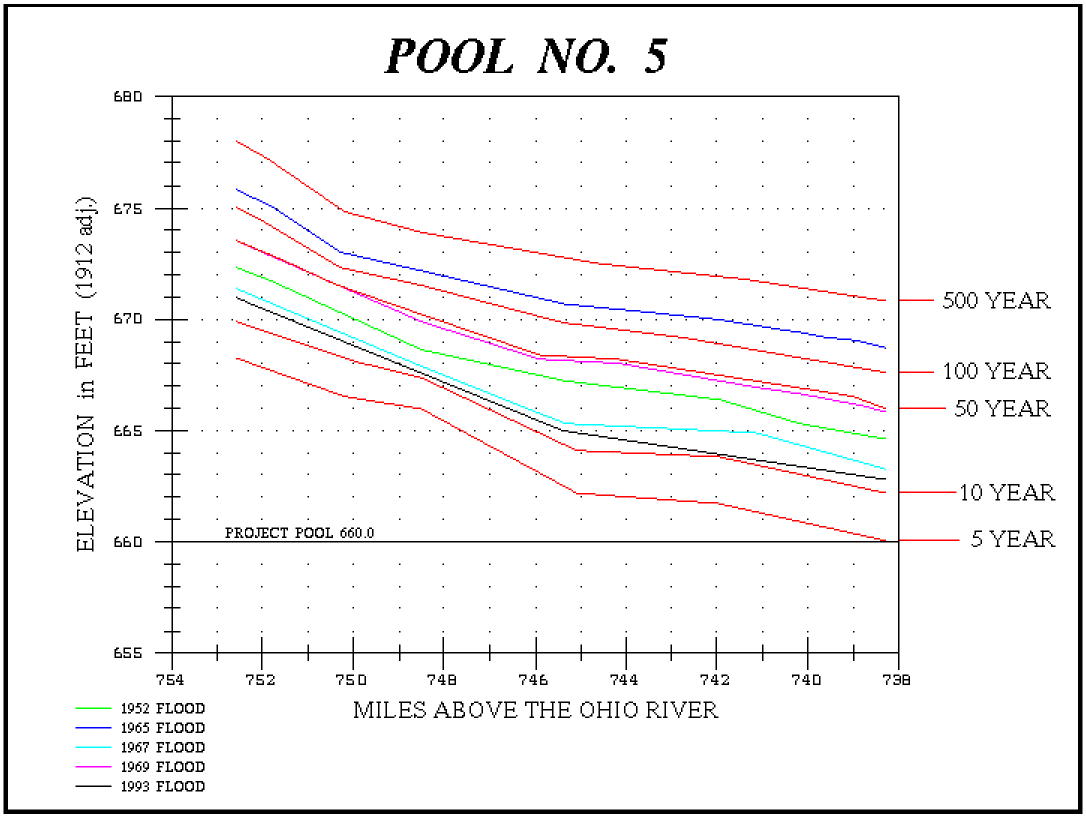


Figure 8-3. Water Surface Profiles - Flood Frequencies and Historic Floods

IX – WATER CONTROL MANAGEMENT

9-01. Responsibilities and Organization.

a. Corps of Engineers. The Corps of Engineers is the owner, operator, and regulator for Lock and Dam No. 5. The St. Paul District, Water Control Section has direct day-to-day responsibility for gate adjustments at the dam. Construction and Operations Division is responsible for operation and maintenance of the lock and the dam. The following shows the working relationship for the locks and dams within the St. Paul District.

St. Paul District Office
← ← ← District Engineer → → →

↓	↓
Chief Engineering Division	**Chief Con-Ops Division**
↓	↓
Chief H&H Branch	**Chief Lock & Dam Project Office**
↓	↓
Chief Water Control Section	**Area Lockmaster**
↓	↓

Water Control Manager → → → → → Lockmaster

b. Other Federal Agencies. During high water, the National Weather Service (NWS) forecasts stage heights for the Dam No. 4 tailwater (Alma, Wisconsin). Water Control Section provides the NWS with the daily output from the Mississippi Basin Modeling System to aid them in making their forecast. The US Geological Survey (USGS) maintains the gage site at Zumbro Falls, Minnesota (gage # 05374000). Daily discharge values are printed annually in the USGS *Water Resources Data – Minnesota* report. Daily discharge values can also be obtained from their web site at wwwmn.cr.usgs.gov. The US Fish and Wildlife Service (USFWS) maintains the Mississippi River National Wildlife and Fish Refuge, part of which is located in Pool No. 5.

9-02. Interagency Coordination.

a. Local Press and Corps Bulletins. Information concerning regulation of Lock and Dam No. 5 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 to the NWS by 0930-hours. The NWS uses this information to forecast stages along the Mississippi River, which includes Dam No. 4 tailwater (Alma, Wisconsin) in Pool No. 5.

c. US Geological Survey. To maintain the vast network of stream gages necessary for operation of the locks and dams in the St. Paul District would require multiple gage crews. 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. 5, this includes the Zumbro River at Zumbro Falls. 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 – Minnesota*. Data are also available from their web site wwwmn.cr.usgs.gov.

d. US Fish and Wildlife Service. The St. Paul District, in coordination with the US Fish and Wildlife Service, and other Federal, State, and local agencies is currently evaluating 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. 5.

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, Minnesota Department of Natural Resources, Wisconsin Department of Natural Resources, Minnesota Department of Transportation, Wisconsin Department of Transportation, 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. National 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 once a year.

EXHIBIT A
SUPPLEMENTARY PERTINENT DATA

General Information

Location:	Mississippi River Mile 738.1 Lat 44 09’ 42”N Long 91 48’ 42” W Minneiska, Minnesota 14.7 miles below Lock and Dam No. 4 9.6 miles above Lock and Dam No. 5A
Type of Project:	Lock and Dam for Navigation Purposes
Project Owner:	Corps of Engineers
Operating Agency:	St. Paul District; Construction-Operations Division 24 hrs a day, 7 days a week
Regulating Agency:	St. Paul District; Water Control Section
Completion Date:	December 1935

Hydrology

Drainage Area:	58,845 square miles
Design Flood:	Flood of 1880 Design High Water: Elevation 655.5 ft Design Discharge: 178,000 cfs
Minimum Flow:	Of Record: 1934 Discharge 2,250 cfs Post Const: Dec 1980 Discharge 2,400 cfs
Maximum Flow:	19 Apr 1965: Discharge 270,000 cfs
Average Annual Flow:	Years 1959-1993: Discharge 31, 600 cfs
Maximum Monthly Flow:	April 2001: Discharge 152,200 cfs
Maximum Daily Flow:	19 April 1965: Discharge 259,500 cfs
Key Stream Flow Locations:	Mississippi River @ TW of Lock and Dam No. 4 Mississippi River near Alma, Wisconsin (control point) Zumbro River @ Zumbro Falls, Minnesota Voice Modem: 507-753-2689

Data Recorded at Dam Site:	Pool & Tailwater Elevations (4-hr)
	Discharge (4-hr)
	Control Point Elevation near Alma (4-hr)
	Gate Openings (4-hr)
	Air Temperature (8-hr)
	Wind Speed & Direction (8-hr)
	Water Temperature (daily)
	Precipitation (daily)
	Snow Depth & Water Content (weekly)
	Pool & Tailwater Ice Coverage (observed weekly)
	Pool & Tailwater Ice Thickness (observed weekly)
Precipitation Gages:	Lock & Dam No. 4 and 5
	Mississippi River near Alma, Wisconsin (control point)
Snow Survey:	At LD No. 5 (weekly by site personnel)
	Zumbro River Basin (late Feb by gage crew)
	Rochester and Zumbrota, Minnesota

Physical Features

Moveable Dam:	Roller Gates:	6 Gates	60 feet by 20 feet
	Tainter Gates:	28 Gates	35 feet by 15 feet
	Roller Gate Sill:		Elevation 645.0 ft
	Tainter Gate Sill:		Elevation 640.0 ft
	Roller Gate End Sill:		Elevation 643.0 ft
	Tainter Gate End Sill:		Elevation 643.0 ft
	Roller Gate Submergence:		3 feet below PP
	Bulkheads:	Roller Gates: 6 @	4’-2” by 64’-2”
		Tainter Gates: 8 @	4’-2” by 37’-6”
	Top of Bridge Deck:		Elevation 688.0 ft
Lock:	Main Lock Chamber:		110 ft by 600 ft
	Top of Lock Walls:		Elevation 665.0 ft
	Top of Upper Gate Sill (main):		Elevation 642.0 ft
	Top of Upper Gate Sill (aux):		Elevation 639.0 ft
	Top of Lower Gate Sill:		Elevation 639.0 ft
	Lock Chamber Floor:		Elevation 637.0 ft
	Height of Upper Miter Gates (main):		20.0 feet
	Height of Upper Miter Gates (aux):		23.0 feet
	Height of Lower Miter Gates:		23.0 feet
	Upper Guidewall Length:		521 feet
	Lower Guidewall Length:		504 feet
	Average Filling/Emptying Time:		10 minutes

	Average Double Lockage Time:	1.5 to 2.0 hours
Earthen Dam:	Length:	18,219 feet
	Crest Elevation:	670.0 to 672.0 ft
	Top Width:	20.0 feet
	Maximum Height:	30 feet
	Pool Side Slope:	1V:3 H
	Tailwater Side Slope:	1V:5.5 H
	Slope Protection:	12 inch riprap
	To crest on pool side.	
	To elevation 653.0 ft on TW side.	
Pool:	Normal (Project) Upper Pool:	Elevation 660.0 ft
	Normal (Project) Lower Pool:	Elevation 651.0 ft
	Primary Control Point (Alma):	Elevation 660.0 ft
	Total Pool Area (at Project Pool):	12,580 ac
	Length in River Miles:	14.7 miles
	Navigation Channel Width;	
	Straight Reaches:	300 feet
	Curved Reaches:	300-550 feet
	Most Frequent Dredge Site:	Fisher Island

EXPANDED RATING TABLE

05374000 DATE PROCESSED: 01-30-2002 @ 14:49 BY mitton TYPE: LOG
ZUMBRO RIVER AT ZUMBRO FALLS, MN DD: 7 TYPE: 001 RATING NO: 39.0
OFFSET: .00 START DATE/TIME: 10-01-2000 (0001)

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) .00	.01	.02	.03	.04	.05	.06	.07	.08	.09
6.00	68.00	69.23	70.48	71.76	73.05	74.36	75.70	77.06	78.44	79.84
6.10	81.26	82.71	84.18	85.68	87.20	88.74	90.31	91.90	93.52	95.16
6.20	96.83	98.53	100.3	102.0	103.8	105.6	107.4	109.3	111.2	113.1
6.30	115.1	117.0	119.1	121.1	123.2	125.3	127.4	129.6	131.8	134.1
6.40	136.4	138.7	141.0	143.4	145.8	148.3	150.8	153.3	155.9	158.5
6.50	161.2	163.9	166.6	169.4	172.2	175.0	177.9	180.9	183.9	186.9
6.60	190.0	192.8	195.7	198.6	201.6	204.6	207.6	210.7	213.8	216.9
6.70	220.1	223.4	226.7	230.0	233.3	236.8	240.2	243.7	247.3	250.9
6.80	254.5	258.2	261.9	265.7	269.5	273.4	277.3	281.3	285.4	289.5
6.90	293.6	297.8	302.0	306.3	310.7	315.1	319.6	324.1	328.7	333.3
7.00	338.0	342.7	347.6	352.4	357.4	362.3	367.4	372.5	377.7	382.9
7.10	388.3	393.6	399.1	404.6	410.2	415.8	421.5	427.3	433.2	439.1
7.20	445.1	451.2	457.4	463.6	469.9	476.3	482.7	489.3	495.9	502.6
7.30	509.4	516.2	523.2	530.2	537.3	544.5	551.8	559.1	566.6	574.1
7.40	581.8	589.5	597.3	605.2	613.3	621.4	629.6	637.9	646.2	654.7
7.50	663.3	672.0	680.8	689.7	698.7	707.8	717.1	726.4	735.8	745.3
7.60	755.0	761.9	768.8	775.8	782.8	789.9	797.0	804.2	811.5	818.8
7.70	826.1	833.6	841.0	848.6	856.2	863.8	871.5	879.3	887.1	895.0
7.80	902.9	910.9	919.0	927.1	935.3	943.6	951.9	960.3	968.7	977.2
7.90	985.8	994.4	1003	1012	1021	1030	1039	1048	1057	1066
8.00	1075	1082	1090	1097	1104	1112	1119	1127	1135	1142
8.10	1150	1157	1165	1173	1181	1189	1197	1205	1213	1221
8.20	1229	1237	1245	1253	1262	1270	1278	1287	1295	1304
8.30	1312	1321	1329	1338	1347	1355	1364	1373	1382	1391
8.40	1400	1408	1416	1424	1431	1439	1447	1455	1463	1471

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND .00	.01	.02	.03	.04	(EXPANDED PRECISION) .05	.06	.07	.08	.09
8.50	1480	1488	1496	1504	1512	1521	1529	1537	1546	1554
8.60	1563	1571	1580	1588	1597	1606	1614	1623	1632	1641
8.70	1650	1658	1667	1676	1685	1694	1703	1712	1722	1731
8.80	1740	1749	1758	1767	1776	1785	1794	1803	1812	1821
8.90	1831	1840	1849	1859	1868	1877	1887	1896	1906	1915
9.00	1925	1931	1937	1943	1949	1955	1961	1967	1973	1979
9.10	1985	1991	1997	2003	2009	2015	2021	2027	2033	2039
9.20	2045	2051	2058	2064	2070	2076	2082	2088	2095	2101
9.30	2107	2113	2120	2126	2132	2139	2145	2151	2158	2164
9.40	2170	2177	2183	2189	2196	2202	2209	2215	2222	2228
9.50	2235	2241	2248	2254	2261	2267	2274	2280	2287	2293
9.60	2300	2308	2317	2325	2333	2342	2350	2359	2367	2376
9.70	2384	2393	2401	2410	2418	2427	2436	2444	2453	2462
9.80	2471	2479	2488	2497	2506	2515	2523	2532	2541	2550
9.90	2559	2568	2577	2586	2595	2604	2613	2623	2632	2641
10.00	2650	2658	2667	2675	2683	2692	2700	2709	2717	2726
10.10	2734	2743	2751	2760	2768	2777	2785	2794	2803	2811
10.20	2820	2829	2837	2846	2855	2864	2873	2881	2890	2899
10.30	2908	2917	2926	2935	2943	2952	2961	2970	2979	2988
10.40	2997	3007	3016	3025	3034	3043	3052	3061	3070	3080
10.50	3089	3098	3107	3117	3126	3135	3145	3154	3163	3173
10.60	3182	3192	3201	3211	3220	3230	3239	3249	3258	3268
10.70	3278	3287	3297	3307	3316	3326	3336	3345	3355	3365
10.80	3375	3385	3394	3404	3414	3424	3434	3444	3454	3464
10.90	3474	3484	3494	3504	3514	3524	3534	3544	3555	3565
11.00	3575	3585	3595	3606	3616	3626	3637	3647	3657	3668
11.10	3678	3689	3699	3710	3720	3731	3741	3752	3762	3773
11.20	3783	3794	3805	3815	3826	3837	3847	3858	3869	3880
11.30	3891	3901	3912	3923	3934	3945	3956	3967	3978	3989
11.40	4000	4011	4022	4033	4044	4055	4067	4078	4089	4100

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)				
11.50	4111	4123	4134	4145	4156	4168	4179	4190	4202	4213
11.60	4225	4236	4248	4259	4271	4282	4294	4305	4317	4329
11.70	4340	4352	4364	4375	4387	4399	4411	4423	4434	4446
11.80	4458	4470	4482	4494	4506	4518	4530	4542	4554	4566
11.90	4578	4590	4602	4614	4627	4639	4651	4663	4675	4688
12.00	4700	4709	4719	4728	4738	4747	4757	4766	4776	4785
12.10	4795	4804	4814	4823	4833	4842	4852	4862	4871	4881
12.20	4890	4900	4910	4919	4929	4939	4949	4958	4968	4978
12.30	4987	4997	5007	5017	5026	5036	5046	5056	5066	5076
12.40	5085	5095	5105	5115	5125	5135	5145	5155	5165	5175
12.50	5185	5195	5205	5215	5225	5235	5245	5255	5265	5275
12.60	5285	5295	5305	5315	5325	5335	5346	5356	5366	5376
12.70	5386	5396	5407	5417	5427	5437	5448	5458	5468	5478
12.80	5489	5499	5509	5520	5530	5540	5551	5561	5572	5582
12.90	5592	5603	5613	5624	5634	5645	5655	5666	5676	5687
13.00	5697	5708	5718	5729	5739	5750	5761	5771	5782	5792
13.10	5803	5814	5824	5835	5846	5856	5867	5878	5889	5899
13.20	5910	5921	5932	5942	5953	5964	5975	5986	5997	6007
13.30	6018	6029	6040	6051	6062	6073	6084	6095	6106	6117
13.40	6128	6139	6150	6161	6172	6183	6194	6205	6216	6227
13.50	6238	6249	6260	6271	6283	6294	6305	6316	6327	6339
13.60	6350	6361	6372	6383	6395	6406	6417	6429	6440	6451
13.70	6463	6474	6485	6497	6508	6519	6531	6542	6554	6565
13.80	6576	6588	6599	6611	6622	6634	6645	6657	6669	6680
13.90	6692	6703	6715	6726	6738	6750	6761	6773	6785	6796
14.00	6808	6820	6831	6843	6855	6867	6878	6890	6902	6914
14.10	6925	6937	6949	6961	6973	6985	6996	7008	7020	7032
14.20	7044	7056	7068	7080	7092	7104	7116	7128	7140	7152
14.30	7164	7176	7188	7200	7212	7224	7236	7248	7261	7273
14.40	7285	7297	7309	7321	7334	7346	7358	7370	7383	7395

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)				
14.50	7407	7419	7432	7444	7456	7469	7481	7493	7506	7518
14.60	7530	7543	7555	7568	7580	7593	7605	7618	7630	7643
14.70	7655	7668	7680	7693	7705	7718	7730	7743	7756	7768
14.80	7781	7793	7806	7819	7831	7844	7857	7870	7882	7895
14.90	7908	7921	7933	7946	7959	7972	7985	7997	8010	8023
15.00	8036	8049	8062	8075	8088	8100	8113	8126	8139	8152
15.10	8165	8178	8191	8204	8217	8230	8244	8257	8270	8283
15.20	8296	8309	8322	8335	8348	8362	8375	8388	8401	8414
15.30	8428	8441	8454	8467	8481	8494	8507	8521	8534	8547
15.40	8561	8574	8587	8601	8614	8628	8641	8655	8668	8681
15.50	8695	8708	8722	8735	8749	8762	8776	8790	8803	8817
15.60	8830	8844	8858	8871	8885	8899	8912	8926	8940	8953
15.70	8967	8981	8995	9008	9022	9036	9050	9063	9077	9091
15.80	9105	9119	9133	9147	9160	9174	9188	9202	9216	9230
15.90	9244	9258	9272	9286	9300	9314	9328	9342	9356	9370
16.00	9384	9399	9413	9427	9441	9455	9469	9483	9498	9512
16.10	9526	9540	9554	9569	9583	9597	9612	9626	9640	9655
16.20	9669	9683	9698	9712	9726	9741	9755	9770	9784	9798
16.30	9813	9827	9842	9856	9871	9885	9900	9915	9929	9944
16.40	9958	9973	9987	10000	10020	10030	10050	10060	10080	10090
16.50	10100	10120	10130	10150	10160	10180	10190	10210	10220	10240
16.60	10250	10270	10280	10300	10310	10330	10340	10360	10370	10390
16.70	10400	10420	10430	10450	10460	10480	10490	10510	10520	10540
16.80	10550	10570	10580	10600	10610	10630	10640	10660	10670	10690
16.90	10700	10720	10730	10750	10760	10780	10800	10810	10830	10840
17.00	10860	10870	10890	10900	10920	10930	10950	10960	10980	11000
17.10	11010	11030	11040	11060	11070	11090	11100	11120	11130	11150
17.20	11170	11180	11200	11210	11230	11240	11260	11270	11290	11300
17.30	11310	11320	11340	11350	11360	11370	11390	11400	11410	11420
17.40	11440	11450	11460	11480	11490	11500	11510	11530	11540	11550

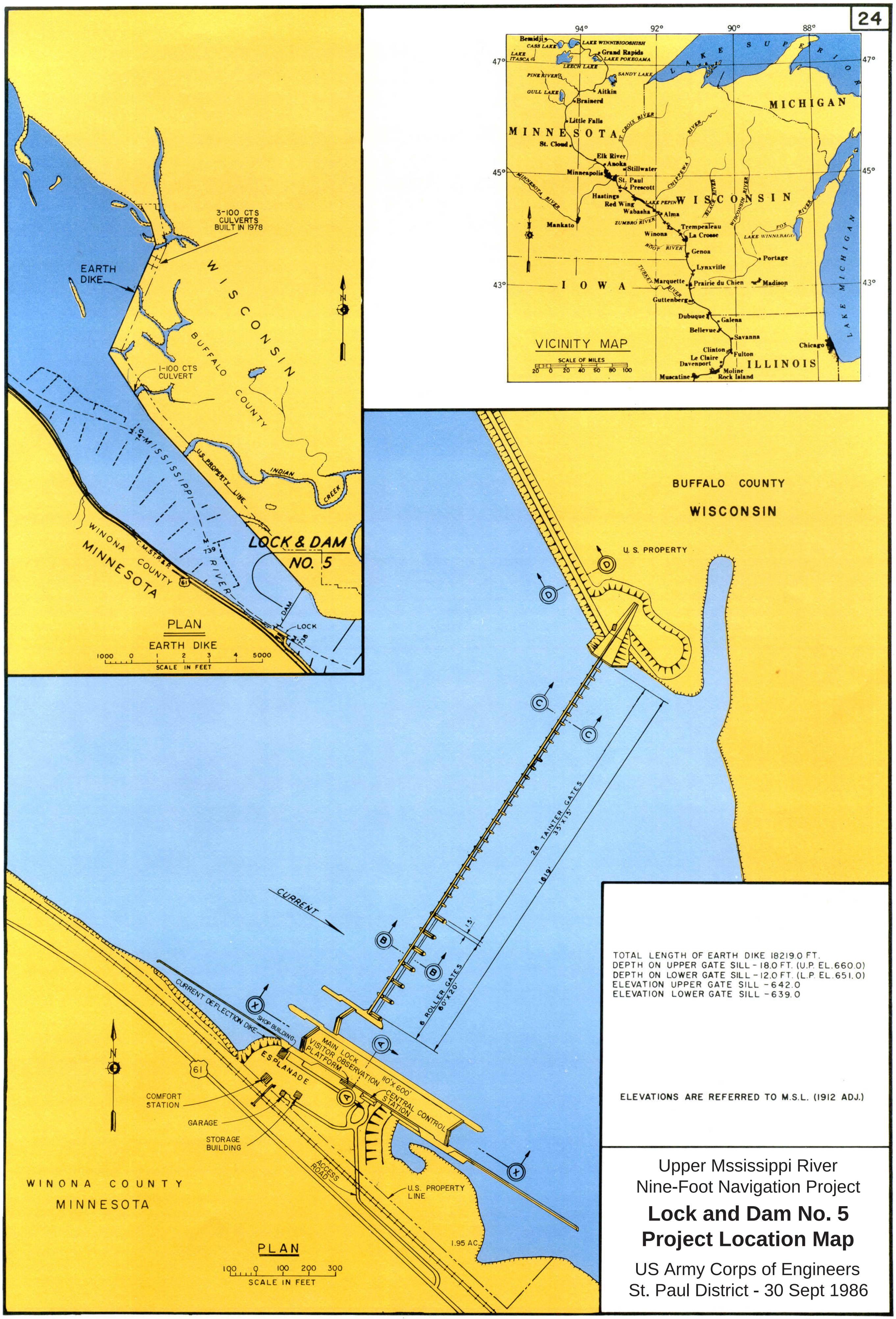
GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)				
17.50	11560	11580	11590	11600	11620	11630	11640	11650	11670	11680
17.60	11690	11710	11720	11730	11740	11760	11770	11780	11800	11810
17.70	11820	11830	11850	11860	11870	11890	11900	11910	11920	11940
17.80	11950	11960	11980	11990	12000	12020	12030	12040	12050	12070
17.90	12080	12090	12110	12120	12130	12150	12160	12170	12190	12200
18.00	12210	12220	12240	12250	12260	12280	12290	12300	12320	12330
18.10	12340	12360	12370	12380	12400	12410	12420	12440	12450	12460
18.20	12470	12490	12500	12510	12530	12540	12550	12570	12580	12590
18.30	12610	12620	12630	12650	12660	12670	12690	12700	12710	12730
18.40	12740	12750	12770	12780	12790	12810	12820	12840	12850	12860
18.50	12880	12890	12900	12920	12930	12940	12960	12970	12980	13000
18.60	13010	13020	13040	13050	13060	13080	13090	13100	13120	13130
18.70	13150	13160	13170	13190	13200	13210	13230	13240	13250	13270
18.80	13280	13300	13310	13320	13340	13350	13360	13380	13390	13400
18.90	13420	13430	13450	13460	13470	13490	13500	13510	13530	13540
19.00	13560	13570	13580	13600	13610	13630	13640	13650	13670	13680
19.10	13690	13710	13720	13740	13750	13760	13780	13790	13810	13820
19.20	13830	13850	13860	13880	13890	13900	13920	13930	13940	13960
19.30	13970	13990	14000	14010	14030	14040	14060	14070	14080	14100
19.40	14110	14130	14140	14160	14170	14180	14200	14210	14230	14240
19.50	14250	14270	14280	14300	14310	14320	14340	14350	14370	14380
19.60	14400	14410	14420	14440	14450	14470	14480	14500	14510	14520
19.70	14540	14550	14570	14580	14590	14610	14620	14640	14650	14670
19.80	14680	14700	14710	14720	14740	14750	14770	14780	14800	14810
19.90	14820	14840	14850	14870	14880	14900	14910	14930	14940	14950
20.00	14970	14980	15000	15010	15030	15040	15060	15070	15080	15100
20.10	15110	15130	15140	15160	15170	15190	15200	15220	15230	15240
20.20	15260	15270	15290	15300	15320	15330	15350	15360	15380	15390
20.30	15410	15420	15430	15450	15460	15480	15490	15510	15520	15540
20.40	15550	15570	15580	15600	15610	15630	15640	15660	15670	15690

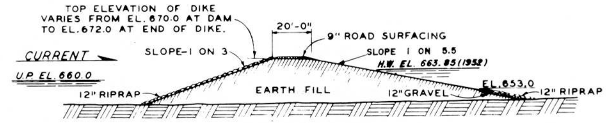
GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) .00	.01	.02	.03	.04	.05	.06	.07	.08	.09
20.50	15700	15710	15730	15740	15760	15770	15790	15800	15820	15830
20.60	15850	15860	15880	15890	15910	15920	15940	15950	15970	15980
20.70	16000	16010	16030	16040	16060	16070	16090	16100	16120	16130
20.80	16150	16160	16180	16190	16210	16220	16240	16250	16270	16280
20.90	16300	16310	16330	16340	16360	16370	16390	16400	16420	16430
21.00	16450	16460	16480	16490	16510	16520	16540	16550	16570	16580
21.10	16600	16620	16630	16650	16660	16680	16690	16710	16720	16740
21.20	16750	16770	16780	16800	16810	16830	16840	16860	16870	16890
21.30	16910	16920	16940	16950	16970	16980	17000	17010	17030	17040
21.40	17060	17070	17090	17110	17120	17140	17150	17170	17180	17200
21.50	17210	17230	17240	17260	17280	17290	17310	17320	17340	17350
21.60	17370	17380	17400	17420	17430	17450	17460	17480	17490	17510
21.70	17520	17540	17560	17570	17590	17600	17620	17630	17650	17670
21.80	17680	17700	17710	17730	17740	17760	17770	17790	17810	17820
21.90	17840	17850	17870	17880	17900	17920	17930	17950	17960	17980
22.00	18000	18010	18030	18040	18060	18070	18090	18110	18120	18140
22.10	18150	18170	18190	18200	18220	18230	18250	18270	18280	18300
22.20	18310	18330	18340	18360	18380	18390	18410	18420	18440	18460
22.30	18470	18490	18500	18520	18540	18550	18570	18580	18600	18620
22.40	18630	18650	18670	18680	18700	18710	18730	18750	18760	18780
22.50	18790	18810	18830	18840	18860	18870	18890	18910	18920	18940
22.60	18960	18970	18990	19000	19020	19040	19050	19070	19090	19100
22.70	19120	19130	19150	19170	19180	19200	19220	19230	19250	19260
22.80	19280	19300	19310	19330	19350	19360	19380	19400	19410	19430
22.90	19450	19460	19480	19490	19510	19530	19540	19560	19580	19590
23.00	19610	19630	19640	19660	19680	19690	19710	19720	19740	19760
23.10	19770	19790	19810	19820	19840	19860	19870	19890	19910	19920
23.20	19940	19960	19970	19990	20010	20020	20040	20060	20070	20090
23.30	20110	20120	20140	20160	20170	20190	20210	20220	20240	20260
23.40	20270	20290	20310	20320	20340	20360	20370	20390	20410	20420

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)				
23.50	20440	20460	20480	20490	20510	20530	20540	20560	20580	20590
23.60	20610	20630	20640	20660	20680	20690	20710	20730	20750	20760
23.70	20780	20800	20810	20830	20850	20860	20880	20900	20910	20930
23.80	20950	20970	20980	21000	21020	21030	21050	21070	21080	21100
23.90	21120	21140	21150	21170	21190	21200	21220	21240	21260	21270
24.00	21290	21310	21320	21340	21360	21380	21390	21410	21430	21440
24.10	21460	21480	21500	21510	21530	21550	21570	21580	21600	21620
24.20	21630	21650	21670	21690	21700	21720	21740	21760	21770	21790
24.30	21810	21820	21840	21860	21880	21890	21910	21930	21950	21960
24.40	21980	22000	22020	22030	22050	22070	22090	22100	22120	22140
24.50	22160	22170	22190	22210	22230	22240	22260	22280	22300	22310
24.60	22330	22350	22370	22380	22400	22420	22440	22450	22470	22490
24.70	22510	22520	22540	22560	22580	22590	22610	22630	22650	22670
24.80	22680	22700	22720	22740	22750	22770	22790	22810	22820	22840
24.90	22860	22880	22900	22910	22930	22950	22970	22980	23000	23020
25.00	23040	23060	23070	23090	23110	23130	23140	23160	23180	23200
25.10	23220	23230	23250	23270	23290	23310	23320	23340	23360	23380
25.20	23390	23410	23430	23450	23470	23480	23500	23520	23540	23560
25.30	23570	23590	23610	23630	23650	23660	23680	23700	23720	23740
25.40	23760	23770	23790	23810	23830	23850	23860	23880	23900	23920
25.50	23940	23950	23970	23990	24010	24030	24050	24060	24080	24100
25.60	24120	24140	24150	24170	24190	24210	24230	24250	24260	24280
25.70	24300	24320	24340	24360	24370	24390	24410	24430	24450	24460
25.80	24480	24500	24520	24540	24560	24570	24590	24610	24630	24650
25.90	24670	24690	24700	24720	24740	24760	24780	24800	24810	24830
26.00	24850	24870	24890	24910	24930	24940	24960	24980	25000	25020
26.10	25040	25050	25070	25090	25110	25130	25150	25170	25180	25200
26.20	25220	25240	25260	25280	25300	25320	25330	25350	25370	25390
26.30	25410	25430	25450	25460	25480	25500	25520	25540	25560	25580
26.40	25600	25610	25630	25650	25670	25690	25710	25730	25750	25760

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)				
26.50	25780	25800	25820	25840	25860	25880	25900	25910	25930	25950
26.60	25970	25990	26010	26030	26050	26070	26080	26100	26120	26140
26.70	26160	26180	26200	26220	26240	26260	26270	26290	26310	26330
26.80	26350	26370	26390	26410	26430	26450	26460	26480	26500	26520
26.90	26540	26560	26580	26600	26620	26640	26650	26670	26690	26710
27.00	26730	26750	26770	26790	26810	26830	26850	26870	26880	26900
27.10	26920	26940	26960	26980	27000	27020	27040	27060	27080	27100
27.20	27120	27130	27150	27170	27190	27210	27230	27250	27270	27290
27.30	27310	27330	27350	27370	27390	27400	27420	27440	27460	27480
27.40	27500	27520	27540	27560	27580	27600	27620	27640	27660	27680
27.50	27700	27720	27730	27750	27770	27790	27810	27830	27850	27870
27.60	27890	27910	27930	27950	27970	27990	28010	28030	28050	28070
27.70	28090	28110	28130	28150	28160	28180	28200	28220	28240	28260
27.80	28280	28300	28320	28340	28360	28380	28400	28420	28440	28460
27.90	28480	28500	28520	28540	28560	28580	28600	28620	28640	28660
28.00	28680	28700	28720	28740	28760	28780	28800	28820	28840	28860
28.10	28880	28900	28920	28940	28950	28970	28990	29010	29030	29050
28.20	29070	29090	29110	29130	29150	29170	29190	29210	29230	29250
28.30	29270	29290	29310	29330	29350	29370	29390	29410	29430	29450
28.40	29470	29490	29510	29530	29550	29570	29590	29610	29630	29650
28.50	29670	29700	29720	29740	29760	29780	29800	29820	29840	29860
28.60	29880	29900	29920	29940	29960	29980	30000	30020	30040	30060
28.70	30080	30100	30120	30140	30160	30180	30200	30220	30240	30260
28.80	30280	30300	30320	30340	30360	30380	30400	30420	30440	30460
28.90	30480	30510	30530	30550	30570	30590	30610	30630	30650	30670
29.00	30690	30710	30730	30750	30770	30790	30810	30830	30850	30870
29.10	30890	30910	30940	30960	30980	31000	31020	31040	31060	31080
29.20	31100	31120	31140	31160	31180	31200	31220	31240	31260	31280
29.30	31310	31330	31350	31370	31390	31410	31430	31450	31470	31490
29.40	31510	31530	31550	31570	31600	31620	31640	31660	31680	31700

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	DISCHARGE IN CUBIC FEET PER SECOND					(EXPANDED PRECISION)				
29.50	31720	31740	31760	31780	31800	31820	31840	31870	31890	31910
29.60	31930	31950	31970	31990	32010	32030	32050	32070	32090	32120
29.70	32140	32160	32180	32200	32220	32240	32260	32280	32300	32330
29.80	32350	32370	32390	32410	32430	32450	32470	32490	32510	32540
29.90	32560	32580	32600	32620	32640	32660	32680	32700	32720	32750
30.00	32770	32790	32810	32830	32850	32870	32890	32910	32940	32960
30.10	32980	33000	33020	33040	33060	33080	33110	33130	33150	33170
30.20	33190	33210	33230	33250	33280	33300	33320	33340	33360	33380
30.30	33400	33420	33450	33470	33490	33510	33530	33550	33570	33590
30.40	33620	33640	33660	33680	33700	33720	33740	33770	33790	33810
30.50	33830	33850	33870	33890	33920	33940	33960	33980	34000	34020
30.60	34040	34070	34090	34110	34130	34150	34170	34200	34220	34240
30.70	34260	34280	34300	34320	34350	34370	34390	34410	34430	34450
30.80	34480	34500	34520	34540	34560	34580	34610	34630	34650	34670
30.90	34690	34710	34740	34760	34780	34800	34820	34840	34870	34890
31.00	34910									

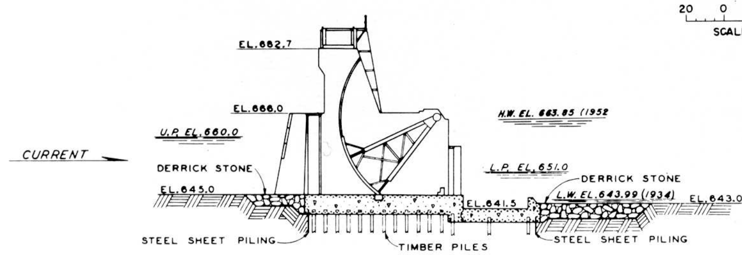

24
VICINITY MAP
SCALE OF MILES
MINNESOTA
WISCONSIN
MICHIGAN
IOWA
ILLINOIS
LAKE SUPERIOR
LAKE MICHIGAN
Minneapolis
St. Paul
Winona
La Crosse
Chicago
3-100 CTS CULVERTS BUILT IN 1978
EARTH DIKE
1-100 CTS CULVERT
WISCONSIN
BUFFALO COUNTY
MISSISSIPPI RIVER
U.S. PROPERTY LINE
INDIAN CREEK
LOCK & DAM NO. 5
WINONA COUNTY
MINNESOTA
C.M.ST.P.&P.
DAM
LOCK
PLAN
EARTH DIKE
SCALE IN FEET
BUFFALO COUNTY
WISCONSIN
U. S. PROPERTY
28 TAINTER GATES 35' X 15'
1619'
6 ROLLER GATES 60' X 20'
CURRENT
CURRENT DEFLECTION DIKE
SHOP BUILDING
MAIN LOCK 110' X 600'
VISITOR OBSERVATION PLATFORM
ESPLANADE
CENTRAL CONTROL STATION
COMFORT STATION
GARAGE
STORAGE BUILDING
ACCESS ROAD
U.S. PROPERTY LINE
1.95 AC.
WINONA COUNTY
MINNESOTA
PLAN
SCALE IN FEET
TOTAL LENGTH OF EARTH DIKE 18219.0 FT.
DEPTH ON UPPER GATE SILL - 18.0 FT. (U.P. EL. 660.0)
DEPTH ON LOWER GATE SILL - 12.0 FT. (L.P. EL. 651.0)
ELEVATION UPPER GATE SILL - 642.0
ELEVATION LOWER GATE SILL - 639.0
ELEVATIONS ARE REFERRED TO M.S.L. (1912 ADJ.)
Upper Mssissippi River
Nine-Foot Navigation Project
Lock and Dam No. 5
Project Location Map
US Army Corps of Engineers
St. Paul District - 30 Sept 1986



SECTION D-D

EARTH DIKE

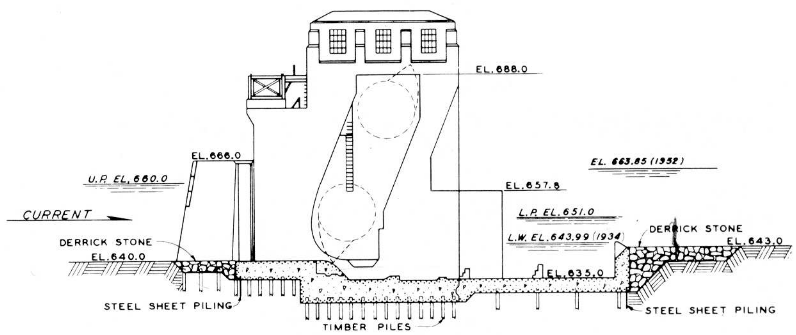
20 0 20 40 60 SCALE IN FEET



SECTION C-C

TAINTER GATE

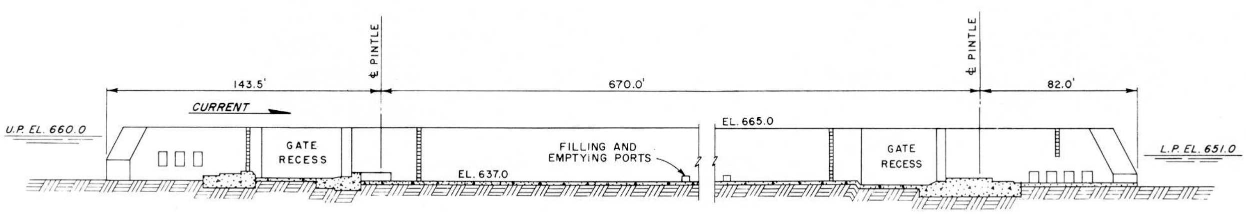
10 0 10 20 30 SCALE IN FEET



SECTION B-B

ROLLER GATE

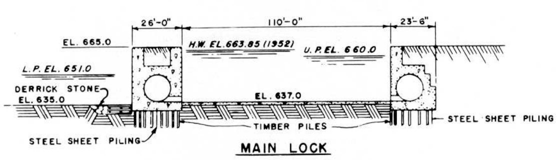
10 0 10 20 30 SCALE IN FEET



SECTION X-X

MAIN LOCK

20 0 20 40 60 SCALE IN FEET



SECTION A-A

LOCK

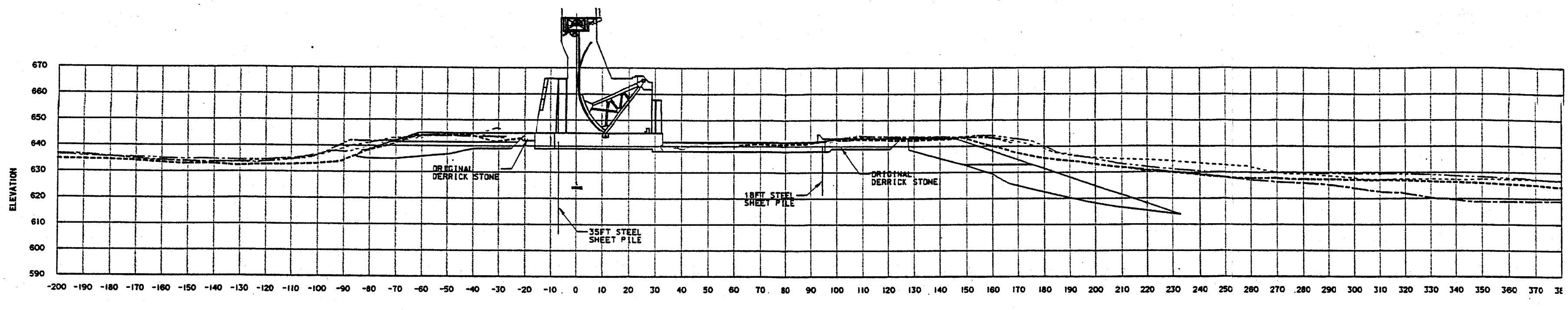
20 0 20 40 60 SCALE IN FEET

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

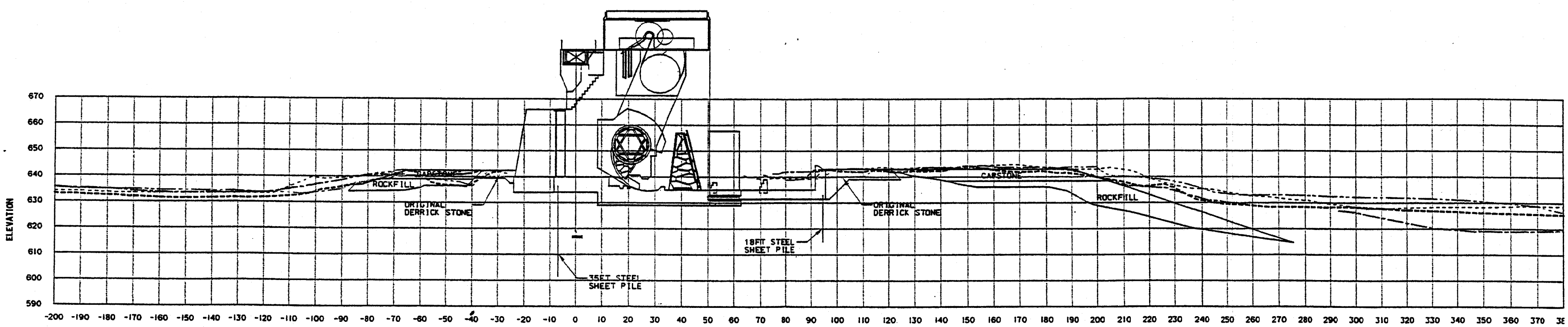
Upper Mssissippi River
Nine-Foot Navigation Project

Lock and Dam No. 5
Cross Sections

US Army Corps of Engineers
St. Paul District - 30 Sept 1977



P-8



P-7

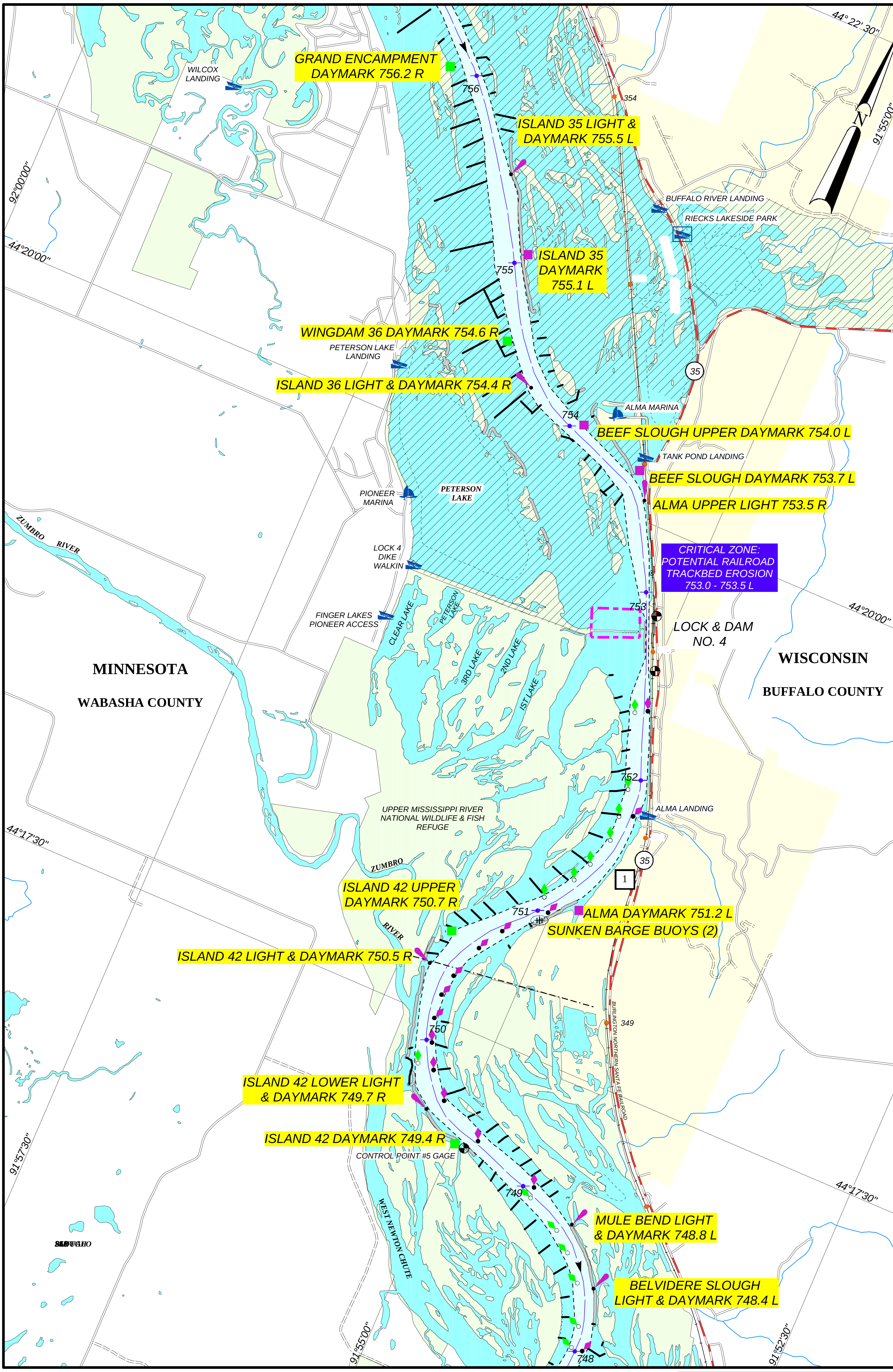
KEY
1999
1998
1997
1996

Upper Mississippi River
Nine-Foot Navigation Project

Scour Protection
Upstream and Downstream of Dam 5
Capstone and Rockfill Placed in 1983 and 1984

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

Plate 2-3



2001

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

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

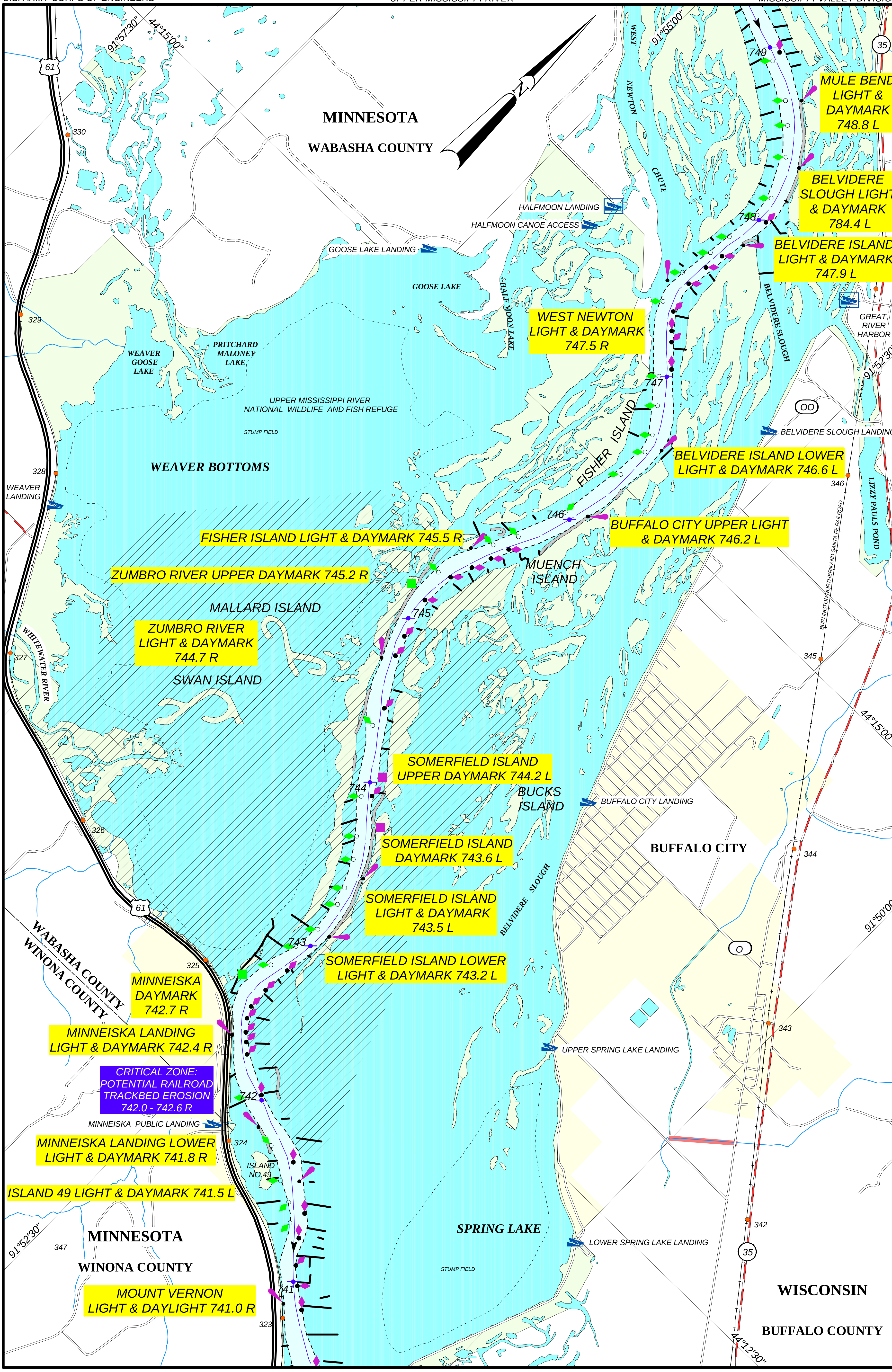
1 0.5 0 1 MILES

1 0.5 0 1 KILOMETERS

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

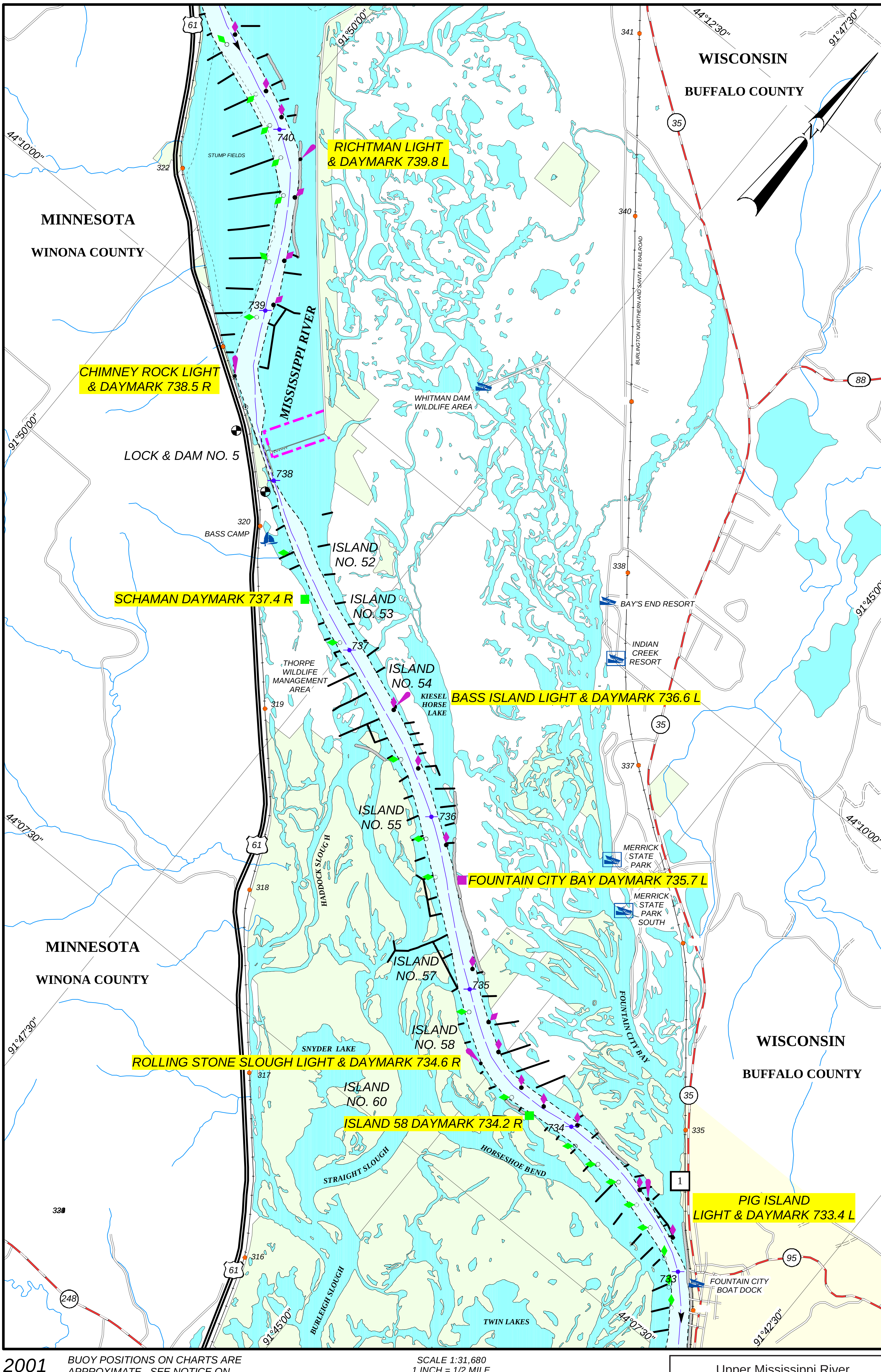


2001

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

SCALE 1:31,680
1 INCH = 1/2 MILE
1 0.5 0 1 MILES
1 0.5 0 1 KILOMETERS

Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 741 to 749
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN

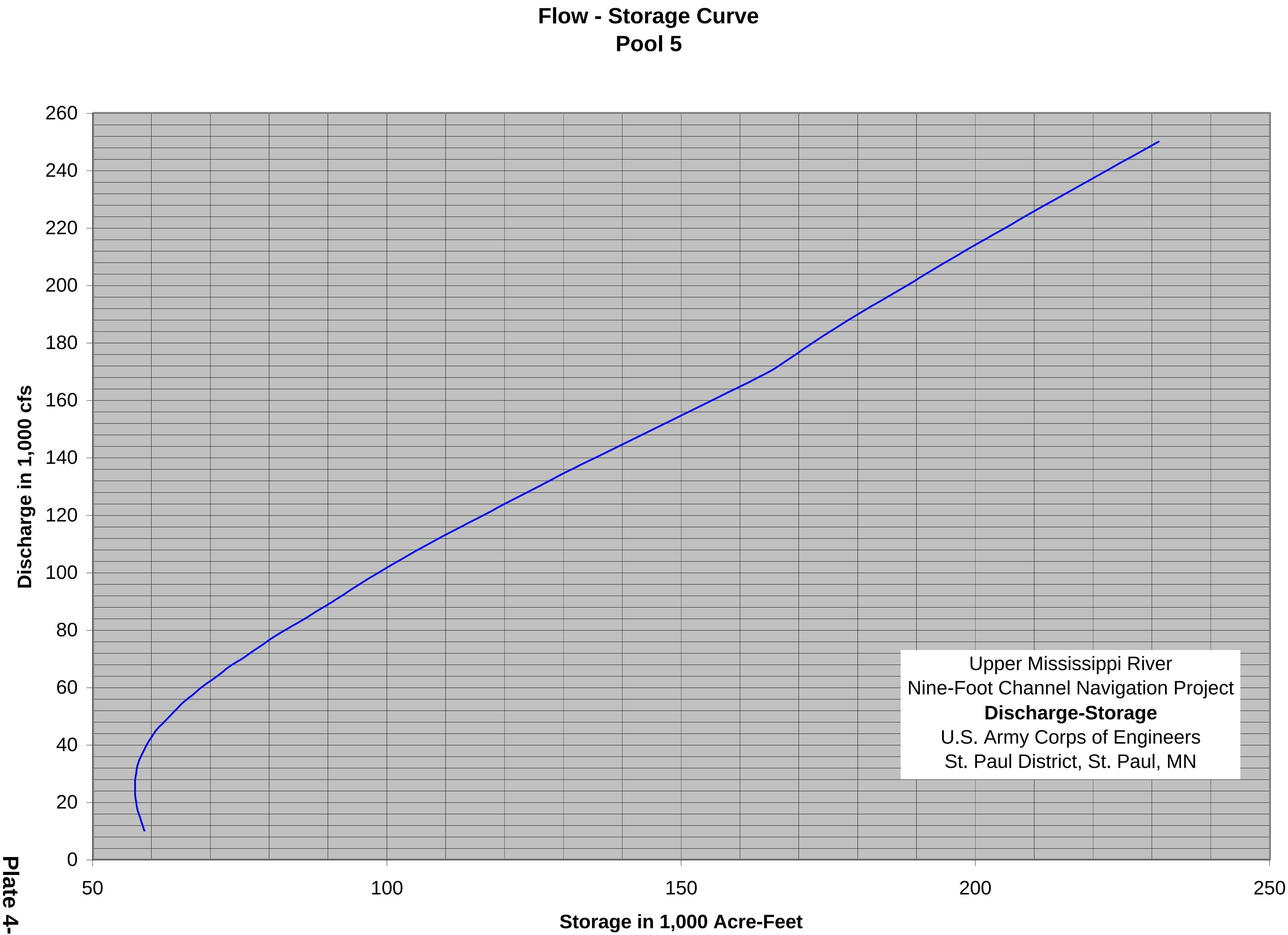


2001

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

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

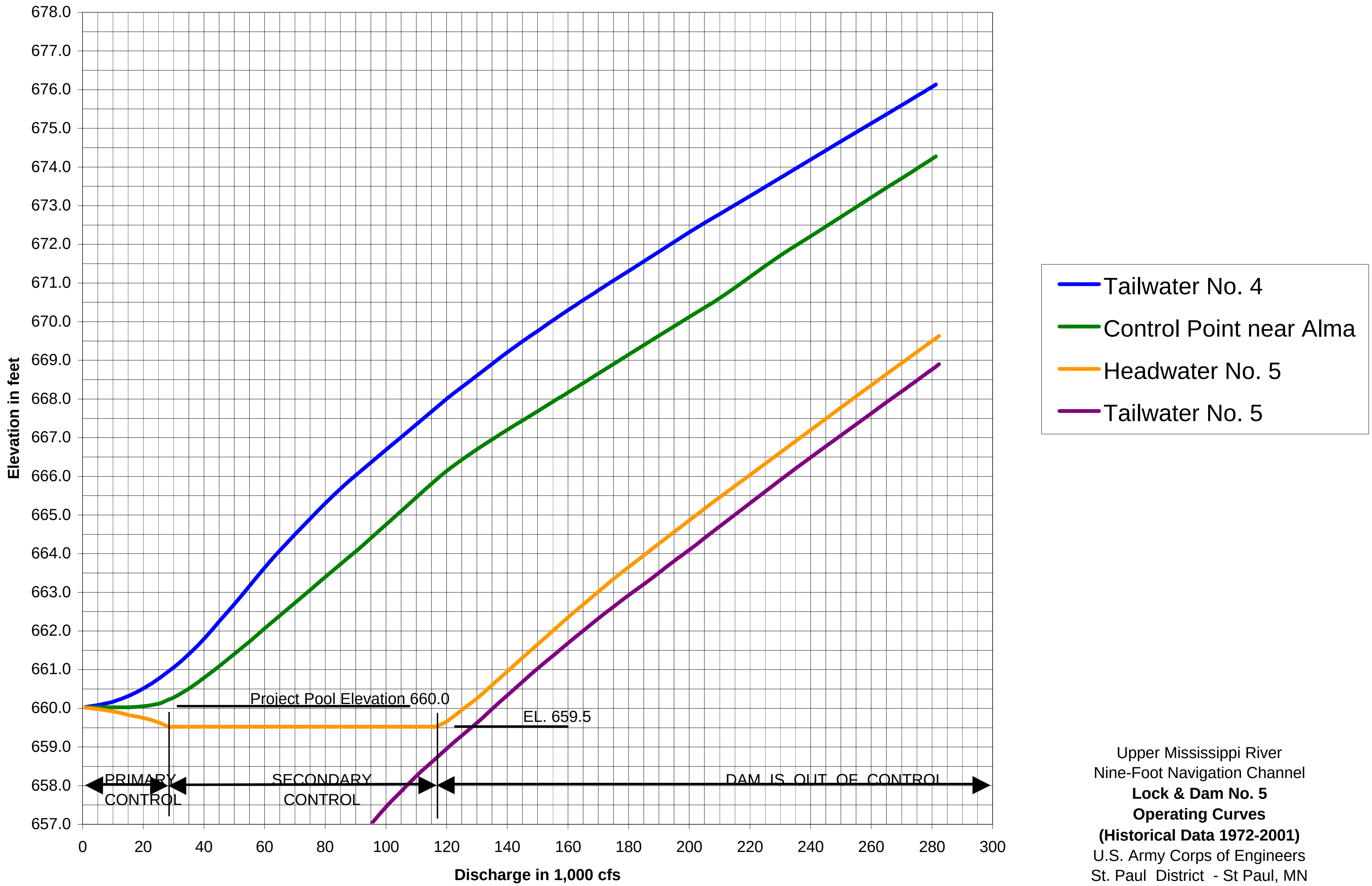
Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 733 to 740
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN



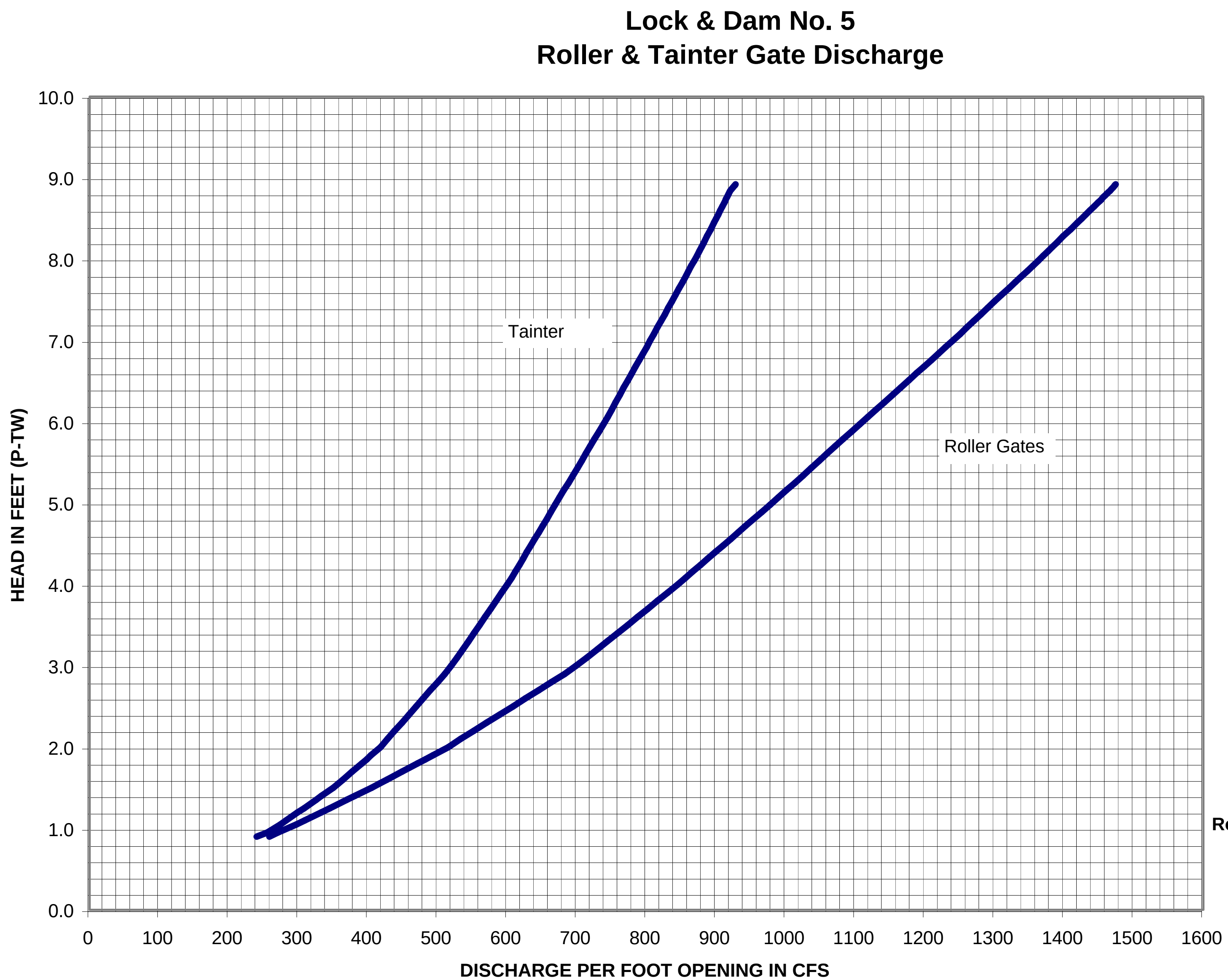
Flow - Storage Curve
Pool 5
Discharge in 1,000 cfs
Storage in 1,000 Acre-Feet
0
20
40
60
80
100
120
140
160
180
200
220
240
260
50
100
150
200
250
Upper Mississippi River
Nine-Foot Channel Navigation Project
Discharge-Storage
U.S. Army Corps of Engineers
St. Paul District, St. Paul, MN

Plate 4-1

LOCK & DAM NO. 5 OPERATING CURVES



Upper Mississippi River
Nine-Foot Navigation Channel
Lock & Dam No. 5
Operating Curves
(Historical Data 1972-2001)
U.S. Army Corps of Engineers
St. Paul District - St Paul, MN



Upper Mississippi River
Nine-Foot Channel Navigation
Project

Lock & Dam No. 5
Roller & Tainter Gate Discharges
For a Single Gate

U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN
September 1969

Plate 7-2