**US Army Corps**
**of Engineers®**
St. Paul District

# WATER CONTROL MANUAL

MISSISSIPPI RIVER NINE FOOT CHANNEL
NAVIGATION PROJECT

# LOCK AND DAM NO. 6

TREMPEALEAU, WISCONSIN

APPENDIX 6 OF THE MASTER WATER CONTROL MANUAL

JANUARY 2016

# WATER CONTROL MANUAL

MISSISSIPPI RIVER NINE-FOOT CHANNEL

## LOCK AND DAM NO. 6

**APPENDIX 6**

JAN 2016

US Army Corps of Engineers®
St. Paul District

# WATER CONTROL MANUAL

## LOCK AND DAM No. 6
## TREMPEAULEAU, WISCONSIN

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

## APPENDIX No. 6
## Of The
## MASTER WATER CONTROL MANUAL

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

## JANUARY 2016

**Updated from**
**Reservoir Regulation Manual, November 2001**
**Operation of Navigation Pools, February 1943**

**LOCK AND DAM No. 6**

**TREMPEALEAU, WISCONSIN**

**Aerial View Looking Downstream – Summer 1995**

**5 Roller Gates and 10 Tainter Gates**
**Project Pool 645.5 feet (1912 Adjustment)**

**LOCK AND DAM No. 6**

**TREMPEALEAU, WISCONSIN**


**Lock and Dam No. 6 Control House**
**Dedicated July 1999**

**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. A Master Regulation Manual replaced it in September 1969. Appendices for each lock and dam were added during the years 1970 through 1972, with Appendix No. 6 being completed in November 1970. Appendix No. 6 was updated in November 2001. This manual is an update of the November 2001 manual.

## EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise (e.g. gate failure, excessive rainfall), the Lockmaster, Locks and Dams Chief, and Water Management should be notified as to the extent of the event. During normal water management duty hours (i.e. 0630 to 1500 hrs weekdays), contact with water management can be made at 651-290-5633. On weekends and holidays, the Duty Regulator's mobile number can be used. The Duty Regulator is the person listed below who issued the most recent regulation orders. If communication with Water Management cannot be established, the following list can be used as a guide for establishing contact.

| **Water Management Regulation Assistance** | | | |
|---|---|---|---|
| Daniel M. Fasching | Primary Mississippi River Regulator<br>daniel.m.fasching@usace.army.mil | Duty:<br>[redacted] | 651-290-5786<br>[redacted] |
| Elizabeth A. Nelsen | Hydraulic Engineer<br>elizabeth.a.nelsen@usace.army.mil | Duty:<br>[redacted] | 651-290-5306<br>[redacted] |
| Brian K. Johnson | Hydraulic Engineer<br>brian.ke.johnson@usace.army.mil | Duty:<br>[redacted] | 651-290-5652<br>[redacted] |
| Eric V. Novotny | Hydraulic Engineer<br>eric.v.novotny@usace.army.mil | Duty: | 651-290-5164 |
| William R. Odell | Water Management Gage Crew<br>william.r.odell@usace.army.mil | Duty:<br>[redacted] | 651-290-5218<br>[redacted] |
| Jim Rand | Mississippi River Navigation Manager<br>jimmy.t.rand@usace.army.mil | Duty:<br>[redacted] | 651-290-5986<br>[redacted] |
| Michael R. Knoff | Chief, Hydraulics & Hydrology Br<br>michael.r.knoff@usace.army.mil | Duty: | 651-290-5600 |
| Michael J. Bart | Chief, Engineering Division<br>michael.j.bart@usace.army.mil | Duty:<br>[redacted] | 651-290-5303<br>[redacted] |

**Lock and Dam No. 6**
**Trempealeau, Wisconsin**

**U.S. Army Corps of Engineers**
**St. Paul District –January 2016**

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**Location:** Lock and Dam No. 6 is located on the Mississippi River, 714.3 river miles above the mouth of the Ohio River, 14.2 river miles below Lock and Dam No. 5A, and 11.8 river miles above Lock and Dam No. 7. The lock is on the left bank of the river adjacent to the village of Trempealeau, Wisconsin at approximate latitude 43º 60' 00" N and longitude 91º 26' 18" W. **All elevations in this manual use the Mean Sea Level Datum (MSL1912) unless otherwise stated. Subtract 0.472 ft. from MSL 1912 to convert NAVD 88.**

**Drainage Area:** 60,030 square miles

**Datum:** MSL – 1912 adjustment

**Fixed Height Dam:**

| | |
|---|---|
| Type: | Earth Dike with Fixed Crest Spillway |
| Total Length | 3,050 feet |
| Length of Earth Dam | 2,050 feet |
| Crest of Earth Dam | Elevation 654.5 feet (1912 adjustment) |
| Top Width of Earth Dam | 32 feet – 9 inches |
| Max Height of Earth Dam | 19 feet |
| Length of Fixed Crest Spillway | 1,000 feet |
| Crest of Concrete Spillway | Elevation 645.5 feet |

**Moveable Dam:**

| | | |
|---|---|---|
| Roller Gates | 5 Gates | 80 feet by 20 feet |
| Tainter Gates | 10 Gates | 35 feet by 15 feet |
| Roller Gate Sill | Elevation 625.5 feet | |
| Tainter Gate Sill | Elevation 630.5 feet | |

**Lock:**

| | |
|---|---|
| Main Lock Chamber | 110 feet by 600 feet |
| Top of Lock Walls | Elevation 654.5 feet |
| Top of Upper Gate Sill (Main) | Elevation 628.5 feet |
| Top of Upper Gate Sill (Auxiliary) | Elevation 626.5 feet |
| Top of Lower Gate Sill | Elevation 626.5 feet |
| Lock Floor | Elevation 624.0 feet |
| Height of Upper Miter Gates (Main) | 23.0 feet |
| Height of Upper Miter Gates (Aux.) | 25.0 feet |
| Height of Lower Miter Gates | 25.0 feet |

**Pool:**

| | |
|---|---|
| Normal (Project) Upper Pool | Elev. 645.5 ft (1912) 644.96 (1988) |
| Normal (Project) Lower Pool | Elev. 639.0 ft (1912) 638.50 (1988) |
| Total Pool Area (at Project Pool) | 8,870 acres |
| Effective Pool Area (at Project Pool) | 5,910 acres |
| Primary Control Point (Winona, MN) | Elev. 645.5 ft (1912) 644.96 (1988) |
| Secondary Control Point (Lock & Dam 6) | Elev. 644.5 ft (1912) 644.03 (1988) |

**Notes:** Roller gates are submergible to 3.0 feet below Normal Pool (645.5 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 6 Regulation Manual dated November 2001 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 Management Section activities for most foreseeable conditions and occurrences. The manual covers all Water 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 by the Rivers and Harbors Act of 1930 (PL 71-520; 46 Stat. 918), when Congress approved the nine-foot channel. Lock and Dam No. 6 was completed on 3 February 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 6, Lock and Dam No. 6, Trempealeau, Wisconsin*, Department of the Army, St. Paul District, Corps of Engineers, November 1970.
f. *Final Environmental Impact Statement for Operation and Maintenance of the 9-Foot Navigation Channel, Upper Mississippi River, Head of Navigation to Guttenberg, Iowa*, US Army Corps of Engineers, St. Paul District, 1974.
g. *Creativity, Conflict & Controversy: A History of the St. Paul District, U.S. Army Corps of Engineers*, by Raymond H Merritt, 1979.
h. *Final Environmental Impact Statement:* Great River Environmental Action Team I Study of the Upper Mississippi River, Guttenberg, Iowa, to the Head of Navigation at Minneapolis, Minnesota; Great River Environmental Action Team (GREAT), Volume 9, 1980.
i. *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.
j. *Effects of Increased Commercial Navigation Traffic on Freshwater Mussels in the Upper Mississippi River: Final Synthesis Report*, US Army Corps of Engineers, Waterways Experiment Station, TR EL-96-6, May 1996.
k. *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.
l. *Environmental Assessment:* Major rehabilitation, Locks and Dams 2 through 10, Upper Mississippi River, US Army Corps of Engineers, St. Paul District, 1987.
m. *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.
n. *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.

o. *Authorized and Operating Purposes of Corps of Engineers Reservoirs*, Department of the Army, U.S. Army Corps of Engineers, Washington D. C., July 1992.
p. *Trempealeau National Wildlife Refuge, Habitat Rehabilitation and Enhancement Project*, Definite Project Report/Environmental Assessment (SP-15), January 1994.
q. *Channel Maintenance Management Plan*, Upper Mississippi River Navigation System, U.S. Army Corps of Engineers, St. Paul District, 1996.
r. *Record of Decision (ROD) for Final Environmental Impact Statement, Channel Maintenance Management Plan*, Major General Robert B. Flowers, Commander and Division Engineer, Mississippi Valley Division, US Army Corps of Engineers, June 1997.
s. *Zebra Mussel Response Plan*, U.S. Army Corps, St. Paul District, November, 1997.
t. *Locks and Dams Sounding Reports, Volume 2*, U.S. Army Corps of Engineers, St. Paul District, 1999.
u. *Biological Opinion for the Operation and Maintenance of the 9-Foot Navigation Channel on the Upper Mississippi River System*, US Fish and Wildlife Service, 15 May 2000.
v. *2001 Annual Report – Water Quality Management Program*, US Army Corps of Engineers, St. Paul District, January 2002.
w. Engineering Regulation, ER 200-1-5, *Policy for Implementation and Integrated Application of the US Army Corps of Engineers (USACE) Environmental Operating Principles (EOP) and Doctrine*, 30 October 2003.

**1-04. Project Owner.** The United States Government is the owner of Lock and Dam No. 6.

**1-05. Operating Agency.** Lock and Dam No. 6 is operated by the U.S. Army Corps of Engineers, St. Paul District. Operation and maintenance is the responsibility of Operations Division.

**1-06. Regulating Agency.** Regulation of Lock and Dam No. 6 is under the supervision of the Water Management and Hydrology Section in the Hydraulics and Hydrology Branch, Engineering and Construction Division.

The project is attended 24 hours a day, every day of the year. The Chief,

Operations Division and the Chief, Engineering and Construction Division are located in the St. Paul District Office, whereas the Lock and Dam Project Office is located in Fountain City, Wisconsin.

## II – DESCRIPTION OF PROJECT

**2-01. Location.** Lock and Dam No. 6 is located on the Mississippi River, 714.3 river miles above the mouth of the Ohio River, 14.2 river miles below Lock and Dam No. 5A, and 11.8 river miles above Lock and Dam No. 7. The lock is on the left bank of the river adjacent to the village of Trempealeau, Wisconsin at approximate latitude 43º 60' 00" N and longitude 91º 26' 18" W. The project is bordered by Trempealeau County on the Wisconsin side and Winona County on the Minnesota side. The project location is shown on **Plate 2-1**.

**2.02. Purpose.** Lock and Dam No. 6 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. 6 are navigation and recreation under Public Laws PL 71-520 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. 6 consists of a main and uncompleted auxiliary lock, a movable dam section, a concrete fixed-crest spillway, and an earthen dike. The locks, moveable dam, and spillway are supported on timber piling driven into sand and gravel with sheet pile cutoff walls. The following describes the hydraulic feature of each component in detail.

**a. Lock.** Lock and Dam No. 6 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 23.0 feet and 25.0 feet respectively. The respective sill elevations are 628.5 feet and 626.5 feet (1912 adjustment). A walkway is located atop the miter gates. It extends three feet above the top of miter gates (elevation 651.5 feet) to meet the top of lock walls (elevation 654.5 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 25 feet high with a sill elevation of 626.5

**Figure 2-1. Lock and Dam No. 6 Looking Upstream**

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 C-C). Flow then enters the lock chamber through ports along the lock wall (Section X-X) and the water level in the lock chamber rises until it equals the pool elevation. The upper tainter valves are then closed and the lower tainter valves are opened

thus emptying the lock chamber. Under normal conditions, filling and emptying times are about seven minutes.

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

Guidewalls are located upstream and downstream of the lock to provide a landing for down bound and up bound tows (**Plate 2-1**). As originally built, they were each approximately 600 feet in length. In 1951, the upstream guidewall was extended to 1200 feet due to outdraft problems.

**b. Moveable Dam.** The moveable dam section extends from the auxiliary lock to the right bank of main channel (see page ii). The moveable dam consists of five roller gates, 80 feet by 20 feet, and 10 tainter gates, 35 feet by 15 feet (**Figure 2-1**). The sill elevation of the roller gates is 625.5 feet (1912 adjustment), while the tainter gates sill elevation is 630.5 feet. The end sill elevations for the roller and tainter gates are 625.5 feet and 628.5 feet respectively. The roller gates can be submerged up to three feet below normal pool (elevation 645.5 feet). The tainter gates have electric side seal heaters, but the heaters are seldom able to free the tainter gates from the ice so they can be moved. 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 with the use of steam.

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

**Figure 2-2. Roller Gate Position Indicator**

the hoist mechanism. There are five bulkheads stored on site, measuring 4 feet – 2 inches by 85 feet – ½ inches. The sill elevation is 625.5 feet; therefore, the top of the bulkheads would be at elevation 646.17 feet (i.e. 646 feet – 2 inches).

Each tainter gate is individually operated by machinery consisting of an electrically operated central driving unit and two chain hoisting units. The electric controls consist of push buttons located on the deck rail. A position indicator is mounted on the pier about midway between the trunion and the gate surface. The indicator is marked in 0.1-foot increments. The tainter gates move at a rate similar to the roller gates. Gate movements between 0.0 and 4.0 feet are limited to one foot movements without using the bypass button. That is, once the gate is set in motion, movement is either terminated by the operator or after one foot of movement. There are four bulkheads stored on site measuring 4 feet – 2 inches by 37 feet – 6 inches. The sill is at elevation

630.5 feet; therefore, the top of the bulkheads would be at elevation 647.17 feet (i.e. 647 feet – 2 inches).

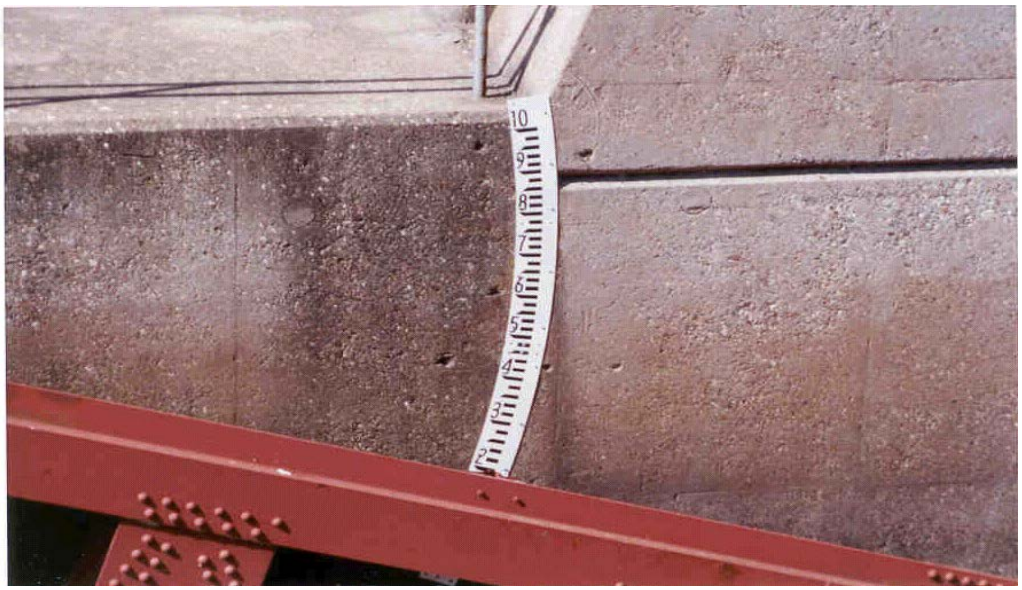


**Figure 2-3. Tainter Gate Position Indicator**

A service bridge, at elevation 674.75 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 25-ton capacity, was replaced in 1978. The new crane has a boom length of 40 feet and a capacity of 20 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 A-A and B-B 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, 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 622.5 feet (1912 adjustment). The derrick stone extended 27 feet downstream of the end sill. Upstream protection consisted of a 13.5 foot wide, 3 foot thick, section of derrick stone with a top elevation of 624.5 feet. The scour holes that formed upstream and downstream of the derrick stone were filled in 1983 with a horizontal capstone section 42 inches thick, underlain by a rockfill section a minimum of 30 inches thick. The capstone extends 55 feet downstream of the end sill and 40 feet upstream from the dam. The horizontal capstone was placed to the same elevation as the derrick stone on the downstream (elevation 622.5 feet) and 42 inches higher (capstone layer thickness) than the derrick stone on the upstream (elevation 624.5 feet).

**(2) Tainter Gates.** Downstream protection originally consisted of derrick stone 4 feet thick with a top of rock elevation of 628.5 feet (1912 adjustment). It extends 27 feet downstream of the end sill for the two tainter gates closest to the roller gates, about 65 feet for the next two tainter gates, and 42 feet for the remaining tainter gates. Upstream, the derrick stone section was 12 feet wide and 3 feet thick with a top of rock elevation of 629.5 feet. The scour hole upstream and downstream of the derrick stone was filled in 1983 by a horizontal capstone section 42 inches thick, underlain by a rockfill section a minimum of 30 inches thick. The capstone extends 27.5 feet downstream of the end sill at the two-tainter gates closest to the roller gates and 42.0 feet for the remaining gates. Upstream, the capstone protection extends 35 feet from the dam. The horizontal capstone was placed to the same elevation as the derrick stone (i.e. elevation 628.5 feet downstream and 629.5 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 622.5 feet (1912 adjustment) at the auxiliary lock to 624.0 feet downstream of the main lock. No scour protection was placed upstream of the locks; however, repairs in the early 1950's included placement of rock along a portion of the guidewall. In 1983, a minimum 30-inch thick rockfill section was placed upstream of the auxiliary lock for a distance of 110 feet.

**(4) Storage Yard**. Original scour protection downstream of the storage yard consisted of riprap placed on a 1V:5.5 H slope from the top of bank down to elevation 638.0 feet. In 1983, rockfill, 30 inches thick, was placed along the bank upstream of the storage yard for a distance of 200 feet.

**d. Earthen Dam and Fixed Crest Spillway.** An earthen dam, 3,050 feet in length, extends from the end of the moveable dam section to the high ground on the Minnesota side of the river (**Plate 2-1**). The dam has a crest elevation of 654.5 feet (1912 adjustment), a top width of 32.75 feet, and a maximum height of 19 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 three feet above the lower project pool (i.e. 639.0 + 3.0 = 642.0 ft).

Within the earthen dike is a concrete fixed-crest spillway (see figure on page ii). The spillway is 1,000 feet in length and is located near the Minnesota end. The crest elevation is 645.5 feet (i.e. Project Pool Elevation). In 1969 a slot was cut into the spillway to provide aeration to the backwater areas upstream

and downstream of the dam. The slot is 10.0 feet long and 3.0 feet deep. At project pool elevation of 645.5 feet, a continuous flow of 135 cfs is maintained.

**2-04. Related Control Facilities.** Beginning about three miles upstream of Lock and No. 6 and extending upstream for about seven miles, the embankment for the main line of the Burlington Northern Railroad divides the pool into two parts (**Plates 2-5 and 2-6**). The railroad embankment, constructed in 1880, isolated a wetland area of about 5,700 acres. In 1911, farmers constructed dikes to reroute the Trempealeau River around the wetland area, such that the Trempealeau River now enters the main channel through an opening in the railroad embankment just south of the wetland. Rerouting of the Trempealeau River completely isolated the wetland area from surface water inflows. With construction of the lock and dam in 1935, water levels within the wetland area became stabilized. In 1978, the US Fish and Wildlife Service purchased the wetland area which was owned by the Delta Fur Farm and created what is currently known as the Trempealeau National Wildlife Refuge. A series of dikes and pumps control water levels within the refuge. The US Fish and Wildlife Service manage water levels. While the total pool area is 8,870 acres at project pool elevation, 2,960 acres lie within the National Wildlife Refuge, which is separated from the main channel. Therefore, the pool may be considered to only encompass 5,910 acres.

**Figure 2-4. Pool No. 6 Looking Upstream**
**Trempealeau National Wildlife Refuge on Right**

**2-05. Real Estate Acquisition.** The Corps of Engineers acquired 326.41 acres of land and water area in fee for the Lock and Dam No. 6 project. In addition to this, the Corps has 1,458.99 acres in overflow and submerged permit from the US Fish and Wildlife Service. Of the Federal lands owned in fee, about 1,640 acres are above the project pool elevation of 645.5 feet (1912 adjustment).

**2-06. Public Facilities.** Lock and Dam No. 6 has two observation platforms, a comfort station, and a picnic table available for public use. One platform is located along the lower one-third of the lock chamber and sits atop the comfort station. Two concrete picnic tables are located nearby. The other platform was converted from the old lock house when major rehab was performed in 1993. This platform and the comfort station are handicap accessible.

There are two major parks adjacent to the pool. Perrot State Park in Wisconsin and Latsch Prairie Park in Minnesota. Perrot State Park is located three miles upstream of the dam and just downstream of the Trempealeau National Wildlife Refuge (**Plate 2-6**). In addition to these parks, there are numerous other facilities located throughout the pool.

**Table 2-1**
**Pool No. 6 Recreation Facilities**

| River Mile | Name | Manager | Fee | Slips | Parking | Camp Sites | Toilets | Picnic Tables |
|---|---|---|---|---|---|---|---|---|
| 728.2 R | Prairie Island Park | Winona | | | 100 | Yes | Yes | Yes |
| 728.0 L | Breezy Point Marina | Private | Yes | 30 | 20 | | | |
| 726.2 L | Dicks Marina | Private | | 186 | 50 | | Yes | |
| 725.8 L | City Harbor Access | Winona | | | 25 | | Yes | |
| 725.7 L | Mertes Slough Landing | USFWS | | | 12 | | | |
| 725.6 L | Latsch Island Park | Winona | | | 5 | | Yes | Yes |
| 724.8 R | Winona Yacht Club | Private | | 57 | 10 | | Yes | |
| 724.6 R | St. Charles St. Access | Winona | | | 30 | | | |
| 723.7 R | East End Ramp | Winona | | | 50 | | | |
| 720.8 R | Homer Landing | Homer | | | 1 | | | |
| 719.5 L | Trempealeau NW Refuge | USFWS | | | 10 | | | |
| 718.0 R | Winona KOA-Riverside | Private | Yes | | | Yes | Yes | Yes |
| 717.2 L | Perrot State Park | WDNR | | | 40 | Yes | Yes | Yes |
| 714.4 L | Trempealeau Marina | Private | | 150 | 50 | | Yes | |
| 714.4 L | Trempealeau Public Access | Trempealeau | Yes | | 50 | | Yes | Yes |

## III – HISTORY OF PROJECT

**3-01. Authorization.** The Lock and Dam No. 6 project was authorized by the Rivers and Harbors Act of 1930 (PL 71-520; 46 Stat. 918), 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. The upstream end of the pool rises with the discharge while the downstream end of the pool falls as the discharge through the dam increases, resulting in a drawdown at the dam. Drawdown at the dam is such that the water surface will be maintained at project pool elevation at a predetermined point, upstream of the dam, known as the "primary control point". Its location is near the point of intersection of the "project pool" (flat pool level) and the "ordinary high water" profile. The ordinary high water mark can be considered "the point up to which the presence and action of the water is so continuous as to destroy the value of the land for agricultural purposes by preventing the growth of vegetation, constituting what may be termed any ordinary agricultural crop". The government of the United States holds an easement to use the riparian lands up to the ordinary high water, in the public interest. Therefore, land inundated by the lock and dam above the ordinary high water profile was purchased in fee. This land lies between the primary control point and the dam.

The original design for Lock and Dam No. 6 had provided for the project pool to be maintained at elevation 651.0 feet (1912 adjustment), but at this elevation, Winona, Minnesota would have been damaged considerably. Therefore, the project pool was lowered to elevation 645.5 feet and Lock and Dam 5A was constructed about three miles above Winona with a lift from elevation 645.5 feet to elevation 651.0 feet. This resulted in a primary control point for Lock and Dam No. 6 to be located at Winona, Minnesota. The project pool elevation 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 643.0 feet (changed to 1.0 foot after 1959). As discharges increase, the gates are raised to maintain the maximum drawdown. As discharge continues to increase, eventually all the gates are raised above the water surface and open river conditions exist.

The total number of gates required at each site is based on the allowable swellhead at extreme high water. For Lock and Dam No. 6 the swellhead is 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 valley and the main channel at the lock and dam are both narrow. The double locks occupy so much of the main channel that the five roller gates utilize much of the remaining space, leaving room for only 10 tainter gates. To obtain the required spillway area, a 1,000-foot long concrete fixed crest spillway was constructed within the earthen embankment with a crest height set at the project pool elevation of 645.5 feet. In 1969 a notch was cut into the concrete spillway to provide flow through the upstream and downstream backwater areas and thus aerates the water for fish habitat. It is 10.0 feet long and 3.0 feet deep. At project pool, it provides a constant flow of 135 cfs. The project design flood for Lock and Dam No. 6 was the flood of 1880. The design high water was elevation 651.8 feet with a flow rate of 180,500 cfs.

**3-03. Construction.** Construction of the lock began on 22 November 1933 and was completed on 3 February 1935. Construction of the dam began on 15 October 1934 and was completed on 20 August 1936. The earth dike was completed on 28 June 1935.

**3-04. Related Projects.** Lock and Dam No. 6 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.

**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. Pursuant to the 19 June 1948 amendment to the Fish and Wildlife Coordination Act, codified at 16 U.S.C. 665a, "dam structures, shall generally operate and maintain pool levels as though navigation was carried on throughout the year.

**b. 1959 Modification.** The original maximum allowable drawdown for Lock and Dam No. 6 was 2.5 feet and was established in 1935. Maximum drawdown was based on the fact that further drawdown may result in jeopardizing navigation depths upstream of the dam, and would have very little effect on the water surface elevation at the primary control point. In 1959, to reduce the adverse effects of the drawdown on navigation, riverfront property, and conservation interests, the maximum allowable drawdown was reduced to 1.0 foot, or elevation 644.5 feet (1912 adjustment). This remains today as the secondary control elevation.

**c. 1974 Modification.** The 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.

**d. 1985 Modification.** In 1981 the Waterways Experiment Station now the Engineer Research and Development Center 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 1985. 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. Therefore, a new Gate Regulation Schedule was developed showing the new maximum allowable gate openings.

**e. 1993 Modification.** The motors that operate the lock miter gates were raised in 1993. Before this, the motors were pulled when the pool reached elevation 648.2 feet. Since the motors were raised, the lock does not go out of operation

until the pool is at or near the top of the upstream miter gates at elevation 651.5 feet (1912 adjustment).

**f. 1995 Modification.** Historically, winter regulation allowed a 0.25-foot drawdown at the primary control point. The drawdown 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, request that drawdown be abandoned on a trial basis. Further more, they requested Water Management to operate on the high side of the band (i.e. 645.5 ± 0.3 feet) 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.

**g. 2001 Modification.** Outflow measurements for the roller and tainter gates were taken between October 1994 and October 1996. The results published by Toltz, King, Duvall, and Anderson and Associates in December 1996 showed a shift in the discharge per foot for the roller and tainter gates at high head differentials. A new Gate Regulation Schedule (**Table 7-4**) was developed based on these findings.

**3-06. Principal Regulation Problems.** Outdraft problems for down bound tows and zebra mussels have been minor principal regulation problems at Lock and Dam 6. Zebra mussel populations along the Upper Mississippi River experience sporadic spikes and die offs adding varying degrees of maintenance from year to year. Zebra mussel buildup is monitored yearly, and they are removed when necessary to prevent the fouling of gage wells, water intakes, bubbler systems, concrete surfaces, and untreated metal surfaces such as the lock miter gates. Masses of dead zebra mussel shells have also accumulated in and around the lock, hindering operation. The shells have been removed mechanically and disposed of according

to the "Zebra Mussel Response Plan". The St. Paul District developed the "Zebra Mussel Response Plan" in November 1997. The plan also identified five methods for short-term control at the locks and dams. The tables below show the possible problems and the recommended control techniques identified in the study. According to the Corps Dive Team, physical removal by scraping has been the most effective removal technique to date.

**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. 6 totals 60,030 square miles in Minnesota and Wisconsin. Except for several small creeks, the only major tributary that flows into Pool No. 6 is the Trempealeau River with a total drainage area of 750 square miles. The Trempealeau River enters the pool from the Wisconsin side of the Mississippi River. The Trempealeau River was rerouted in 1911 such that it enters the Mississippi River about three miles upstream of the dam. Just upstream of the confluence of the Trempealeau River, the embankment for the main line of the Burlington Northern Railroad divides Pool No. 6 in two parts (see Chapter 2). The railroad embankment, constructed in 1880, combined with the rerouting of the Trempealeau River resulted in isolating a wetland area of about 5,700 acres. With construction of the lock and dam in 1935, water levels within the wetland area became stabilized. The US Fish and Wildlife Service manages water levels within the area now known as the Trempealeau National Wildlife Refuge. At project pool elevation of 645.5 feet (1912 adjustment), the pool has a total surface area of 8,870 acres; however, this includes 2,960 acres that are located within the Trempealeau National Wildlife Refuge. Therefore, the effective pool area is 5,910 acres.

**4-02. Topography.** The Master Water Control Manual for Locks and Dams contains a description of the topography for the Upper Mississippi River basin. The only major tributary to Pool No. 6 is the Trempealeau River. The Trempealeau River basin covers an area of about 750 square miles located in west central Wisconsin about midway between the Cities of La Crosse and Eau Claire. The main stem rises about nine miles east of Hixton, about 84 miles above the confluence with the Mississippi River. It then flows in a generally westerly direction to Independence, and then south to join the Mississippi River near River Mile 717. The entire drainage area of the Trempealeau River lies within an unglaciated driftless area. Water surface elevations range from 1,360 feet in the headwaters to about 650 feet in the vicinity of the confluence. The uplands are deeply dissected into rugged ridges and rounded hills. Covered by relatively impervious soils, the

steep slopes allow for rapid runoff of surface waters. The broad valley of the Trempealeau River is the result of lateral erosion by the meandering stream. The general slope of the river ranges from three to four feet per mile. There are steep slopes in the headwaters of the basin, as much as 30 feet per mile in the uppermost reaches above Hixton. This increases the average slope of the stream based on a total fall of 555 feet in 84 miles to about 6.5 feet per mile. The river is flowing throughout its length. Land use is primarily agriculture with steeper sloped areas kept mainly in woodlot.

**4-03. Geology and Soils.** During the ice age four great glaciers advanced and retreated across most of the Upper Mississippi River Drainage Basin. The movement of these great sheets of ice created the basin's gentle, rolling hills and level plains, studded with thousands of lakes. As the glaciers melted and receded northward, drift was deposited, forming till plains over the southern part of the basin and moraines which are belts of hills in other regions. An area of southwestern Wisconsin and which extends into Minnesota and Iowa is part of an unglaciated region which was completely surrounded but never covered by the glaciers and is commonly known as the "driftless area". The melting glaciers released large quantities of water which filled low basins and formed temporary glacial lakes. Glacial Lake Agassiz covered large areas in the Dakotas, Canada, and northwestern Minnesota. The outflow from Lake Agassiz flowed southeastward, eroding the wide, deep valley of glacial river Warren which is today the valley of the Minnesota River. When the lake was completely drained, it left the present flat surface of northwestern Minnesota. The Mississippi River flows through a valley excavated by a much larger, early glacial stream and follows a winding course between low banks in a wide flood plain bordered by high bluffs of sedimentary rock.

All of the Upper Mississippi River Basin in the St. Paul District is underlain by a series of Precambrian igneous and metamorphic rocks. The igneous rocks such as granite and gabbro where formed as molten rock solidified, and the metamorphic

rocks which are now compact and crystalline were formed from preexisting rocks by the action of pressure, heat, and water. In southeastern Minnesota and southwestern Wisconsin, a huge trough in the old Precambrian rocks is filled with several thousand feet of Precambrian conglomerates, sandstone, shale and a thick series of younger limestone, shale, and dolomites of Paleozoic Age. These sedimentary rocks were formed by the accumulation of rock debris which was eroded from the land and deposited in seas which repeatedly submerged parts of the area and then retreated.

A large part of the surface of the Upper Mississippi River Basin is level or gently rolling land, but in some sections the area has considerable relief. In Itasca State Park at the origin of the Mississippi River, the elevation is 1465 feet above sea level, and many isolated hills rise to an altitude of 1800 feet. The Mississippi River leaves the St. Paul District at Guttenberg, Iowa at an elevation of about 603 feet.

**4-04. Sediment.** Part of the nine-foot navigation plan authorized by Congress included periodic dredging of sediment. There are five sites within Pool No. 6 navigation channel that require periodic dredging. Also requiring periodic dredging is the lower approach to Lock No. 6 (Pool No. 7) and a side channel in Pool No. 6. Quantities and frequency of dredging these areas is presented in **Table 4-1**.

| Table 4-1<br>Summary of Dredging Activity – 1970 through 2009 | | | | | |
|---|---|---|---|---|---|
| **Cut Name** | **River Mile** | **Avg. Vol. Per Year** | **Avg. Vol. Per Job** | **Freq. of Dredging** | **Last Year Dredged** |
| Lower Approach LD 5A | 728.5 | 246 yd | 4,910 yd | 5% | 1983 |
| Blackbird Slough (backwater area) | 727.8 | 142 yd | 4,400 yd | 3% | 1980 |
| Below Winona RR Bridge | 723.4 to 723.8 | 9,965 yd | 26,575 yd | 38% | 2009 |
| Gravel Point | 721.8 to 722.9 | 966 yd | 12,879 yd | 8% | 2009 |
| Homer | 720.0 to 721.1 | 5,055 yd | 33,697 yd | 15% | 2008 |
| Blacksmith Slough | 719.1 to 719.3 | 1,318 yd | 17,576 yd | 8% | 2008 |
| LaMoille Light | 716.9 to 717.2 | 250 yd | 9,984 yd | 3% | 2008 |
| Upper Approach LD 6 | 714.5 to 714.6 | 37 yd | 1,466 yd | 3% | 2000 |
| Lower Approach LD 6 | 714.0 to 714.3 | 5,861 yd | 23,442 yd | 25% | 2009 |

**4-05. Climate.** The National Weather Service maintains temperature and precipitation records for Lock and Dam No. 6. Temperature and precipitation data shown in the following tables were taken from National Oceanic and Atmospheric Administration's *Climatological Data Annual Summaries*, for Trempealeau Lock and Dam 6, Wisconsin. The 30-year normal period used was 1981 to 2010. Pan evaporation data was collected at Lock and Dam No. 6, but stopped after 1997. Pool evaporation was estimated by assuming a pan coefficient of 0.7.

| Table 4-2<br>30-Year Normal Monthly Temperature in Degrees Fahrenheit | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
| 17.2 | 22.4 | 34.0 | 48.4 | 59.3 | 68.5 | 72.7 | 70.5 | 62.1 | 49.8 | 35.3 | 21.6 | 46.8 |

**Table 4-3**
**30-Year Normal Monthly Precipitation in Inches**

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.06 | 1.03 | 1.75 | 3.42 | 3.74 | 3.77 | 4.38 | 4.48 | 3.78 | 2.35 | 2.07 | 1.33 | 33.16 |

**Table 4-4**
**Pan and Pool Monthly Evaporation in Inches**

| | 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. 6. While this information is valuable for the regulation of the dam, it is of little value for presenting monthly highest wind speeds and directions. The *Climatic Atlas of the United States* (June 1968) contains monthly Fastest Mile information for La Crosse, Wisconsin. Fastest Mile wind speeds are defined as the fastest speed at which wind travels one mile measured over one month. Fastest Mile wind speeds are typically obtained from a short period of time, usually less than two minutes duration. The Fastest Mile wind speeds presented in the Atlas were modified to time-dependent (1-hour) average wind speeds using procedures presented in the US Army Corps of Engineers' *Shore Protection Manual* (1984).

**Table 4-5**
**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 to either up river or down river. The wind blowing across the pool surface exerts a horizontal force on the water surface and induces a surface current in the general direction of the wind. The horizontal currents induced by the wind essentially cause water to "pile up" on the downwind side, resulting in a water level rise downwind and a water level drop upwind. The change in water level is due to "wind setup". The rise in water can be estimated by (EM 1110-2-1414):

$$S = (U^2 F)/(1400\ d)$$

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

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

**4-06. Storms and Floods.** While an isolated storm over the Trempealeau River basin can have a significant impact on water levels in Pool No.6 during low flows, it is high inflows from upstream that produce flooding of the pool. After construction of the Lock and Dam in 1936, the first significant flood events didn't occur until spring of 1951. On the 18th of April, the Mississippi River at Winona crested at 4.4 feet above flood stage with a gage height of 17.4 feet. This stage was exceeded the following year. On 20 April 1952, the Winona gage peaked at 17.9 feet with a peak pool gage elevation of 651.07 feet (1912 adjustment). Estimated discharge was 190,000 cfs. This remained the flood of record until 1965. **Table 4-6** gives a summary of peak elevations and discharges followed by a brief description of some of the larger events.

**Table 4-6**
**Summary of Peak Stages/Elevations and Discharges**

| Winona, MN – Control Point | | | Lock and Dam No. 6 | | | |
|---|---|---|---|---|---|---|
| Date | Stage Ft | Elev. ft (1912) | Date | Pool ft (1912) | Tailwater ft (1912) | Discharge cfs |
| 18 Apr 51 | 17.40 | 657.52 | 18 Apr 51 | 650.50 | 649.55 | |
| 20 Apr 52 | 17.90 | 658.02 | 20 Apr 52 | 651.07 | 649.97 | ~190,000 |
| **20 Apr 65** | **20.70** | **660.82** | **21 Apr 65** | **654.65** | **653.02** | **273,000** |
| 19 Apr 69 | 19.44 | 659.56 | 19 Apr 69 | 652.00 | 650.80 | 213,000 |
| 2 May 75 | 16.60 | 656.72 | 2 May 75 | 650.24 | 649.27 | 177,300 |
| 7 Apr 86 | 16.53 | 656.65 | 7 Apr 86 | 650.12 | 649.12 | 174,200 |
| 27 Jun 93 | 16.51 | 656.63 | 26 Jun 93 | 650.33 | 649.80 | 188,700 |
| 12 Apr 97 | 18.30 | 658.42 | 12 Apr 97 | 651.33 | 650.06 | 163,800 |
| 17 Apr 01 | 20.08 | 660.20 | 17 Apr 01 | 652.72 | 651.43 | 225,300 |
| 15 Apr 11 | 16.58 | 656.70 | 15 Apr 11 | 650.14 | 649.26 | 162,200 |

**a. April - May 1965.** Because of the magnitude of the snow-water content on the ground, forecasts and warnings of floods were issued by the Weather Bureau (now the National Weather Service). An advisory on the flood potential in the Upper Mississippi River basin was published as early as the 19th of March 1965. The forecast predicted a stage of 14.5 feet at Winona, Minnesota (flood stage is 13.0 feet) with normal precipitation and a snowmelt of more than three days. The forecast cautioned that if rainfall of one inch should occur before or during the crest, the resulting peak stage at Winona would be near the 1952 level. Almost four inches of rain fell in the first two weeks of April. The Weather Bureau revised the forecast for Winona, predicting a stage of 21.0 feet. The forecasted discharge of almost 270,000 cfs translated into a predicted elevation of 654.0 feet (1912 adjustment) at the dam. Based on this, the earthen dike with a crest elevation of 654.5 feet was raised 3 feet to provide sufficient freeboard and the spillway abutments were protected by sandbags. Because the top of the lock walls are also at elevation 654.5 feet, the central control station had to be ringed with sandbags. The rapid increase of inflow began on the 1st of April when the discharge rose from 13,600 cfs on this date to 78,000 cfs on the 6th of April. By this time the

head at the dam had been reduced to 0.33 foot and the gates were removed from the water. The motors that operate the lock miter gates must be pulled when the pool stage reaches elevation 648.2 feet. This stage was reached on the 12th of April, thus shutting Lock No. 6 down to navigation. Early in the morning on the 17th of April, a break in the railroad embank below Winona allowed floodwater to flow into the area operated by the Delta Fur and Fish Farm. It was estimated that the flood crest in Winona would have been 0.5 foot higher if the break did not occur. The Mississippi River crested at elevation 660.82 feet (stage 20.7 ft) at Winona on the 20th of April. This was 7.7 feet above flood stage and was about three feet higher than the peak stage of 1952. The City of Winona, assisted by the Corps of Engineers, National Guard, Coast Guard, Red Cross, Civil Defense, and hundreds of volunteer workers, waged a massive flood fight which successfully protected a 510 block residential and business area. The pool at Lock and Dam No. 6 crested on the 21st of April at elevation 654.65 feet with a peak flow 273,000 cfs. The pool fell below elevation 648.2 feet on the 4th of May and the motors were reinstalled, thus opening the lock to navigation. The pool returned to secondary control (elevation 644.5 feet) on the 27th of May and the dam was put back into operation. Primary control was not restored until the 28th of July.

**b. April 1997.** The magnitude of the snow-water content on the ground indicated a high potential for flooding along the Upper Mississippi River. On the 13th of March, the National Weather Service outlook predicted a stage of 19.0 feet at Winona, Minnesota. On the 12th of April, Winona crested at 18.3 feet (elevation 658.42 feet – 1912 adjustment). There was little damage to the City of Winona due to the Corps of Engineers flood control projects constructed in 1967 and 1988. The pool at the dam crested on the 12th of April at elevation 651.33 feet. Peak discharge was 163,800 cfs. The motors that operate the lock miter gates were relocated to higher elevation in 1993. The lock was only closed to navigation from the 11th 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. 6. 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. 6. In the early morning of 18 April, the stage at Winona, Minnesota peaked at 20.08 feet. On the 17th of April, the pool at Lock and Dam No. 6 peaked at elevation 652.63 feet (1912 adjustment) with a discharge of 224,700 cfs. The pool reached the closure elevation of 651.5 feet in the early morning of the 15th of April and did not fall below elevation 951.5 feet until the afternoon of the 22nd of April. However, additional rainfall runoff resulted in a second crest of elevation 652.10 feet on the 29th of April. The pool did not fall below elevation 651.5 feet until the 3rd of May. While the lock may have been in operation before the 15th of April, and for the week in between crests, 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 649.0 feet.

**4-07. Runoff Characteristics.** The mean annual discharge at Lock and Dam No. 6 is 34,200 cfs based on a period of record from 1960 to 2002. The following table shows the monthly average discharges.

**Table 4-7**
**Monthly Average Flow in cfs – (Years 1960 to 2002)**

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17,400 | 17,900 | 35,200 | 71,900 | 57,400 | 44,100 | 36,500 | 25,400 | 26,000 | 28,000 | 28,700 | 21,300 |

The maximum discharge of 273,000 cfs occurred, at the dam, on 21 April 1965 (**Table 4-6**). The lowest winter discharge recorded was 2,500 cfs on 13 December 1980. The minimum discharge during navigation season occurred with the drought of 1988 when the discharge got as low as 6,300 cfs on 3 July 1988. A

discharge frequency curve for Winona, Minnesota is shown on **Figure 8-1**. The following table shows the discharge-duration at the dam.

**Table 4-8**
**Discharge-Duration at Lock and Dam No. 6**
**Percent Time At or Above Indicated Discharge (Years 1972-2010)**

| Discharge | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 220,000 | | | | 0.2 | | | | | | | | | |
| 215,000 | | | | 0.3 | | | | | | | | | |
| 210,000 | | | | 0.6 | | | | | | | | | |
| 205,000 | | | | 0.6 | | | | | | | | | |
| 200,000 | | | | 0.8 | 0.2 | | | | | | | | |
| 195,000 | | | | 0.9 | 0.2 | | | | | | | | |
| 190,000 | | | | 1.1 | 0.3 | | | | | | | | 0.1 |
| 185,000 | | | | 1.4 | 0.3 | 0.3 | | | | | | | 0.2 |
| 180,000 | | | | 1.4 | 0.4 | 0.5 | | | | | | | 0.2 |
| 175,000 | | | | 1.5 | 0.7 | 0.5 | 0.2 | | | | | | 0.2 |
| 170,000 | | | | 1.7 | 0.8 | 0.6 | 0.3 | | | | | | 0.3 |
| 165,000 | | | | 1.9 | 0.9 | 0.6 | 0.4 | | | | | | 0.3 |
| 160,000 | | | | 2.2 | 1.0 | 0.7 | 0.5 | | | | | | 0.4 |
| 155,000 | | | | 2.4 | 1.2 | 0.7 | 0.6 | | 0.2 | | | | 0.4 |
| 150,000 | | | | 2.8 | 1.2 | 0.8 | 0.7 | | 0.3 | | | | 0.5 |
| 145,000 | | | 0.2 | 3.1 | 1.4 | 0.8 | 0.7 | | 0.4 | 0.2 | | | 0.6 |
| 140,000 | | | 0.3 | 3.6 | 1.6 | 0.8 | 1.2 | | 0.4 | 0.3 | | | 0.7 |
| 135,000 | | | 0.5 | 4.4 | 1.8 | 0.8 | 1.4 | | 0.4 | 0.3 | | | 0.8 |
| 130,000 | | | 0.7 | 5.1 | 2.2 | 0.8 | 1.5 | | 0.5 | 0.3 | | | 0.9 |
| 125,000 | | | 0.8 | 5.9 | 2.7 | 0.9 | 1.6 | | 0.9 | 0.4 | | | 1.1 |
| 120,000 | | | 1.1 | 7.0 | 3.3 | 0.9 | 1.7 | | 0.9 | 0.6 | | | 1.3 |
| 115,000 | | | 1.2 | 8.2 | 4.0 | 0.9 | 1.7 | | 0.9 | 0.6 | | | 1.5 |
| 110,000 | | | 1.4 | 9.7 | 4.5 | 0.9 | 1.8 | | 0.9 | 1.0 | | | 1.7 |
| 105,000 | | | 1.9 | 11.5 | 5.3 | 1.8 | 1.9 | | 0.9 | 1.3 | | | 2.1 |
| 100,000 | | | 2.2 | 13.9 | 6.6 | 2.5 | 2.0 | | 0.9 | 1.5 | | | 2.5 |
| 95,000 | | | 2.8 | 16.8 | 8.4 | 3.0 | 2.2 | 0.2 | 1.0 | 2.0 | | | 3.0 |
| 90,000 | | | 3.6 | 21.1 | 11.3 | 3.6 | 2.8 | 0.2 | 1.0 | 2.3 | | | 3.8 |
| 85,000 | | | 4.6 | 24.7 | 14.1 | 5.1 | 3.1 | 0.3 | 1.0 | 2.7 | | | 4.6 |
| 80,000 | | | 5.9 | 29.5 | 18.9 | 7.5 | 3.5 | 0.4 | 1.2 | 3.6 | | | 5.9 |
| 75,000 | | | 7.8 | 36.1 | 23.7 | 9.6 | 4.4 | 0.5 | 1.2 | 4.5 | | | 7.3 |
| 70,000 | | | 9.4 | 43.5 | 29.3 | 11.7 | 6.2 | 1.3 | 1.3 | 5.2 | 0.7 | | 9.1 |
| 65,000 | | 0.2 | 11.8 | 51.7 | 35.0 | 14.6 | 8.6 | 2.5 | 1.8 | 6.5 | 1.4 | | 11.2 |
| 60,000 | | 0.5 | 14.8 | 60.5 | 42.4 | 19.7 | 12.7 | 4.2 | 2.1 | 8.2 | 3.4 | | 14.1 |
| 55,000 | | 0.6 | 19.0 | 66.5 | 48.8 | 25.6 | 19.2 | 6.0 | 4.2 | 11.6 | 6.2 | | 17.4 |
| 50,000 | | 0.9 | 23.2 | 73.6 | 55.4 | 35.1 | 27.0 | 9.1 | 8.4 | 15.0 | 9.7 | 0.9 | 21.6 |
| 45,000 | | 1.2 | 27.1 | 79.0 | 62.7 | 46.2 | 33.4 | 12.7 | 13.2 | 19.3 | 12.7 | 1.8 | 25.8 |
| 40,000 | 0.3 | 1.9 | 33.1 | 82.7 | 69.5 | 56.9 | 41.6 | 17.7 | 19.7 | 25.2 | 18.6 | 3.5 | 31.0 |
| 35,000 | 0.7 | 2.9 | 40.5 | 86.7 | 76.5 | 66.7 | 49.7 | 25.6 | 26.7 | 32.3 | 30.8 | 8.7 | 37.4 |
| 30,000 | 4.5 | 6.0 | 50.4 | 90.9 | 83.2 | 75.3 | 61.0 | 34.5 | 35.7 | 40.4 | 46.0 | 21.0 | 45.9 |
| 25,000 | 15.9 | 13.9 | 63.3 | 96.8 | 88.8 | 81.7 | 68.4 | 45.3 | 44.7 | 50.0 | 61.2 | 36.3 | 55.7 |
| 20,000 | 33.5 | 33.3 | 75.9 | 99.1 | 93.5 | 88.3 | 74.5 | 60.8 | 58.2 | 64.6 | 75.9 | 53.2 | 67.7 |
| 15,000 | 67.1 | 65.7 | 90.7 | 99.8 | 96.6 | 94.7 | 82.3 | 78.0 | 74.2 | 77.9 | 90.4 | 73.3 | 82.6 |
| 10,000 | 91.5 | 91.7 | 99.1 | 100.0 | 100.0 | 98.1 | 94.7 | 91.5 | 95.0 | 96.2 | 96.8 | 91.3 | 95.5 |
| 5,000 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 | 99.7 | 100.0 | 100.0 | 99.8 | 100.0 |
| 0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Construction of the lock and dam greatly influenced stage-duration curves throughout the pool. Based on a period of record from 1972 to 2010, the following three elevation-duration tables were developed for the pool, tailwater, and the control point at Winona, Minnesota. 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 635.20 feet, while for the Winona gage it is elevation 640.12 feet.

**Table 4-9**
**Elevation-Duration, Lock and Dam No. 6 Tailwater**
**Percent of Time At or Above Indicated Elevation (Years 1972 to 2010)**

| Elev. | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 651.0 | | | | 0.4 | | | | | | | | | |
| 650.5 | | | | 0.9 | 0.2 | | | | | | | | |
| 650.0 | | | | 1.5 | 0.4 | | | | | | | | 0.2 |
| 649.5 | | | | 2.1 | 0.5 | 0.4 | | | | | | | 0.3 |
| 649.0 | | | | 2.6 | 0.8 | 0.5 | 0.3 | | | | | | 0.3 |
| 648.5 | | | | 3.3 | 1.2 | 0.7 | 0.5 | | | | | | 0.5 |
| 648.0 | | | | 4.0 | 1.4 | 0.8 | 0.7 | | 0.4 | | | | 0.6 |
| 647.5 | | | 0.5 | 4.7 | 1.7 | 0.8 | 1.2 | | 0.7 | 0.3 | | | 0.8 |
| 647.0 | | | 0.8 | 6.2 | 2.1 | 0.8 | 1.5 | | 0.9 | 0.4 | | | 1.1 |
| 646.5 | | | 1.1 | 7.8 | 3.3 | 0.9 | 1.7 | | 0.9 | 0.6 | | | 1.4 |
| 646.0 | | | 1.7 | 10.0 | 4.8 | 1.3 | 1.7 | | 0.9 | 1.2 | | | 1.8 |
| 645.5 | | | 2.5 | 13.3 | 6.5 | 2.2 | 1.9 | | 1.0 | 1.4 | | | 2.4 |
| 645.0 | | | 2.9 | 19.1 | 9.5 | 3.4 | 2.2 | 0.3 | 1.0 | 2.1 | | | 3.4 |
| 644.5 | | 0.5 | 4.4 | 24.8 | 13.0 | 5.5 | 3.0 | 0.3 | 1.1 | 2.5 | | | 4.6 |
| 644.0 | | 0.6 | 6.5 | 31.7 | 20.0 | 7.6 | 3.6 | 0.6 | 1.2 | 4.0 | | 0.3 | 6.3 |
| 643.5 | | 0.8 | 9.0 | 41.2 | 27.6 | 10.6 | 5.0 | 1.2 | 1.3 | 5.1 | 0.7 | 0.5 | 8.6 |
| 643.0 | | 1.0 | 12.5 | 49.5 | 35.6 | 15.4 | 8.6 | 3.0 | 2.1 | 6.4 | 1.4 | 0.9 | 11.4 |
| 642.5 | | 1.1 | 16.7 | 57.5 | 42.7 | 20.9 | 13.1 | 5.1 | 3.3 | 9.4 | 3.4 | 2.0 | 14.6 |
| 642.0 | 0.5 | 1.5 | 21.7 | 66.3 | 50.2 | 28.1 | 20.9 | 6.5 | 6.5 | 12.5 | 6.5 | 4.7 | 18.9 |
| 641.5 | 2.7 | 3.0 | 30.9 | 73.8 | 57.8 | 38.9 | 30.1 | 10.7 | 11.5 | 16.5 | 10.6 | 10.2 | 24.8 |
| 641.0 | 8.4 | 9.6 | 38.0 | 79.7 | 67.0 | 51.3 | 38.8 | 16.3 | 17.5 | 22.6 | 16.9 | 19.5 | 32.2 |
| 640.5 | 19.9 | 20.2 | 51.1 | 85.8 | 75.4 | 66.6 | 50.3 | 25.8 | 26.1 | 31.9 | 32.5 | 31.1 | 43.1 |
| 640.0 | 43.2 | 44.0 | 74.4 | 93.4 | 85.8 | 79.3 | 65.0 | 41.3 | 39.7 | 45.5 | 54.7 | 49.8 | 59.7 |
| 639.5 | 89.4 | 92.7 | 96.3 | 99.3 | 94.8 | 90.9 | 82.9 | 78.2 | 75.0 | 74.9 | 87.1 | 83.7 | 87.0 |
| 639.0 | 99.6 | 100.0 | 100.0 | 100.0 | 100.0 | 99.8 | 99.8 | 99.6 | 99.6 | 99.5 | 99.7 | 99.0 | 99.7 |
| 638.5 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

## Table 4-10
## Elevation-Duration for Winona, MN
## Percent of Time At or Above Indicated Elevation (Years 1972 to 2010)

| Elev. | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 660.0 | | | | 0.2 | | | | | | | | | |
| 659.5 | | | | 0.5 | | | | | | | | | |
| 659.0 | | | | 0.8 | 0.2 | | | | | | | | |
| 658.5 | | | | 1.0 | 0.3 | | | | | | | | 0.1 |
| 658.0 | | | | 1.8 | 0.3 | | | | | | | | 0.2 |
| 657.5 | | | | 2.2 | 0.4 | | | | | | | | 0.2 |
| 657.0 | | | | 2.2 | 0.5 | | | | | | | | 0.2 |
| 656.5 | | | | 2.6 | 0.7 | 0.3 | | | | | | | 0.3 |
| 656.0 | | | | 3.1 | 1.0 | 0.5 | 0.2 | | | | | | 0.4 |
| 655.5 | | | | 3.5 | 1.2 | 0.5 | 0.3 | | | | | | 0.5 |
| 655.0 | | | | 3.9 | 1.3 | 0.6 | 0.5 | | | | | | 0.5 |
| 654.5 | | | 0.3 | 4.5 | 1.6 | 0.6 | 0.6 | | 0.3 | | | | 0.6 |
| 654.0 | | | 0.6 | 5.3 | 2.0 | 0.7 | 1.0 | | 0.4 | 0.2 | | | 0.8 |
| 653.5 | | | 0.8 | 6.6 | 2.6 | 0.7 | 1.4 | | 0.6 | 0.3 | | | 1.1 |
| 653.0 | | | 1.1 | 7.8 | 3.6 | 0.8 | 1.6 | | 0.8 | 0.5 | | | 1.4 |
| 652.5 | | | 1.9 | 9.3 | 4.4 | 0.8 | 1.7 | | 0.9 | 1.1 | | | 1.7 |
| 652.0 | | | 2.2 | 11.6 | 5.8 | 1.1 | 1.8 | | 0.9 | 1.2 | | | 2.1 |
| 651.5 | | | 2.7 | 15.2 | 7.7 | 2.1 | 1.9 | 0.2 | 1.0 | 1.4 | | | 2.7 |
| 651.0 | | | 3.2 | 19.3 | 9.8 | 3.0 | 2.2 | 0.3 | 1.0 | 2.0 | | | 3.4 |
| 650.5 | | | 4.4 | 23.5 | 13.0 | 4.4 | 2.6 | 0.3 | 1.1 | 2.6 | | 0.3 | 4.4 |
| 650.0 | | | 6.0 | 28.7 | 17.6 | 6.5 | 3.2 | 0.4 | 1.2 | 3.1 | | 0.4 | 5.6 |
| 649.5 | | | 7.6 | 36.4 | 24.1 | 8.2 | 4.1 | 0.5 | 1.2 | 4.5 | 0.3 | 0.6 | 7.3 |
| 649.0 | | | 9.6 | 44.0 | 31.1 | 12.1 | 6.0 | 1.7 | 1.7 | 5.5 | 0.9 | 0.8 | 9.5 |
| 648.5 | | | 12.6 | 53.8 | 38.8 | 16.7 | 9.6 | 3.9 | 2.1 | 7.1 | 2.2 | 1.4 | 12.4 |
| 648.0 | | 0.9 | 15.4 | 61.3 | 44.9 | 22.8 | 14.4 | 5.1 | 3.8 | 10.0 | 4.3 | 3.0 | 15.6 |
| 647.5 | 0.3 | 1.3 | 19.6 | 68.6 | 51.9 | 31.6 | 23.0 | 7.6 | 6.2 | 13.9 | 7.9 | 6.1 | 19.9 |
| 647.0 | 2.1 | 2.4 | 26.8 | 75.6 | 60.1 | 40.7 | 30.6 | 11.1 | 11.4 | 17.7 | 12.1 | 12.3 | 25.4 |
| 646.5 | 9.5 | 9.6 | 35.1 | 80.2 | 68.6 | 54.8 | 40.2 | 16.5 | 18.0 | 24.2 | 18.1 | 21.6 | 33.1 |
| 646.0 | 23.7 | 20.6 | 51.3 | 86.4 | 79.2 | 70.2 | 52.1 | 28.9 | 30.4 | 37.0 | 40.0 | 36.6 | 46.5 |
| 645.5 | 80.3 | 85.4 | 91.0 | 97.1 | 94.7 | 95.0 | 93.0 | 83.3 | 86.1 | 93.5 | 91.1 | 84.4 | 89.6 |
| 645.0 | 100.0 | 99.7 | 99.9 | 99.7 | 100.0 | 99.9 | 99.8 | 99.9 | 100.0 | 100.0 | 100.0 | 98.9 | 99.8 |

**Table 4-11**
**Elevation-Duration, Lock and Dam No. 6 Pool**
**Percent of Time At or Above Indicated Elevation (Years 1972 to 2010)**

| Elev. | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 652.6 | | | | 0.2 | | | | | | | | | |
| 652.4 | | | | 0.3 | | | | | | | | | |
| 652.2 | | | | 0.3 | | | | | | | | | |
| 652.0 | | | | 0.6 | | | | | | | | | |
| 651.8 | | | | 0.8 | | | | | | | | | |
| 651.6 | | | | 0.9 | 0.2 | | | | | | | | |
| 651.4 | | | | 1.0 | 0.3 | | | | | | | | 0.1 |
| 651.2 | | | | 1.5 | 0.3 | | | | | | | | 0.2 |
| 651.0 | | | | 1.8 | 0.3 | | | | | | | | 0.2 |
| 650.8 | | | | 2.0 | 0.4 | | | | | | | | 0.2 |
| 650.6 | | | | 2.1 | 0.4 | | | | | | | | 0.2 |
| 650.4 | | | | 2.1 | 0.5 | | | | | | | | 0.2 |
| 650.2 | | | | 2.3 | 0.7 | 0.2 | | | | | | | 0.3 |
| 650.0 | | | | 2.5 | 0.8 | 0.4 | | | | | | | 0.3 |
| 649.8 | | | | 2.7 | 0.9 | 0.5 | | | | | | | 0.3 |
| 649.6 | | | | 3.1 | 1.0 | 0.5 | 0.2 | | | | | | 0.4 |
| 649.4 | | | | 3.3 | 1.1 | 0.5 | 0.3 | | | | | | 0.4 |
| 649.2 | | | | 3.4 | 1.2 | 0.6 | 0.3 | | | | | | 0.5 |
| 649.0 | | | | 3.5 | 1.2 | 0.6 | 0.5 | | | | | | 0.5 |
| 648.8 | | | | 3.7 | 1.4 | 0.7 | 0.5 | | 0.3 | | | | 0.5 |
| 648.6 | | | 0.2 | 4.0 | 1.5 | 0.7 | 0.6 | | 0.4 | | | | 0.6 |
| 648.4 | | | 0.4 | 4.4 | 1.6 | 0.7 | 0.7 | | 0.4 | 0.2 | | | 0.7 |
| 648.2 | | | 0.6 | 4.8 | 1.7 | 0.8 | 0.7 | | 0.4 | 0.3 | | | 0.8 |
| 648.0 | | | 0.7 | 5.1 | 1.7 | 0.8 | 0.9 | | 0.8 | 0.3 | | | 0.9 |
| 647.8 | | | 0.7 | 5.6 | 2.1 | 0.8 | 1.3 | | 0.9 | 0.3 | | | 1.0 |
| 647.6 | | | 0.9 | 6.4 | 2.3 | 0.8 | 1.4 | | 0.9 | 0.4 | | | 1.1 |
| 647.4 | | | 1.1 | 6.9 | 2.7 | 0.8 | 1.5 | | 0.9 | 0.4 | | | 1.2 |
| 647.2 | | | 1.1 | 7.6 | 3.3 | 0.8 | 1.6 | | 0.9 | 0.6 | | | 1.3 |
| 647.0 | | | 1.5 | 8.0 | 3.9 | 0.9 | 1.6 | | 0.9 | 1.0 | | | 1.5 |
| 646.8 | | | 1.7 | 8.7 | 4.4 | 0.9 | 1.7 | | 0.9 | 1.2 | | | 1.6 |
| 646.6 | | | 1.9 | 10.0 | 4.8 | 0.9 | 1.7 | | 0.9 | 1.2 | | | 1.8 |
| 646.4 | | | 2.2 | 11.0 | 5.3 | 1.6 | 1.7 | | 0.9 | 1.3 | | | 2.0 |
| 646.2 | | | 2.5 | 12.0 | 5.8 | 2.0 | 1.8 | | 1.0 | 1.4 | | | 2.2 |
| 646.0 | | | 2.7 | 14.2 | 7.0 | 2.6 | 1.8 | | 1.0 | 1.5 | | | 2.6 |
| 645.8 | | | 2.8 | 15.7 | 7.8 | 2.9 | 2.2 | 0.3 | 1.1 | 1.7 | | | 2.9 |
| 645.6 | | 0.2 | 3.4 | 18.2 | 9.6 | 4.6 | 5.5 | 3.7 | 4.4 | 4.1 | 1.5 | 0.7 | 4.7 |
| 645.4 | 2.1 | 1.7 | 6.5 | 20.3 | 12.0 | 9.2 | 17.1 | 15.1 | 20.0 | 19.0 | 11.3 | 5.2 | 11.7 |
| 645.2 | 18.4 | 16.2 | 15.3 | 23.4 | 17.0 | 16.6 | 28.2 | 37.7 | 40.8 | 38.6 | 26.2 | 24.2 | 25.3 |
| 645.0 | 40.2 | 37.8 | 28.5 | 26.8 | 23.0 | 23.5 | 34.9 | 51.0 | 56.6 | 51.8 | 38.7 | 40.6 | 37.8 |
| 644.8 | 54.8 | 55.9 | 44.5 | 34.0 | 34.7 | 34.5 | 42.9 | 61.5 | 65.0 | 60.9 | 50.3 | 60.3 | 49.9 |
| 644.6 | 76.2 | 77.7 | 70.6 | 60.0 | 61.2 | 62.4 | 63.7 | 78.5 | 82.0 | 79.4 | 74.3 | 79.8 | 72.1 |
| 644.4 | 96.5 | 96.2 | 91.7 | 93.2 | 93.7 | 94.6 | 93.4 | 94.9 | 96.9 | 96.3 | 96.0 | 95.5 | 94.9 |
| 644.2 | 100.0 | 100.0 | 99.1 | 99.9 | 99.9 | 99.4 | 97.4 | 97.9 | 100.0 | 100.0 | 99.9 | 99.4 | 99.4 |
| 644.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 99.6 | 97.4 | 98.1 | 100.0 | 100.0 | 100.0 | 99.9 | 99.6 |

At a flat pool elevation of 645.5 feet (project pool), the storage volume in Pool No. 6 is 41,500 acre-feet. At moderate flows, there is a one-foot drawdown at the dam. That is, while the elevation at the dam is 644.5 feet, the elevation at the control point (Winona, MN) is a minimum of 645.5 feet. When the pool is at these elevations, the storage volume is around 39,000 acre-feet. Assuming an average volume of 40,500 acre-feet, a flow rate of 20,500 cfs would result in a

daily exchange in storage. The following table shows the storage volume in Pool No. 6 for various elevations at Winona and Lock Dam No. 6 pool. A relationship of storage to discharge is shown on **Plate 4-1**.

**Table 4-12**
**Storage Volume of Pool No. 6 in 1,000 Ac-Ft**

| Pool Elev. | Elevation at Winona, Minnesota – Control Point – 1912 Adjustment | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 658 | 657 | 656 | 655 | 654 | 653 | 652 | 651 | 650 | 649 | 648 | 647 | 646 | 645 | 644 | 643 | 642 |
| 652 | 132 | 125 | 117 | | | | | | | | | | | | | | |
| 651 | 128 | 121 | 113 | 107 | | | | | | | | | | | | | |
| 650 | 124 | 117 | 110 | 104 | 97 | | | | | | | | | | | | |
| 649 | | 113 | 107 | 101 | 94 | 88 | | | | | | | | | | | |
| 648 | | | 104 | 98 | 92 | 85 | 79 | | | | | | | | | | |
| 647 | | | | 94 | 88 | 82 | 77 | 71 | 65 | 60 | | | | | | | |
| 646 | | | | | 84 | 79 | 74 | 68 | 63 | 58 | 53 | 49 | 45 | | | | |
| 645 | | | | | | 76 | 71 | 65 | 60 | 55 | 50 | 46 | 42 | 39 | | | |
| 644 | | | | | | | 68 | 62 | 58 | 52 | 48 | 43 | 40 | 36 | 33 | | |
| 643 | | | | | | | | 60 | 55 | 50 | 45 | 41 | 38 | 34 | 31 | 29 | |
| 642 | | | | | | | | | 52 | 47 | 43 | 39 | 36 | 33 | 30 | 27 | |
| 641 | | | | | | | | | | 45 | 41 | 37 | 34 | 31 | 28 | 25 | |
| 640 | | | | | | | | | | | 38 | 35 | 32 | 29 | 26 | 24 | |
| 639 | | | | | | | | | | | | 33 | 30 | 27 | 24 | 22 | 20 |
| 638 | | | | | | | | | | | | | 28 | 25 | 23 | 21 | 18 |
| 637 | | | | | | | | | | | | | | 24 | 21 | 19 | 17 |
| 636 | | | | | | | | | | | | | | | 20 | 18 | 16 |
| 635 | | | | | | | | | | | | | | | | 17 | 15 |
| 634 | | | | | | | | | | | | | | | | | 14 |

**4-08. Water Quality.** The St. Paul District does not collect water quality information for Pool No. 6. However, as an element of the Environmental Management Program (EMP), the Corps of Engineers oversees the Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System. The LTRMP was implemented to provide decision makers with the information needed to maintain the Upper Mississippi River System as a viable multiple-use large river ecosystem. The LTRMP is being implemented by the US Geological Survey (USGS) in cooperation with the states of Illinois, Iowa, Minnesota, Missouri and Wisconsin with guidance and overall program responsibility by the Corps of Engineers.

**4-09. Channel and Floodway Characteristics.** The top of the lower lock sill elevation at Lock and Dam No. 5A is elevation 633.0 feet and the top of the upper lock sill

elevation at Lock and Dam No. 6 is elevation 628.5 feet. Therefore, there is a 4.5-foot drop in sill elevation along the pool, which has a length of 14.2 miles as measured along the navigation channel. The navigation channel is 300 feet in width in the straight stretches, and varies from 300 feet to 550 feet in the bends. The line of navigation is shown on **Plates 2-4 through 2-7**.

**4-10. Upstream Structures.** Lock and Dam No. 5A is located 14.2 miles upstream of Lock and Dam No. 6. The drainage area above Lock 5A is 59,105 square miles. The lock and dam system continues upstream to the Upper St. Anthony Falls lock and dam located in Minneapolis, Minnesota.

**4-11. Downstream Structures.** Lock and Dam No. 7 is located 11.8 miles downstream of Lock and Dam No. 6. The drainage area above Lock 7 is 62,340 square miles. The lock and Dam system continues downstream to Lock and Dam No. 27 in St. Louis, Missouri; however, St. Paul District terminates with Lock No. 10.

**4-12. Economic Data.**

**a. Population.** Pool No. 6 lies on the Minnesota-Wisconsin border. Winona County lies on the western side and Trempealeau and a portion of Buffalo Counties lie on the eastern side. **Table 4-13** displays the trends in population from 2000 to 2010. Based on the US Census Bureau, county populations have increased slightly.

| Table 4-13<br>County and City Populations Near Pool No. 6 | | | | |
|---|---|---|---|---|
| | 2000 | 2010 | Difference | Change |
| **County** | | | | |
| Winona, MN | 49,985 | 51,461 | 1,476 | 3.0 % |
| Trempealeau, WI | 27,010 | 28,816 | 1,806 | 6.7 % |
| Buffalo. WI | 13,804 | 13,587 | -217 | -1.6 % |
| **City** | | | | |
| Winona, MN | 27,069 | 27,592 | 523 | 1.9% |
| Trempealeau, WI | 1,319 | 1,529 | 210 | 15.9% |

**b. Agriculture.** **Table 4-14** shows basic statistics on farms in the basin. Livestock, poultry, and their products is the dominant agricultural activity in the basin.

| Table 4-14<br>Agriculture Statistics by County from the 2012 Census on Pool No. 6 | | | |
|---|---|---|---|
| Item | Winona | Trempealeau | Buffalo |
| Number of farms | 1,115 | 1,436 | 1,061 |
| Amount of cropland in farms (acres) | 180,009 | 197,816 | 162,746 |
| Average estimated market value of land and buildings per farm ($) | 1,165,445 | 719,451 | 968,226 |
| Market value of agricultural products sold ($1,000) | 303,949 | 268,881 | 225,796 |

**c. Industry.** **Table 4-15** shows basis statistics on employment by industry in the basin.

| Table 4-15<br>Employment by Industry – Counties on Pool No. 6 (2009) | | | |
|---|---|---|---|
| Industry | Winona | Trempealeau | Buffalo |
| Forestry, fishing, hunting, and Agriculture support | See note #1 | See note #1 | See note #1 |
| Mining, quarrying, and oil and gas extraction | See note #1 | - | - |
| Utilities | See note #1 | See note #1 | See note #1 |
| Construction | 532 | 193 | 126 |
| Manufacturing | 4,871 | 5,609 | 407 |
| Wholesale trade | 539 | 249 | See note #1 |
| Retail trade | 3,092 | 998 | 290 |
| Transportation and warehousing | 928 | See note #1 | See note #1 |
| Information | 827 | See note #1 | See note #1 |
| Finance and insurance | 619 | 393 | 150 |
| Real estate, rental, leasing | 149 | 17 | See note #1 |
| Professional, Scientific, Tech Services | 531 | 197 | 159 |
| Management of companies and enterprises | See note #1 | See note #1 | - |
| Admin & Support, Waste Management | 327 | See note #1 | 87 |
| Education Services | See note #1 | See note #1 | See note #1 |
| Health Care & Social Services | 3,606 | 1,366 | 322 |
| Arts, Entertainment & Recreation | 165 | 38 | See note #1 |
| Accommodations & Food Services | 2,101 | 650 | 314 |
| Other Services | 900 | 283 | 112 |
| Totals | 22,151 | 11,140 | 4,352 |

Note #1: Withheld to avoid disclosing data for individual companies.

**d. Flood Damages.** The locks and dams provide no flood control benefits. They were constructed strictly for navigation purposes. The dam operates on a run-of- the-river principal. As discharge increases, the gates are opened. At around 75,000 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.

## 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. Inflow to Pool No. 6 from Dam 5A is computed as part of the regulation program, using pool and tailwater elevations, and the gate settings. When the gates are raised clear of the water, a rating table is used. About three miles downstream of Lock No. 5A is the Pool No. 6 primary control point gage. It is located just downstream of the Highway 54 bridge crossing the Mississippi River at Winona, Minnesota.

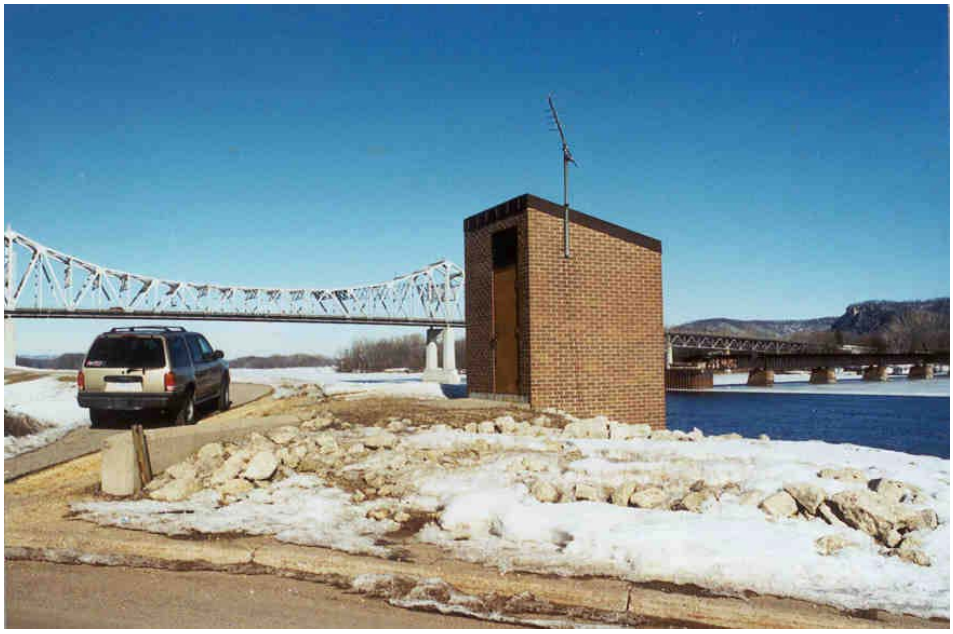


**Figure 5-1. Winona, MN Stream Gage**

The main tributary to the pool is the Trempealeau River, which enters the Mississippi River about three miles upstream of the lock and dam. A gage is located 9.0 miles upstream of the confluence at Dodge, Wisconsin. **Exhibit B** contains the US Geological Survey rating table. While the equipment at Winona and Dodge are owned by the COE, the gages are maintained by the USGS through a cooperative agreement.

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 600 feet from the lock chamber. Each gage house has a well with a float and tape system that reports elevation to the Water Log H-522+ Data Logger located in the lock house. Staff gages are mounted inside the gage houses and serve as backup or are used for verification of the tape in the well. The locations of these gage sites are shown on **Plate 5-1**.

**Figure 5-2. Water Log H-522+ Data Logger**

A water temperature sensor, reading in degrees Fahrenheit, is located in the upper ladder recess. A standard eight-inch precipitation gage is located near the lock house. 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 lock house. The NWS has a Fisher-Porter digital data logger installed at the site. Data types and equipment are listed in **Table 5-1**.

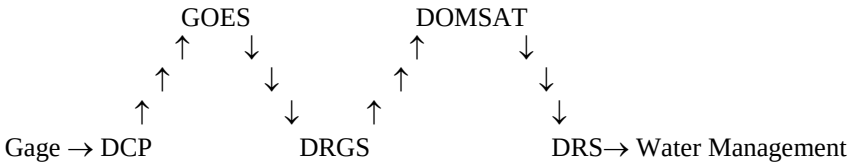

**Figure 5-3. Water Log Shaft Encoder**

**Table 5-1**
**Hydrometeorological Stations**

| Location | Data Type | Equipment | Notes |
|---|---|---|---|
| Mississippi River at Winona, Minnesota | Water Surface Elevation and Stage | Sutron Sat Link II Data Recorder GOES Telemetry | Gage Zero: 640.12 (1912) Flood Stage: 13.0 ft Co-Op Gage |
| Trempealeau River at Dodge, Wisconsin | Water Surface Elevation | Campbell CR10-X Data Recorder GOES Telemetry | Gage Zero: 661.42 (1929) Flood Stage: 9.0 ft Co-Op Gage |
| Lock & Dam No. 6 Lock House | Water Surface Elevation | Water Log H522+ Data Recorder GOES Telemetry | Maintained by Corps Gage Crew & site personnel. |
| Lock & Dam No. 6 Upper Guidewall | Pool Elevation | Water Log H-331 Shaft Encoder Staff Gage | Electronically transmitted to lock house. |
| Lock & Dam No. 6 Lower Guidewall | Tailwater Elevation | Water Log H-331 Shaft Encoder Staff Gage | Electronically transmitted to lock house. |
| Lock & Dam No. 6 | Snow Depth & Water Content | Snow Rod, Snow Tube, Scale | Maintained by site personnel. |
| Lock & Dam No. 6 Lock House Roof | Wind Speed & Direction | Anemometer | Maintained by site personnel. |
| Lock & Dam No. 6 Upper Ladder Recess | Water Temperature | Water Temperature Sensor | Electronically transmitted to lock house. |
| Lock & Dam No. 6 | Precipitation | Standard 8-inch Rain Gage | Recorded daily. |
| Lock & Dam No. 6 | Precipitation | Fischer-Porter - Digital Data Logger | NWS Gage |

**b. Reporting.** The information needed to regulate the lock and dam is provided to Water Management, via computer by dam personnel, daily at 0630- hours. While morning data is collected between 0600 and 0630-hours, it is archived as 0800-hours thereby maintaining a record on four-hour intervals. Each morning lock and dam operators obtain the data from the Water Management web site at www.mvp-wc.usace.army.mil. for gaging stations located on the Trempealeau River at Dodge, Wisconsin, the Black River at Galesville, Wisconsin, and the Mississippi River at Winona, Minnesota. Hourly DCP gage readings are reported to Water Management through a satellite system. The DCP sends a signal to the US Geostationary Operational Environmental Satellite (GOES). The GOES satellite sends the signal to a Direct Readout Ground Station (DRGS) at Wallops Island Virginia. The data is reformatted and sent to the Domestic Communication Satellite (DOMSAT), which transmits the data to the DOMSAT Receive Station (DRS) located at the St. Paul District Office. This data is available from the Water Management web site at www.mvp-wc.usace.army.mil.

**Transmission Path of DCP Data**




These stages/elevations are part of the 0630-hour data report. While the Black River is tributary to Pool No. 7, the data for the Galesville gage is input by Lock and Dam No 6 staff due to when voice modems were used to collect data and it was a local call. This is also true for the Winona gage. While the Winona gage is in Pool No. 6, the data is input by Lock and Dam 5A personnel. Pool and tailwater readings, as well as individual gate settings for the roller and tainter gates, are entered in four-hour increments beginning with the previous day's 0800-hour reading. Wind speed and direction along with air temperature are entered into the computer at eight-hour intervals,

beginning with the 0800-hour reading (actual reading between 0600 and 0630-hours). Precipitation total for last 24 hours is measured each morning and reported as an 0800-hour reading. The maximum and minimum air temperatures for the last 24 hours are recorded at 1900-hours daily. The water temperature is measured at 0700-hours daily. During the winter months, percent of ice coverage over the lower pool and upper tailwater; ice thickness, snow depth, and snow-water content (all in inches) are recorded once a week on Sundays. The snow-water content is determined by instructions contained in the National Weather Service Snow Measurement Guidelines for NWS Cooperative Observers.

**c. Maintenance.** The equipment at the gages located at Winona, MN, Dodge, WI, and Galesville, WI are property of the Corps of Engineers; however, they are maintained by the USGS on a periodic basis. The Water Management Gage Crew provides emergency backup. Operation and maintenance of the pool and tailwater gages are the responsibility of the Gage Crew. The anemometer, water temperature sensor, and standard 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 Management. The Fischer-Porter precipitation gage is maintained by the National Weather Service. Repair of the snow survey equipment is the responsibility of the Water Management Gage Crew.

**5-02. Water Quality Stations.** There are no water quality stations in Pool No. 6; however, site personnel may be asked, on occasion, to assist district office personnel or contractors to collect water samples and/or water quality measurements in the project area.

**5-03. Sediment Stations.** Suspended sediment data was collected at the Winona, Minnesota gage from December 1974 to September 1981. Since then, there has been no sampling in Pool No. 6; however, routine dredging of sediment is part of the nine-foot navigation plan. There are several sites in Pool No. 6 that require

periodic dredging due to sedimentation. Dredging is the responsibility of the St. Paul District's Fountain City Boat Yard located at Fountain City, Wisconsin. As soon as the ice leaves the river, hydrographic surveys are made to get an early indication of channel conditions. After spring high water, surveys of the historic problem spots are performed. Equipment is lined up and a priority list is made. Table 4-1 gives a summary of dredging in Pool No. 6 and in the lower lock approach since 1970.

**5-04. Recording Hydrologic Data.** Pool and tailwater elevations, roller and tainter gate settings, and Trempealeau and Black River stages are entered on log sheets. Up until 2001, log sheets were mailed to Water Management where they were periodically micro filmed. Beginning in 2001, log sheets are now stored electronically and are available on the Water Management web site at *www.mvp-wc.usace.army.mil*. Water Management Section maintains DSS files of hourly stage/elevation data for the gages located at Winona, MN, Dodge, WI, and Galesville, WI beginning 01 December 1997. All daily data received by Water Management Section from the dam site is compiled and archived using Hydraulic Engineering Center's Data Storage System (HEC-DSS) and is accessible from the Water Management web site. The US Geological Survey (USGS) is responsible for maintaining a discharge record for each site. The data are archived in the USGS WATSTORE database in Reston, Virginia and are available from the annual publications of the USGS Water-Data Report, Water Resources Data, Wisconsin. The daily record of max-min temperature, precipitation, weather characteristics, river stages and general remarks are recorded on National Weather Service (NWS) Form B-91. This form is electronically submitted to the NWS in Green Bay, Wisconsin.

**5-05. Communication Network.** The communication network consists of computer terminal, internet, telephone, facsimile, FM radio, voice modem, satellite, and the US Postal Service. Computer communication is done via email, and "Secure CRT" which allows remote access to the Water Management network. When the

computer is down, the transfer of data is by facsimile or telephone. During non-duty hours on weekends and holidays, dam personnel can contact the duty river regulator by calling the mobile number listed in the front of this manual. The gage sites at Winona, MN, Dodge, WI, and Galesville, WI send stage/elevation data hourly via satellite to Water Management. In addition, the Wisconsin gages send hourly cumulative precipitation. This information is made available to the dam site from the Water Management web site; *www.mvp-wc.usace.army.mil*. The internet ensures communication between Water Management and the Mississippi River Valley Division Office (MVD) in Vicksburg, Mississippi.

## 5-06. Communication with Project.

**a. Regulating Office with Project Office.** Dam site personnel input and transmit their data, via computer, to Water Management every day by 0630-hours. Water Management issues orders to Lock and Dam No. 6 every morning at approximately 0800-hours during the navigation season and around 0730-hours during the non-navigation season. Orders are typically delivered via email with the telephone serving as backup. Should the dam site have computer problems, such that the transfer of data is not possible, a facsimile is then sent to Water Management (651-290-5841). The Water Management river manager then enters the information into the Regulation Program and the Enterprise Service Desk 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 information from the project staff, either by telephone, email, in person, or through the local news media. The Water Management web site has enhanced available information to the general public. 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 Management every morning. The lock operator may make gate changes required to remain within the pool band issued by Water Management provided it is less than 15 percent of the total flow. If the pool goes out of the band after 0400-hours, no gate changes are to be made by project staff until Water Management issues its morning orders. Gate changes to aid work efforts (e.g. painting) are to be coordinated with Water Management. Problems with machinery that operate the gates are to be reported to Water Management Section and Operations Division.

**5-08. Warnings.** In the event the lock operator makes a gate change to remain within the pool band issued by Water Management, Lock No. 6 personnel should notify Lock No. 7 of the cut or opening that was made. In the event of a gate failure, communications must be established as quickly as possible with the Water Management Section and the Operations Division. The installation of any bulkheads must be coordinated with Water Management.

## VI – HYDROLOGIC FORECASTS

**6.01. General.** During periods of low flow, the gates at the dam are regulated to pass inflow under pooled conditions, while during high flow they are raised free of the water surface and except for a slight swellhead due to the effect of the piers, the dam offers little obstruction to the flow. The storage capacity created by the dam is relatively small as compared with the volume of flow and inasmuch as the dam is out of operation at high discharges, to use the dam to control floods is not possible. The lock goes out of operation at elevation 651.5 feet (1912 adjustment) at which time water begins to flow over the upstream miter gates. The timing and elevation of the crest is important for planning sand bagging operations and forecasting when the lock would go out of operation. In addition the timing on the receding limb of the hydrograph aids in determining when the lock would go back into service. In 1997, the St. Paul District developed an unsteady-flow model of the Mississippi River. The Mississippi Basin Model System utilizes the computer program UNET for forecasting purposes.

**a. Role of the Corps.** The St. Paul District previously relied solely on the National Weather Service (NWS) for Mississippi River forecasts. However, the NWS only forecasts for designated sites along the Mississippi River. The nearest forecast site to Lock and Dam No. 6 is Winona, Minnesota. Also, the NWS forecast typically is only a seven-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 the Water Management Section 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 situation.

**b. Roles of Other Agencies.** The National Weather Service (NWS) electronically provides the District forecasted flow hydrographs of the major tributaries to the Mississippi River by 0830-hours daily. Water Management Section inputs these hydrographs into the Mississippi Basin River System model and makes a run. The results are then electronically transferred to the NWS River Forecast Center in Chanhassen, Minnesota by 0930-hours. The NWS uses the UNET results and the results from their Mississippi River forecast model to provide stage forecasts at various points along the Mississippi River. The forecast site for Pool No. 6 is the control point at Winona, Minnesota.

**6-02. Flood Condition Forecasts.** Since 1997, St. Paul District has been using the Mississippi Basin Modeling System (MBMS) to forecast flood conditions on the Mississippi River from Upper St. Anthony Falls to Lock and Dam No. 10. 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 14-day forecasted stage hydrographs for the major tributaries to Water Management by 0830-hours daily. The hydrographs typically include the 24-hour quantitative precipitation forecast (QPF). Water Management extrapolates the tributary stage hydrographs to 30 days. Forecasts beyond five-days are very approximate due to unknowns such as additional rainfall.

Modeling efforts as part of the Corps of Engineers Water Management System (CWMS) began in 2001. CWMS will contain hydrologic and hydraulic models of the District's reservoirs and the locks and dams. When the Mississippi River portion of CWMS becomes 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. Conservation Purpose Forecasts.** Forecasting for water-related activities such as hydropower regulation, recreation, fish spawning, water supply and water quality are not a part of the daily Water Control Section routine. Short-term projections of water level, flows, temperature and local hydrologic conditions may be obtained from Water Control upon request.

**6-04. 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.

**6-05. Drought Forecast.** The lock and dam system operates as "run of the river". That is what ever flow enters the pool is passed on. Therefore, during low flow periods, the project pool elevation is maintained. This pool elevation is maintained provided there is sufficient inflow to meet withdrawal needs and pool evaporation. There is no drought forecasting model other than the Mississippi Basin Modeling System previously discussed.

# VII - WATER CONTROL PLAN

**7-01. General Objectives.** The general objective of the water management plan is to maintain a minimum depth of nine feet along the navigation channel of Pool No. 6, without inducing higher stages during flood events. Project pool elevation for Lock and Dam No. 6 is 645.5 ± 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. 6, the "primary control point" is located just downstream of the Highway 54 bridge crossing the Mississippi River at Winona, Minnesota (see **Figure 5-1**). Maintaining project pool elevation at this location during periods of low flows ensures a minimum channel depth of nine feet; 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 645.5 ± 0.2 feet (1912 adjustment) at the primary control point at Winona, MN. This is "project pool" or "normal pool" for Lock and Dam No. 6. 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 one foot in 1959 due to adverse effects on navigation, riverfront property, and conservation interests. Therefore, drawdown at the dam is constrained to elevation 644.5 ± 0.2 feet.

**b. Maximum Outflow Velocity.** Downstream scour protection limits outflow velocities from the roller and tainter gates. The design plan set maximum outflow velocities at 4.5 feet per second for standard operating procedures

with an allowance to go to 6.0 feet per second for an emergency situation. In 1983, additional riprap was placed upstream and downstream of the dam. Since this time, routine maximum gate openings have been computed based on a maximum outflow velocity of 6.0 feet per second. However, it should be noted that during flood events, flow velocities exceed 8.0 feet per second with no disturbance of the riprap occurring. Therefore, the design velocity of 6.0 feet per second may be exceeded for short periods of time (15 to 20 minutes) during emergency operations (e.g. barge incident, passing of debris).

**c. Open River Conditions.** The dam is in "open river conditions" when the gates are raised clear of the water surface. This typically happens when the differential head is less than one foot and the discharge is around 75,000 cfs. When gates are put back in the water, the total gate openings are 75 feet on roller gates and 100 feet on tainter gates.

**d. Closure of the Lock to Navigation.** Prior to 1993, 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 648.2 feet (1912 adjustment). As part of the major rehabilitation work in 1993, 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. This is at elevation 651.5 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 or closure of the river to navigation by the Coast Guard.

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. In late February, early March, the ice becomes thin enough for some tow traffic and the lock is opened. The ice thickness on Lake Pepin (Pool No. 4) is

monitored weekly. When the ice is down to about six inches of blue ice, tow traffic can soon be expected. The following table shows some of the recent history of opening and closing dates for Lock and Dam No. 6.

**Table 7-1**
**Spring Opening and Fall Closing Dates**

| Year | Opening Date | Closing Date | Year | Opening Date | Closing Date |
|---|---|---|---|---|---|
| 1972 | 23 Mar | 11 Dec | 1993 | 21 Mar | 27 Nov |
| 1973 | 17 Mar | 06 Dec | 1994 | 24 Mar | 30 Nov |
| 1974 | 14 Mar | 13 Dec | 1995 | 12 Mar | 28 Nov |
| 1975 | 20 Mar | 14 Dec | 1996 | 25 Mar | 26 Nov |
| 1976 | 03 Mar | 06 Dec | 1997 | 20 Mar | 26 Nov |
| 1977 | 23 Mar | 09 Dec | 1998 | 08 Mar | 17 Dec |
| 1978 | 03 Apr | 30 Nov | 1999 | 08 Mar | 14 Dec |
| 1979 | 30 Mar | 08 Dec | 2000 | 03 Mar | 02 Dec |
| 1980 | 25 Mar | 05 Dec | 2001 | 28 Mar | 06 Dec |
| 1981 | 07 Mar | 04 Dec | 2002 | 14 Mar | 29 Nov |
| 1982 | 23 Mar | 08 Dec | 2003 | 27 Mar | 03 Dec |
| 1983 | 03 Mar | 14 Dec | 2004 | 18 Mar | 05 Dec |
| 1984 | 03 Mar | 30 Nov | 2005 | 20 Mar | 02 Dec |
| 1985 | 17 Mar | 05 Dec | 2006 | 20 Mar | 30 Nov |
| 1986 | 21 Mar | 05 Dec | 2007 | 24 Mar | 29 Nov |
| 1987 | 09 Mar | 01 Dec | 2008 | 25 Mar | 05 Dec |
| 1988 | 19 Mar | 01 Dec | 2009 | 20 Mar | 04 Dec |
| 1989 | 27 Mar | 24 Nov | 2010 | 05 Apr | 28Nov |
| 1990 | 12 Mar | 29 Nov | 2011 | 19 Mar | 03 Dec |
| 1991 | 21 Mar | 24 Nov | 2012 | 15 Mar | 03 Dec |
| 1992 | 08 Mar | 02 Dec | | | |

**e. Maximum Number of Gates Closed.** At times it is necessary to close one or more gates for maintenance purposes. All gate closures shall be coordinated with the river regulation desk at the Water Management Section. The maximum number of gates allowed to be closed will be at the discretion of Water Management 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 Management.

**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 20,000 | 5 | Below 32,000 | 10 |
| 20,000 – 27,000 | 4 | 32,000 – 34,000 | 9 |
| 27,000 – 35,000 | 3 | 34,000 – 36,000 | 8 |
| 35,000 – 44,000 | 2 | 36,000 – 39,000 | 7 |
| 44,000 – 54,000 | 1 | 39,000 – 42,000 | 6 |
| Above 54,000 | 0 | 42,000 – 46,000 | 5 |
| | | 46,000 – 49,000 | 4 |
| | | 49,000 – 53,000 | 3 |
| | | 53,000 – 57,000 | 2 |
| | | 57,000 -61,000 | 1 |
| | | Above 61,000 | 0 |

## 7-03. Overall Plan for Water Management.

**a. General Plan.** The navigation channel of Pool No. 6 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. 6, 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 25,000 cfs, the pool is fairly flat. To meet depth requirements in the upper pool requires the pool elevation at Winona, Minnesota to be at elevation 645.5 feet (1912 adjustment). Therefore, "project pool" elevation for Lock and Dam No. 6 is 645.5 ± 0.2 feet, and Winona acts as the "primary control point" for maintaining this elevation. As discharges increase, gates are opened at the dam to maintain project pool at Winona. This results in a draw down in the water surface elevation at the dam. Maximum allowable drawdown is one foot below project pool elevation or 644.5 ± 0.2 feet. The lock and dam is now in "secondary control". As discharges continue to rise to around 75,000 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 in "open river conditions". On the recession limb of the hydrograph, the gates are put back into the water, maintaining secondary control, and as flow continues to decrease, control passes from secondary to primary. The operating curves, shown on **Plate 7-1**, were updated for this manual based on historical data.

**Table 7-3**
**Control Conditions at Lock and Dam No. 6**

| Control Conditions | Approximate Discharge | Winona Gage Elevation | Lock and Dam 6 Pool Elevation |
|---|---|---|---|
| Primary | < 25,000 cfs | 645.5 ft | ≤ 645.5 ft |
| Primary to Secondary | 25,000 to 33,000 cfs | > 645.5 ft | < 645.5 ft<br>> 644.5 ft |
| Secondary | 33,000 to 75,000 cfs | > 645.5 ft | 644.5 ft |
| Open-River | > 75,000 cfs | > 645.5 ft | > 644.5 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 jump from computed outflows to the tailwater rating curve, outflows are transitioned to the tailwater rating.

Discharge ratings for the gates were originally developed based on laboratory tests on a hydraulic model. A Gate Regulation Schedule was developed based on gate discharge, maximum outflow velocity of 4.5 feet per second, and an effort to equally distribute flow across the dam. In 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.

In 1996, the St Paul District contracted with Toltz, King, Duvall, Anderson and Associates, Inc. (TKDA) to verify the measurements taken in 1974. The discharge measurements were made using an Acoustic Doppler Current Profiler (ADCP). Flow equations were developed for different head conditions. Some adjustments were required to produce a smooth curve. A comparison of the 1974 and 1996 results are shown on **Plate 7-2**. The 1996 results indicate similar discharge measurements at low head; however, at high head differentials, the ADCP showed greater discharge in the tainter gates and lesser discharge in the roller gates. The Gate Regulation Schedule was updated to reflect the change in discharge per foot opening of the gates. The distribution of flow was based on equalizing the outflow velocities. For example, consider a flow of 36,000 cfs and a respective head across the dam of 4.0 feet with a tailwater elevation of 640.5 feet. The discharge per foot opening for roller and tainter gates are 1,058 cfs and 606 cfs respectively. By setting the roller gates at a total opening of 20.0 feet (20 x 1,058 = 21,200 cfs) and the tainter gates at 24.5 feet (24.5 x 606 = 14,800 cfs) gives a total discharge of 36,000 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 80 feet long with a pier width of 16 feet. Tainter gates are 35 feet long with a pier width of 7 feet. The respective end sill elevations for roller and tainter gates are 625.5 feet and 628.5 feet. Therefore, the flow velocities are;

Roller Gate
Q = VA
(20 ft/5 roller gates) 1,058 cfs = V (80 ft + 16 ft) (640.5 ft – 625.5 ft)
V = 2.94 ft/sec

Tainter Gate
Q = VA
(24.5 ft/10 tainter gates) 606 cfs = V (35 ft + 7 ft) (640.5 ft – 628.5 ft)
V = 2.95 ft/sec

To complete the update of the Gate Regulation Schedule to reflect the change in per foot discharge, also requires a change in the maximum allowable gate openings. Maximum allowable gate openings are based on flow velocity at the end sill downstream of the gates. Again, let's consider a discharge of 36,000 cfs and a differential head of 4.0 feet with a tailwater elevation of 640.5 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
1,058 cfs (max gate opening in ft) = 6.0 fps (80 ft + 16 ft) (640.5 ft – 625.5 ft)
Max Gate Opening = 8.2 ft

Tainter Gate
Q = VA
606 cfs (max gate opening in ft) = 6.0 fps (35 ft + 7 ft) (640.5 ft – 628.5 ft)
Max Gate Opening = 5.0 ft

**Table 7-4** shows the new Gate Regulation Schedule.

**Table 7-4**
**Gate Regulation Schedule**
**5 Roller Gates and 10 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 | 4.0 | 3.5 | 645.45 | 639.07 | 6.38 | 1,250 | 840 | 5,000 | 2,900 | 6.3 | 3.2 |
| 9,000 | 4.5 | 4.0 | 645.43 | 639.09 | 6.34 | 1,248 | 837 | 5,600 | 3,300 | 6.3 | 3.2 |
| 10,000 | 5.0 | 4.5 | 645.42 | 639.10 | 6.32 | 1,247 | 836 | 6,200 | 3,800 | 6.3 | 3.2 |
| 11,000 | 5.5 | 5.0 | 645.40 | 639.13 | 6.27 | 1,245 | 833 | 6,800 | 4,200 | 6.3 | 3.2 |
| 12,000 | 6.0 | 5.5 | 645.38 | 639.16 | 6.22 | 1,242 | 830 | 7,400 | 4,600 | 6.3 | 3.2 |
| 13,000 | 6.5 | 6.0 | 645.33 | 639.20 | 6.13 | 1,234 | 824 | 8,000 | 4,900 | 6.4 | 3.3 |
| 14,000 | 7.0 | 6.5 | 645.30 | 639.22 | 6.08 | 1,230 | 821 | 8,600 | 5,300 | 6.4 | 3.3 |
| 15,000 | 7.5 | 7.0 | 645.25 | 639.25 | 6.00 | 1,225 | 816 | 9,200 | 5,700 | 6.5 | 3.3 |
| 16,000 | 8.0 | 8.0 | 645.20 | 639.28 | 5.92 | 1,218 | 796 | 9,700 | 6,400 | 6.5 | 3.4 |
| 17,000 | 8.5 | 8.5 | 645.15 | 639.30 | 5.85 | 1,211 | 792 | 10,300 | 6,700 | 6.6 | 3.4 |
| 18,000 | 9.0 | 9.5 | 645.10 | 639.35 | 5.75 | 1,205 | 774 | 10,800 | 7,300 | 6.6 | 3.5 |
| 19,000 | 9.5 | 10.0 | 645.03 | 639.40 | 5.63 | 1,198 | 757 | 11,400 | 7,600 | 6.7 | 3.6 |
| 20,000 | 10.0 | 11.0 | 644.98 | 639.43 | 5.55 | 1,190 | 751 | 11,900 | 8,300 | 6.7 | 3.7 |
| 21,000 | 10.5 | 11.5 | 644.90 | 639.49 | 5.41 | 1,180 | 742 | 12,400 | 8,500 | 6.8 | 3.7 |
| 22,000 | 11.0 | 12.5 | 644.85 | 639.53 | 5.32 | 1,170 | 728 | 12,900 | 9,100 | 6.9 | 3.8 |
| 23,000 | 12.0 | 13.0 | 644.78 | 639.56 | 5.22 | 1,162 | 719 | 13,900 | 9,300 | 7.0 | 3.9 |
| 24,000 | 12.5 | 13.5 | 644.70 | 639.60 | 5.10 | 1,153 | 710 | 14,400 | 9,600 | 7.0 | 3.9 |
| 25,000 | 13.0 | 14.5 | 644.62 | 639.70 | 4.92 | 1,140 | 695 | 14,800 | 10,100 | 7.2 | 4.1 |
| 26,000 | 14.0 | 15.5 | 644.50 | 639.78 | 4.72 | 1,122 | 675 | 15,700 | 10,400 | 7.3 | 4.2 |
| 27,000 | 14.5 | 16.0 | 644.50 | 639.83 | 4.67 | 1,116 | 672 | 16,200 | 10,800 | 7.4 | 4.2 |
| 28,000 | 15.0 | 17.0 | 644.50 | 639.90 | 4.60 | 1,111 | 668 | 16,700 | 11,300 | 7.5 | 4.3 |
| 29,000 | 15.5 | 18.0 | 644.50 | 639.97 | 4.53 | 1,106 | 658 | 17,100 | 11,800 | 7.5 | 4.4 |
| 30,000 | 16.0 | 19.0 | 644.50 | 640.03 | 4.47 | 1,100 | 648 | 17,600 | 12,300 | 7.5 | 4.5 |

**Table 7-4 – Continued**
**Gate Regulation Schedule**
**5 Roller Gates and 10 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 | 17.0 | 19.5 | 644.50 | 640.11 | 4.39 | 1,095 | 640 | 18,600 | 12,500 | 7.7 | 4.6 |
| 32,000 | 17.5 | 20.5 | 644.50 | 640.20 | 4.30 | 1,088 | 634 | 19,000 | 13,000 | 7.8 | 4.7 |
| 33,000 | 18.0 | 21.5 | 644.50 | 640.26 | 4.24 | 1,080 | 629 | 19,400 | 13,500 | 7.9 | 4.7 |
| 34,000 | 18.5 | 23.0 | 644.50 | 640.35 | 4.15 | 1,072 | 620 | 19,800 | 14,200 | 8.0 | 4.8 |
| 35,000 | 19.0 | 24.0 | 644.50 | 640.40 | 4.10 | 1,070 | 613 | 20,300 | 14,700 | 8.0 | 4.9 |
| 36,000 | 20.0 | 24.5 | 644.50 | 640.50 | 4.00 | 1,058 | 606 | 21,200 | 14,800 | 8.2 | 5.0 |
| 37,000 | 20.5 | 26.0 | 644.50 | 640.60 | 3.90 | 1,050 | 595 | 21,500 | 15,500 | 8.3 | 5.1 |
| 38,000 | 21.5 | 27.0 | 644.50 | 640.70 | 3.80 | 1,038 | 582 | 22,300 | 15,700 | 8.4 | 5.3 |
| 39,000 | 22.5 | 27.5 | 644.50 | 640.78 | 3.72 | 1,030 | 579 | 23,200 | 15,900 | 8.5 | 5.3 |
| 40,000 | 23.0 | 29.0 | 644.50 | 640.87 | 3.63 | 1,025 | 570 | 23,600 | 16,500 | 8.6 | 5.5 |
| 41,000 | 23.5 | 30.0 | 644.50 | 640.93 | 3.57 | 1,020 | 566 | 24,000 | 17,000 | 8.7 | 5.5 |
| 42,000 | 24.5 | 31.5 | 644.50 | 641.05 | 3.45 | 1,006 | 554 | 24,600 | 17,400 | 8.9 | 5.7 |
| 43,000 | 25.5 | 33.0 | 644.50 | 641.15 | 3.35 | 992 | 537 | 25,300 | 17,700 | 9.1 | 5.9 |
| 44,000 | 26.0 | 35.0 | 644.50 | 641.24 | 3.26 | 985 | 529 | 25,600 | 18,500 | 9.2 | 6.1 |
| 45,000 | 27.0 | 35.5 | 644.50 | 641.35 | 3.15 | 974 | 529 | 26,300 | 18,800 | 9.4 | 6.1 |
| 46,000 | 28.0 | 36.5 | 644.50 | 641.45 | 3.05 | 963 | 521 | 27,000 | 19,000 | 9.5 | 6.3 |
| 47,000 | 29.0 | 38.5 | 644.50 | 641.55 | 2.95 | 948 | 510 | 27,500 | 19,600 | 9.8 | 6.4 |
| 48,000 | 30.0 | 39.5 | 644.50 | 641.65 | 2.85 | 937 | 502 | 28,100 | 19,800 | 9.9 | 6.6 |
| 49,000 | 31.0 | 41.0 | 644.50 | 641.73 | 2.77 | 926 | 493 | 28,700 | 20,200 | 10.1 | 6.8 |
| 50,000 | 32.0 | 42.5 | 644.50 | 641.80 | 2.70 | 918 | 488 | 29,300 | 20,700 | 10.2 | 6.9 |
| 51,000 | 33.0 | 43.5 | 644.50 | 641.85 | 2.65 | 910 | 484 | 30,000 | 21,000 | 10.3 | 7.0 |
| 52,000 | 34.0 | 44.0 | 644.50 | 641.90 | 2.60 | 905 | 480 | 30,800 | 21,100 | 10.4 | 7.0 |
| 53,000 | 35.0 | 46.5 | 644.50 | 642.00 | 2.50 | 890 | 470 | 31,100 | 21,900 | 10.6 | 7.2 |

**Table 7-4 – Continued**
**Gate Regulation Schedule**
**5 Roller Gates and 10 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 | 36.0 | 48.5 | 644.50 | 642.10 | 2.40 | 880 | 462 | 31,700 | 22,400 | 10.9 | 7.4 |
| 55,000 | 37.0 | 50.0 | 644.50 | 642.15 | 2.35 | 873 | 455 | 32,300 | 22,700 | 11.0 | 7.6 |
| 56,000 | 38.0 | 51.0 | 644.50 | 642.20 | 2.30 | 867 | 450 | 32,900 | 23,000 | 11.1 | 7.7 |
| 57,000 | 39.0 | 54.0 | 644.50 | 642.30 | 2.20 | 850 | 442 | 33,100 | 23,900 | 11.4 | 7.9 |
| 58,000 | 40.0 | 57.0 | 644.50 | 642.40 | 2.10 | 832 | 432 | 33,300 | 24,600 | 11.7 | 8.1 |
| 59,000 | 41.0 | 59.0 | 644.50 | 642.45 | 2.05 | 825 | 428 | 33,800 | 25,200 | 11.8 | 8.2 |
| 60,000 | 42.0 | 61.0 | 644.50 | 642.50 | 2.00 | 820 | 420 | 34,400 | 25,600 | 11.9 | 8.4 |
| 61,000 | 43.5 | 63.0 | 644.50 | 642.60 | 1.90 | 810 | 410 | 35,200 | 25,800 | 12.2 | 8.7 |
| 62,000 | 45.0 | 65.0 | 644.50 | 642.70 | 1.80 | 792 | 406 | 35,600 | 26,400 | 12.5 | 8.8 |
| 63,000 | 46.5 | 66.0 | 644.50 | 642.75 | 1.75 | 788 | 400 | 36,600 | 26,400 | 12.6 | 9.0 |
| 64,000 | 48.0 | 69.0 | 644.50 | 642.80 | 1.70 | 770 | 392 | 37,000 | 27,000 | 12.9 | 9.2 |
| 65,000 | 49.5 | 71.0 | 644.50 | 642.90 | 1.60 | 760 | 386 | 37,600 | 27,400 | 13.2 | 9.4 |
| 66,000 | 52.0 | 73.0 | 644.50 | 643.00 | 1.50 | 740 | 377 | 38,500 | 27,500 | 13.6 | 9.7 |
| 67,000 | 54.0 | 73.5 | 644.50 | 643.07 | 1.43 | 734 | 372 | 39,600 | 27,400 | 13.8 | 9.9 |
| 68,000 | 55.5 | 77.0 | 644.50 | 643.14 | 1.36 | 718 | 365 | 39,800 | 28,100 | 14.2 | 10.1 |
| 69,000 | 57.0 | 81.5 | 644.50 | 643.21 | 1.29 | 700 | 357 | 39,900 | 29,100 | 14.6 | 10.4 |
| 70,000 | 59.0 | 83.5 | 644.50 | 643.28 | 1.22 | 690 | 351 | 40,700 | 29,300 | 14.8 | 10.6 |
| 71,000 | 61.0 | 87.0 | 644.50 | 643.35 | 1.15 | 670 | 347 | 40,900 | 30,200 | 15.3 | 10.8 |
| 72,000 | 63.0 | 90.0 | 644.50 | 643.42 | 1.08 | 658 | 340 | 41,400 | 30,600 | 15.7 | 11.1 |
| 73,000 | 66.0 | 93.0 | 644.50 | 643.49 | 1.01 | 640 | 331 | 42,200 | 30,800 | 16.3 | 11.4 |
| 74,000 | 69.0 | 97.0 | 644.50 | 643.56 | 0.94 | 615 | 325 | 42,400 | 31,500 | 16.9 | 11.7 |
| 75,000 | 74.0 | 98.0 | 644.50 | 643.63 | 0.87 | 590 | 320 | 43,700 | 31,300 | 17.7 | 11.9 |
| 76,000 | Out of Control – Gates raised clear of water. Put gates back in at 75 ft Roller Gates and 100 ft Tainter Gates. | | | | | | | | | | |

**c. Regulation Procedure.** Each morning at 0645-hours, the Water Management regulator prints the Regulation Sheets containing all the input from the lock and dam sites. Regulation for Lock and Dam No. 6 begins at Lock and Dam No. 4. Gate changes at Lock and Dam No. 4 directly influence action needed at Dam No. 5, which in turn directly influences Dam No. 5A, which then impacts Dam No. 6. After regulating Lock and Dam 5A, inflow to Pool No. 6 is determined. Inflow consists of outflow from Lock and Dam No. 5A, inflow from the Trempealeau River, and any miscellaneous inflow. Outflow from Lock and Dam 5A is computed as part of the daily regulation. Inflow from the Trempealeau River will appear on the Regulation Sheet from input by site personnel. Miscellaneous inflow will vary seasonally but for simplicity it is assumed to be a constant 300 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 400 cfs is added to the miscellaneous inflow. Inflow is totaled and the 24-hour change is noted. Also noted is the change in outflow and any gate changes made in the past 24-hours. Next the rate of fall or rise of the pool is calculated. This is done at the dam 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 300 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 5,910 acres. Once the needed change in discharge is determined, the Gate Regulation Schedule is used to distribute flow and hence set gate changes. The “daily orders” are displayed on 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 645.4 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 645.5 ± 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 Management 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 Management would then provide any gate change verbally over the telephone or are displayed on the St. Paul District's intranet. The following is a sample of the regulation of Lock and Dam No. 6. The portion printed in black represents the daily regulation sheet while that printed in blue represents regulation notes.

**Regulation of Lock and Dam No. 6 for 23 September 2001**

Orders to LD 5A: Open 2 ft RG. Increase 2,500 to 19,500 cfs.
Note: There were no gate changes in the past 24-hours.

| | | | | | 5-RG Total Roller Gate | 10-TG Total Tainter Gate | [primary = 645.50 for flow<27,000] CP-6 Winona TM5A |
|---|---|---|---|---|---|---|---|
| gates in/out: | | 75/100 @ 75,000 | | | | | |
| LOCK 6 | sec: 644.50 | Tail | Flow | | | | |
| 22SEP01 | 0800 | 645.31 | 639.59 | 17400 | 7.5 | 10.0 | 645.67 |
| | 1200 | 645.28 | 639.65 | 17200 | 7.5 | 10.0 | |
| | 1600 | 645.30 | 639.66 | 17200 | 7.5 | 10.0 | |
| | 2000 | 645.31 | 639.62 | 17300 | 7.5 | 10.0 | |
| | 2400 | 645.33 | 639.67 | 17300 | 7.5 | 10.0 ← Opened 1 ft | |
| 23SEP01 | 0400 | 645.33 | 639.77 | 18400 | 8.5 | 10.0 | |
| | 0630 | 645.34 | 639.80 | 18400 | 8.5 | 10.0 | 645.69 |
| | | up 0.03 | | up 1000 | | | up 0.02 |
| phone | HEAD | 5.5 | | | | Dodge: | 5.30 |
| ##030 | Q/foot | 1185/750 | | | | TM6 | |
| | temp. | 56 | | | | Flow: | 841 |
| | precip. | 0.95 | | | | | |
| | wind (dir&speed) | | 360 @ 2 | | | | |
| | INFLOW: | | | | | | |
| | L/D 5A - | 19500 | | | | | |
| | Tremp. R. | 800 | | | | | |
| | 300 CFS - | | | | | | |
| | Misc. - | 300 | | | | | |
| | | ------ | | | | | |
| | | 20600+400=21,000 | | | | | |
| | | up 680 | | | | | |

Orders:
Open 1.5 ft on RG
Inc. Flow 1,600 to 20,000 cfs
Hold 45.20 ± 0.2 ft

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 6.
Computed inflow from LD 5A was 17,000 cfs.
LD 5A orders were to open up 2,500 cfs to 19,500 cfs.
The Trempealeau River is at 800 cfs.
Miscellaneous inflow is 300 cfs.
Rainfall was 0.95 inches, so add 400 cfs to inflow.
Total Inflow = 21,000 cfs (up 680 cfs from yesterday).
Step 2. Note change in outflow.
Up 1,000 cfs due to gate change.
Step 3. Note change in pool elevation.
Pool is up 0.03 feet at the dam.
Pool is up 0.02 feet at Winona.
Wind is minimal.
Step 4. Primary or Secondary Control?
Flow is less than 27,000 cfs; therefore, Primary Control.
For Primary Control, maintain Winona at 645.50 ± 0.2 ft.
Step 5. Estimate needed change in discharge.
Inflow is up 680 cfs from yesterday.
The pool is fairly steady but a little on the high side.
Need to open, as a minimum, the opening made at LD 5A.
Therefore, we want to open 2,500 cfs; however, an opening was made between midnight and 0400hours (increased 1,100 cfs).
We need (2,500-1,100) 1,400 cfs increase in outflow.
Step 6. Set gate change.
The Gate Reg Schedule shows ideal gate settings for 19,000 cfs to be 9.5 ft on RG and 10.0 ft on TG.
Therefore, the gate opening will be on the Roller Gates.
A one-foot opening on RG's would increase outflow 1,100 cfs.
Because the pool is on the high side,
"Open 1.5 ft on RG. Increases flow 1,600 to 20,000."
Step 7. Set the pool band.
The pool is a little high (i.e. target at Winona is 645.50 ft).
We want an opening if the pool goes up; therefore,
"Hold elevation 645.20 ± 0.2 feet."

**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 Management 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, MN. "Average November Flow" was plotted against the "Minimum Winter Flow". A curve was drawn through the lowest data points. 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. However, discharges through the roller gates are computed for 0.5 and 1.0 feet submerged. These discharges are deducted from the estimated minimum base flow. Tainter gate settings are then determined for the remainder of the flow. These gate settings are sent to the Lockmaster for evaluation. The Lockmaster assesses the Water Management 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.

During the winter, on the weekends and holidays, the shifts are limited to one person at the dam site. Two people are required to make a gate change. There is a one half hour overlap in the morning between the 0730 and 0800-hours. Therefore, Water Management makes an effort to get orders out by 0730-hours. 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 Winona gage is typically maintained at elevation 645.5 ± 0.3 feet. Because of the added benefit to fish habitat, Water Management operates on the high side of the band during winter months to reduce oxygen depletion in the backwater areas.

| Table 7-5<br>Discharge Through Submerged Roller Gate – cfs | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pool Elevation | Head Feet | Depth of Submerged Gate | | | | | |
| | | 0.5 ft | 1.0 ft | 1.5 ft | 2.0 ft | 2.5 ft | 3.0 ft |
| 645.5 | 7.0 | 280 | 580 | 960 | 1370 | 1620 | 1930 |
| | 6.0 | 260 | 560 | 920 | 1320 | 1570 | 1880 |
| 645.4 | 7.0 | 250 | 560 | 920 | 1320 | 1560 | 1860 |
| | 6.0 | 240 | 530 | 880 | 1270 | 1510 | 1810 |
| 645.3 | 7.0 | 230 | 530 | 880 | 1270 | 1490 | 1790 |
| | 6.0 | 220 | 500 | 840 | 1220 | 1440 | 1740 |
| 645.2 | 7.0 | 210 | 500 | 840 | 1220 | 1430 | 1710 |
| | 6.0 | 200 | 470 | 800 | 1180 | 1380 | 1660 |
| 645.1 | 7.0 | 190 | 470 | 810 | 1180 | 1380 | 1640 |
| | 6.0 | 180 | 440 | 770 | 1130 | 1320 | 1590 |
| 645.0 | 7.0 | 170 | 450 | 770 | 1130 | 1320 | 1570 |
| | 6.0 | | 420 | 730 | 1080 | 1270 | 1520 |
| 644.9 | 7.0 | | 430 | 740 | 1090 | 1270 | 1510 |
| | 6.0 | | 400 | 700 | 1040 | 1220 | 1460 |
| 644.8 | 6.0 | | 390 | 670 | 1000 | 1170 | 1390 |
| | 5.0 | | 350 | 630 | 950 | 1120 | 1340 |
| 644.7 | 6.0 | | 370 | 650 | 960 | 1130 | 1330 |
| | 5.0 | | 340 | 600 | 910 | 1070 | 1280 |
| 644.6 | 6.0 | | 360 | 620 | 930 | 1080 | 1280 |
| | 5.0 | | 320 | 580 | 870 | 1020 | 1220 |
| 644.5 | 5.0 | | 310 | 560 | 840 | 970 | 1170 |
| | 4.0 | | 280 | 510 | 780 | 920 | 1110 |
| 644.5 | 3.0 | | 240 | 460 | 710 | 850 | 1050 |
| | 2.0 | | 190 | 390 | 620 | 760 | 980 |

## 7-04. Standing Instructions to Lock and Dam No. 6 Staff.

**a. Data Collection.** Lock and dam personnel are to collect and report various hydraulic data to Water Management via computer by 0630-hours. The data entry interval varies from once a day to every four hours. Four-hour data begins at 0800-hours and includes pool elevation, tailwater elevation, gate settings, and tainter valve settings (winter only). Eight-hour data begins at 0800-hours and includes air temperature and wind speed and direction. Daily data includes max-min air temperature (2400-hours), water temperature (0800-hours), precipitation (0800-hours), and the stages for the Trempealeau River at Dodge and Black River at Galesville (Note: Lock and Dam No. 5A calls the Winona gage each morning and inputs the information at their site.).

All 0800-hour data are actually collected at 0600-hours. Max-min air temperature is actually taken at 1900-hours.

During the winter months site personnel are to report percent of pool and tailwater ice coverage, pool and tailwater ice thickness, snow depth, and snow-water equivalent (all in inches) via computer. These data are collected once a week on Sundays. The snow-water content is to be determined by instructions contained in the National Weather Service Snow Measurement Guidelines for NWS Cooperative Observers.

**b. Lock and Dam Operations.** The Water Management regulator analyzes the field data and at around 0800-hours, the daily orders for gate movements are displayed on the St. Paul District's intranet site. On weekends and holidays during the winter operations, orders are sent by 0730-hours due to limited staffing at the dam site. Gate changes are then made as soon as possible. If Water Management has notified the site that they will contact them again later in the day, 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 Management are 0630 to 1500-hours during the week, and 0630 to 1030-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. When a gate change is made, Lock and Dam No. 7 is to be notified. The site is limited to changes of up to 15 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 after 0400-hours, no gate change will be made. Water Management will provide the necessary gate change and band limit with the morning's orders. The following is a list of Water Management 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 in **Table 7-6**. Lock personnel contacting Water Management personnel during non-duty hours 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.

**Table 7-6**
**Water Management Personnel Telephone Numbers**

| Name | Duty Telephone No. | Mobile Telephone No. |
|---|---|---|
| Daniel Fasching | 651-290-5786 | 651-242-3279 |
| Liz Nelsen | 651-290-5306 | 651-724-3392 |
| Brian Johnson | 651-290-5652 | 651-724-3394 |

If lock personnel have any questions regarding the Water Management order, they are to contact the river regulator via telephone (651-290-5633) and the question will be resolved. During computer outages, log sheets will be faxed to Water Management (651-290-5841) and orders will be given via telephone.

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 Management Section and Operations (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 Management will coordinate gate movements with site personnel in preparation for installation and removal of the bulkheads.

**7-05. Flood Control.** Lock and Dam No. 6 has no flood control benefits. It is operated strictly for navigation. While it may seem possible that the pools be drawdown over the winter months to provide storage for spring runoff, this plan has no merit for two reasons. First, the applicable statute, 16 USC 665a, requires maintenance of "pool levels as though navigation was carried on throughout the year."

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. 6 is fishing 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 habitat. As for recreational boating, there were over 1,300 recreation boat lockages in the year 2012. **Table 7-7** shows a comparison of recreational to towboat lockages.

**Table 7-7**
**Commercial & Recreational Lockages at Lock No. 6**

| Year | Commercial Lockages | Recreational Lockages | Recreation Vessels | Other Lockages | Total Lockages | Percent Recreation |
|---|---|---|---|---|---|---|
| 1991 | 2,563 | 3,162 | 12,334 | 89 | 5,814 | 54 |
| 1992 | 2,770 | 2,983 | 12,604 | 83 | 5,836 | 51 |
| 1993 | 1,616 | 2,251 | 6,649 | 64 | 3,931 | 57 |
| 1994 | 1,938 | 3,366 | 11,859 | 165 | 5,469 | 62 |
| 1995 | 2,283 | 3,106 | 12,101 | 105 | 5,494 | 57 |
| 1996 | 2,489 | 2,975 | 13,230 | 98 | 5,562 | 53 |
| 1997 | 2,266 | 2,554 | 11,206 | 106 | 4,926 | 52 |
| 1998 | 2,481 | 2,716 | 11,534 | 97 | 5,294 | 51 |
| 1999 | 2,716 | 2,477 | 10,201 | 103 | 5,296 | 47 |
| 2000 | 2,396 | 2,553 | 8,030 | 174 | 5,123 | 50 |
| 2001 | 1,799 | 2,250 | 7,059 | 162 | 4,211 | 53 |
| 2002 | 2,553 | 2,241 | 7,049 | 147 | 4,941 | 45 |
| 2003 | 1,992 | 2,417 | 7,144 | 105 | 4,514 | 54 |
| 2004 | 1,689 | 2,261 | 6,344 | 98 | 4,048 | 56 |
| 2005 | 1,668 | 2,414 | 6,233 | 63 | 4,145 | 58 |
| 2006 | 1,706 | 2,153 | 5,397 | 75 | 3,934 | 55 |
| 2007 | 1,670 | 1,901 | 4,833 | 41 | 3,612 | 53 |
| 2008 | 1,073 | 1,778 | 4,235 | 92 | 2,943 | 60 |
| 2009 | 1,435 | 1,821 | 4,516 | 85 | 3,341 | 55 |
| 2010 | 1,462 | 1,571 | 4,083 | 74 | 3,107 | 51 |
| 2011 | 1,405 | 1,204 | 3,376 | 118 | 2,727 | 44 |
| 2012 | 1,420 | 1,362 | 3,119 | 62 | 2,844 | 48 |

**7-07. Water Quality.** The Corps of Engineers does not perform any water quality analysis in Pool No. 6.

**7-08. Fish and Wildlife.** Until 1969, during low to moderate flows, the only water flowing into Pool No. 7 was passed through the dam. In 1969, a notch, 10.0 feet long and 3.0 feet deep was cut into the concrete spillway located within the earthen dike portion of the dam. The notch provides a constant flow of 135 cfs when the pool is at project level. This aids fish habitat by aerating the water upstream and downstream.

Because the lock and dam was constructed for the purpose of navigation, the pool would sometimes be drawn down in non-navigation season. The U.S. Code citation (16 USC 665a) prevented any winter drawdown of the pool. The pool is to be regulated the same as during navigation season. The higher stage in the backwater areas reduces the oxygen depletion. Because of this, Water Management typically operates on the high side of the band during the winter months.

**7-09. Water Supply.** The city of Winona, MN and the village of Trempealeau, WI obtain their water from wells. Pool No. 6 does not provide water supply.

**7-10. Hydroelectric Power.** There is no hydroelectric power at Lock and Dam No. 6.

**7-11. Navigation.** The primary purpose of Lock and Dam No. 6 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 seven minutes. Lockage time for a double lockage depends on the

experience of the deck hands breaking and making couplings, number of loaded and empty barges, wind speed and direction, flow conditions, and whether it is an up bound or down bound tow. A down bound tow will take longer due to outdraft conditions at the dam. On average, a double lockage takes about 1 hour and 30 minutes to 2 hours.

**7-12. Drought Contingency Plans.** There is no Drought Contingency Plan. Operation of the dam is basically run of the river. Therefore, rate of release change is nature driven. While not desirable, outflows may be reduced to zero to maintain navigation.

**7-13. Flood Emergency Action Plans.** The Emergency Action Plan is a stand-alone document entitled *Emergency Plan for Lock and Dam 6, Trempealeau, Wisconsin,* July 1986. 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. 6 include excess seepage, sabotage, extreme storm, failure of foundation, abutment and equipment, and slope failure.

Other emergency situations not addressed in the Emergency Action Plan are barge incidents and chemical spills. When a barge or barges go into the dam, Water Management is to be notified as soon as possible. Most likely, the manipulation of gates will be necessary to accommodate removal of the barge(s). All gate movements are to be coordinated with Water Management to reduce the potential for erosion of the channel bottom downstream of the dam. In the event of a chemical spill resulting from a barge incident or other disaster, the Lockmaster is to immediately notify the National Response Center. The telephone number is on the Emergency Notification Chart at the site. The Lockmaster is also to notify Water Management (651-290-5633) and the Emergency Operations Center (EOC)

at 651-290-5220. Water Management will coordinate with the lock site as well as Emergency Management and Environmental Branch.

There are several protective measures taken at Lock and Dam No. 6 when a flood occurs. When the pool level is forecasted to go above elevation 647.0 feet (1912 adjustment) the abutments to the concrete spillway are protected with sand bags. Sand bags are placed on the unprotected portion of the earthen dike for a distance of 100 feet on each side. As the pool rises other actions are required. The following gives a brief summary of the steps to be taken as water levels go higher.

**Table 7-8**
**Flood Action Plan**

| Pool Elevation | Action Taken |
|---|---|
| 647.0 feet | Sandbag the bank of the spillway abutments. |
| 651.5 feet | Lock is closed to navigation; Limit switches are protected. |
| 652.5 feet | Central Control Station is sandbagged. |
| 653.5 feet | Miter gate handrails are removed. |
| 654.0 feet | Lower and upper haulage motor is removed. |

**7-14. 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.

**7-15. Deviation from Normal Regulation.** There are three forms of deviation; (1) a deviation because of an emergency situation, (2) an unplanned minor deviation due to an unplanned event, and (3) a planned deviation, typically to accomplish some task. To deviate from the operating plan requires prior permission from the Division Office (MVD), except for an emergency.

**a. Emergency.** Under an emergency deviation, the District Engineer or Chief of Engineering Division may authorize a deviation in an attempt to abate the problem. The Division Office is to be notified as soon as practical. Written confirmation of the deviation is to be sent to the Division Water Control Manager.

**b. Unplanned Minor Deviation.** The general objective of the water management plan is to maintain a minimum depth of nine feet along the navigation channel of Pool No. 6, while in primary control, the pool is to be maintained at elevation 645.5 ± 0.2 feet at the primary control point (Winona) as best as possible. During low flows, the pool is not to be intentionally raised above or lowered below this elevation; however, unplanned minor deviations are permitted. A minor deviation is when the pool is slightly out of the limits set by primary and secondary control. Because these minor deviations are unplanned and are only temporary, while actions are being are being taken to correct the situation, these exceptions do not require notification of the division office. The Division Office (MVD) must be notified when a deviation is outside the limits set by primary and secondary control and is intentional for a prolonged period of time.

**c. Planned Deviations.** Requests for planned minor deviations may be submitted to the Division Water Control Manager by e-mail. Major deviations must be presented formally to the Division Water Control Manager by a memorandum from the Chief, Engineering Division. The request should include sufficient data on navigation and watershed conditions, and benefits to be expected.

An example of a major deviation was the "planned" drawdown of Pool 6. It was implemented in 2010 using Operation & Maintenance (O&M) funding and authority. The drawdown was 1.0 foot below Secondary Control at Lock and Dam 6 and was initiated on June 18, 2010. River flows were consistently within the range needed to maintain a drawdown, and the drawdown was in effect until September 3, 2010. Due to the high summer flows only the lower portions (below Winona, MN) experienced the effects of the drawdown. Preliminary monitoring indicates that up to 200 acres were exposed and that robust plant growth occurred

in the exposed mudflats as a result of the drawdown. An increase in aquatic vegetation in the lower pool resulted as shown in **Figure 7-1**.

The effects on commercial navigation facilities in Pool 6 were minimal because this type of development is all located in the upper portion of the pool, where less effect of the drawdown was experienced. Certain recreational access points experienced challenges with the drawdown. The agency team made every effort to effectively manage these challenges.

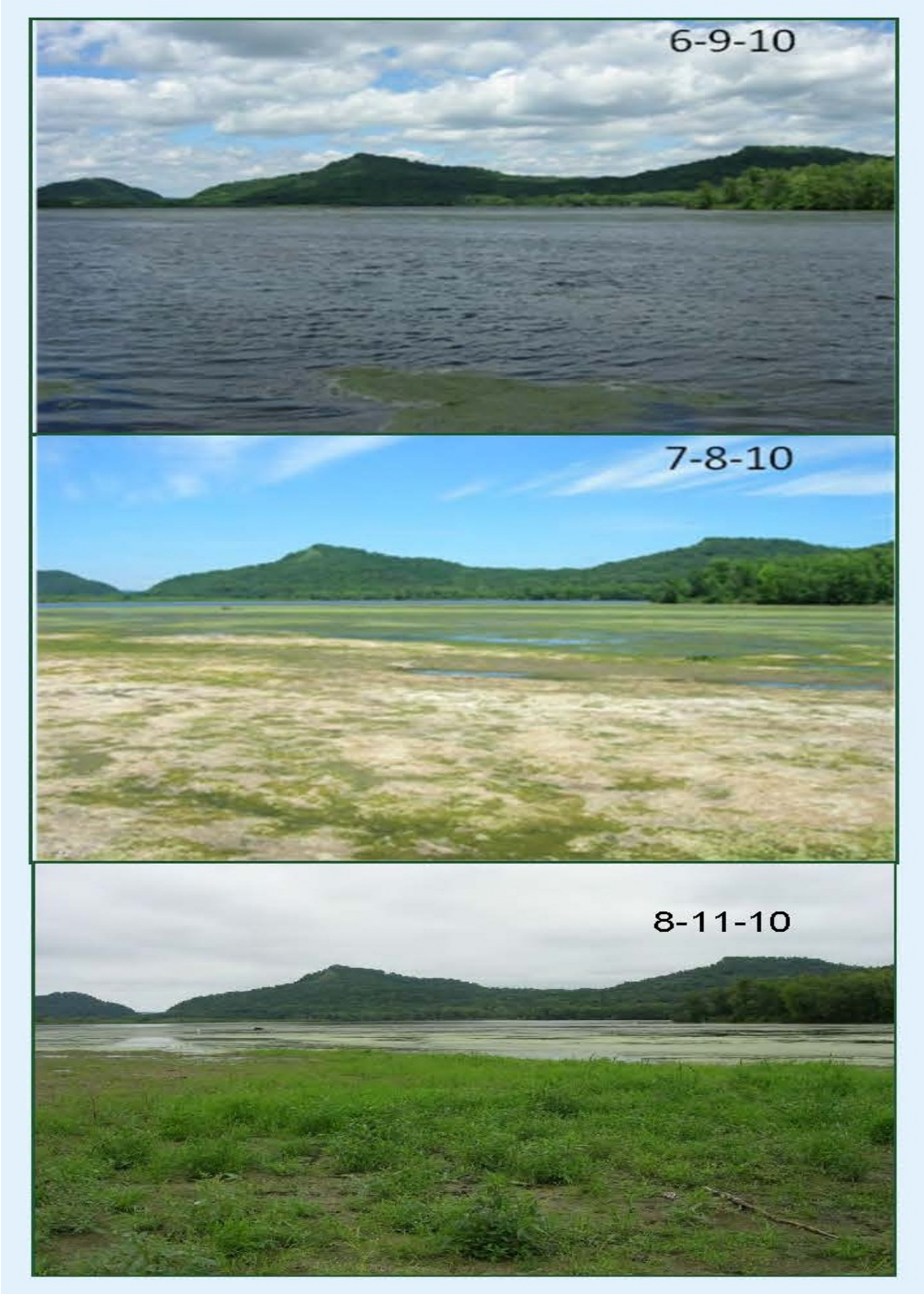



**Figure 7-1. Channel – River Mile 716**

**7-16. Rate of Release Change.** The only guideline for rate of release change is the "fifteen percent rule" (**Section 7-04**). During Water Management'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 fifteen 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 nature driven.

## VIII – EFFECT OF WATER CONTROL PLAN

**8-01. General.** The effect of the water control plan for Lock and Dam No. 6 is to maintain a nine-foot depth in the navigation channel of Pool No. 6. Lock and Dam No. 6 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 1930's. A more complete description of this development is available in the Master Water Control Manual for the Locks and Dams.

**8-02. Flood Control.** The locks and dams provide no flood control benefits. They were constructed strictly for navigation purposes. The dam operates on a run-of-the-river principal. As discharge increases, the gates are opened. At around 75,000 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 two recreation qualities associated with Pool No. 6 are fishing 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 habitat. While Lock and Dam No.6 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 1,300 recreation boat lockages in the year 2012.

**8-04. Fish and Wildlife.** The Trempealeau National Wildlife Refuge is located in Pool No. 6 just south of Winona, Minnesota. The marsh that is now the refuge was isolated from the Mississippi River in 1880 by a railroad embankment. Surface water influence was removed in 1911 when dikes were constructed to reroute the Trempealeau River around the wetland area (for a photo of the area see

**Paragraph 2-04**). These barriers prevented flooding in the marsh. Then in 1936, the completion of Lock and Dam No. 6 stabilized water levels in Pool No. 6, thus eliminating low water periods and preventing droughts in the marsh. Without cycles of flood and drought, which are critical for a healthy floodplain marsh, habitat declined and the role of the refuge as a major feeding and resting area for migratory birds declined. Therefore, there was a need to lower the water surface in some areas of the refuge while raising it in others. A contract was awarded for refuge management in 1995. Construction was completed in 1999. Over three miles of dikes were constructed to divide the 5,700-acre refuge into separate management areas called pools. The design includes gravity flow structures as well as pump stations to manage water levels in the many pools.

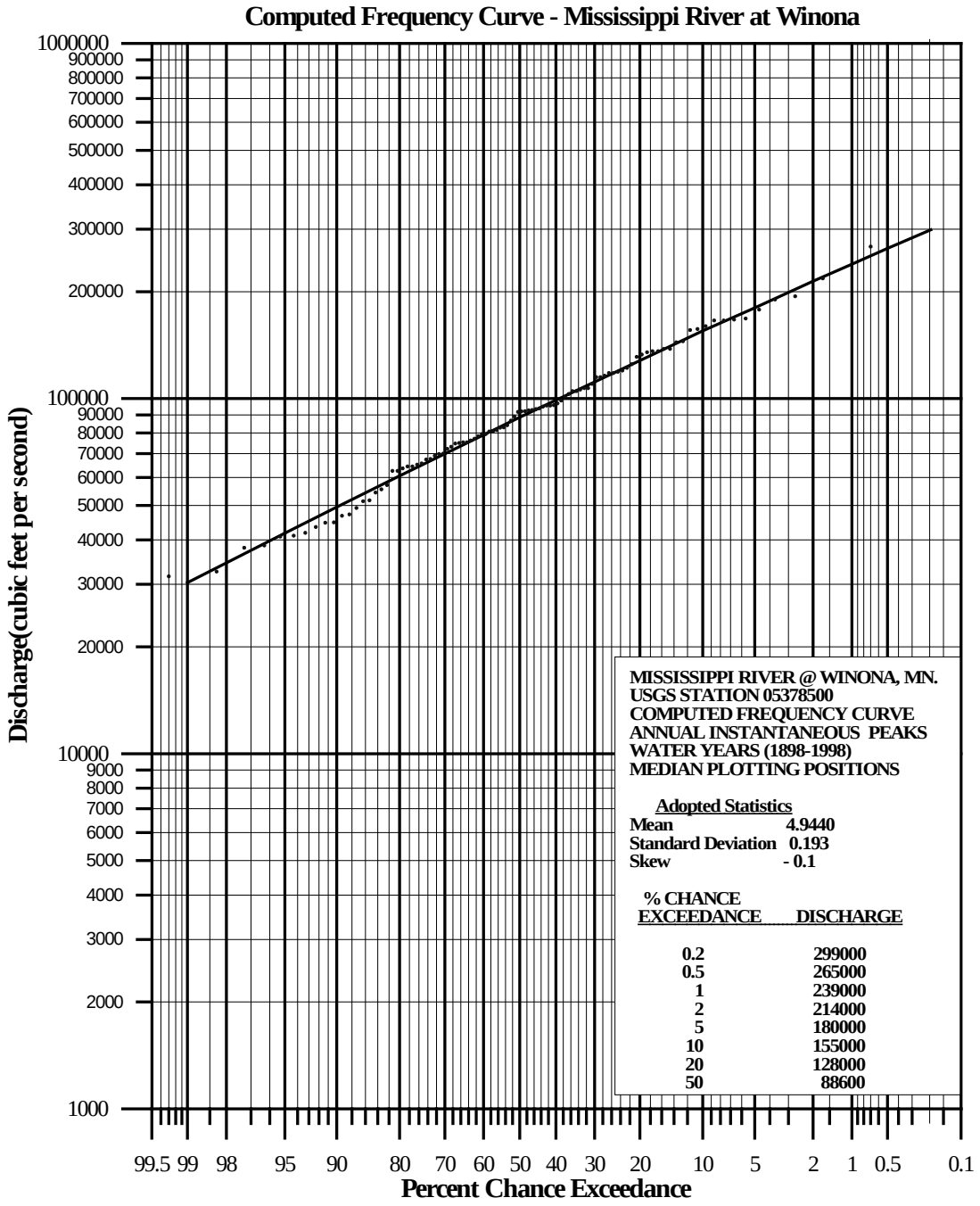
**8-05. Navigation.** The Upper Mississippi River Nine-Foot Channel Project originated in the 1920's when it was promoted as a way to alleviate the Nation's worsening farm crisis. It was also aimed at allaying the inequities in commercial rail and water freight rates. The project was authorized by the Rivers and Harbors Act of 1930 (PL 71-520; 46 Stat. 918), with most of the locks and dams, including Lock No. 6, being constructed in the 1930's. The project was not without its controversy. For example, railroads claiming damage to their right-of-ways and conservationists fearing its effects on the environment. Ultimately, the economic benefits overrode all other concerns. After completion of the project, river traffic increased from 2,400,000 tons in 1939 to 68,400,000 in 1976. **Table 8-1** shows the recent history of tonnage commodities at Lock and Dam No. 6. For more historical information concerning the Nine-Foot Channel Project, see the Master Water Control Manual for the Locks and Dams.

## Table 8-1
## Lock and Dam No. 6 Tonnage – Commodities

| Year | Coal | Petrol Product | Chemical Products | Crude Material | Manu Goods | Farm Products | Equip Mach | Misc Product | Total Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | 911,957 | 609,054 | 1,876,697 | 1,066,381 | 571,358 | 9,604,606 | 13,800 | 223,183 | 14,877,036 |
| 2001 | 792,528 | 254,353 | 1,556,334 | 1,396,398 | 448,346 | 7,323,227 | 7,628 | 177,464 | 11,956,278 |
| 2002 | 740,669 | 395,517 | 1,685,199 | 1,438,807 | 642,827 | 9,298,918 | 10,080 | 237,675 | 14,449,692 |
| 2003 | 770,351 | 327,856 | 1,863,266 | 1,385,810 | 447,242 | 7,383,143 | 14,116 | 40,617 | 12,232,401 |
| 2004 | 1,030,657 | 307,920 | 1,591,330 | 1,843,435 | 858,671 | 5,082,061 | 6,674 | 34,251 | 10,754,999 |
| 2005 | 884,193 | 503,749 | 1,403,755 | 1,900,791 | 717,701 | 4,921,216 | 14,220 | 35,604 | 10,381,229 |
| 2006 | 1,028,011 | 306,800 | 1,215,321 | 1,945,668 | 814,354 | 5,615,388 | 13,710 | 26,605 | 10,965,857 |
| 2007 | 1,076,881 | 505,327 | 1,622,417 | 1,563,404 | 443,294 | 5,165,438 | 26,429 | 6,070 | 10,409,260 |
| 2008 | 794,717 | 219,876 | 1,311,836 | 1,971,253 | 270,972 | 2,588,022 | 67,039 | 17,041 | 7,240,756 |
| 2009 | 647,641 | 469,700 | 1,142,326 | 1,968,917 | 360,657 | 4,865,449 | 14,777 | 15,100 | 9,484,567 |
| 2010 | 513,997 | 422,804 | 1,552,127 | 1,550,352 | 597,095 | 4,961,364 | 21,527 | 55,641 | 9,674,907 |
| 2011 | 386,927 | 292,804 | 1,812,993 | 1,719,321 | 723,123 | 4,497,509 | 18,350 | 15,550 | 9,466,577 |

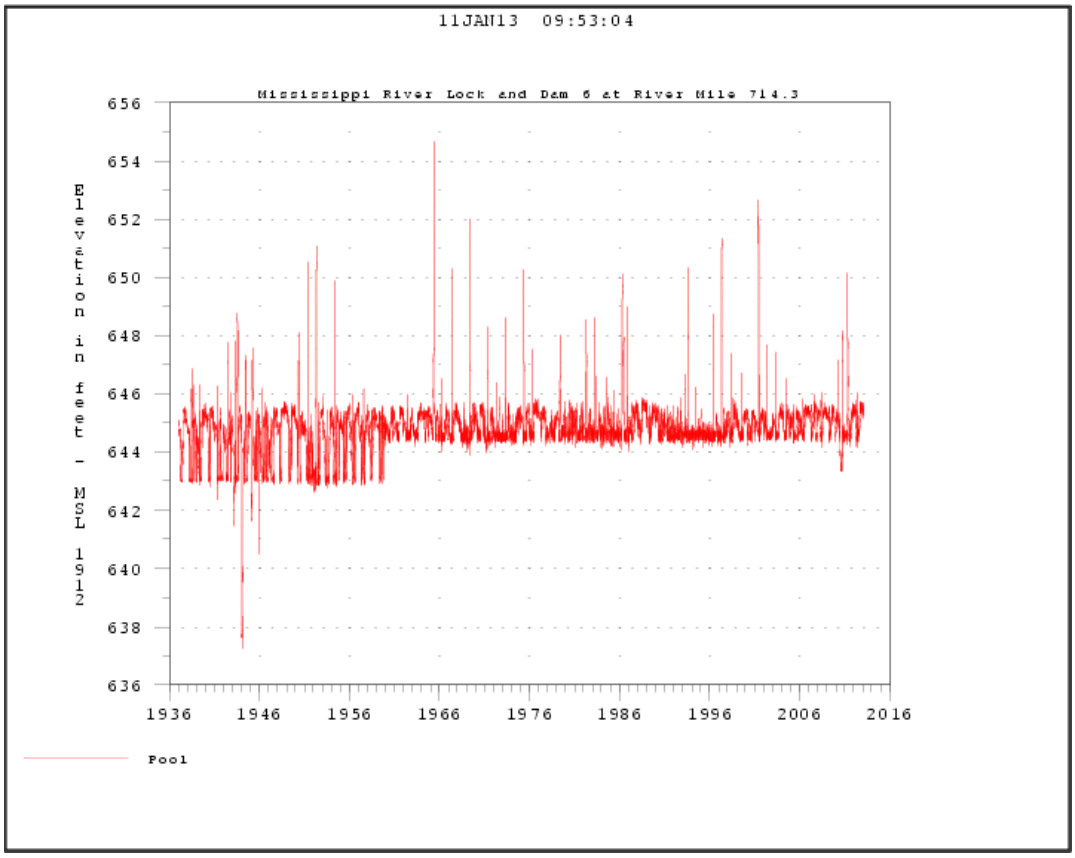
**8-06. Frequencies.** The Corps of Engineers recently developed a discharge-frequency curve for the control point at Winona, Minnesota in 1999. The Winona gage is about three miles downstream of Lock and Dam No. 5A, and about eight miles upstream of the Trempealeau River confluence.

**Figure 8-1.**



Construction of the dam was completed in August 1936. By November, 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 643.0 feet (1912 adjustment). In the spring of 1960, drawdown of the pool was reduced to one foot thus making the secondary control elevation 644.5 feet. Prior to 1948, the pools were sometimes drawn down below primary and secondary elevations during the winter months, since that, U.S. Code citation (16 USC 665a), winter draw down of the pools was prevented. The greatest drawdown occurred in January 1944 when the pool was draw down to elevation 637.23 feet.

**Figure 8-2.**
**History of Pool Elevation**

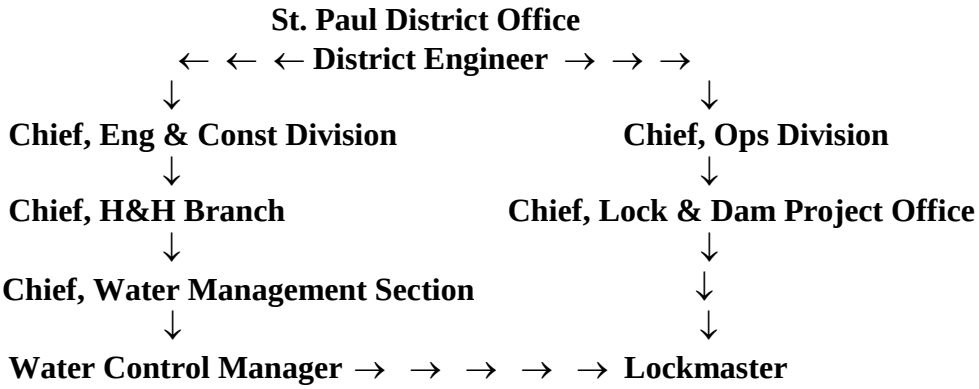


Water surface profile frequencies were developed in 2003 as part of the 2003 Flow Frequency Study. **Plate 8-1** shows the water surface profiles for 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year floods in Pool No. 5A, 6, 7, and 8. Also included are the profiles for the floods of 1965, 1969, 1993, 1997, and 2001.

## 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. 6. The St. Paul District, Water Management Section has direct day-to-day responsibility for gate adjustments at the dam. 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.




**b. Other Federal Agencies.** During high water, the National Weather Service (NWS) forecasts stage heights for the control point at Winona, Minnesota. Water Management 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 Winona, Minnesota (gage # 05378500). Daily discharge values are printed annually in the USGS *Water Resources Data – Minnesota* report. Hourly stage and discharge values can also be obtained from the USGS link on the Water Control web site at *www.mvp-wc.usace.army.mil*. The US Fish and Wildlife Service (USFWS) operates and maintains the Trempealeau National Wildlife Refuge, which is located in Pool No.6. The USFWS manipulates water

surface elevations of the many pools located on 5,700-acre wetland. One feature includes a water pump that can pump water into, or out of, the Mississippi River.

**9-02. Interagency Coordination.**

**a. Local Press and Corps Bulletins.** Information concerning regulation of Lock and Dam No. 6 is provided by the St. Paul District's Public Affairs Office (PAO) to the local news media in response to their requests. In addition, Operations Division coordinates with PAO to provide News Releases regarding the opening or closing of the lock to navigation.

**b. National Weather Service.** By 0830-hours each day, the National Weather Service (NWS) electronically transfers to Water Management the five-day forecast stage-hydrographs for tributaries to the Mississippi River lock and dam system. The five-day forecast includes the 24-hour quantitative precipitation forecast (QPF). Water Control inputs these hydrographs to the Mississippi Basin Modeling System (MBMS), which is an unsteady flow model utilizing the computer program UNET. The MBMS produces a 30-day forecast for the locks and dams and points of interest along the Mississippi River. The forecast is based on the water that is already in the system plus the NWS's 24-hour QPF. Output from the model is sent to the NWS around 0930-hours. The NWS uses this information to forecast stages along the Mississippi River, which includes Winona, Minnesota in Pool No. 6.

**c. US Geological Survey.** To maintain the vast network of stream gages for operation of the locks and dams in the St. Paul District would be a costly undertaking. Because of the existing infrastructure of the US Geological Survey (USGS), the St Paul District enters into a cooperative agreement each year with the USGS to maintain many of the gages on the Mississippi River and its tributaries. As for Pool No.6, this includes the Mississippi River at Winona, Minnesota, the Trempealeau River at Dodge, Wisconsin, and the

Black River at Galesville, Wisconsin. This requires a cooperative agreement with the Wisconsin USGS and the Minnesota USGS. St. Paul District owns all the gage equipment. The Wisconsin USGS publishes the daily discharges for Trempealeau River at Dodge and the Black River at Galesville gages annually as part of their *Water Resources Data – Wisconsin*. The Minnesota USGS annually publishes the daily discharge for the Mississippi River at Winona as part of their *Water Resources Data – Minnesota*. Daily data can be obtained through the USGS link on the Water Control web site at *www.mvp-wc.usace.army.mil*.

**d. US Fish and Wildlife Service.** The St. Paul District, in coordination with the US Fish and Wildlife, constructed Habitat Rehabilitation and Enhancement Project within the Trempealeau National Wildlife Refuge located in Pool No. 6. A combination of earth fill, concrete, pumps, and rock fill were used to create a water level management project. It gives fish and wildlife managers the ability to simulate natural high and low water conditions which optimizes habitat conditions for migratory birds and other aquatic species that use the refuge marsh.

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

**9-03. Reports.** "Operators Log" Form 2198 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, this form is electronically submitted to the NWS in Green Bay, Wisconsin.

# EXHIBIT A
# SUPPLEMENTARY PERTINENT DATA

## General Information

| | |
|---|---|
| **Location:** | Mississippi River Mile 714.4<br>Lat 43 60' 00"N Long 91 26' 18" W<br>Trempealeau, Wisconsin<br>14.2 miles below Lock and Dam No. 5A<br>11.8 miles above Lock and Dam No. 7 |
| **Datum:** | All elevations in this manual use the Mean Sea Level Datum (MSL1912) unless otherwise stated. Subtract 0.472 ft. from MSL 1912 to convert NAVD 88. |
| **Type of Project:** | Lock and Dam for Navigation Purposes |
| **Project Owner:** | Corps of Engineers |
| **Operating Agency:** | St. Paul District; Construction-Operations Division<br>24 hrs a day, 7 days a week |
| **Regulating Agency:** | St. Paul District; Water Management Section |
| **Completion Date:** | August 1936 |

## Hydrology

| | |
|---|---|
| **Drainage Area:** | 60,030 square miles |
| **Design Flood:** | Flood of 1880<br>Design High Water: Elevation 651.8 ft (MSL1912)<br>Design Discharge: 180,000 cfs |
| **Minimum Flow:** | Of Record: 1934 Discharge 2,300 cfs<br>Post Const: Sep 1976 Discharge 4,600 cfs |
| **Maximum Flow:** | 21 Apr 1965: Discharge 273,000 cfs |
| **Average Annual Flow:** | Years 1959-1993: Discharge 32,600 cfs |
| **Maximum Monthly Flow:** | April 1965: Discharge 152,500 cfs |
| **Maximum Daily Flow:** | 20 April 1965: Discharge 267,000 cfs |

| | |
|---|---|
| **Key Steam Flow Locations:** | Mississippi River @ TW of Lock and Dam No. 5A<br>Mississippi River @ Winona, Minnesota<br>Trempealeau River @ Dodge, Wisconsin |
| **Data Recorded at Dam:** | Pool & Tailwater Elevations (4-hr)<br>Discharge (4-hr)<br>Control Pt Elevation at Winona (daily)<br>Trempealeau River Stage & Discharge (daily)<br>Wind Speed & Direction (daily)<br>Water Temperature (daily)<br>Precipitation (daily)<br>Snow Depth & Water Content (weekly)<br>Pool & Tailwater Ice Coverage (weekly)<br>Pool & Tailwater Ice Thickness (weekly) |
| **Precipitation Gages:** | Lock & Dam No. 5A and 6<br>Trempealeau River @ Dodge, Wisconsin |
| **Snow Survey:** | At LD No. 6 (weekly by site personnel)<br>Trempealeau Basin (late Feb by Gage Crew)<br>Blair and Osseo, Wisconsin |

## Physical Features

| | | | |
|---|---|---|---|
| **Moveable Dam:** | Roller Gates: | 5 Gates | 80 feet by 20 feet |
| | Tainter Gates: | 10 Gates | 35 feet by 15 feet |
| | Roller Gate Sill: | | Elevation 625.5 ft |
| | Tainter Gate Sill: | | Elevation 630.5 ft |
| | Roller Gate End Sill: | | Elevation 625.5 ft |
| | Tainter Gate End Sill: | | Elevation 628.5 ft |
| | Roller Gate Submergence: | | 3 feet below PP |
| | Bulkheads: | Roller Gates: 5 @ | 4’-2” by 85’-0.5” |
| | | Tainter Gates: 4 @ | 4’-2” by 37’-6” |
| | Top of Bridge Deck: | | Elevation 674.75 ft |
| **Lock:** | Main Lock Chamber: | | 110 ft by 600 ft |
| | Top of Lock Walls: | | Elevation 654.5 ft |
| | Top of Upper Gate Sill (main): | | Elevation 628.5 ft |
| | Top of Upper Gate Sill (aux): | | Elevation 626.5 ft |
| | Top of Lower Gate Sill: | | Elevation 626.5 ft |
| | Lock Chamber Floor: | | Elevation 624.0 ft |
| | Height of Upper Miter Gates (main): | | 23.0 feet |
| | Height of Upper Miter Gates (aux): | | 25.0 feet |
| | Height of Lower Miter Gates: | | 25.0 feet |
| | Lift: | | 6.5 feet |

| | | |
|---|---|---|
| | Upper Guidewall Length: | 1200 feet |
| | Lower Guidewall Length: | 504 feet |
| | Freeboard @ Project Pool: | 9 feet |
| | Average Filling/Emptying Time: | 7 minutes |
| | Average Double Lockage Time: | 1.5 to 2.0 hours |
| **Earthen Dam:** | Length: | 3,050 feet |
| | Crest Elevation: | 654.5 ft (1912) |
| | Top Width: | 32.75 feet |
| | Maximum Height: | 19 feet |
| | Pool Side Slope: | 1V:3H |
| | Tailwater Slope: | 1V:5.5H |
| | Slope Protection: | 12 inch riprap |
| | To crest on pool side. | |
| | To elevation 642.0 ft on tailwater side. | |
| **Concrete Spillway:** | Length: | 1,000 feet |
| **(within earthen dam)** | Crest Elevation: | 645.5 feet (1912) |
| | Slot in Spillway: | 10 feet long, 3 feet deep |
| | Flow @ Project Pool: | 135 cfs |
| **Pool:** | Normal (Project) Upper Pool: | Elevation 645.5 ft |
| | Normal (Project) Lower Pool: | Elevation 639.0 ft |
| | Total Pool Area (at Project Pool): | 8,870 ac |
| | Effective Pool Area (at Project Pool): | 5,910 ac |
| | Primary Control Point (Winona): | Elevation 645.5 ft |
| | Secondary Control Point: | Elevation 644.5 ft |
| | Length in River Miles: | 14.2 miles |
| | Navigation Channel Width; | |
| | Straight Reaches: | 300 feet |
| | Curved Reaches: | 300-550 feet |
| | Most Frequent Dredge Site: | Below Winona Railroad Bridge |

STATION AGENCY="USGS " NUMBER="05379500
STATION NAME = "TREMPEALEAU RIVER AT DODGE, WI"

"Extended rating for hi water"
"Scour during rise of event. Shift confirmed by Qmeas No. 731."

RETRIEVED: 2012-12-13 20:47:02
FILE TYPE="NWIS RATING"
RATING ID="41.1"
RATING EXPANSION="logarithmic"
RATING OFFSET1=1.50

| GAGE HEIGHT (FEET) | DISCHARGE IN CUBIC FEET PER SECOND | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
| 3.90 | 200 | 202 | 204 | 205 | 207 | 209 | 211 | 213 | 214 | 216 |
| 4.00 | 218 | 220 | 222 | 223 | 225 | 227 | 229 | 231 | 232 | 234 |
| 4.10 | 236 | 238 | 240 | 241 | 243 | 245 | 247 | 249 | 250 | 252 |
| 4.20 | 254 | 256 | 258 | 260 | 262 | 264 | 266 | 268 | 270 | 272 |
| 4.30 | 274 | 276 | 278 | 280 | 282 | 284 | 286 | 288 | 290 | 292 |
| 4.40 | 294 | 296 | 298 | 300 | 302 | 304 | 306 | 308 | 310 | 312 |
| 4.50 | 314 | 316 | 318 | 320 | 322 | 324 | 326 | 328 | 330 | 332 |
| 4.60 | 334 | 336 | 338 | 340 | 342 | 344 | 346 | 348 | 350 | 352 |
| 4.70 | 354 | 356 | 358 | 360 | 362 | 364 | 366 | 368 | 370 | 372 |
| 4.80 | 374 | 376 | 378 | 381 | 383 | 385 | 387 | 389 | 392 | 394 |
| 4.90 | 396 | 398 | 400 | 403 | 405 | 407 | 409 | 411 | 414 | 416 |
| 5.00 | 418 | 420 | 422 | 425 | 427 | 429 | 431 | 433 | 436 | 438 |
| 5.10 | 440 | 442 | 445 | 447 | 450 | 452 | 455 | 457 | 460 | 462 |
| 5.20 | 465 | 467 | 470 | 472 | 475 | 477 | 480 | 482 | 485 | 487 |
| 5.30 | 490 | 492 | 495 | 497 | 500 | 502 | 505 | 507 | 510 | 512 |
| 5.40 | 515 | 517 | 520 | 522 | 525 | 527 | 530 | 532 | 535 | 537 |
| 5.50 | 540 | 543 | 546 | 549 | 552 | 555 | 558 | 561 | 564 | 567 |
| 5.60 | 570 | 573 | 576 | 579 | 582 | 585 | 588 | 591 | 594 | 597 |
| 5.70 | 600 | 603 | 606 | 609 | 612 | 615 | 618 | 621 | 624 | 627 |
| 5.80 | 630 | 633 | 636 | 639 | 642 | 645 | 648 | 651 | 654 | 657 |
| 5.90 | 660 | 663 | 666 | 669 | 672 | 675 | 678 | 681 | 684 | 687 |
| 6.00 | 690 | 693 | 696 | 699 | 702 | 705 | 708 | 711 | 714 | 717 |
| 6.10 | 720 | 723 | 726 | 729 | 732 | 735 | 738 | 741 | 744 | 747 |
| 6.20 | 750 | 753 | 756 | 759 | 762 | 765 | 768 | 771 | 774 | 777 |
| 6.30 | 780 | 783 | 786 | 789 | 792 | 795 | 798 | 801 | 804 | 807 |
| 6.40 | 810 | 813 | 816 | 819 | 822 | 825 | 828 | 831 | 834 | 837 |
| 6.50 | 840 | 843 | 847 | 850 | 854 | 857 | 861 | 864 | 868 | 871 |
| 6.60 | 875 | 878 | 882 | 885 | 889 | 892 | 896 | 899 | 903 | 906 |
| 6.70 | 910 | 913 | 917 | 920 | 924 | 927 | 931 | 934 | 938 | 941 |
| 6.80 | 945 | 948 | 952 | 955 | 959 | 962 | 966 | 969 | 973 | 976 |
| 6.90 | 980 | 983 | 987 | 990 | 994 | 997 | 1000 | 1000 | 1010 | 1010 |
| 7.00 | 1020 | 1020 | 1020 | 1030 | 1030 | 1030 | 1040 | 1040 | 1040 | 1050 |

**Exhibit B**
**Trempealeau River at Dodge Rating Table**

STATION AGENCY="USGS " NUMBER="05379500
STATION NAME = "TREMPEALEAU RIVER AT DODGE, WI"

"Extended rating for hi water"
"Scour during rise of event. Shift confirmed by Qmeas No. 731."

RETRIEVED: 2012-12-13 20:47:02
FILE TYPE="NWIS RATING"
RATING ID="41.1"
RATING EXPANSION="logarithmic"
RATING OFFSET1=1.50

| GAGE HEIGHT (FEET) | DISCHARGE IN CUBIC FEET PER SECOND | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
| 7.10 | 1050 | 1050 | 1060 | 1060 | 1070 | 1070 | 1070 | 1080 | 1080 | 1090 |
| 7.20 | 1090 | 1090 | 1100 | 1100 | 1110 | 1110 | 1110 | 1120 | 1120 | 1130 |
| 7.30 | 1130 | 1130 | 1140 | 1140 | 1150 | 1150 | 1150 | 1160 | 1160 | 1170 |
| 7.40 | 1170 | 1170 | 1180 | 1180 | 1190 | 1190 | 1190 | 1200 | 1200 | 1200 |
| 7.50 | 1210 | 1210 | 1220 | 1220 | 1220 | 1230 | 1230 | 1240 | 1240 | 1250 |
| 7.60 | 1250 | 1260 | 1260 | 1260 | 1270 | 1270 | 1280 | 1280 | 1280 | 1290 |
| 7.70 | 1300 | 1300 | 1300 | 1310 | 1310 | 1320 | 1320 | 1320 | 1330 | 1330 |
| 7.80 | 1340 | 1350 | 1350 | 1350 | 1360 | 1360 | 1370 | 1370 | 1370 | 1380 |
| 7.90 | 1380 | 1390 | 1390 | 1400 | 1400 | 1410 | 1410 | 1410 | 1420 | 1420 |
| 8.00 | 1420 | 1430 | 1430 | 1440 | 1440 | 1440 | 1450 | 1460 | 1460 | 1460 |
| 8.10 | 1470 | 1470 | 1480 | 1480 | 1480 | 1490 | 1490 | 1500 | 1500 | 1510 |
| 8.20 | 1510 | 1520 | 1520 | 1530 | 1530 | 1530 | 1540 | 1540 | 1550 | 1550 |
| 8.30 | 1560 | 1560 | 1570 | 1570 | 1570 | 1580 | 1580 | 1590 | 1590 | 1590 |
| 8.40 | 1600 | 1600 | 1610 | 1610 | 1620 | 1620 | 1630 | 1630 | 1630 | 1640 |
| 8.50 | 1640 | 1650 | 1650 | 1650 | 1660 | 1670 | 1670 | 1680 | 1680 | 1690 |
| 8.60 | 1690 | 1700 | 1700 | 1710 | 1710 | 1720 | 1720 | 1730 | 1740 | 1740 |
| 8.70 | 1750 | 1750 | 1760 | 1760 | 1770 | 1770 | 1780 | 1780 | 1790 | 1800 |
| 8.80 | 1810 | 1810 | 1820 | 1820 | 1830 | 1840 | 1840 | 1850 | 1850 | 1860 |
| 8.90 | 1870 | 1880 | 1880 | 1890 | 1900 | 1900 | 1910 | 1910 | 1920 | 1930 |
| 9.00 | 1930 | 1940 | 1940 | 1950 | 1960 | 1970 | 1970 | 1980 | 1980 | 1990 |
| 9.10 | 2000 | 2000 | 2010 | 2010 | 2020 | 2030 | 2040 | 2050 | 2050 | 2060 |
| 9.20 | 2060 | 2070 | 2080 | 2080 | 2090 | 2090 | 2100 | 2110 | 2120 | 2130 |
| 9.30 | 2140 | 2150 | 2160 | 2160 | 2170 | 2180 | 2190 | 2200 | 2200 | 2210 |
| 9.40 | 2230 | 2230 | 2240 | 2250 | 2260 | 2270 | 2270 | 2280 | 2290 | 2300 |
| 9.50 | 2300 | 2310 | 2320 | 2340 | 2340 | 2350 | 2360 | 2370 | 2380 | 2380 |
| 9.60 | 2390 | 2400 | 2410 | 2420 | 2430 | 2440 | 2450 | 2460 | 2470 | 2480 |
| 9.70 | 2480 | 2490 | 2500 | 2510 | 2520 | 2530 | 2540 | 2560 | 2570 | 2580 |
| 9.80 | 2590 | 2600 | 2610 | 2620 | 2630 | 2640 | 2650 | 2660 | 2670 | 2690 |
| 9.90 | 2700 | 2710 | 2720 | 2730 | 2740 | 2750 | 2760 | 2770 | 2780 | 2790 |
| 10.00 | 2800 | 2810 | 2830 | 2840 | 2850 | 2860 | 2870 | 2880 | 2890 | 2900 |

**Exhibit B**
**Trempealeau River at Dodge Rating**

STATION AGENCY="USGS " NUMBER="05379500
STATION NAME = "TREMPEALEAU RIVER AT DODGE, WI"

"Extended rating for hi water"
"Scour during rise of event. Shift confirmed by Qmeas No. 731."

RETRIEVED: 2012-12-13 20:47:02
FILE TYPE="NWIS RATING"
RATING ID="41.1"
RATING EXPANSION="logarithmic"
RATING OFFSET1=1.50

| GAGE HEIGHT (FEET) | DISCHARGE IN CUBIC FEET PER SECOND | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
| 10.10 | 2910 | 2920 | 2930 | 2940 | 2960 | 2970 | 2980 | 2990 | 3000 | 3010 |
| 10.20 | 3020 | 3030 | 3040 | 3050 | 3060 | 3070 | 3090 | 3100 | 3110 | 3120 |
| 10.30 | 3130 | 3140 | 3150 | 3160 | 3170 | 3180 | 3190 | 3200 | 3220 | 3230 |
| 10.40 | 3240 | 3250 | 3260 | 3270 | 3280 | 3290 | 3300 | 3310 | 3330 | 3340 |
| 10.50 | 3360 | 3390 | 3400 | 3420 | 3430 | 3450 | 3460 | 3480 | 3490 | 3510 |
| 10.60 | 3520 | 3540 | 3550 | 3580 | 3600 | 3610 | 3630 | 3640 | 3660 | 3670 |
| 10.70 | 3690 | 3700 | 3720 | 3730 | 3750 | 3780 | 3790 | 3810 | 3820 | 3840 |
| 10.80 | 3850 | 3870 | 3880 | 3900 | 3910 | 3930 | 3940 | 3970 | 3990 | 4000 |
| 10.90 | 4020 | 4030 | 4050 | 4060 | 4080 | 4090 | 4110 | 4120 | 4140 | 4150 |
| 11.00 | 4180 | 4200 | 4220 | 4240 | 4260 | 4280 | 4300 | 4320 | 4340 | 4360 |
| 11.10 | 4380 | 4400 | 4440 | 4460 | 4470 | 4490 | 4510 | 4530 | 4550 | 4570 |
| 11.20 | 4590 | 4610 | 4630 | 4650 | 4680 | 4700 | 4720 | 4740 | 4760 | 4780 |
| 11.30 | 4800 | 4820 | 4840 | 4860 | 4880 | 4900 | 4940 | 4960 | 4980 | 5000 |
| 11.40 | 5020 | 5040 | 5060 | 5080 | 5100 | 5130 | 5150 | 5170 | 5190 | 5230 |
| 11.50 | 5250 | 5270 | 5290 | 5310 | 5340 | 5360 | 5380 | 5400 | 5420 | 5440 |
| 11.60 | 5460 | 5500 | 5520 | 5540 | 5560 | 5580 | 5590 | 5610 | 5630 | 5650 |
| 11.70 | 5670 | 5690 | 5710 | 5750 | 5770 | 5790 | 5820 | 5840 | 5860 | 5880 |
| 11.80 | 5900 | 5920 | 5940 | 5960 | 5980 | 6020 | 6050 | 6070 | 6100 | 6120 |
| 11.90 | 6150 | 6170 | 6200 | 6220 | 6250 | 6270 | 6300 | 6320 | 6370 | 6400 |
| 12.00 | 6420 | 6450 | 6470 | 6500 | 6530 | 6560 | 6590 | 6620 | 6650 | 6680 |
| 12.10 | 6740 | 6770 | 6800 | 6830 | 6860 | 6890 | 6920 | 6950 | 6980 | 7010 |
| 12.20 | 7040 | 7070 | 7130 | 7160 | 7190 | 7220 | 7250 | 7280 | 7310 | 7340 |
| 12.30 | 7370 | 7400 | 7430 | 7460 | 7520 | 7550 | 7580 | 7610 | 7640 | 7670 |
| 12.40 | 7700 | 7730 | 7760 | 7790 | 7820 | 7850 | 7880 | 7910 | 7940 | 7970 |
| 12.50 | 8000 | 8040 | 8080 | 8120 | 8160 | 8200 | 8240 | 8280 | 8320 | 8360 |
| 12.60 | 8400 | 8440 | 8490 | 8530 | 8570 | 8610 | 8650 | 8700 | 8740 | 8780 |
| 12.70 | 8820 | 8870 | 8910 | 8950 | 9000 | 9040 | 9080 | 9130 | 9170 | 9220 |
| 12.80 | 9260 | 9300 | 9350 | 9390 | 9440 | 9480 | 9530 | 9580 | 9620 | 9670 |
| 12.90 | 9710 | 9760 | 9810 | 9850 | 9900 | 9950 | 10000 | 10000 | 10100 | 10100 |
| 13.00 | 10200 | | | | | | | | | |

**Exhibit B**
**Trempealeau River at Dodge Rating Table**

# STANDING INSTRUCTIONS TO THE PROJECT MANAGER FOR WATER CONTROL
# Exhibit B1

## LOCK AND DAM NO. 6
## MISSISSIPPI RIVER

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

**January 2016**

**Lock and Dam No. 6**
**U.S. Army Corps of Engineers**
**St. Paul District**

Table of Contents

**Lock and Dam No. 6**
**U.S. Army Corps of Engineers**
**St. Paul District**

## SUPPLEMENTARY PERTINENT DATA

### General Information

**Location:** Mississippi River Mile 714.4
Lat 43 60' 00"N Long 91 26' 18" W
Trempealeau, Wisconsin
14.2 miles below Lock and Dam No. 5A
11.8 miles above Lock and Dam No. 7

**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 Management Section

**Completion Date:** August 1936

### Hydrology

**Drainage Area:** 60,030 square miles

**Design Flood:** Flood of 1880
Design High Water: Elevation 651.8 ft
Design Discharge: 180,000 cfs

**Minimum Flow:** Of Record: 1934 Discharge 2,300 cfs
Post Const: Sep 1976 Discharge 4,600 cfs

**Maximum Flow:** 21 Apr 1965: Discharge 273,000 cfs

**Average Annual Flow:** Years 1959-1993: Discharge 32,600 cfs

**Maximum Monthly Flow:** April 1965: Discharge 152,500 cfs

**Maximum Daily Flow:** 20 April 1965: Discharge 267,000 cfs

**Key Steam Flow Locations:** Mississippi River @ TW of Lock and Dam No. 5A
Mississippi River @ Winona, Minnesota Trempealeau River @ Dodge, Wisconsin

**Data Recorded at Dam:** Pool & Tailwater Elevations (4-hr)

Discharge (4-hr)
Control Pt Elevation at Winona (daily)
Trempealeau River Stage & Discharge (daily)
Wind Speed & Direction (daily)
Water Temperature (daily)
Precipitation (daily)
Snow Depth & Water Content (weekly)
Pool & Tailwater Ice Coverage (weekly)
Pool & Tailwater Ice Thickness (weekly)

**Precipitation Gages:** Lock & Dam No. 5A and 6
Trempealeau River @ Dodge, Wisconsin

**Snow Survey:** At LD No. 6 (weekly by site personnel)
Trempealeau Basin (late Feb by Gage Crew)
Blair and Osseo, Wisconsin

## Physical Features

**Moveable Dam:** Roller Gates: 5 Gates 80 feet by 20 feet
Tainter Gates: 10 Gates 35 feet by 15 feet
Roller Gate Sill: Elevation 625.5 ft
Tainter Gate Sill: Elevation 630.5 ft
Roller Gate End Sill: Elevation 625.5 ft
Tainter Gate End Sill: Elevation 628.5 ft
Roller Gate Submergence: 3 feet below PP
Bulkheads: Roller Gates: 5 @ 4'-2" by 85'-0.5"
Tainter Gates: 4 @ 4'-2" by 37'-6"
Top of Bridge Deck: Elevation 674.75 ft

**Lock:** Main Lock Chamber: 110 ft by 600 ft
Top of Lock Walls: Elevation 654.5 ft
Top of Upper Gate Sill (main): Elevation 628.5 ft
Top of Upper Gate Sill (aux): Elevation 626.5 ft
Top of Lower Gate Sill: Elevation 626.5 ft
Lock Chamber Floor: Elevation 624.0 ft
Height of Upper Miter Gates (main): 23.0 feet
Height of Upper Miter Gates (aux): 25.0 feet
Height of Lower Miter Gates: 25.0 feet
Lift: 6.5 feet
Upper Guidewall Length: 1200 feet
Lower Guidewall Length: 504 feet
Freeboard @ Project Pool: 9 feet
Average Filling/Emptying Time: 7 minutes
Average Double Lockage Time: 1.5 to 2.0 hours

**Earthen Dam:** Length: 3,050 feet

Crest Elevation: 654.5 ft (1912)
Top Width: 32.75 feet
Maximum Height: 19 feet
Pool Side Slope: 1V:3H
Tailwater Slope: 1V:5.5H
Slope Protection: 12 inch riprap
To crest on pool side.
To elevation 642.0 ft on tailwater side.

**Concrete Spillway:** Length: 1,000 feet
**(within earthen dam)** Crest Elevation: 645.5 feet (MSL 1912)
Slot in Spillway: 10 feet long, 3 feet deep
Flow @ Project Pool: 135 cfs

**Pool:** Normal (Project) Upper Pool: Elevation 645.5 ft
Normal (Project) Lower Pool: Elevation 639.0 ft
Total Pool Area (at Project Pool): 8,870 ac
Effective Pool Area (at Project Pool): 5,910 ac
Primary Control Point (Winona): Elevation 645.5 ft
Secondary Control Point: Elevation 644.5 ft
Length in River Miles: 14.2 miles
Navigation Channel Width;
Straight Reaches: 300 feet
Curved Reaches: 300-550 feet
Most Frequent Dredge Site: Below Winona
Railroad Bridge

1. Background and Responsibilities
    a. General Information

        i. **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 6 Regulation Manual dated November 2001 and was prepared in compliance with the guidelines presented in:
            1. Engineering Regulation, ER 1110-2-240, *Water Control Management*, 8 October 1982, amended 30 April 1987 and 1 March 1994.
            2. Engineering Manual, EM 1110-2-3600, *Management of Water Control Systems*, 30 November 1987.
            3. Division Regulation, DIVR 1110-2-240, *Water Control Management, Preparation of Water Control Plans and Manuals*, 1 January 1992.
            4. Engineering Regulation, ER 1110-2-8156, *Preparation of Water Control Manuals*, 31 August 1995.

        ii. **Project location and Description.** Lock and Dam No. 6 is located on the Mississippi River, 714.3 river miles above the mouth of the Ohio River, 14.2 river miles below Lock and Dam No. 5A, and 11.8 river miles above Lock and Dam No. 7. The lock is on the left bank of the river adjacent to the village of Trempealeau, Wisconsin at approximate latitude 43$^{o}$ 60' 00" N and longitude 91$^{o}$ 26' 18" W. The project is bordered by Trempealeau County on the Wisconsin side and Winona County on the Minnesota side. The project location is shown on Plate 2-1. Lock and Dam No. 6 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. 6 are navigation and recreation under Public Laws PL 71-520 and PL 78-534

respectively. Access and facilities are provided for recreation but water is not controlled for that purpose**.**

iii. **Project Owner and Operation Agency.** The United States Government is the owner. Lock and Dam No. 6 is operated by the U.S. Army Corps of Engineers, St. Paul District. Operation and maintenance is the responsibility of Operations Division. Regulation of Lock and Dam No. 6 is under the supervision of the Water Management and Hydrology Section in the Hydraulics and Hydrology Branch, Engineering and Construction Division. The project is attended 24 hours a day, every day of the year. The Chief, Operations Division and the Chief, Engineering and Construction Division are located in the St. Paul District Office, whereas the Lock and Dam Project Office is located in Fountain City, Wisconsin.

iv. **Project Purposes.** Lock and Dam No. 6 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. 6 are navigation and recreation under Public Laws PL 71-520 and PL 78-534 respectively. Access and facilities are provided for recreation but water is not controlled for that purpose.

v. **Project Constraints.** For low discharges, the pool is maintained at elevation 645.5 ± 0.2 feet (1912 adjustment) at the primary control point at Winona, MN. This is "project pool" or "normal pool" for Lock and Dam No. 6. 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 one foot in 1959 due to adverse effects on navigation, riverfront property, and conservation interests. Therefore, drawdown at the dam is constrained to elevation 644.5 ± 0.2 feet. The design plan set maximum outflow velocities at 4.5 feet per second for standard operating procedures with an allowance to go to 6.0 feet per second for an emergency situation. However, it should be noted that during flood events, flow velocities exceed 8.0 feet per second with no disturbance of the riprap occurring. During flood events the dam is in "open river conditions" when the gates are raised clear of the water surface. If the water levels continue to rise navigation can be closed. The lock is also closed when ice is too thick to permit tow traffic. At times it is necessary to close one or more gates for maintenance purposes. All gate closures shall be coordinated with the river regulation desk at the Water Management Section. The maximum

number of gates allowed to be closed will be at the discretion of Water Management based on conditions as they exist.

b. **Role of Project Manager**

i. **Normal Hydrometeorological Conditions (including floods and droughts):** The Project Manager will be instructed by Water Management in the St. Paul District office on a day-to-day basis for water control actions under normal hydrometeorological conditions.

ii. **Emergency Conditions:** Conditions become emergency if needed to protect the safety of the structure, to avoid health hazards, or to avoid any other critical situation that may arise. The Project Manager will issue adequate warning or otherwise alert all affected interests to possible hazards caused by project regulation.

**2. Hydrometeorological Data Collection and Reporting**

a. **Normal Hydrometeorological Conditions (including floods and droughts):** Lock and dam personnel are to collect and report various hydraulic data to Water Management via computer by 0630-hours. The data entry interval varies from once a day to every four hours. Four-hour data begins at 0800-hours and includes pool elevation, tailwater elevation, gate settings, and tainter valve settings (winter only). Eight-hour data begins at 0800-hours and includes air temperature and wind speed and direction. Daily data includes max-min air temperature (2400-hours), water temperature (0800-hours), precipitation (0800-hours), and the stages for the Trempealeau River at Dodge and Black River at Galesville (Note: Lock and Dam No. 5A calls the Winona gage each morning and inputs the information at their site.). All 0800-hour data are actually collected at 0600-hours. Max-min air temperature is actually taken at 1900-hours.
During the winter months site personnel are to report percent of pool and tailwater ice coverage, pool and tailwater ice thickness, snow depth, and snow-water equivalent (all in inches) via computer. These data are collected once a week on Sundays. The snow-water content is to be determined by instructions contained in the National Weather Service Snow Measurement Guidelines for NWS Cooperative Observers.

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

## 3. Water Control Action and Reporting

a. **Low Hydrometeorological Conditions (droughts):** There is no Drought Contingency Plan. Operation of the dam is basically run of the river. Therefore, rate of release change is nature driven. While not desirable, outflows may be reduced to zero to maintain navigation.

b. **Normal Hydrometeorological Conditions:** The general objective of the water management plan is to maintain a minimum depth of nine feet along the navigation channel of Pool No. 6, without inducing higher stages during flood events. Project pool elevation for Lock and Dam No. 6 is 645.5 ± 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. 6, the "primary control point" is located just downstream of the Highway 54 bridge crossing the Mississippi River at Winona, Minnesota (see **Figure 5-1**). Maintaining project pool elevation at this location during periods of low flows ensures a minimum channel depth of nine feet; however, periodic dredging is required.

c. **High Hydrometeorological Conditions (Floods):**
   i. **Spring Floods**: The locks and dams provide no flood control benefits. They were constructed strictly for navigation purposes. The dam operates on a run-of- the-river principal. As discharge increases, the gates are opened. At around 75,000 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.

d. **Emergency Conditions:** The Emergency Action Plan is a stand-alone document entitled *Emergency Plan for Lock and Dam 6, Trempealeau, Wisconsin*, July 1986. 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. 6 include excess seepage, sabotage, extreme storm, failure of foundation, abutment and equipment, and slope failure.

   Other emergency situations not addressed in the Emergency Action Plan are barge incidents and chemical spills. When a barge or barges go into the dam, Water Management is to be notified as soon as possible. Most likely, the manipulation of gates will be necessary to accommodate removal of the barge(s).

   There are several protective measures taken at Lock and Dam No. 6 when a flood occurs. When the pool level is forecasted to go above elevation 647.0 feet (1912 adjustment) the abutments to the concrete spillway are protected with sand bags.

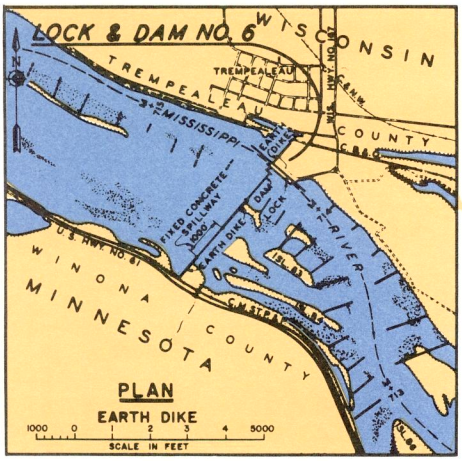
Sand bags are placed on the unprotected portion of the earthen dike for a distance of 100 feet on each side. As the pool rises other actions are required. There are three forms of deviation; (1) a deviation because of an emergency situation, (2) an unplanned minor deviation due to an unplanned event, and (3) a planned deviation, typically to accomplish some task. To deviate from the operating plan requires prior permission from the Division Office (MVD), except for an emergency. Under an emergency deviation, the District Engineer or Chief of Engineering Division may authorize a deviation in an attempt to abate the problem. The Division Office is to be notified as soon as practical. Written confirmation of the deviation is to be sent to the Division Water Control Manager.

e. **Inquiries:** All significant inquires received by the Project Manager from citizens, constituents or interest groups regarding water control procedures or actions must be referred to Water Management.

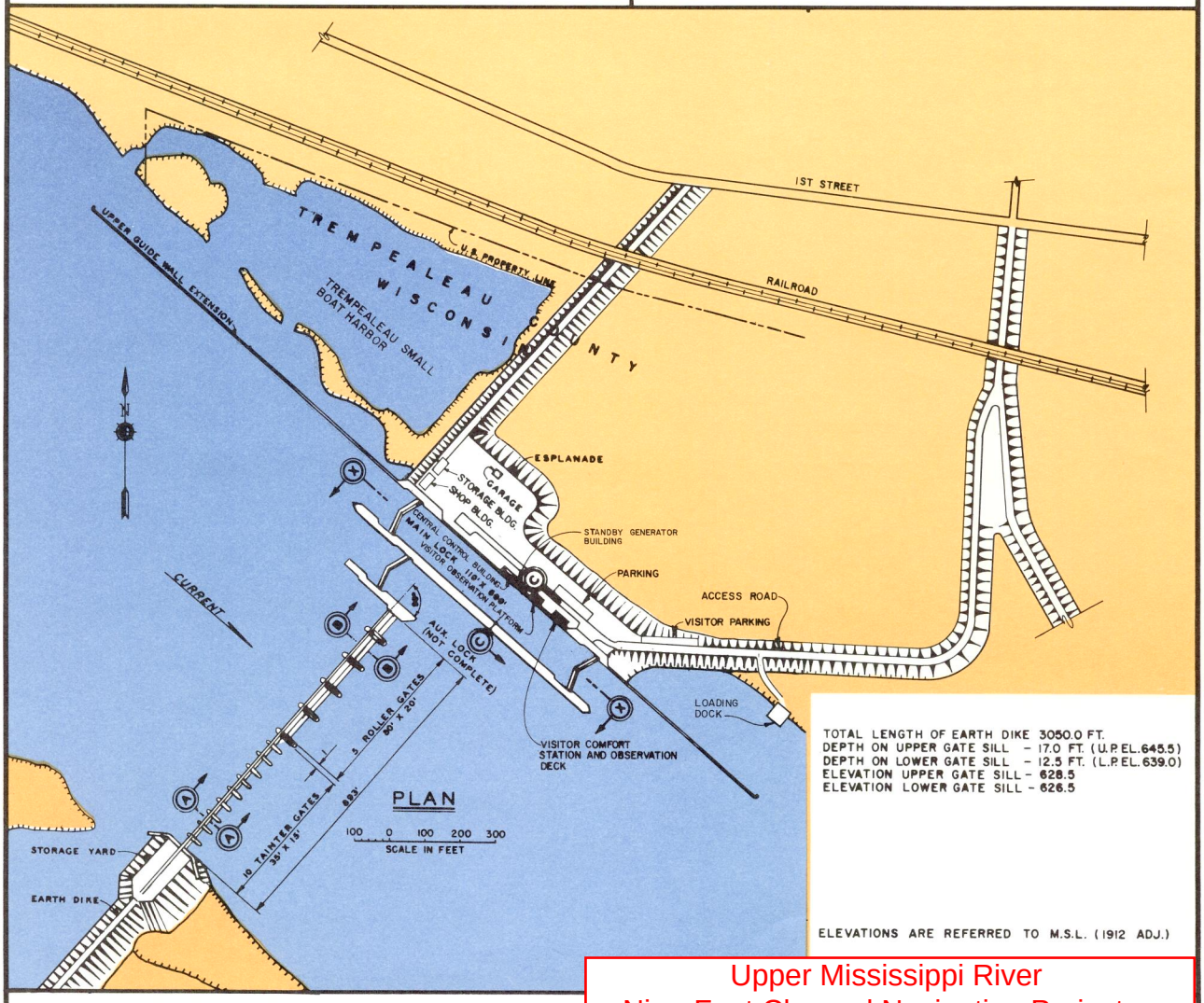
f. **Water Control Problems:** Water Management must be contacted immediately by the most rapid means available in the event an operational malfunction, erosion, or other incident occurs that could impact project integrity in general or water control capability in particular.

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

28







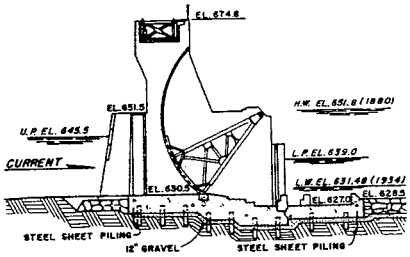

TOTAL LENGTH OF EARTH DIKE 3050.0 FT.
DEPTH ON UPPER GATE SILL - 17.0 FT. (U.P.EL.645.5)
DEPTH ON LOWER GATE SILL - 12.5 FT. (L.P.EL.639.0)
ELEVATION UPPER GATE SILL - 628.5
ELEVATION LOWER GATE SILL - 626.5

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

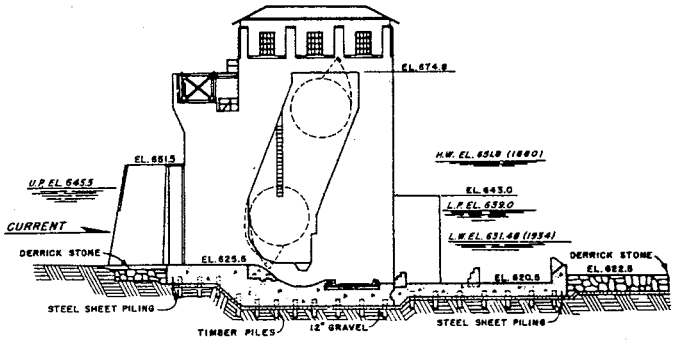
Upper Mississippi River
Nine-Foot Channel Navigation Project

Lock and Dam 6 Project Location Map

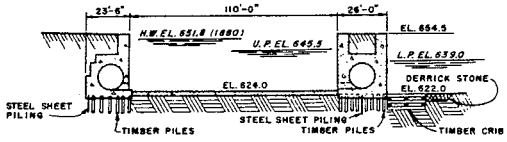
US Army Corps of Engineers
St. Paul District - 30 SEP 1992



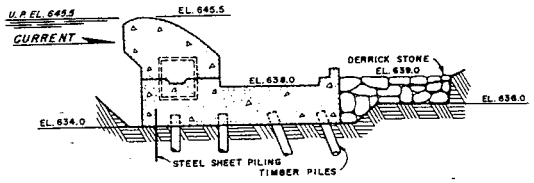

SECTION A-A
TAINTER GATE
10 0 10 20 30
SCALE IN FEET



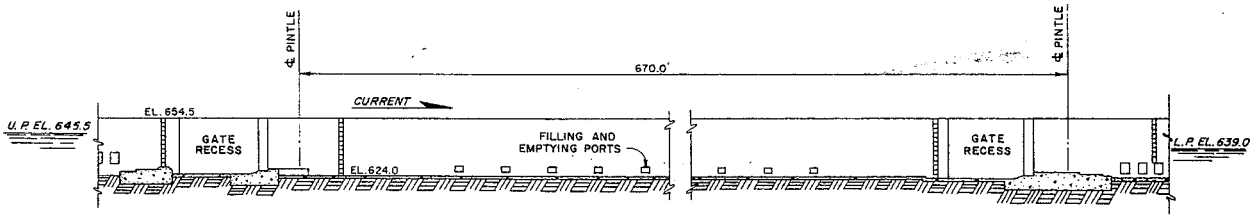

SECTION B-B
ROLLER GATE
10 0 10 20 30
SCALE IN FEET



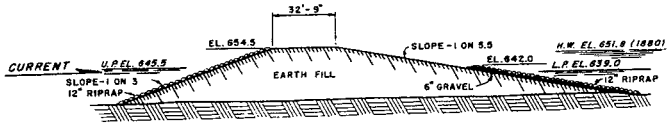

SECTION C-C
LOCK
20 0 20 40 60
SCALE IN FEET




SPILLWAY SECTION
5 0 5 10 15
SCALE IN FEET




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




EARTH DIKE SECTION
20 0 20 40 60
SCALE IN FEET

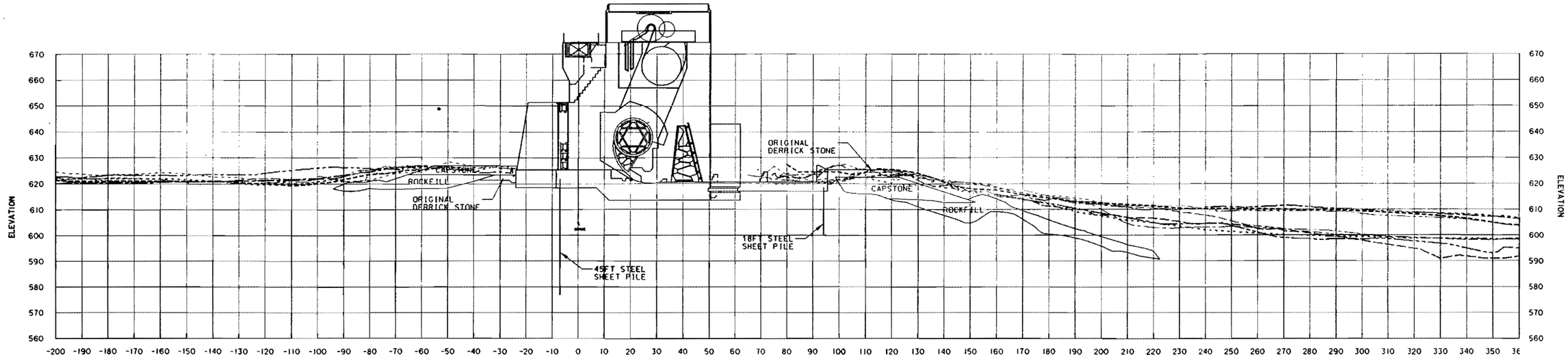
ELEVATIONS ARE REFERRED TO M.S.L. (1912 ADJ.)

Upper Mississippi River
Nine-Foot Channel Navigation Project

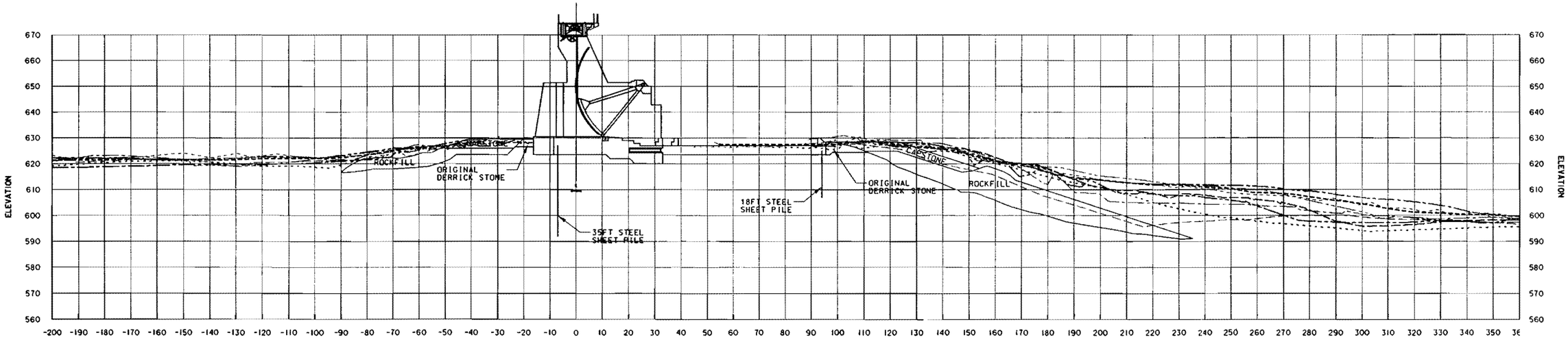
**Lock and Dam No. 6**
**Cross-Sections**

US Army Corps of Engineers
St. Paul District – 30 Sep 1977

**Plate 2-2**




P-6




P-7

KEY

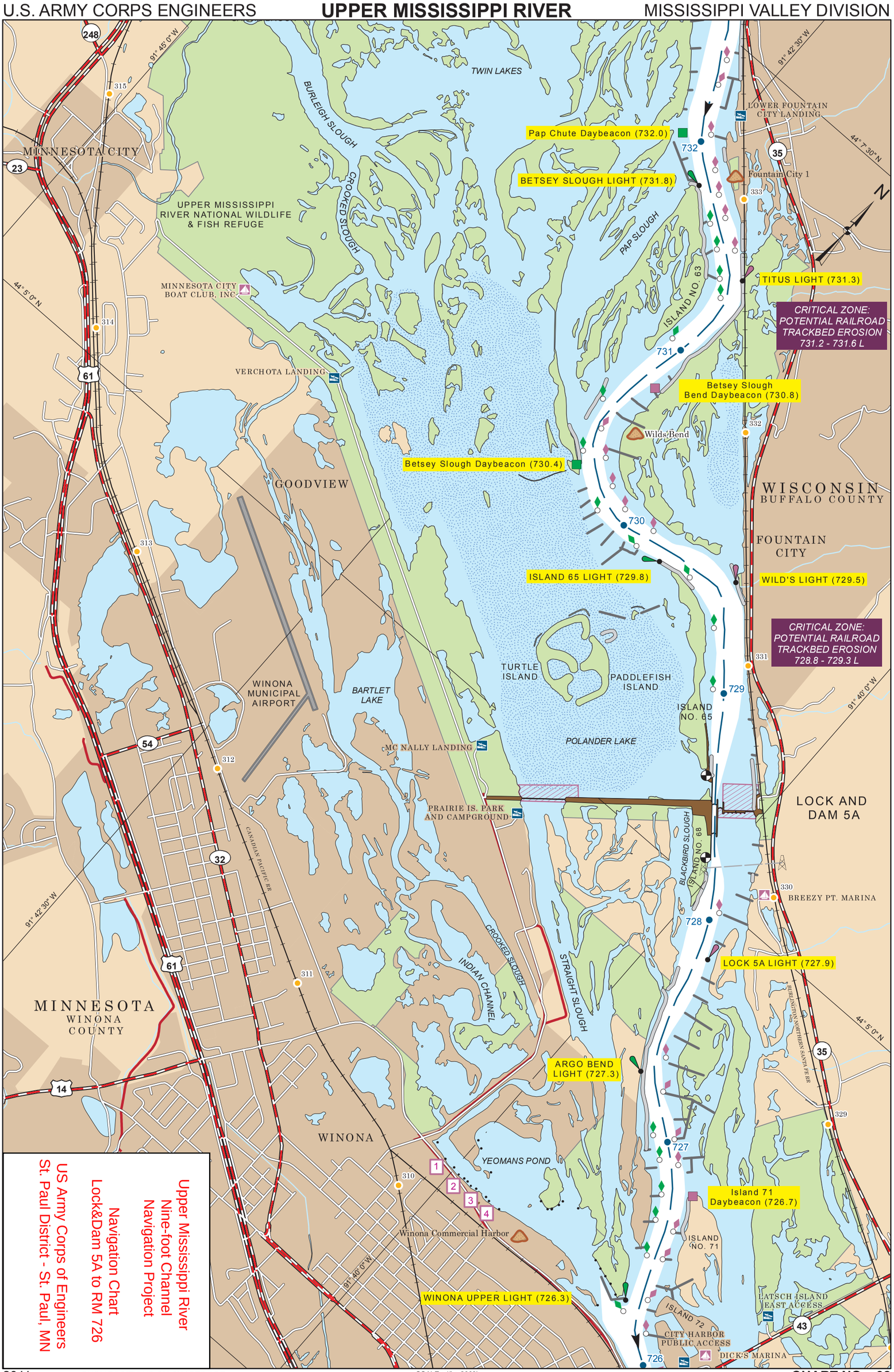
1998
1997
1996
1994
1992
1991
1990
1989
1988

Upper Mississippi River
Nine-Foot Channel Navigation Project

**Scour Protection**
**Upstream & Downstream Of Dam**
**Capstone & Rockfill Placed in 1983**

US Army Corps of Engineers
St. Paul District – St. Paul, MN

**Plate 2-3**




Upper Mississippi River
Nine-foot Channel
Navigation Project

Navigation Chart
Lock&Dam 5A to RM 726

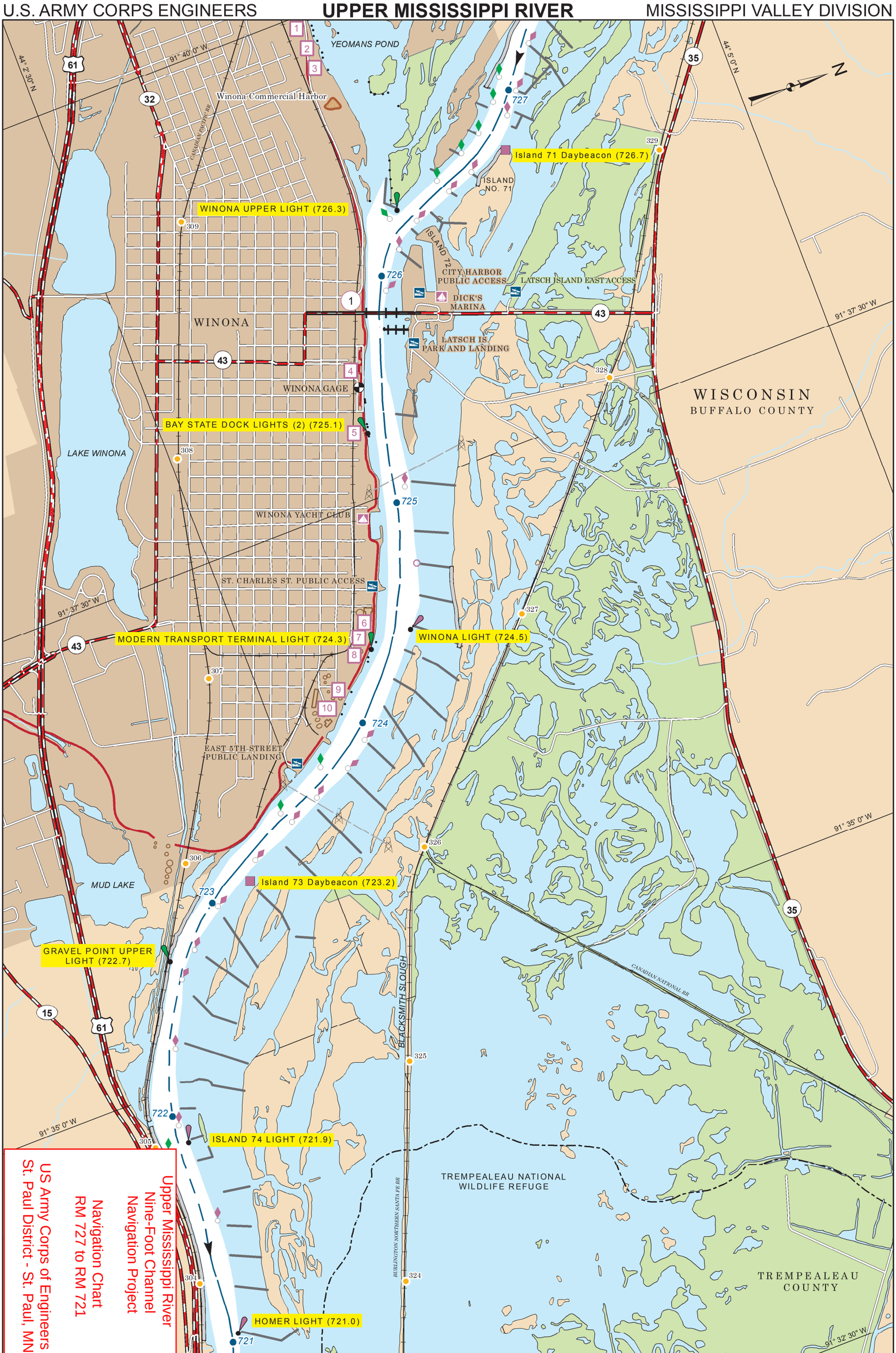
US Army Corps of Engineers
St. Paul District - St. Paul, MN

2011

*BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE IN LEGEND*

SCALE : 1" = 2000'
0 2,000 4,000 6,000 Feet

**CHART NO. 32**
RIVER MILE 726 TO 732




Upper Mississippi River
Nine-Foot Channel
Navigation Project

Navigation Chart
RM 727 to RM 721

US Army Corps of Engineers
St. Paul District - St. Paul, MN

Plate 2-5

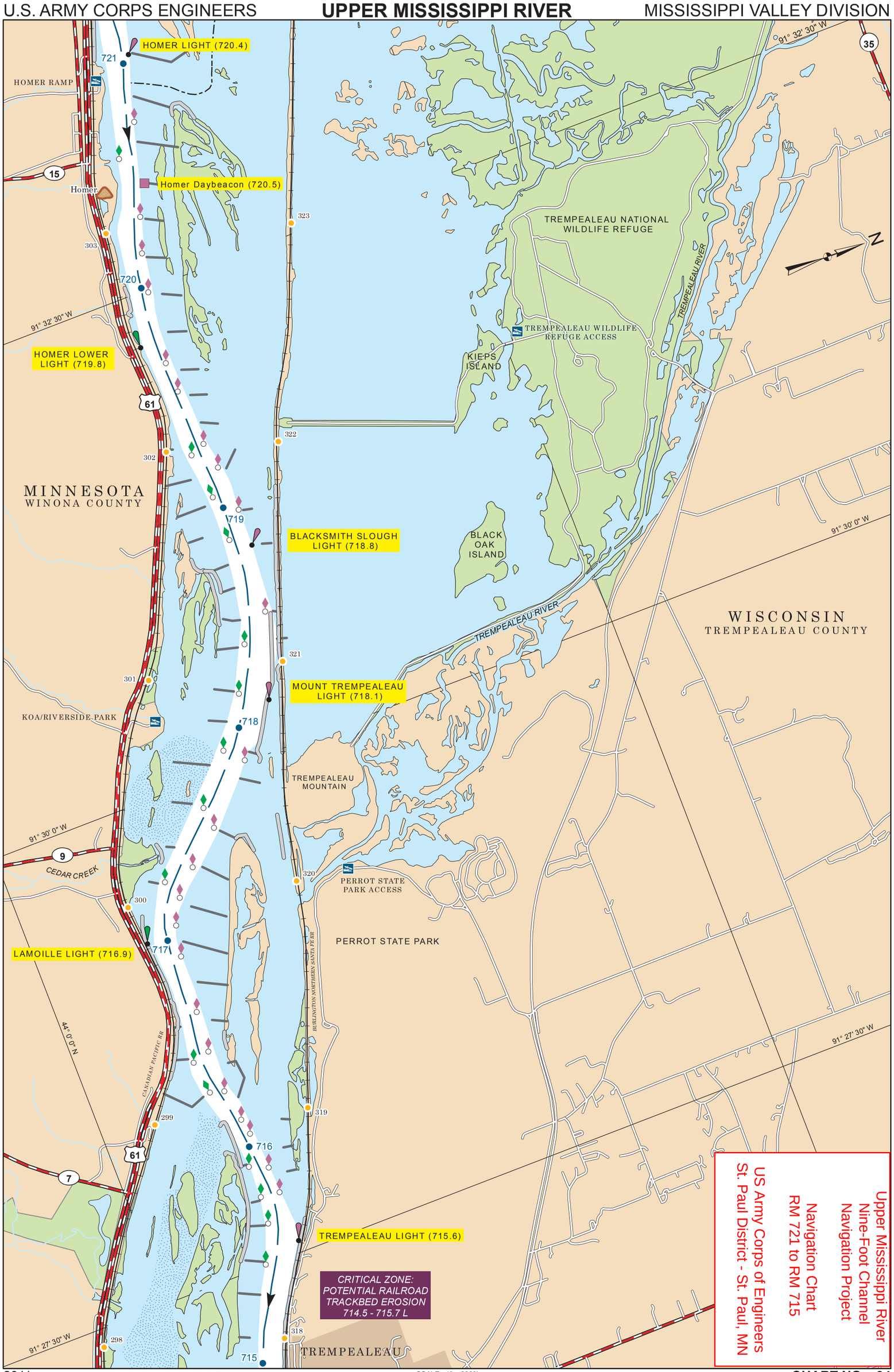
2011

*BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE IN LEGEND*

SCALE : 1" = 2000'

0 2,000 4,000 6,000 Feet

**CHART NO. 33**
RIVER MILE 721 TO 727




Upper Mississippi River
Nine-Foot Channel
Navigation Project

Navigation Chart
RM 721 to RM 715

US Army Corps of Engineers
St. Paul District - St. Paul, MN

Plate 2-6

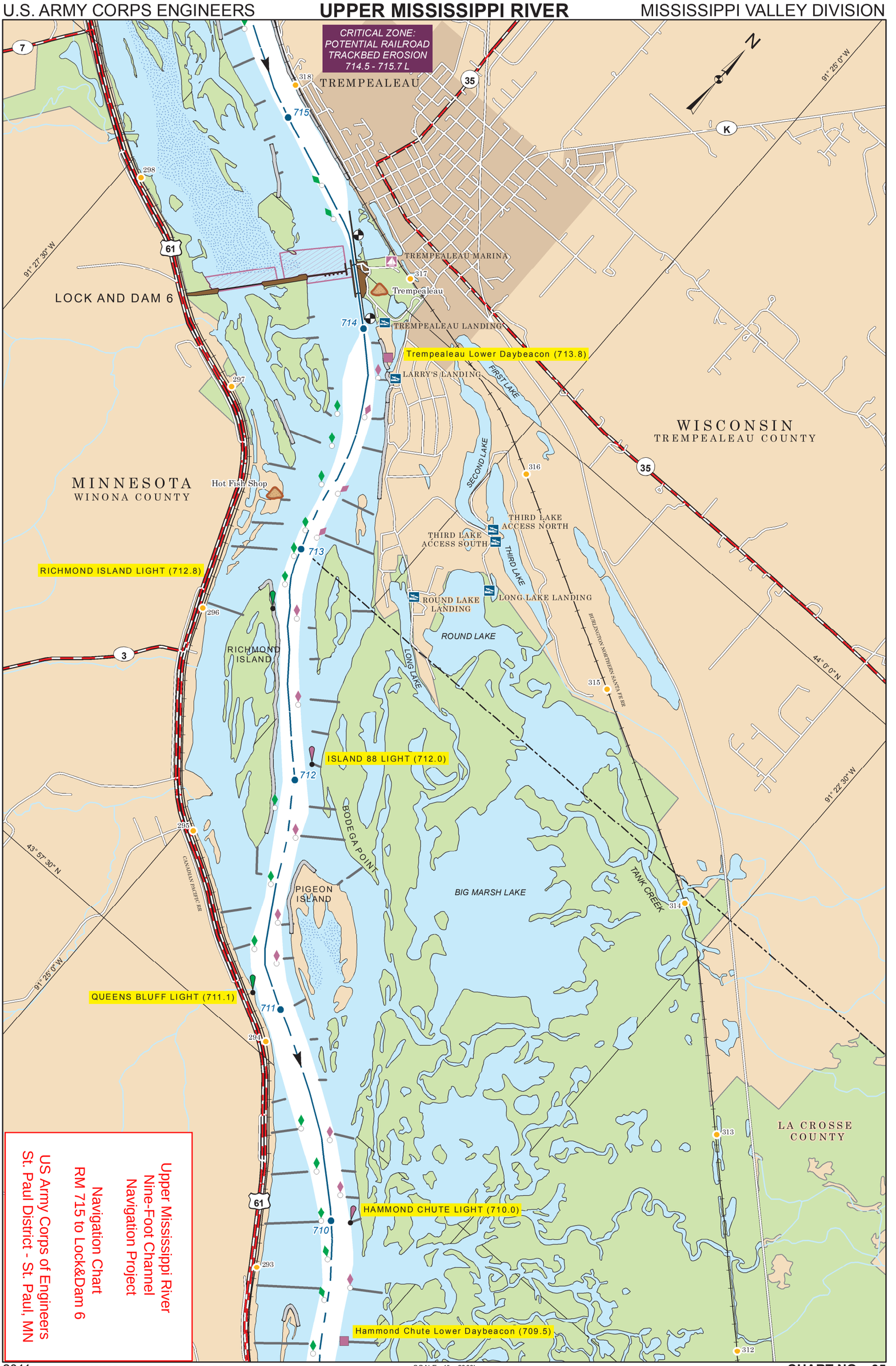
2011

*BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE IN LEGEND*

SCALE : 1" = 2000'

0 2,000 4,000 6,000 Feet

**CHART NO. 34**
RIVER MILE 715 TO 721




Upper Mississippi River
Nine-Foot Channel
Navigation Project

Navigation Chart
RM 715 to Lock&Dam 6

US Army Corps of Engineers
St. Paul District - St. Paul, MN

Plate 2-7

2011

*BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE IN LEGEND*

SCALE : 1" = 2000'

0 2,000 4,000 6,000 Feet

**CHART NO. 35**
RIVER MILE 710 TO 715

## Flow - Storage Curve

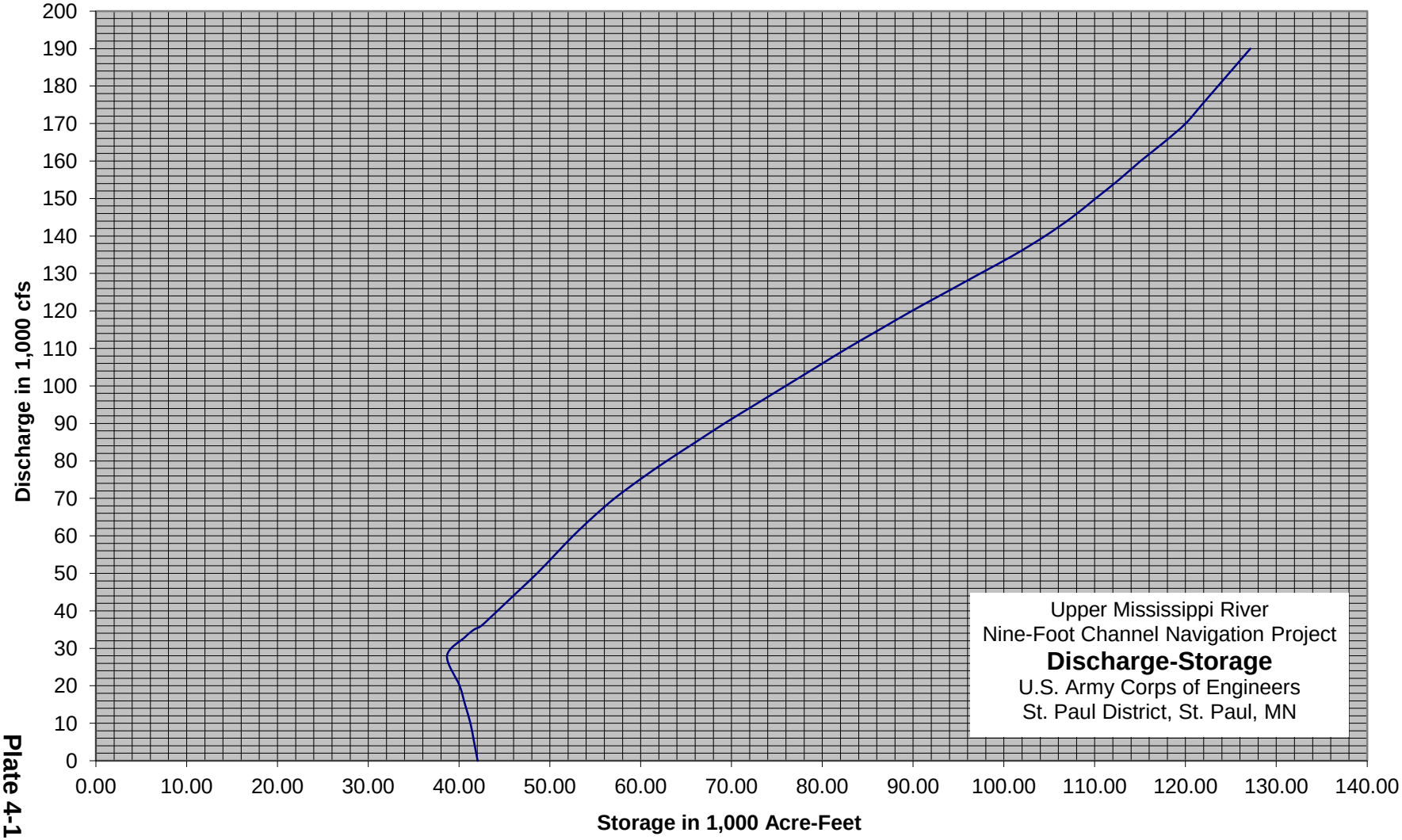
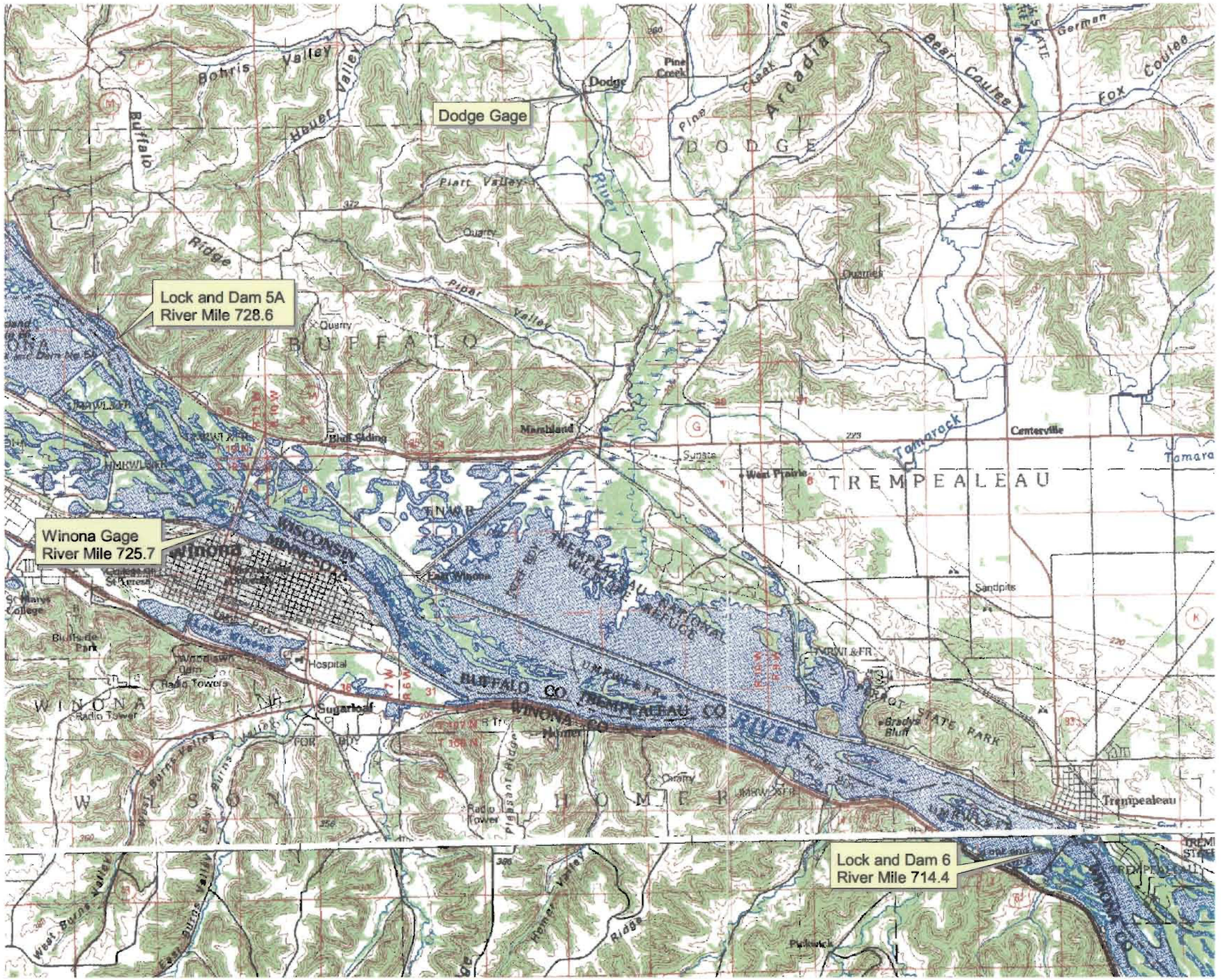



Plate 4-1




5 0 5 10 Miles

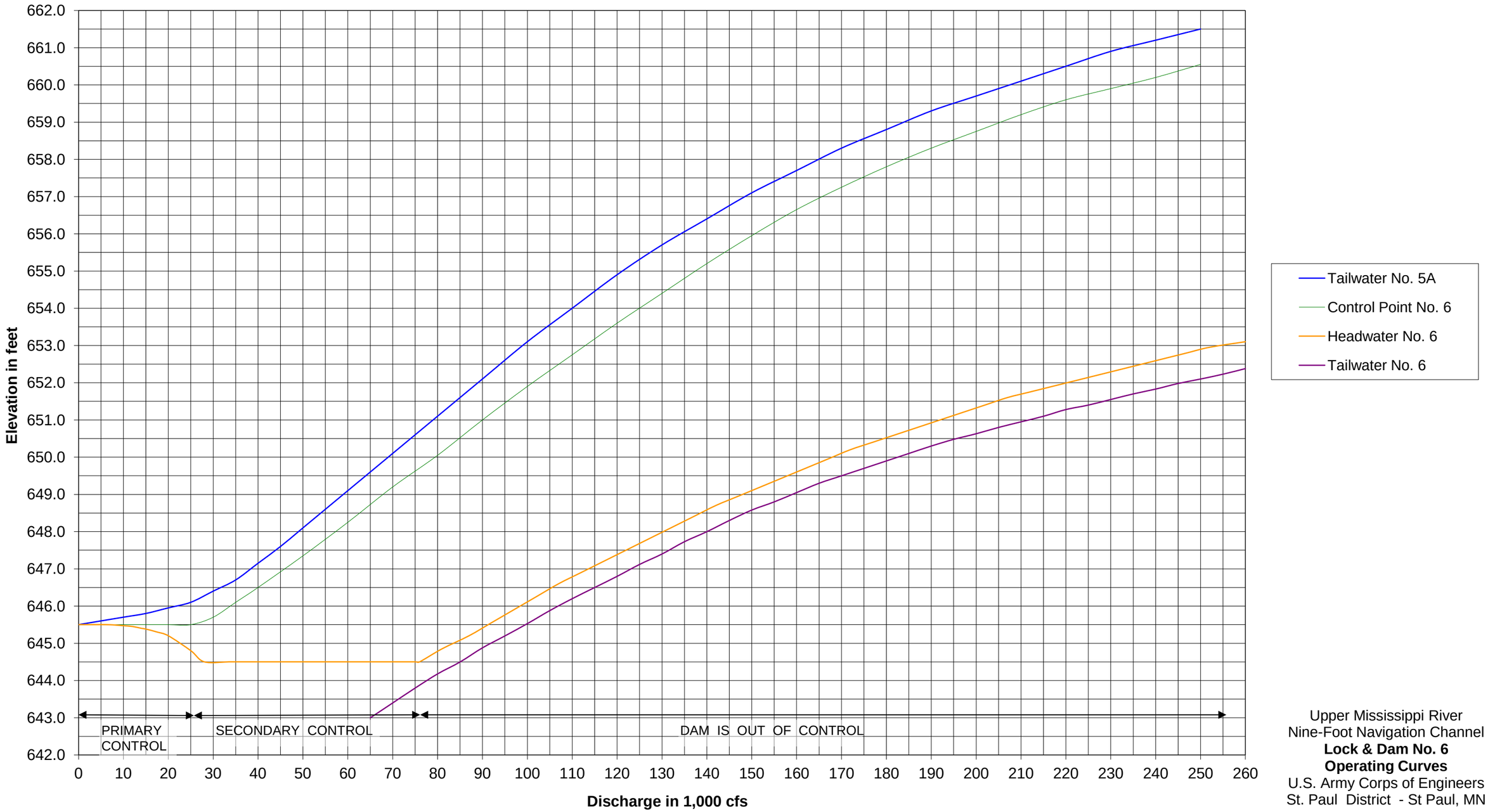
Upper Mississippi River
Nine-Foot Channel Navigation Project

**Pool No. 6**
**Gage Location Map**

US Army Corps of Engineers
St. Paul District - St. Paul, MN

**Plate 5-1**

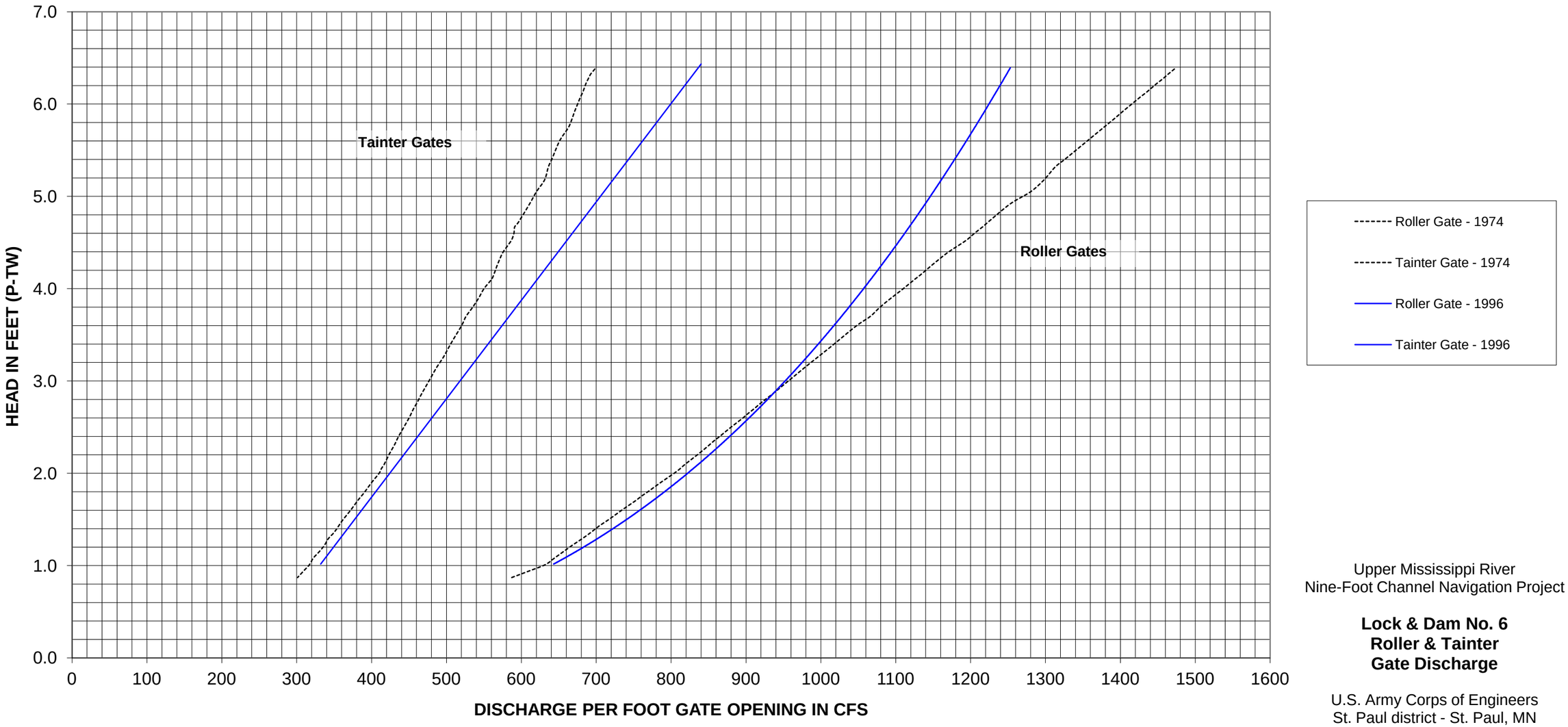
# LOCK & DAM NO. 6 OPERATING CURVES




Upper Mississippi River
Nine-Foot Navigation Channel
**Lock & Dam No. 6**
**Operating Curves**
U.S. Army Corps of Engineers
St. Paul District - St Paul, MN

**Plate 7-1**

# LOCK & DAM NO. 6
# ROLLER & TAINTER GATE DISCHARGE

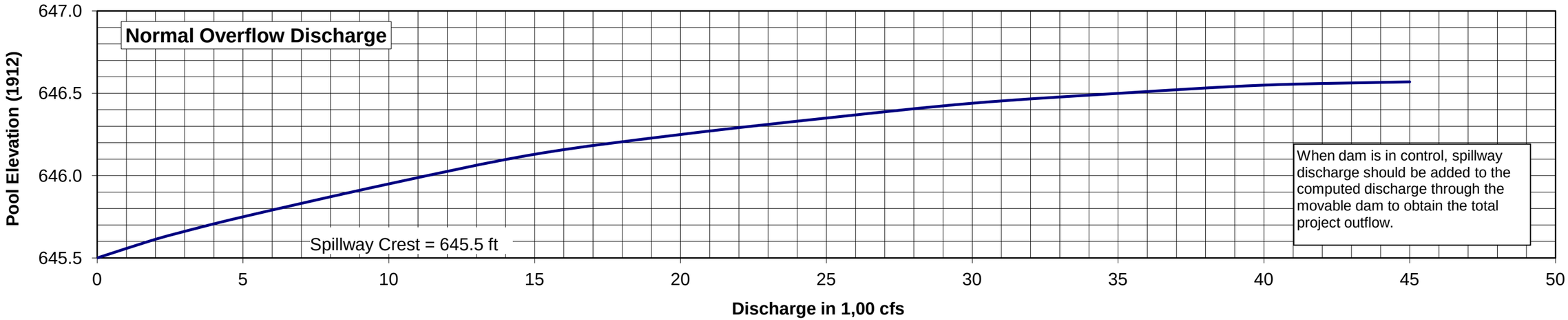


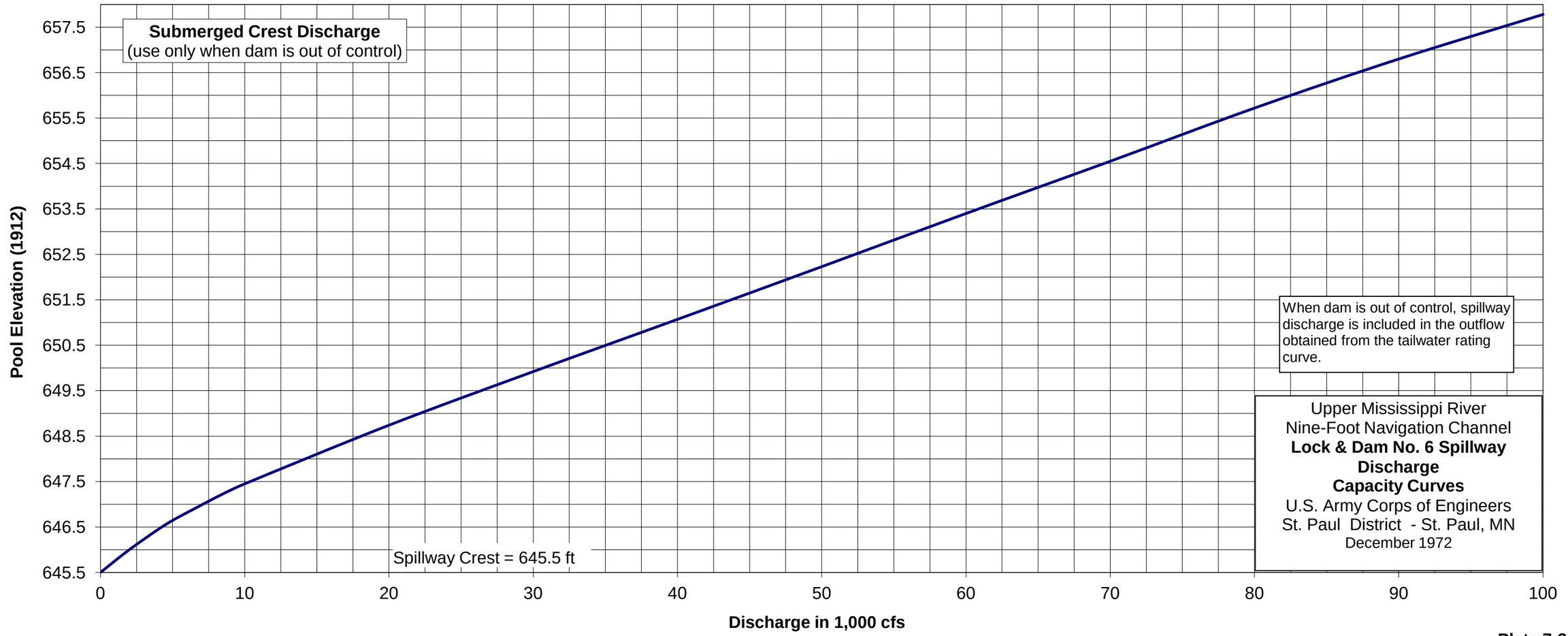

Upper Mississippi River
Nine-Foot Channel Navigation Project

**Lock & Dam No. 6**
**Roller & Tainter**
**Gate Discharge**

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

**Plate 7-2**




Upper Mississippi River
Nine-Foot Navigation Channel
**Lock & Dam No. 6 Spillway Discharge Capacity Curves**
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN
December 1972

**Plate 7-3**

CORPS OF ENGINEERS

U. S. ARMY

TREMPEALEAU RIVER DRAINAGE AREA 750 SQ. M.

Q 500=298,500 CFS
Q 200=264,000 CFS
Q 100=238,500 CFS
Q 50=213,000 CFS
Q 25=187,500 CFS
Q 10=154,000 CFS
Q 5=127,500 CFS
Q 2=88,000 CFS

BLACK RIVER CAHNNEL DRAINAGE AREA 2,250 SQ. M.

Q 500=300,000 CFS
Q 200=266,000 CFS
Q 100=240,000 CFS
Q 50=215,000 CFS
Q 25=189,500 CFS
Q 10=156,000 CFS
Q 5=129,000 CFS
Q 2=89,500 CFS

LACROSSE RIVER DRAINAGE AREA 480 SQ. M.

Q 500=303,000 CFS
Q 200=269,000 CFS
Q 100=244,000 CFS
Q 50=219,000 CFS
Q 25=194,000 CFS
Q 10=160,000 CFS
Q 5=133,000 CFS
Q 2= 93,000 CFS.

ROOT RIVER DRAINAGE AREA 1660 SQ. M.

Q 500=304,000 CFS
Q 200=270,000 CFS
Q 100=245,000 CFS
Q 50=220,000 CFS
Q 25=195,000 CFS
Q 10=161,000 CFS
Q 5=134,000 CFS
Q 2=94,000 CFS.

COON CREEK DRAINAGE AREA 140 SQ. M.

Q 500=306,500 CFS
Q 200=273,000 CFS
Q 100=248,000 CFS
Q 50=223,000 CFS
Q 25=198,000 CFS
Q 10=164,500 CFS
Q 5=137,500 CFS
Q 2=97,000 CFS.

WINONA, MN
FEDERAL LEVEE
TOP OF LEVEE PROFILE

DAM NO. 5
POOL 660.0

DAM NO. 5A POOL 651.0

DAM NO. 6 POOL 645.5

DAM NO. 7 POOL 639.0

DAM NO. 8 POOL 631.0

500 YEAR
200 YEAR
100 YEAR
50 YEAR
25 YEAR
10 YEAR
5 YEAR
2 YEAR

1965
2001
1969
1997
1993

DAM NO. 5 POOL M. 738.27 TAILWATER M. 737.90 GAGE 0=600.0

DAM NO. 5A POOL M. 728.65 TAILWATER M. 728.28 GAGE 0=600.0

WINONA GAGE M. 725.5 0=640.12

DAM NO. 6 POOL M. 714.44 TAILWATER M. 714.07 GAGE 0=600.0

DAKOTA (C.P. 70 M. 707.23 GAGE 0=600.0

DAM NO. 7 POOL M. 702.61 TAILWATER M. 702.32 GAGE 0=600.0

LACROSSE, WIS. (U.S. W.B. GAGE) M. 697.78 GAGE 0=626.32

LACROSSE, WIS. (C.P. 8) M. 696.85 GAGE 0=600.0

LACROSSE, MINN. M. 688.25 GAGE 0=600.0

BROWNSVILLE, MINN. M. 688.25

DAM ON. 8 POOL M. 679.39 TAILWATER M. 678.94 GAGE 0=600.0

ELEVATION ABOVE MEAN SEA LEVEL (1912 ADJUSTMENT)

MILES ABOVE OHIO RIVER

FOUNTAIN CITY, WIS. M. 733.4

STATE HIGHWAY 54 BRIDGE M. 725.83

CHICAGO & NORTHWESTERN R.R. BRIDGE WINONA, MINN. M. 725.66

TREMPEALEAU RIVER M. 717.21

BLACK RIVER CHANNEL M. 709.08

DRESBACH, MINN. 705.73

INTERSTATE 90 HWY BRIDGE M. 702.82

LECRESCENT, MINN. M. 700.37

CHICAGO MILW. ST.P. & P. R.R. BR. M. 699.8

LACROSSE RIVER M. 698.37

STATE HWY 61 BRIDGE M. 697.52

ROOT RIVER M. 693.99

BROWNSVILLE, MINN. M. 688.25

U.S. ARMY CORPS OF ENGINEERS

# 2003 FLOW FREQUENCY STUDY

APPENDIX B

## MISSISSIPPI RIVER
## FLOOD PROFILES - 1912 ADJ

ST. PAUL DISTRICT

2, 5, 10, 25, 50, 100, 200 & 500 YEAR FLOOD
&
1965 HISTORIC FLOOD

RIVER MILES 679.08 TO 737.9

Plate 8-1