US Army Corps
of Engineers®
St. Paul District

WATER CONTROL MANUAL

MISSISSIPPI RIVER NINE FOOT CHANNEL
NAVIGATION PROJECT

LOCK AND DAM NO. 9

LYNXVILLE, WISCONSIN

APPENDIX 9 OF THE MASTER WATER CONTROL MANUAL

UPDATED MAY 2003

WATER CONTROL MANUAL

LOCK AND DAM No. 9
LYNXVILLE, WISCONSIN

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

APPENDIX No. 9
of the
MASTER WATER CONTROL MANUAL

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

MAY 2003

Updated from
Reservoir Regulation Manual, March 1972
Operation of Navigation Pools, February 1943

LOCK AND DAM No. 9

LYNXVILLE, WISCONSIN

Aerial View Looking Upstream – Summer 1995

5 Roller Gates and 8 Tainter Gates
Project Pool 620.0 feet (1912 Adjustment)

LOCK AND DAM No. 9

LYNXVILLE, WISCONSIN

Lock and Dam No. 9 Control House – February 2002

Lock Chamber in Foreground

NOTICE TO USERS OF THIS MANUAL

This Water Control Manual complies with the latest US Army Corps of Engineers guidelines regarding management of water control systems and preparation of water control manuals. The St. Paul District prepared the *Preliminary Report on Operation of Navigation Pools* on 16 February 1943. This document provided the operational information for Lock and Dams 1 through 10. This was replaced by a Master Regulation Manual in September 1969. Appendices for each lock and dam were added during the years 1970 through 1972, with Appendix No. 9 being completed in March 1972. This manual is an update of Appendix No. 9. The manual is published in loose-leaf form to facilitate modifications. In the future, only those sections, or parts thereof, requiring changes will be revised and replaced.

EMERGENCY REGULATION ASSISTANCE PROCEDURES

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

Water Control Regulation Assistance		
Scott R. Bratten	Primary Mississippi River Regulator scott.r.bratten@usace.army.mil	Duty: 651-290-5624 [redacted]
Duty Regulator	Mississippi River Duty Regulator; Pager and Fax	Pager: 612-660-8053 Fax: 651-290-5841
Dennis D. Holme	Physical Scientist dennis.d.holme@usace.army.mil	Duty: 651-290-5614 [redacted]
Theodore D. Petersen	Water Control Gage Crew theodore.d.Pedersen@usace.army.mil	Duty: 651-290-5253 [redacted]
Ferris W. Chamberlin	Hydraulic Engineer ferris.w.chamberlin@usace.army.mil	Duty: 651-290-5619 [redacted]
Robert G. Engelstad	Chief, Water Control Section robert.g.engelstad@usace.army.mil	Duty: 651-290-5610 [redacted]
Michael R. Knoff	Chief, Hydraulics & Hydrology Br michael.r.knoff@usace.army.mil	Duty: 651-290-5600 [redacted]
John J. Bailen	Chief, Engineering Division john.j.bailen@usace.army.mil	Duty: 651-290-5303

Lock and Dam No. 9
Lynxville, Wisconsin

U.S. Army Corps of Engineers
St. Paul District – May 2003

TABLE OF CONTENTS

TABLES

EXHIBITS

FIGURES

PLATES

PERTINENT DATA

Location: Lock and Dam No. 9 is located on the Mississippi River, 647.9 river miles above the mouth of the Ohio River, 31.3 river miles below Lock and Dam No. 8, and 32.8 river miles above Lock and Dam No. 10. The lock is on the left bank river, about 3 miles below the village of Lynxville, Wisconsin and 13 miles above Prairie Du Chien, Wisconsin at approximate latitude 43^{o} 12' 42" N and longitude 91^{o} 05' 42" W.

Drainage Area: 66,610 square miles

Datum: MSL 1912 Adjustment

Fixed Height Dam:

Type:	Earth Dike - Fixed Crest Spillway	
Total Length	11,600 feet	
Length of Earth Dam	9,100 feet	
Crest of Earth Dam	Elevation 633.0 feet	
Top Width of Earth Dam	20 feet	
Max Height of Earth Dam	27 feet	
Length of Fixed Crest Spillway	1,350 feet	
Crest of Concrete Spillway	Elevation 620.0 feet	

Moveable Dam:

Roller Gates	5 Gates	80 feet by 20 feet
Tainter Gates	8 Gates	35 feet by 15 feet
Roller Gate Sill	Elevation 600.0 feet	
Tainter Gate Sill	Elevation 605.0 feet	

Lock:

Main Lock Chamber	110 feet by 600 feet
Top of Lock Walls	Elevation 633.0 feet
Top of Upper Gate Sill (Main)	Elevation 604.0 feet
Top of Upper Gate Sill (Auxiliary)	Elevation 601.0 feet
Top of Lower Gate Sill	Elevation 598.0 feet
Lock Floor	Elevation 597.0 feet
Height of Upper Miter Gates (Main)	27.0 feet
Height of Upper Miter Gates (Aux.)	30.0 feet
Height of Lower Miter Gates	33.0 feet

Pool:

Normal (Project) Upper Pool	Elevation 620.0 feet	
Normal (Project) Lower Pool	Elevation 611.0 feet	
Total Pool Area (at Project Pool)	29,125 acres	
Primary Control Point	Lansing, Iowa	Elev. 620.0 ft
Secondary Control Point	Lock & Dam 9	Elev. 619.0 ft

Notes: 1. All elevations are 1912 adjustment (MSL).
2. Roller gates are submergible to 5.0 feet below Normal Pool (620.0 feet).

I – INTRODUCTION

1-01. Authorization for Preparation of this Manual. Pursuant to the instructions from the Chief of Engineers dated 15 May 1942 and 29 August 1942, subject "Operation of Flood Control and Multiple-Purpose Reservoirs", the methods and the technique used in operating the navigation pools on the Mississippi River in the St. Paul District was documented in February 1943. Authority to prepare regulation manuals for the locks and dams was granted by Engineering Regulation (ER) 1110-2-240, *Reservoir Regulation*, 1958. While ER 1110-2-240 has been updated and amended many times since the date of issuance, the document continues to give the Corps of Engineers authority to prepare what became known as "Water Control Manuals" by ER 1110-2-240, *Water Control Management*, 1982. This manual supercedes Lock and Dam 9 Regulation Manual dated March 1972 and was prepared in compliance with the guidelines presented in:

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

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

1-03. Related Manuals and Reports. The Upper Mississippi River Lock and Dam system was authorized when Congress approved the nine-foot channel on 3 July 1930. Construction of the lock was completed on 4 March 1935, the earthen dike was completed on 22 December 1936, and the moveable dam was completed on

30 April 1937. 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 9, Lock and Dam No. 9, Lynxville, Wisconsin*, Department of the Army, St. Paul District, Corps of Engineers, March 1972.
f. *Operation and Maintenance, 9-Foot Navigation Channel, Upper Mississippi River, Head of Navigation to Guttenberg, Iowa, Final Environmental Impact Statement*, US Army Corps of Engineers, St. Paul District, August 1974.
g. *The Morphometry, Benthos and Sedimentation Rates of a Floodplain Lake in Pool 9 of the Upper Mississippi River,* J.W. Eckblad, N.L. Peterson, K. Ostlie, and A. Temte, The American Naturalist, Vol. 97, No. 2, pp. 433-433, 1977.
h. *An Assessment of Sediment Accumulation in Pool 9 of the Upper Mississippi River,* J.R. McHenry and J.C. Ritchie, Submitted to the Great Rivers Environmental Action Team by the Sedimentation Laboratory, Oxford, Mississippi, 1977.
i. *Creativity, Conflict & Controversy: A History of the St. Paul District, U.S. Army Corps of Engineers,* by Raymond H Merritt, 1979.
j. *The Effects of Commercial and Recreational Navigation on Selected Physical and Chemical Variables in Navigation Pool No. 9, Upper Mississippi River*, T.O. Claflin, R.G. Rada, M.M. Smart, D.N. Nielsen, J.K. Scheidt, B.A. Biltgen, 1981.
k. *Baseline Studies and Impacts of Navigation on the Benthos and Drift (Work Task 6), on the Quantity of Flow to Side Channels (Work Task 16) of Pool 9 of the Upper Mississippi River,* J.W. Eckblad, 1981.
l. *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.
m. *Emergency Plan for Lock and Dam 9, Lynxville, Wisconsin,* US Army Corps of Enginners, St. Paul District, August 1986
n. *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.

o. *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.
p. *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.
q. *Authorized and Operating Purposes of Corps of Engineers Reservoirs*, Department of the Army, U.S. Army Corps of Engineers, Washington D. C., July 1992.
r. *Channel Maintenance Management Plan*, Upper Mississippi River Navigation System, U.S. Army Corps of Engineers, St. Paul District, 1996.
s. *Channel Maintenance Management Plan, Final Environmental Impact Statement (FEIS)*, Lead Agency U.S. Army Corps of Engineers, St. Paul District, Volumes I and II, 6 June 1997.
t. *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, U.S. Army Corps of Engineers, June 1997.
u. *Zebra Mussel Response Plan*, U.S. Army Corps, St. Paul District, November, 1997.
v. *Discharge Ratings for Control Gates for Lock and Dam 9 (Lynxville, WI) and Lock and Dam 10 (Guttenberg, IA)*, Barr Engineering Company prepared for U.S. Army Corps of Engineers, St. Paul District, January 1999.
w. *Locks and Dams Sounding Reports, Volume 2*, U.S. Army Corps of Engineers, St. Paul District, 1999.
x. *2001 Annual Report – Water Quality Management Program,* St. Paul District, Corps of Engineers, January 2002.

1-04. Project Owner. The United States Government is the owner of Lock and Dam No. 9. The US Army Corps of Engineers, St. Paul District, St. Paul Minnesota, is responsible for regulation of Lock and Dam No. 9.

1-05. Operating Agency. Lock and Dam No. 9 is regulated, operated, and maintained by the US Army Corps of Engineers, St. Paul District. Regulation is the responsibility of Engineering Division, while operation and maintenance is the responsibility of Construction and Operations (Con-Ops) Division. The chart on the following page shows the command structure for Lock and Dam No. 9.

The project is attended 24 hours a day, every day of the year. The Chief, Con-Ops Division and the Chief, Engineering Division are located in the St. Paul

District Office, whereas the Lock and Dam Project Office is located in Fountain City, Wisconsin and the Area Lockmaster is stationed at Lock and Dam No. 9.

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

↓	↓
Chief Engineering Division	**Chief Con-Ops Division**
↓	↓
Chief H&H Branch	**Chief Lock & Dam Project Office**
↓	↓
Chief Water Control Section	**Area Lockmaster**
↓	↓
Water Control Manager	**Lock Leader**
651-290-5624 → → → → → →	608-874-4311
fax 651-290-5841	fax 608-874-4537

1-06. Regulating Agency. Regulation of Lock and Dam No. 9 is under the supervision of the Water Control Section as by the above command structure.

II – DESCRIPTION OF PROJECT

2-01. Location. Lock and Dam No. 9 is located on the Mississippi River, 647.9 river miles above the mouth of the Ohio River, 31.3 river miles below Lock and Dam No. 8, and 32.8 river miles above Lock and Dam No. 10. The lock is on the left bank of the river about 3 river miles below the city of Lynxville, Wisconsin at approximate latitude 43^{o} 12' 42" N and longitude 91^{o} 05' 42" W. The project is bordered by Crawford County on the Wisconsin side and Allamakee County on the Iowa side. The project location is shown on **Plate 2-1**.

2-02. Purpose. Lock and Dam No. 9 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. 9 are navigation under the Rivers and Harbors Act of 1930 (PL 71-250) and recreation under the Flood Control Act (PL 78-534). Access and facilities are provided for recreation but water is not controlled for that purpose.

2-03. Physical Components. Lock and Dam No. 9 consists of a main and uncompleted auxiliary lock, a movable dam section, a fixed-crest spillway, and an earthen dike (**Figure 2-1**). The locks, and moveable dam, are supported on timber piling driven into sand and gravel with steel sheet pile cutoff walls. The following describes each component in detail.

Figure 2-1. Lock and Dam No. 9

a. Lock. Lock and Dam No. 9 has a main and an uncompleted auxiliary lock (**Plate 2-2**). The upper and lower miter gates of the main lock have a height of 27.0 feet and 33.0 feet respectively. The respective sill elevations are 604.0 feet and 598.0 feet (1912 adjustment). A walkway is located atop the miter gates. It extends two feet above the top of miter gates (elevation 631.0 feet) to meet the top of lock walls (elevation 633.0 feet). While the main lock is fully functional, the auxiliary lock consists of only an upper gate bay. The miter gates on the auxiliary lock are 30 feet high with a sill elevation of 601.0 feet. The gates of the auxiliary lock have no machinery and therefore are inoperable.

The main lock chamber is 110 feet wide with a clear length of 600 feet. The filling and emptying of the lock chamber is controlled by tainter valves; two at the upstream (upper) end of the lock and two at the downstream (lower) end. During the filling or emptying process, the miter gates are closed thus sealing the lock chamber. For a filling operation, the upper tainter valves are opened allowing flow to enter the culverts (**Plate 2-2**, Section A-A). Flow then enters the lock chamber through ports along the lock wall (Section X-X) and the water level in the lock chamber rises until it equals the pool elevation. The upper tainter valves are then closed and the lower tainter valves are opened thus emptying the lock chamber. Under normal conditions, filling time is around eight minutes and emptying time is approximately 10 minutes.

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

Guidewalls are located upstream and downstream of the lock to provide a landing for down bound and up bound tows (**Plate 2-1**). The upper guidewall extends 521.0 feet upstream and the lower guidewall extends 504.0 feet downstream. To provide additional room for down bound tows to land on the upper guidewall, a 595-foot extension was proposed in 1946. While it shows up on the 1961 Project Location Map (**Plate 2-1**) as a proposed extension, it was never constructed.

b. Moveable Dam. The moveable dam section extends from the auxiliary lock to the right bank of the main channel (**Figure 2-1**). The moveable dam consists of five roller gates, 80-feet wide by 20-feet high, and eight tainter gates, 35-feet wide by 15–feet high. The sill elevation of the roller gates is 600.0 feet (1912 adjustment), while the tainter gates sill elevation is 605.0 feet. The end sill elevations for the roller and tainter gates are 598.0 feet and 603.0 feet, respectively. The roller gates can be submerged up to five feet below normal pool to elevation 615.0 feet.

Each roller gate is equipped with an individual electrically operated hoist enclosed in an operating house located on the pier. The roller gates are driven from one end only. The travel rate of the gate is approximately 0.75 feet per minute. A position indicator, marked in increments of 0.1 feet, is attached to the hoist mechanism **(Figure 2-2)**.

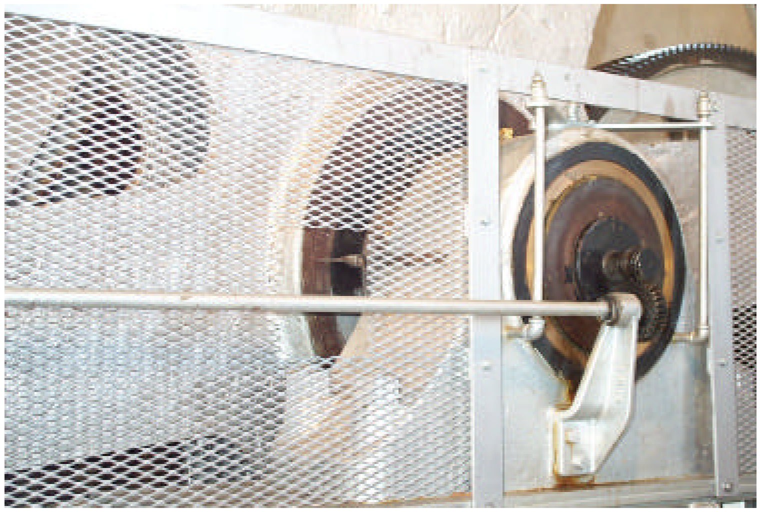


Figure 2-2. Roller Gate Position Indicator

An alternative position indicator, marked in increments of 0.5 ft, is attached to a shaft with a gear driven by the hoist mechanism **(Figure 2-3)**. There are five bulkheads stored on site, measuring 4 feet – 2 inches by 85 feet – ½ inches. The sill elevation is 600.0 feet; therefore, the top of the bulkheads would be at elevation 620.83 feet (i.e. 620 feet – 10 inches).

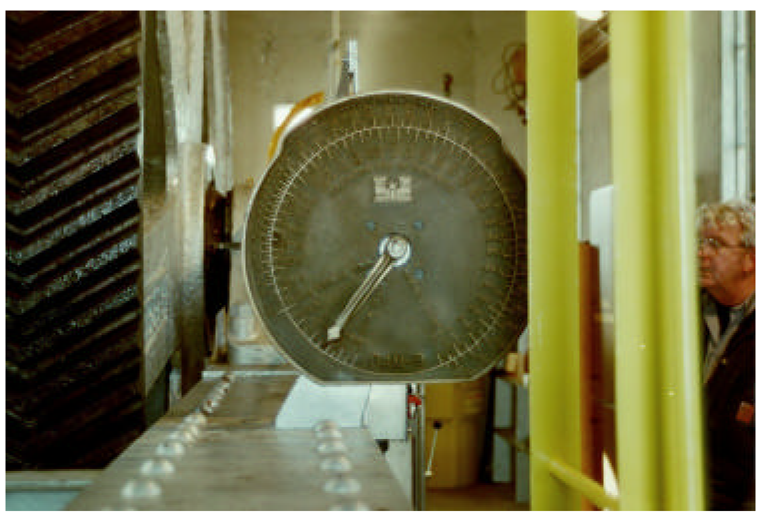


Figure 2-3. Alternate Roller Gate Position Indicator

Each tainter gate is individually operated by machinery consisting of an electrically operated central driving unit and two chain hoisting units. The electric controls consist of push buttons located on the deck rail. A position indicator is mounted on the pier about midway between the trunion and the gate surface **(Figure 2-4)**. The indicator is marked in 0.1-foot increments. The tainter gates move at a rate similar to the roller gates. There are four bulkheads stored on site measuring 4 feet – 2 inches by 37 feet – 6 inches. The sill is at elevation 605.0 feet; therefore, the top of the bulkheads would be at elevation 621.67 feet (i.e. 621 feet – 8 inches).

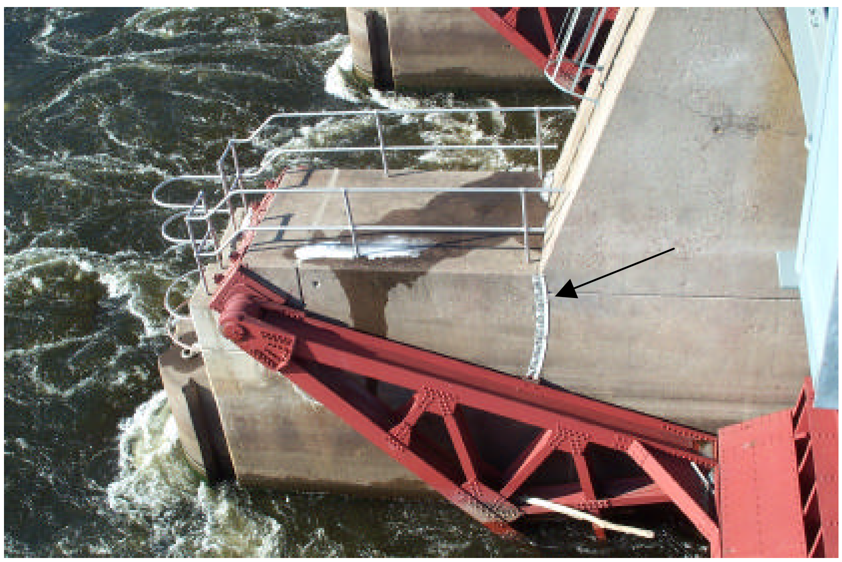


Figure 2-4. Tainter Gate Position Indicator

A service bridge, at elevation 651.5 feet, spans the entire length of the moveable dam and storage yard and provides for the operation of the locomotive crane. The original 45-foot boom crane, with 25-ton capacity was replaced with a new crane in the fall of 1981. The new bridge crane has the same capacity with a boom length of 60 feet.

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. It is periodically surveyed to monitor any further erosion. **Plate 2-3** shows two transects of the survey. 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, 2-feet thick placed on top of a 3-foot thick stone and brush protection mat with a top of rock elevation of 596.0 feet (1912 adjustment). The protection extended 41.5 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 599.0 feet. The scour holes that formed upstream and downstream of the derrick stone were filled in 1982 and 1983. In 1982, quarried rockfill was placed to elevation 586.0 downstream of the roller gates. In 1983 the rockfill was covered with a horizontal capstone section 42-inches thick. The capstone extended 46.5 feet downstream of the end sill and 25 feet upstream from the dam. Upstream of the dam the capstone was underlain by a rockfill section with a minimum thickness of 30-inches, which extended upstream of the gates a minimum of 65 feet. The horizontal capstone was placed to the same elevation as the derrick stone both upstream (elevation 599.0) and downstream (elevation 596.0 feet).

(2) **Tainter Gates.** Downstream protection originally consisted of derrick stone 2-feet thick placed on top of a 3-foot thick stone and brush protection mat with a top of rock elevation of 601.75 feet (1912 adjustment). It extended 41.5 feet downstream of the end sill for the two tainter gates closest to the roller gates, about 80 feet for the next two tainter gates, and 44 feet for the remaining tainter gates. Upstream, the derrick stone section

was 13.5-feet wide and 3-feet thick with a top of rock elevation of 604.0 feet. The scour hole upstream and downstream of the derrick stone was filled in 1982 and 1983 by a horizontal capstone section 42-inches thick, underlain by a rockfill section a minimum of 30-inches thick. The capstone extended 46.5 feet downstream of the end sill at the two-tainter gates closest to the roller gates, up to 80 feet downstream for the next two gates, and 44.0 feet for the four remaining gates. Upstream, the capstone protection extended 25 feet from the dam. The horizontal capstone was placed to the same elevation as the original derrick stone upstream (elevation 604.0 feet) and nearly the same elevation downstream (elevation 602.0 feet).

(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 by 439-foot long section of rock filled cribs was placed on the riverward side of the intermediate lock wall. A 12-foot wide section of derrick stone 3-feet thick extended from the auxiliary lock to a point 100 feet downstream on the lower guidewall. The top of rock elevation varied from 594.0 feet (1912 adjustment) at the auxiliary lock to 596.0 feet downstream of the main lock. The scour protection that was placed upstream of the locks was limited to a 3- to 5-foot thick by 15-foot wide band of derrick stone placed around the upstream nose of the intermediate lock wall. In 1982, a minimum 30-inch thick rockfill section was placed downstream of the auxiliary lock chamber. In 1983, a similar 30-inch thick rockfill section was placed to a minimum elevation of 599.0 feet for a distance of 50 feet upstream of the end of the riverward lock wall.

In 1983, scour protection was placed on the upstream side of the strut at the main lock chamber, which is located upstream of the upper apron, and along the entire length of upper guidewall. The protection consisted of a

20-foot wide, 30-inch thick riprap section underlain by a 12-inch bedding layer placed with a top elevation coincident with the top of concrete elevation. A similar layer of protection was placed along the upper guidewall with a base of bedding elevation that correlated with the base of the concrete wall. Scour protection along the downstream apron of the main lock chamber and the lower guidewall consisted of a 30-inch riprap section underlain by 12-inch bedding as was used upstream of the lock. A 20-foot wide horizontal section was placed adjacent to the downstream apron and for 165 feet downstream along the guidewall. The top of rock elevation adjacent to the apron correlated with the top of apron and the base of the bedding material adjacent to the lower guidewall correlated with the base of the concrete wall.

(4) Storage Yard. Original scour protection both upstream and downstream of the storage yard consisted of riprap placed on a 1V:3H slope from the top of bank down to approximately elevation 612.0 feet (1912 adjustment). In 1983, rockfill, 30-inches thick, was placed upstream of the storage yard on the existing ground to a maximum distance of 225 feet.

d. Earthen Dam and Fixed Crest Spillway. An earthen dam, 9,100 feet in length, extends from the end of the moveable dam section to the high ground on the Iowa side of the river (**Plate 2-1**). The dam has a crest elevation of 633.0 feet (1912 adjustment), a top width of 20.0 feet, and a maximum height of 27 feet (**Plate 2-2**). The pool side slope is 1V:3H, while the tailwater slope is 1V:5.5H. The side slopes are protected by 12-inch riprap. Protection on the pool side extends to the dam crest; whereas protection on the tailwater slope extends to three feet above the lower project pool (i.e. 611.0 + 3.0 = 614.0 ft).

Within the earthen dike is a fixed-crest spillway (**Plate 2-2**). The spillway is 1,350 feet in length and is located at the upstream end of Harpers Slough near the Iowa end. It is riprap protected and has a crest elevation of 620.0 feet (i.e.

Project Pool Elevation). There is a 65-inch by 40-inch, Arch CMP installed through the spillway. It has a level invert at elevation 615.0 feet.

2-04. Related Control Facilities. There are no related control facilities in Pool No. 9; however, there are several Habitat Rehabilitation and Enhancement Projects within the pool.

a. Blackhawk Park. Backwater lakes and sloughs at Black hawk Park were not receiving water flows from the Mississippi River at normal pool levels (river mile 671). In 1990, 7,000 linear feet of channels were excavated to provide flows to the backwater areas. In addition, culverts were installed where the channels crossed local roadways.

Figures 2-5 and 2-6. Blackhawk Park

b. Lansing Big Lake. Sediments were entering Big Lake through several side channels at the upper end of Lansing Big Lake (river mile 670). To alleviate the situation, in 1994, ten of the side channel openings were modified reduced the influx of sediment. This included closing seven side channel openings and placing rock liners in three of the openings.


Figures 2-7 and 2-8. Lansing Big Lake

c. Pool No. 9 Island. Islands in the lake-like lower reaches of the pool have lost 95 percent of their landmass due to erosion (river mile 670). In 1995 a "C" shaped rockfill island complex was constructed. It has a five-foot top width and is one-foot above the normal pool elevation.


Figures 2-9 and 2-10. Pool 9 Island

d. Cold Springs. Cold Springs supports an excellent fishery (river mile 653). The primary habitat deficiencies were low winter dissolved oxygen levels and less deep-water habitat due to sedimentation. To provide more dissolved oxygen, in 1994 a diversion weir across Kettle Creek was constructed where it enters the backwater. In addition a diversion ditch was excavated through the south peninsula with a weir to divert oxygenated creek water into the south lobe during the winter.

Figures 2-11 and 2-12.
Cold Springs Project

2-05. Real Estate Acquisition. In Pool No. 9, The Corps of Engineers acquired about 8,708 acres of land and water area in fee for the Lock and Dam No. 9 project. **Table 2-1** gives a break down of land purchased in fee and flowage easement.

Table 2-1
Corps of Engineers Land in Pool No. 9 (Acres)

State	Minnesota	Wisconsin		Iowa	Totals
County	Houston	Vernon	Crawford	Allamakee	
Fee	1,806.24	555.20	979.02	5,367.67	8,708.13
Easement	---	0.25	244.34	157.53	402.12

In addition to this, the Corps has special rights to an additional 24,808.31 acres. All of this area is under permit to the US Fish and Wildlife Service as part of the Upper Mississippi River National Wildlife and Fish Refuge.

2-06. Public Facilities. Lock and Dam No. 9 has an observation platform, a comfort station, and a picnic table available for public use. There are numerous other facilities located throughout the pool. **Table 2-2** lists the recreational facilities available in Pool No. 9.

Table 2-2
Pool No. 9 Recreation Facilities

River Mile	Name	Manager	Fee	Slips	Parking	Camp Sites	Toilets	Picnic Tables
677.8 L	Dairyland Access	Dairyland			80			
677.0 R	Millstone Landing	USACE				Yes	Yes	Yes
676.0 R	Visgers Landing	USFWS			10			
675.2 L	Bad Axe Landing	USACE			15		Yes	
673.4 R	New Albin Access	IA DNR			40		Yes	
672.7 L	Victory Landing	Victory			2			
671.3 L	Blackhawk–County Ramp	Vernon Cnty	Yes		5			
671.1 L	Blackhawk Park Main	USACE	Yes		35	Yes	Yes	Yes
670.5 L	Blackhawk Park Green Lake	USACE			20	Yes	Yes	Yes
669.6 L	Earls	Private	Yes		1	Yes	Yes	Yes
667.3 L	DeSoto Landing	DeSoto			4			
664.8 L	Winnieshiel Slough Landing	USFWS/DOT			25			
664.0 R	Lansing Marina	Private	Yes	120	25		Yes	
663.5 L	Big Slough Landing	USFWS/DOT			25			
662.3 R	S & S Rentals	Private		68	10		Yes	
662.2 R	Village Creek Access	IA DNR			150		Yes	
660.1 R	Power Plant Access	IA DNR			15			
658.5 L	Ferryville Landing	Ferryville	Yes		20		Yes	Yes
654.2 R	Heytmans Landing	IA DNR			7			
653.9 L	Cold Spring Landing	FWS			15			
651.3 L	Lynxville Landing	Lynxville			2			
651.0 L	Harris Harbor	Private		20	5		Yes	
651.0 L	Witheys	Private	Yes	10	10	Yes	Yes	

III – HISTORY OF PROJECT

3-01. Authorization. The Lock and Dam No. 9 project was authorized on 3 July 1930 when the 71st Congress, second session, passed an act that modified the existing six-foot channel project in accordance with the plan for a comprehensive project to procure a channel of nine-foot depth, submitted in House Document No. 290. The nine-foot channel was to be achieved by construction of a system of locks and dams, supplemented by dredging.

3-02. Planning and Design. The site location was adopted because of the excellent lock situation. Before construction of the lock and dam, a very good 6-foot channel, that required moderate dredging, existed between Dams No. 8 and 9. The lock and dam system is necessary to provide a nine-foot channel during low to moderate flows. The dam was designed to accommodate river flow conditions. In normal operation, all gates are partially open to allow water through. As the river flow increases or decreases, the gate openings are increased or decreased accordingly. If there were no flow in the pool, the pool would be level throughout its entire length. This is the “project pool” level that ensures a nine-foot channel depth. When there is flow, there is a slope to the water surface. Typically the water surface is maintained at the 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 intersection of the project pool and ordinary high water was at river mile 663.0. Therefore, the primary control was established at Lansing, Iowa with a project pool elevation of 620.0 feet (1912 adjustment). 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 617.5 feet. In 1970, the practice of over dredging the river channel stopped. Therefore, in 1971 drawdown at the dam was reduced to 1.0-foot or elevation 619.0 feet. As discharges increase, the gates are raised to maintain the maximum drawdown at the dam. 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. 9 the swellhead is limited to less than one foot. The project design flood for Lock and Dam No. 9 was the flood of 1880. The design high water was elevation 635.8 feet with a flow rate of 193,000 cfs. The swellhead limitation required that the available floodway area be utilized to the greatest possible degree. As a consequence gate sills were set to the lowest possible elevation. The double locks occupy so much of the main channel that the five roller gates utilize much of the remaining space, leaving room for only eight tainter gates. To meet the swellhead limitation required a 1,350-foot long fixed crest spillway to be constructed within the earthen embankment with a crest height set at the project pool elevation of 620.0 feet. The rating curve for the spillway is shown on **Plate 7-2**.

At the recommendation of the US Bureau of Sport Fisheries and Wildlife (now the US Fish and Wildlife Service), aeration culverts were installed at Lock and Dam No. 5, 5A, 8 and 10. By letter response to the St. Paul District, dated 20 May 1964, the agency reported “aeration facilities have improved the water quality and provided better winter conditions for fish life.” Subsequent to this report aeration culverts were installed at other locks and dams including Lock and

Dams No. 9. An arched, flat-bottomed, corrugated metal culvert, 65-inches wide and 40-inches high was installed through the fixed crest spillway to provide flow to Harpers Slough. The pipe has a flat invert elevation of 615.0 feet. Assuming inlet control, at project pool the pipe provides a constant flow of 110 cfs (based on culvert design nomograph for corrugated metal arch pipe, inlet control).

3-03. Construction. Construction of the lock began on 12 January 1934 and was completed on 4 March 1935. Construction of the moveable dam began on 23 July 1936 and was completed on 30 April 1937. The earthen dike was completed on 22 December 1936.

3-04. Related Projects. Lock and Dam No. 9 is one part of the 29 locks and dams on the Mississippi River necessary to maintain the nine-foot navigation channel between Minneapolis, Minnesota and St. Louis, Missouri. Thirteen of the 29 locks and dams are located in the St. Paul District. These include Upper and Lower St. Anthony Falls, as well as Lock and Dam Numbers 1 through 10.

3-05. Modifications to Regulation.

a. 1948 Modification. The nine-foot channel depth was only important during the navigation season. Therefore, the pool could be drawn down over the winter months whenever it was considered necessary. On 19 June 1948, an amendment was made to the act of Congress dated 10 March 1934, entitled "An act to promote the conservation of wildlife, fish and game, and for other purposes". The amendment was Public Law 697 and it prevented drawdown of the pools on the Mississippi River between Rock Island, Illinois and Minneapolis, Minnesota during the non-navigation season. The law states that the "…dam structures shall generally operate and maintain pool levels as though navigation was carried on throughout the year."

b. 1970 Modification. Until 1970, during low and moderate flows, the only water flowing into Pool No. 10 was passed through the dam. In 1970, an arched, flat-bottomed, corrugated metal culvert, 65-inches wide and 40-inches high was installed through the submersible dam. The culvert provides a constant flow of 125 cfs when the pool is at project level. This aids fish habitat by aerating the water upstream and downstream. Flow through the culvert can be controlled by stop logs; however, it is typically left open.

c. **1971 Modification.** The original maximum allowable drawdown for Lock and Dam No. 9 was 2.5 feet and was established in 1937. 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 an attempt to reduce the frequency of dredging, the navigation channel was often over dredged. This practice stopped in 1970. This action combined with the desire to maintain a more stable pool, maximum allowable drawdown was reduced to 1.0 foot, or elevation 619.0 feet (1912 adjustment). This remains today as the secondary control elevation.

d. **1973 Modification.** The discharge through the dam was reevaluated in 1973. 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.

e. **1982-1983 Modification.** Since 1952, hydrographic surveys indicated that scour had occurred upstream and downstream of the dam. In 1981 the Waterways Experiment Station began a study of the scour protection upstream and downstream of the Mississippi River dams and published their results in

Scour Protection for Locks and Dams 2-10, Upper Mississippi River, Technical Report HL-87-4, April 1987. 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 1982 and 1983. The riprap was designed to remain stable for a fully open single gate with normal pool and minimum tailwater. The object of the design was to allow for the passing of debris. In the model test, the gate was opened and then immediately returned to normal. While the rock remained stable for this brief period, it was obvious that failure would soon occur. The previous maximum outflow velocity was 4.5 feet per second with an allowance to go to 6.0 feet per second in an emergency. Because of the additional channel stability, the maximum outflow velocity for routine gate movements was raised to 6.0 feet per second. During emergency situations, this velocity may be exceeded for brief periods (i.e. 15 to 20 minutes). Therefore, in 1985 a new Gate Regulation Schedule was developed showing the new maximum allowable gate openings.

f. 1996 Modification. The motors that operate the lock miter gates were raised in 1996. Before this, the motors were pulled when the pool reached elevation 629.0 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 631.0 feet (1912 adjustment).

g. 2003 Modification. Outflow measurements for the roller and tainter gates were taken between May and October 1998. The results published by Barr Engineering Company in 1999 showed a shift in the discharge per foot for the roller and tainter gates. The largest shift occurs at high head differentials for both the roller and tainter gates. The new discharge ratings were found to not agree well with full-river discharge measurements taken as part of the same study. The full-river discharge measurements were more closely in alignment with the existing rating curves. Therefore the rating curves were not changed at this time. However, an investigation of the maximum allowable gate openings showed the previous calculations to be conservative. New maximum gate openings were developed and are presented in **Table 7-6**.

3-06. Principal Regulation Problems.

a. Outdraft. An outdraft problem occurs at discharges above 55,000 cfs for down bound tows. Problems are more prevalent upstream from the dam, but exist downstream as well. When discharges reach 55,000 cfs, warning signs located at the end of the upstream and downstream guidewalls are swung out into view to alert towboat captains. In addition, a warning light is turned on above each sign. Also, the towboat is often warned via radio upon approach. During spring runoff when channel discharges can run high, towing companies will occasionally hire an assistant towboat to aid in alignment with the lock.

b. Erosion of the Earthen Dike. During high flows, plastic accompanied with sand bags must be installed on the downstream face of the earthen dike in the slough areas. This is done to prevent wave action instigated by high winds from eroding the downstream face of the earthen dike.

c. Zebra Mussels. The infestation of zebra mussels could have significant impact on future operations. Zebra mussel populations are present at all St. Paul District locks and dams on the Upper Mississippi River. It is possible that they may foul the gage wells, concrete surfaces, and untreated metal surfaces such as the lock miter gates. Masses of dead zebra mussels could accumulate in the gate recesses, hindering operation. When the lock was dewatered for inspection during the winter of 1993-1994, it was noted that zebra mussels had attached themselves in sporadic fashion along the lock culverts and other areas. The St. Paul District developed a “Zebra Mussel Response Plan” in November 1997. There were five methods for short-term control identified for locks and dams. The following tables show the possible problems and the recommended control techniques identified in the study.

Table 3-1
Zebra Mussel Control Techniques

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

Table 3-2
Proposed Zebra Mussel Control Techniques for Locks and Dams

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

IV – WATERSHED CHARACTERISTICS

4-01. General Characteristics. At project pool elevation of 620.0 feet (1912 adjustment), the pool has an area 29,125 acres and a shoreline length of 90 miles. The drainage area at the dam totals 66,610 square miles in Minnesota, Iowa, and Wisconsin. Except for several small creeks, the only major tributary that flows into Pool No. 9 is the Upper Iowa River with a total drainage area of 1,060 square miles. The Upper Iowa River enters the pool at river mile 671.0 R.

4-02. Topography. The Master Water Control Manual for Locks and Dams contains a description of the topography for the Upper Mississippi River basin. Pool No. 9 is located in an area known as the “Driftless Area”. This is a region that was not glaciated during the last ice age. As a result the surrounding landscape is distinguished by a rolling topography of bluffs. The Upper Iowa has its source in the southeast corner of Mower County, Minnesota. It flows in a southeasterly direction to Decorah, Iowa. It then flows in an easterly direction, entering the flood plain of the Mississippi about 1.5 miles south of New Albin, Iowa. The total drainage area of the Upper Iowa River is about 1,060 square miles and includes parts of Allamakee, Winneshiek, Howard, and Mitchell Counties of northeastern Iowa, and small areas along the southern boundaries of Houston, Fillmore, and Mower Counties in southeastern Minnesota.

4-03. Sediment. Part of the nine-foot navigation plan authorized by Congress included periodic dredging of sediment. There are seven sites within Pool No. 9 navigation channel that require periodic dredging. Quantities and frequency of dredging these areas is presented in **Table 5-2**.

4-04. Climate. The National Weather Service maintains temperature, and precipitation, records for Lock and Dam No. 9. Temperature and precipitation data shown in the following tables were taken from the National Oceanic and Atmospheric Administration’s *Climatological Data Annual Summaries,* for Lynxville Dam 9.

Table 4-1 30-Year Normal Monthly Temperature in Degrees Fahrenheit (1971-2000)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
17.3	23.4	35.3	48.9	60.8	69.9	74.3	72.1	63.8	52.0	36.7	23.3	48.2

Table 4-2 30-Year Normal Monthly Precipitation in Inches (1971-2000)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1.05	0.97	1.93	3.58	3.80	4.29	4.01	4.37	3.00	2.22	2.36	1.24	32.82

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

Wind speed and direction are recorded each morning at Lock and Dam No. 9. While this information is valuable for the regulation of the dam, it is of little value for presenting monthly highest wind speeds and directions. The *Climatic Atlas of the United States* (June 1968) contains monthly Fastest Mile information for La Crosse, Wisconsin. Fastest Mile wind speeds are defined as the fastest speed at which wind travels one mile measured over one month. Fastest Mile wind speeds are typically obtained from a short period of time, usually less than two minutes duration. The Fastest Mile wind speeds presented in the Atlas were modified to time-dependant (1-hour) average wind speeds using procedures presented in the US Army Corps of Engineers' *Shore Protection Manual* (1984).

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

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

$S = (U^2 F)/(1400 D)$ Where,
S = Wind Setup (ft)
U = Wind Speed (mph)
F = Fetch Length (miles)
D = Average Depth over Fetch (ft)

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

4-05. Storms and Floods. While an isolated storm over the Upper Iowa River basin can have a significant impact on water levels in Pool No.9 during low flows, it is high inflows from upstream that produce flooding of the pool. After construction of the Lock and Dam in 1937 the first significant flood events didn't occur until spring of 1951. A similar event followed in 1952. **Table 4-5** gives a summary of peak elevations and discharges followed by a brief description of some of the larger events.

Table 4-5
Summary of Peak Stages/Elevations and Discharges

Lansing, IA – Control Point			**Lock and Dam No. 9**			
Date	Stage feet	Elev. ft (1912)	Date	Pool ft (1912)	Tailwater Ft (1912)	Discharge cfs
21 Apr 1951	17.76	630.02	21 Apr 1951	628.90	628.38	-
23 Apr 1952	18.14	630.40	23 Apr 1952	629.23	628.68	-
24 Apr 1965	**22.50**	**634.76**	**24 Apr 1965**	**633.78**	**633.12**	**275,500**
22 Apr 1969	18.88	631.14	22 Apr 1969	630.06	629.42	221,500
4 May 1975	17.76	630.02	5 May 1975	629.02	628.45	190,000
10 Apr 1986	16.80	629.06	10 Apr 1986	627.89	627.42	174,000
30 Jun 1993	18.21	630.47	30 Jun 1993	629.52	629.07	193,300
15 Apr 1997	18.38	630.64	16 Apr 1997	629.51	628.92	205,200
21 Apr 2001	18.93	631.19	21 Apr 2001	631.81	631.21	250,500

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 19^{th} of March 1965. The forecast predicted a stage of 16.0 feet at Lansing, Iowa (flood stage is 18.0 feet) if normal precipitation and a snowmelt of more than three days occurred. This meant that at Lock and Dam No. 9 a pool stage of 627.0 feet (1912 adjustment) would be reached with a flow of 169,000 cfs. Also, the forecast cautioned that if rainfall of one inch should occur before or during the crest, the resulting peak stage at Lansing 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 Lansing, predicting a stage of 19.0 to 19.5 feet. The forecasted discharge of almost 226,000 cfs translated into a predicted elevation of 630.5 feet at the dam. Based on this, the earthen dike and the spillway had to be strengthened and protected from scour. By the 18th of April it was apparent that the forecasts were too low and therefore the prediction for Lansing was raised to a stage of 21.0 feet, and on the 20th of April this forecast was again increased to a stage of 22.0 feet. The lock and dam was made ready to withstand a discharge of about 270,000 cfs and a pool level at the dam of elevation 633.3 feet. The rapid increase of inflow began on the 2nd of April when the discharge rose from 29,000 cfs on this date to 75,000 cfs on the 7th of April. By this time the head at the dam had been reduced to 0.4-foot and the gates were removed from the water. The motors that operate the lock miter gates were pulled on the 17th of April and the lock was out of operation until the 5th of May. On the 24th of April, Lansing crested at a stage of 22.50 feet and dam crested at an elevation of 633.78 feet. Primary control was not restored until 8 July 1965. The damages caused by the flood totaled $1,362,000. The Upper Iowa River had crested long before the mainstream crest had reached Lock and Dam No. 9. This stream was out of its banks four times in March and April 1965, and the highest stage reached at Dorchester was 17.85 feet (flood stage is 14.0 feet) on the 1st of March. At the time of the peak flow, the Upper Iowa River contributed only 500 cfs.

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 20.0 feet at Lansing, Iowa (flood stage is 18.0 feet). On the 15th of April, Lansing crested at 18.4 feet and the pool at the dam crested on the 16th of April at elevation 629.51 feet (1912 adjustment). Peak discharge was 205,200 cfs. Because the motors that operate the lock miter gates were relocated to higher elevation in 1996, the lock was able to remain in operation.

c. April 2001. The National Weather Service's (NWS0) 2001 Spring Snowmelt Flood Outlook predicted minor to moderate flooding for Pool No. 9. 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. 9. On the 16th of April the NWS forecasted a crest stage of 20.3 feet at Lansing, Iowa and an elevation of 630.8 feet (1912 adjustment) at Lock and Dam No. 9. At 1300-hours on Saturday 21 April, the stage at Lansing peaked at 19.93 feet (elevation 632.19 feet). Also on the 21st of April, the pool at Lock and Dam No. 9 peaked at elevation 631.86 feet with a discharge of 250,500 cfs. The pool surpassed the closure elevation of 631.0 feet on the 18th of April and did not fall below that elevation until the afternoon of the 24th of April. However, additional rainfall runoff resulted in a second crest of elevation 630.42 feet on the 3rd of May. While the lock may have been in operation before the 18th of April, the Coast Guard closed the river to navigation from the 9th of April to the 9th of May. By this time the pool had fallen to elevation 628.86 feet at Lock and Dam 9.

4-06. Runoff Characteristics. The mean annual discharge at Lock and Dam No. 9 is 39,800 cfs based on a period of record from 1960 through 2002. The following table shows the monthly average discharges.

Table 4-6
Monthly Average Flow in cfs – (Years 1960 through 2002)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
21,100	22,300	42,100	82,200	67,700	50,600	42,300	29,400	30,200	32,600	32,800	24,800

A discharge duration table was developed for discharges at Lock and Dam No. 9. The table indicates the percent of time discharge is at or above the indicated discharge.

Table 4-7
Discharge-Duration at Lock and Dam No. 9
Percent Time At or Above Indicated Discharge (Years 1972-2000)

Discharge	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
225,000				0.9	0.3								0.1
220,000				1.2	0.5								0.1
215,000				1.6	0.8								0.2
210,000				1.6	0.9								0.2
205,000				1.8	0.9								0.2
200,000				2.1	1.0								0.3
195,000				2.3	1.0								0.3
190,000				2.4	1.2	0.1	0.2						0.3
185,000				2.7	1.6	0.2	0.3						0.4
180,000				2.8	1.8	0.3	0.5						0.5
175,000				3.1	2.0	0.4	0.6						0.5
170,000				3.6	2.0	0.4	0.8		0.1				0.6
165,000				3.6	2.4	0.6	0.9		0.2	0.2			0.6
160,000				4.0	2.5	0.6	1.0		0.3	0.3			0.7
155,000			0.2	4.4	2.7	0.7	1.1		0.3	0.5			0.8
150,000			0.4	5.2	2.7	0.8	1.2		0.3	0.6			0.9
145,000			1.0	5.7	2.9	0.8	1.6		0.4	0.8			1.1
140,000			1.2	5.9	3.2	0.8	2.0		0.4	0.8			1.2
135,000			1.4	7.2	3.3	0.9	2.3		0.4	0.9			1.4
130,000			1.7	8.1	4.2	1.0	2.4		0.5	1.0			1.6
125,000			2.0	9.3	5.6	1.0	2.5		0.5	1.0			1.8
120,000			2.3	11.9	6.8	1.0	2.6		0.6	1.1			2.2
115,000			2.6	13.8	7.7	2.0	2.7		0.6	1.2			2.5
110,000			3.1	17.3	9.8	2.7	3.1		0.6	1.8			3.2
105,000			3.7	21.8	12.3	3.4	3.8		0.6	2.3			4.0
100,000			4.6	26.9	16.1	4.1	4.7	0.2	0.7	2.7			5.0
95,000			5.9	31.1	22.4	5.7	5.8	0.7	0.7	2.9			6.3
90,000			7.6	36.2	28.5	8.1	6.5	1.3	0.8	3.7			7.7
85,000		0.1	9.5	42.9	33.3	10.8	7.2	2.5	1.3	4.1	0.4		9.4
80,000		0.4	12.5	49.0	39.0	14.1	8.7	3.9	2.1	5.2	0.8	0.2	11.3
75,000		1.2	14.8	56.2	45.4	17.9	12.4	4.6	2.8	6.1	2.3	0.4	13.7
70,000		1.3	17.1	64.1	50.6	23.1	15.5	5.8	4.6	8.1	5.1	1.1	16.4
65,000		2.1	20.4	67.7	54.1	26.3	18.9	6.6	5.6	9.2	6.7	1.2	18.3
60,000		2.2	24.6	71.3	57.6	30.4	22.2	8.2	7.7	10.1	8.1	1.5	20.4
55,000		2.5	28.7	74.4	61.3	37.7	29.6	10.3	11.1	13.8	10.4	1.9	23.5
50,000	0.2	2.7	33.5	76.6	64.1	44.1	36.1	13.2	15.0	16.2	13.8	3.8	26.8
45,000	0.4	3.8	38.8	80.8	68.6	54.8	43.9	20.1	21.0	21.2	18.0	6.3	31.5
40,000	2.2	5.3	47.0	83.8	74.1	66.1	51.6	26.7	27.2	27.3	28.8	9.9	37.6
35,000	4.0	7.2	55.8	88.1	78.2	74.2	61.3	35.8	34.6	33.8	41.0	17.9	44.4
30,000	16.8	15.3	66.2	94.1	84.2	80.0	69.1	46.7	45.7	46.2	55.4	33.9	54.6
25,000	35.5	32.4	73.1	97.6	88.5	84.0	76.8	60.9	59.0	58.2	71.8	49.8	65.7
20,000	61.9	60.1	87.4	98.9	93.5	89.8	81.9	76.1	74.9	72.5	87.8	66.3	79.3
15,000	83.2	87.6	95.6	99.6	97.6	95.6	89.7	87.3	88.8	87.2	94.7	87.2	91.2
10,000	97.4	98.1	100.0	100.0	100.0	99.0	97.7	96.2	96.3	98.4	99.1	97.3	98.3
5,000	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

The maximum discharge of 275,500 cfs occurred, at the dam, on 24 April 1965 (**Table 4-5**). The minimum discharge since completion of the Lock and Dam was 5,400 cfs and it occurred on 17 August 1977. The lowest discharge during the drought of 1988 was 6,700 cfs on 16 September. The lowest historic discharge of 3,300 cfs was prior to construction of the lock and dam in 1933.

Construction of the lock and dam greatly influenced stage-duration curves throughout the pool. The following three elevation-duration tables were developed for the pool, tailwater, and the control point at Lansing, Iowa.

Table 4-8
Elevation – Duration for Lock and Dam No. 9 Tailwater
Percent of Time At or Above Indicated Elevation (Years 1972-2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
629.0						0.2							
628.5				0.6	0.1	0.3	0.1						0.1
628.0				0.8	0.4	0.5	0.3						0.2
627.5				1.1	0.6	0.5	0.4						0.2
627.0			0.1	1.7	0.8	0.6	0.7			0.3			0.3
626.5			0.4	2.0	1.0	0.7	0.9		0.1	0.7			0.5
626.0			0.7	2.3	1.1	0.7	1.2		0.1	0.8			0.6
625.5			1.2	3.1	1.2	0.8	1.5		0.2	0.8			0.7
625.0			1.5	4.1	1.3	0.8	1.9		0.2	0.9			0.9
624.5			1.8	4.7	1.6	0.8	2.3		0.3	1.0			1.0
624.0			2.1	7.3	1.8	0.9	2.5		0.3	1.1			1.3
623.5			2.3	9.4	2.9	0.9	2.6		0.5	1.2			1.7
623.0			2.7	12.2	4.8	0.9	2.8		0.5	1.5			2.1
622.5			3.1	15.5	8.5	1.7	3.0		0.5	2.0			2.9
622.0			3.5	21.7	11.1	2.2	3.7		0.6	2.5			3.8
621.5			4.3	26.2	15.4	3.6	4.5		0.6	3.0			4.8
621.0			5.8	30.6	21.5	5.6	5.7		0.7	3.5			6.1
620.5		0.2	7.7	37.0	26.3	7.8	6.3	0.9	1.1	3.8			7.6
620.0		0.7	10.2	43.8	31.9	10.0	6.8	2.1	1.4	4.7	0.5	0.3	9.4
619.5		1.2	13.1	52.2	38.5	13.0	8.6	4.0	2.8	6.0	1.5	0.8	11.8
619.0		1.7	17.4	60.1	45.6	17.1	12.5	5.7	3.7	7.3	4.1	1.5	14.8
618.5	0.5	2.2	21.2	65.9	50.2	22.1	17.3	6.7	5.3	9.2	7.1	2.8	17.6
618.0	1.6	3.1	25.1	69.4	54.2	26.6	21.3	8.1	6.9	10.6	9.3	5.0	20.1
617.5	2.7	3.4	31.4	73.7	58.2	33.5	28.2	9.5	11.2	12.3	11.5	7.8	23.7
617.0	4.8	4.0	37.8	75.8	61.2	39.7	33.5	11.9	15.5	15.8	14.8	11.4	27.3
616.5	9.9	8.9	43.3	79.1	65.6	48.6	38.7	16.5	20.0	18.9	17.8	15.6	32.0
616.0	15.8	14.8	49.7	82.1	70.0	55.9	44.8	21.7	24.1	23.7	24.5	24.2	37.7
615.5	24.2	21.8	57.5	84.2	74.0	64.8	50.8	25.8	29.9	30.6	34.0	31.3	44.2
615.0	33.6	30.1	64.9	88.4	78.3	73.6	58.5	35.4	34.1	37.3	45.2	40.3	51.7
614.5	46.4	40.5	76.4	92.0	82.1	78.8	64.7	42.8	41.6	46.0	56.8	49.1	59.8
614.0	57.1	56.8	84.5	95.5	85.7	82.2	71.2	52.1	52.2	52.4	65.8	60.2	68.0
613.5	72.5	78.5	89.7	97.6	90.2	84.6	76.7	64.6	60.0	62.2	75.3	72.7	77.0
613.0	81.3	88.4	93.9	98.6	93.3	87.9	80.5	74.6	71.2	70.9	86.2	81.8	84.0
612.5	90.6	92.9	98.0	99.2	95.7	92.4	85.6	81.5	83.6	80.9	91.4	88.4	90.0
612.0	94.7	95.7	99.0	99.7	98.9	96.6	91.7	89.7	93.2	90.4	95.1	93.6	94.8
611.5	100.0	99.0	99.4	100.0	100.0	99.8	99.3	97.8	97.6	98.8	98.7	99.0	99.1
611.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4-9
Elevation-Duration for Lansing, Iowa (Gage Zero: 612.26 ft)
Percent of Time At or Above Indicated Elevation (Years 1972 to 2000)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
630.5				0.3									
630.0				0.7	0.2	0.3	0.1						0.1
629.5				1.0	0.4	0.5	0.3						0.2
629.0				1.4	0.7	0.6	0.6						0.3
628.5			0.1	1.8	0.9	0.7	0.8		0.1	0.5			0.4
628.0			0.4	2.2	1.1	0.7	1.0		0.2	0.7			0.5
627.5			0.8	2.8	1.2	0.8	1.4		0.3	0.9			0.7
627.0			1.2	3.3	1.3	0.8	1.8		0.3	0.9			0.8
626.5			1.6	4.3	1.4	0.9	2.2		0.5	1.1			1.0
626.0			2.0	6.6	1.8	0.9	2.5		0.6	1.1			1.3
625.5			2.4	9.3	3.3	1.0	2.6		0.6	1.2			1.7
625.0			2.8	12.5	6.0	1.7	2.8		0.6	1.7			2.4
624.5			3.2	17.2	8.5	2.4	3.9		0.7	2.4			3.2
624.0			3.7	23.8	12.7	3.2	5.1	0.4	0.7	3.1			4.4
623.5			5.5	29.6	18.8	4.8	6.1	0.8	0.8	3.6	0.2		5.9
623.0		0.1	8.0	36.3	26.3	7.9	7.2	1.1	1.2	4.2	0.7		7.8
622.5		0.7	10.9	44.8	32.4	11.4	11.4	2.5	1.9	5.4	1.0	0.7	10.3
622.0		1.1	15.2	54.7	39.7	16.2	16.2	5.5	4.2	7.1	2.4	2.0	13.8
621.5	0.3	2.5	22.0	65.1	49.7	23.3	23.3	10.3	7.8	9.7	7.9	4.7	19.2
621.0	3.6	4.5	34.6	73.7	58.6	35.7	35.8	18.7	19.0	15.5	13.7	9.6	27.7
620.5	20.0	19.7	52.7	82.1	73.0	53.4	53.4	35.6	39.1	29.8	28.7	29.5	44.1
620.0	82.2	79.9	89.2	96.4	92.8	91.7	91.7	88.3	85.5	85.4	87.7	85.9	88.3
619.5	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 Lock and Dam No. 9 Pool
Percent of Time At or Above Indicated Elevation (Years 1972-2001)

Elev.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
630.6				0.8									0.1
630.5				0.9	0.2								0.1
630.0				1.2	0.5								0.1
629.5				1.8	0.8	0.2							0.2
629.0				2.2	1.0	0.3	0.1						0.3
628.5				2.5	1.4	0.4	0.3						0.4
628.0				2.7	1.7	0.4	0.4						0.4
627.5			0.1	3.3	2.0	0.6	0.6			0.2			0.6
627.0			0.3	3.8	2.3	0.7	0.9			0.6			0.7
626.5			0.6	4.1	2.4	0.7	1.1		0.1	0.7			0.8
626.0			1.1	4.8	2.6	0.8	1.4		0.2	0.8			1.0
625.5			1.4	5.6	2.8	0.8	1.7		0.3	0.9			1.1
625.0			1.7	6.2	3.1	0.8	2.2		0.3	1.0			1.3
624.5			1.9	8.5	3.4	0.9	2.4		0.3	1.1			1.6
624.0			2.3	10.7	4.6	0.9	2.5		0.4	1.1			1.9
623.5			2.6	13.4	6.2	1.0	2.7		0.4	1.3			2.3
623.0			2.9	16.6	9.5	1.6	2.8		0.4	1.6			2.9
622.5			3.2	22.1	12.7	2.6	3.8		0.6	2.4			4.0
622.0			4.0	27.0	16.0	4.1	5.1		0.6	2.8			5.0
621.5			5.5	31.7	22.1	6.7	6.1	0.1	0.7	3.1			6.3
621.0			7.3	37.2	27.0	9.2	7.3	0.6	0.7	3.5			7.8
620.5		0.6	10.2	44.2	33.6	11.7	8.8	3.3	1.6	4.2	1.1	0.5	10.0
620.0	4.6	2.7	15.1	53.0	40.2	21.8	18.6	19.9	14.7	21.3	13.6	9.8	19.7
619.5	44.8	45.8	45.8	68.2	64.1	40.6	43.5	55.3	57.6	61.5	52.5	57.9	53.1
619.0	84.2	91.9	88.7	94.8	93.2	85.4	86.3	94.1	91.7	93.4	88.8	92.7	90.4
618.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

At a flat pool elevation of 620.0 feet (project pool), the storage volume in Pool No. 9 is 126,000 acre-feet. At moderate flows, there is a one-foot drawdown at the dam. That is, while the elevation at the dam is 619.0 feet, the elevation at the control point (Lansing, Iowa) is a minimum of 620.0 feet. When the pool is at these elevations, the storage volume is around 117,000 acre-feet. Assuming an average volume of 122,000 acre-feet, a flow rate of 61,500 cfs would result in a daily exchange in storage. The following table shows the storage volume in Pool No. 9 for various elevations at Lansing and Lock Dam No. 9 pool. A relationship of storage to discharge is shown on **Plate 4-1**.

Table 4-11
Storage Volume of Pool No. 9 in 1,000 Ac-Ft

Pool Elev.	Elevation at Lansing , Iowa – Control Point – 1912 Adjustment																
	629	628	627	626	625	624	623	622	621	620	619	618	617	616	615	614	613
625	266	256	247	238													
624		246	235	225	214												
623		235	225	214	204	193											
622			215	205	194	184	174										
621			205	195	185	174	164	154									
620				184	174	164	154	144	135	126							
619					166	156	146	136	127	117	108						
618							138	128	118	108	98						
617							127	118	108	99	90	81					
616								108	99	90	82	74					
615								99	90	82	75	68	62				
614									84	76	69	62	57	52			
613										70	63	58	52	48	45		
612											59	53	49	45	42	40	
611												50	46	43	40	37	35
610													43	40	37	35	32

4-07. Water Quality. Following a recommendation by the US Bureau of Sport Fisheries and Wildlife (now the US Fish and Wildlife Service) in May of 1964, an aeration culvert was installed through the embankment at Harpers Slough (**3-02. Planning and Design**). While the culvert has greatly improved fish habitat, no water quality samples were ever taken. In fact, the St. Paul District does not collect water quality information for Pool No. 9. 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. While water quality sampling is conducted as part of the program, no samples are collected in Pool No. 9.

4-08. Channel and Floodway Characteristics. The top of the lower lock sill elevation at Lock and Dam No. 8 is elevation 606.0 feet (1912 adjustment) and the top of the upper lock sill elevation at Lock and Dam No. 9 is elevation 604.0 feet. Therefore, there is a 2-foot drop in sill elevation along the pool, which has a length of 32.1 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 2-8**.

4-09. Upstream Structures. Lock and Dam No. 8 is located 32.1 miles upstream of Lock and Dam No. 9. The drainage area above Lock No. 8 is 64,770 square miles. The lock and dam system continues upstream to the Upper St. Anthony Falls Lock and Dam located in Minneapolis, Minnesota.

4-10. Downstream Structures. Lock and Dam No. 10 is located 32.8 miles downstream of Lock and Dam No. 9. The drainage area above Lock No. 10 is 79,370 square miles. The Lock and Dam system continues downstream to Lock and Dam No. 27 in St. Louis, Missouri; however, St. Paul District terminates with Lock No. 10.

4-11. Economic Data. Pool No. 9 lies on the Minnesota-Wisconsin and Iowa-Wisconsin border. Allamakee and Houston Counties lie on the western side and Crawford and Vernon Counties lie on the eastern side. Based on the US Census Bureau, county populations have increased.

Table 4-12 County and City Populations Near Pool No. 9				
County	**1990**	**2000**	**Difference**	**Change**
Crawford (WI)	15,940	17,243	1,303	8.2 %
Allamakee (IA)	13,855	14,675	820	5.9 %
Houston (MN)	18,497	19,718	1,221	6.6 %
Vernon (WI)	25,617	28,056	2,439	9.5 %
City				
Lynxville, WI	153	176	23	15.0 %
New Albin, IA	534	527	-7	-1.3 %
De Soto, WI	326	366	40	12.3 %
Lansing, IA	1,007	1,012	5	0.5 %
Ferryville, WI	154	174	20	13.0 %

The following table gives a break down of the employment by industry. The data were taken from the US Census Bureau's 2000 Industry Report.

Table 4-13 Employment by Industry – Counties on Pool No. 9 (2000)				
Industry	**Vernon (WI)**	**Houston (MN)**	**Allamakee (IA)**	**Crawford (WI)**
Agriculture, Forestry, Fishing and Hunting	1,526	801	1,049	815
Construction	910	683	574	500
Manufacturing	2,229	1,496	1,490	1,878
Wholesale Trade	470	415	275	164
Retail Trade	1,534	1,275	760	1,029
Transportation and Warehousing, and Utilities	645	421	369	354
Information	152	279	72	95
Finance, Insurance, Real Estate, Rental & Leasing	477	367	221	184
Professional, Scientific, Management, Administration, and Waste Management	554	559	332	351
Education, Health and Social Science	2,872	2,626	1,348	1,580
Arts, Entertainment, Recreation, Accommodation and Food Services	742	493	342	650
Other Services	548	427	248	261
Public Administration	454	263	180	389

V - DATA COLLECTION AND COMMUNICATION NETWORKS

5-01. Hydrometeorological Stations.

a. Facilities. The regulation and proper operation of the dam site requires the collection and evaluation of several hydraulic and hydrologic parameters. The Corps of Engineers (COE), US Geological Survey (USGS), and the National Weather Service (NWS) are involved in the data collection network. About 16 miles downstream of Lock No. 8 is the Pool No. 9 primary control point gage. It is located along the right bank near downtown Lansing, Iowa (**Plate 5-1**). The site is a Data Collection Platform (DCP). The gage is a stilling well type with a Sutron 8200 with speech modem and another Sutron 8200 with GOES Telemetry. The GOES Telemetry allows communication with the satellite system that provides hourly water surface elevations to Water Control. The voice modem allows telephone communication with the gage to obtain an instantaneous water surface elevation. There is a tape indicator on the encoder for a visual reading of the stage. As back up to this, there is a staff gage within the stilling well. It is observed by opening the lower hatch. The DCP is powered by a battery, which in turn is charged through AC power.

Figures 5-1 and 5-2.
Lansing Stream Gage House

The main tributary to the pool is the Upper Iowa River, which enters the Mississippi River about 23 miles upstream of the lock and dam. A gage is located about three miles upstream of the confluence with the Mississippi River near Dorchester, Iowa (**Plate 5-1**). A DCP was installed at this location in 1996. The DCP is equipped with a Sutron data recorder and an Acubar pressure sensor, which is commonly referred to as a "bubbler". The data recorder is a Sutron 8210 with GOES telemetry and voice modem. The equipment is powered by battery, which is charged through AC power. There is no staff gage at the site; however, there is a wire weight gage on the downstream side of the State Highway 76 Bridge. The datum for the gage is 660.00 feet, NGVD 1929. **Appendix B** contains the USGS rating table. While the equipment at Dorchester is owned by the COE, the gage is 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 **(Figures 5-3 and 5-4)**. Each gage house has a well with a float and tape system that reports elevation to the Stevens PAV-C Recorder located in the central control station. Staff gages are mounted inside the gage houses and serve as backup or are used for verification of the tape in the well. For very high water, staff gages are also located on the outside of the gage house. In September of 1996, the Iowa USGS installed a DCP in the tailwater gage house. When operating properly, it transmits hourly data every four hours. The period of record is spotty with many long periods where the transmission consists of one to two water surface elevations every four hours. The data can be viewed from the Water Control web site, "Real Time", "Lock and Dam 9, Tailwater at Lynxville, WI" (www.mvp-wc.usace.army.mil). The location of the gage site is shown on **Plate 5-1**.

Figure 5-3. Pool Gage House

Figure 5-4. Tailwater Gage House

A standard eight-inch precipitation gage is located near the lock house (**Figure 5-5**). The NWS has a Fisher-Porter automatic weighing, punched tape, binary decimal recording gage installed at the site (**Figure 5-6**).

Figure 5-5.
Standard 8-inch Rain Gage.

Figure 5-6.
Fisher-Porter Rain Gage.

A water temperature sensor, reading in degrees Fahrenheit, is submerged four feet in the upper ladder recess. 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 following table summarizes the gage equipment located at the lock and dam as well as the pool and tributaries.

Table 5-1
Hydrometeorological Stations

Location	Data Type	Equipment	Notes
Mississippi River at Lansing, Iowa	Water Surface Elevation and Stage	Sutron 8200 Data Recorder Sutron Shaft Encoder GOES Telemetry Voice Modem Staff Gage	Gage Zero: 612.26 (1912) Flood Stage: 18.0 ft Stilling Well AC Power
Upper Iowa River near Dorchester, Iowa	Water Surface Elevation	Sutron 8210 Data Recorder Sutron Accubar GOES Telemetry Voice Modem Wire Weight (Hwy 76)	Gage Zero: 660.0 (1929) Flood Stage: 14.0 ft Co-Op Gage Bubbler AC Power
Fixed Crest Spillway	Elevation	Tape on Shaft Staff Gage	Tape: Stilling Well Staff: Spillway Abutment
Lock & Dam No. 9 Upper Guidewall	Pool Elevation	Stevens PAV-C Recorder Type P.O. Transmitter Staff Gage	Continuous Strip Chart record of pool elevations. Stilling Well
Lock & Dam No. 9 Lower Guidewall	Tailwater Elevation	Stevens PAV-C Recorder Type P.O. Transmitter Staff Gage Sutron 8200 Data Recorder	Continuous Strip Chart record of TW elevations. Stilling Well DCP property of USGS
Lock & Dam No. 9	Snow Depth & Water Content	Snow Rod , Snow Tube, Scale	Water Control provides replacement as needed.
Lock & Dam No. 9 Lock House Roof	Wind Speed & Direction	Anemometer	Maintained by site personnel.
Lock & Dam No. 9 Upper Ladder Recess	Water Temperature	Water Temperature Sensor	Electronically transmitted to lock house.
Lock & Dam No. 9	Precipitation	Standard 8-inch Rain Gage	Recorded daily.
Lock & Dam No. 9	Precipitation	Fischer-Porter - Weighted Punch Tape	NWS Gage

b. Reporting. Daily log sheets of data are kept at the lock and dam site (**Appendix C**). Data include pool and tailwater elevations at the dam, water surface elevations at Lansing and McGregor, stages at Dorchester, Muscada, and Steuben, roller and tainter gate settings, air and water temperatures, and wind speed and direction. A more complete description is given in **Section 7-04. Standing Instructions the Lock and Dam No. 9 Staff**. In addition to the log sheets, site personnel also enter these data via a remote computer to a program called "sig-na-term". Each morning Water Control collects the 0600-hour data and compiles it with data from the past 24-hours. These data are formatted on to the Regulation Sheets. An example of the data presentation for Lock No. 9 is shown on **Page 7-13**.

The data reported directly to Water Control via remote computer is input to a computer generated log sheet, which is available from the Water Control web site at www.mvp-wc.usace.army.mil. Data includes gate settings and pool and tailwater elevations on four-hour intervals beginning at 0400-hours. Daily elevations for Lansing and McGregor are entered, as are stages at Muscada, Dorchester, and Steuben. USGS rating tables were input to the program such that discharges for these stages are automatically computed. Total river discharge is automatically calculated on a four-hour basis, based on gate settings and pool and tailwater elevations. When the gates are out of the water, a tailwater rating curve is used. A constant flow of 200 cfs is added to the discharge to account for flow through the Harpers Slough culvert. During winter months, the tainter valve openings are automatically converted to discharge via a rating table. Air temperature and wind speed and direction are entered on eight-hour intervals beginning at 0800-hours. The 24-hour precipitation total and water temperature are entered as 0800-hour data. Maximum and minimum air temperatures are entered as being taken at 2400-hours. Note that all 0800-hour data is taken at 0600-hours and max-min air temperature is taken at 1900-hours.

In addition to the electronically generated log sheet, hourly data from the DCP's are also available from the Water Control web site. These sites include the tailwater at the dam, Lansing on the Mississippi River, and Dorchester on the Upper Iowa River.

The Stevens PAV-C strip charts containing the continuous record pool and tailwater elevations are mailed to Water Control at least once a year where they are periodically micro filmed.

c. **Maintenance.** The equipment at the gages located at Lansing, Iowa and Dorchester, Iowa are property of the Corps of Engineers; however, the Dorchester gage is maintained by the USGS. The Water Control Gage Crew provides emergency backup. Operation and maintenance of the Lansing gage and the pool and tailwater gages are the responsibility of the Gage Crew. Dam personnel maintain the Stevens PAV-C strip chart recorders with the Gage Crew used as a backup if necessary. The anemometer, water temperature sensor, and standard precipitation gage are maintained by site personnel; however should the precipitation gage become damaged, a new one would be mailed to the site from Water Control. The Fischer-Porter precipitation gage is maintained by the NWS. Repair of the snow survey equipment is the responsibility of the Gage Crew.

5-02. Water Quality Stations. There are no water quality stations in Pool No. 9; 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. The Corps of Engineers does not collect sediment samples in Pool No. 9; however, there have been several studies conducted by other agencies and institutions concerning suspended sediment. For further information, see **References f, g, i, and j** of **Chapter 1**. Routine dredging of sediment is part of the nine-foot navigation plan. There are several sites in the pool that require periodic dredging due to sedimentation. Dredging is the responsibility of the St. Paul District's Fountain City Boat Yard located at Fountain City, Wisconsin. As soon as the ice leaves the river, hydrographic surveys are made to get an early indication of channel conditions. After spring high water, surveys of the historic problem spots are performed. Equipment is lined up and a priority list is made. **Table 5-2** gives a summary of dredging in Pool No. 9 and in the lower lock approach from 1970 to 2000.

Table 5-2
Summary of Dredging Activity – 1970 through 2000

Cut Name	River Mile	Avg. Vol. Per Year (yd^3)	Avg. Vol. Per Job (yd^3)	Freq. of Dredging	Last Year Dredged
Lower Approach LD 8	678.7 to 679.2	488	5,042	10 %	1988
Island 126	677.5 to 678.4	4,596	47,496	10 %	1998
Twin Island	676.0 to 676.6	200	6,200	3 %	1976
Battle Island	671.0 to 672.0	2,452	25,334	10 %	1980
Indian Camp Light	665.0 to 665.8	16,875	27,533	61 %	1999
Lansing Upper Light	663.8 to 664.9	29,617	45,907	65 %	2000
Above Atchafalaya Bluff	660.0 to 661.0	2,837	87,934	3 %	1970

5-04. Recording Hydrologic Data. Daily log sheets containing pool and tailwater elevations, roller and tainter gate settings, air temperature, water temperature, precipitation, wind speed and direction, and the water surface stage/elevations at Lansing, McGregor, Dorchester, Muscada, and Steuben are kept at the lock and dam. All daily data received by Water Control from the dam site is compiled and archived using Hydraulic Engineering Center's Data Storage System (HEC-DSS). These data are accessible from the Water Control web site at www.mvp-wc.usace.army.mil. Log sheet data begins 1 January 1993. Hourly DCP data (i.e. stage/elevation) for the Lansing and Dorchester stream gages begins 1 December

1997. The US Geological Survey (USGS) maintains a discharge record for the Upper Iowa River at Dorchester. The data are archived in the USGS WATSTORE database in Reston, Virginia and are available from the annual publication of the USGS Water Resources Data, Iowa. The daily record of max-min air temperature, precipitation, weather characteristics, river stages and general remarks are recorded on National Weather Service (NWS) Form B-91. This form is mailed at the end of each month, along with the punched tape from the Fischer-Porter gage, to the NWS in La Crosse, Wisconsin.

5-05. Communication Network. The communication network consists of computer terminals, a T1 line, telephones, pagers, facsimiles, FM radios, voice modems, satellites, and the US Postal Service. Computer communication is done via e-mail, and "sig-na-term" which allows remote access to the Water Control network. When the computer is down, the transfer of data is by facsimile and telephone or FM radio. During non-duty hours on weekends and holidays, dam personnel can contact the river regulator by calling the pager number (612-660-8053). The gage sites at Lansing, Iowa, Muscoda, Wisconsin, Dorchester, Iowa, and Steuben, Wisconsin send stage/elevation data hourly via satellite to Water Control. Rain gage information is available from data recored from the tipping buckets located at the stream gages at Steuben on the Kickapoo River and Muscada on the Wisconsin River. This information is made available to the dam site from the Water Control web site; *www.mvp-wc.usace.army.mil*. All five gages have voice modem and can be contacted by telephone for immediate stage information. A T1 line ensures communication between Water Control and the Mississippi River Valley Division Office (MVD) in Vicksburg, Mississippi. Bulk items like Stevens PAV-C strip charts are delivered to Water Control through the postal service.

5-06. Communication with Project.

a. Regulating Office with Project Office. Dam site personnel input and transmit their data, via computer, to Water Control every day between 0600 and 0630-hours. Water Control issues orders to Lock and Dam No. 9 every morning at approximately 0800-hours with the exception of weekends and holidays during the non-navigation season when orders are sent out at 0730-hours. Orders are typically delivered via e-mail; however, FM radio is available as backup, with the telephone serving as backup to the radio. Should the dam site have computer problems, such that the transfer of data is not possible, a facsimile is then sent to Water Control (651-290-5841). The Water Control river manager then enters the information into the Regulation Program and Information Management (IM) is notified of the computer problem. Communication with the project after orders are delivered is typically by telephone.

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

5-07. Project Reporting Instructions. The project staff reports hydrologic and climatic conditions to Water Control every morning. Outside normal duty hours, the lock operator may make gate changes required to remain within the pool band issued by Water Control provided it is less than 10 percent of the total flow. If the pool goes out of the band after 0400-hours, no gate changes are to be made by project staff until Water Control issues its morning orders. Gate changes to aid work efforts (e.g. painting) are to be coordinated with Water Control. Problems with machinery that operate the gates are to be reported to Water Control Section and Construction-Operations Division.

5-08. Warnings. In the event the lock operator makes a gate change to remain within the pool band issued by Water Control, Lock No. 9 personnel should notify Lock No. 10 of the cut or opening that was made. In the event of a gate failure, communications must be established as quickly as possible with the Water Control Section and the Construction-Operations Division. The installation of any bulkheads must be coordinated with Water Control.

VI – HYDROLOGIC FORECASTS

6-01. General. During periods of low flow, the gates at the dam are regulated to pass inflow under pooled conditions, while during high flow they are raised free of the water surface and except for a slight swellhead due to the effect of the piers and the embankment, the dam offers little obstruction to the flow. The storage capacity created by the dam is relatively small as compared with the volume of flow and inasmuch as the dam is out of operation at high discharges, the use the dam to control floods is not possible. The lock goes out of operation at elevation 631.0 feet (1912 adjustment). 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. 9 is Lansing, Iowa. The NWS forecast typically is only a five-day forecast with a projected crest height and date. The District saw a need for a model to forecast not only the time and elevation of the crest at the dam for planning sand bag operations, but also the receding limb for forecasting when the lock may go back into operation. In 1997, the District developed the Mississippi Basin Model System (MBMS), which utilizes the unsteady flow program UNET. The river regulator in the Water Control 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.

b. Roles of Other Agencies. The National Weather Service (NWS) electronically provides the District forecasted stage hydrographs of the major tributaries to the Mississippi River by 0830-hours daily. Water Control Section inputs these hydrographs into the Mississippi Basin River System model and makes a run. The stage hydrographs are internally converted to discharge hydrographs. Flows are routed and the final discharge hydrographs are converted to stage hydrographs at the locks and dams. The results of the run are 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 nearest Lock and Dam No. 9 is the control point at Lansing, Iowa.

6-02. Flood Condition Forecasts. Since 1997, St. Paul District has been using the Mississippi Basin Modeling System (MBMS) to forecast flood conditions at Lock and Dam No.9. The system utilizes UNET, which is an unsteady flow computer program. UNET was modified to simulate navigation dams according to operating rules. While the program allows the operating rules to vary according to the season, it does not account for gate operation. Therefore, model results are limited while the dam is in a regulated condition. Flow and stage data are required to provide the boundary conditions that drive the model. Observed stages are updated daily. The model is dependent upon forecasted tributary inflow. The National Weather Service (NWS) electronically mails the five-day forecasted stage hydrographs for the major tributaries to Water Control by 0830-hours daily. The hydrographs typically include the 24-hour quantitative precipitation forecast (QPF). Water Control extrapolates the tributary stage hydrographs to 30-days. Forecasts beyond five to seven days are very approximate due to unknowns such as additional rainfall. Therefore, only the five-day forecast for the locks and dams is made available to the public via the Water Control web site; www.mvp-wc.usace.army.mil. The 30-day forecast is available to Corps personnel through the Intranet.

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 Mississippi River. When the Mississippi River portion of CWMS becomes deployed and operational, the functionality of the MBMS model will be replaced. Rather than using UNET, CWMS will use a HEC-RAS unsteady flow model. The sharing of data with the NWS will remain unchanged.

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

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

VII - WATER CONTROL PLAN

7-01. General Objectives. The general objective of the water control plan is to maintain a minimum depth of nine feet along the navigation channel of Pool No. 9, without inducing higher stages during flood events. Project pool elevation for Lock and Dam No. 9 is 620.0 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. 9, the "primary control point" is located on the riverfront in downtown Lansing, Iowa (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 in some locations 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 and embankment 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 to moderate discharges, the pool is maintained at elevation 620.0 ± 0.2 feet (1912 adjustment) at the primary control point at Lansing, Iowa. This is "project pool" or "normal pool" for Lock and Dam No. 9 and was mandated by the 79th Congress (1st Session, House Document No. 137, 9 December 1931). As discharges increase, there is a "drawdown" in the water surface elevation at the dam while the "primary control point" is maintained. The amount of drawdown allowed was based on necessary navigation depths upstream of the dam. A drawdown of 2.5 feet was allowed until 1971 when it was reduced to one foot. This limited the adverse effects on navigation and riverfront property by providing a more stable water surface elevation. Drawdown at the dam is constrained to elevation 619 ± 0.2 feet.

b. Maximum Outflow Velocity. Downstream scour protection limits outflow velocities from the roller and tainter gates. The original design plan set maximum outflow velocities at 4.5 feet per second 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. The design velocity of 6.0 feet per second may be exceeded for short periods of time (15 to 20 minutes) during emergency operations (e.g. barge incident, passing of debris).

c. Open River Conditions. The dam is "out of control" when the gates are raised clear of the water surface and "open river conditions" exist. This typically happens when the differential head is less than one foot and the discharge is around 63,000 cfs. When gates are put back in the water, the total gate openings are 75 feet on roller gates and 85 feet on tainter gates (**Table 7-5**).

d. Closure of the Lock to Navigation. Prior to 1996, 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 628.52 feet (1912 adjustment). As part of the major rehabilitation work in 1996, the motors were raised; therefore, the lock can now technically remains open to navigation provided water is not spilling over the upper miter gates of the main lock. This occurs at elevation 631.0 feet. While this is the physical constraint, closure will often happen before the water level gets this high due to wave action over the miter gates 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. The lock is typically closed in early December. The lock is opened when the ice becomes thin enough for some tow traffic and the lock is opened. This is typically around mid-March. 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. 9.

Table 7-1
Spring Opening and Fall Closing Dates

Year	Opening Date	Closing Date	Year	Opening Date	Closing Date
1972	17 Mar	15 Dec	**1988**	18 Mar	02 Dec
1973	08 Mar	06 Dec	**1989**	25 Mar	25 Nov
1974	13 Mar	14 Dec	**1990**	12 Mar	30 Nov
1975	18 Mar	15 Dec	**1991**	16 Mar	25 Nov
1976	02 Mar	19 Dec	**1992**	05 Mar	02 Dec
1977	17 Mar	18 Dec	**1993**	19 Mar	30 Nov
1978	03 Apr	01 Dec	**1994**	18 Mar	30 Nov
1979	29 Mar	05 Dec	**1995**	12 Mar	30 Nov
1980	24 Mar	05 Dec	**1996**	21 Mar	29 Nov
1981	06 Mar	05 Dec	**1997**	16 Mar	27 Nov
1982	23 Mar	08 Dec	**1998**	07 Mar	18 Dec
1983	01 Mar	18 Dec	**1999**	07 Mar	14 Dec
1984	02 Mar	01 Dec	**2000**	02 Mar	02 Dec
1985	16 Mar	01 Dec	**2001**	18 Mar	06 Dec
1986	20 Mar	05 Dec	**2002**	13 Mar	29 Nov
1987	09 Mar	01 Dec	**2003**	25 Mar	

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

roller gates **or** tainter gates are being closed. Any mixing of roller gate and tainter gate closures would require additional evaluation by Water Control.

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

Flow (cfs)	No. of Roller Gates Closed	Flow (cfs)	No. of Tainter Gates Closed
Below 14,000	5	Below 36,000	8
14,000 – 22,000	4	36,000 – 39,000	7
22,000 – 31,000	3	39,000 – 43,000	6
31,000 – 42,000	2	43,000 – 46,000	5
42,000 – 54,000	1	46,000 – 50,000	4
Above 54,000	0	50,000 – 54,000	3
		54,000 – 59,000	2
		59,000 – 63,000	1
		Above 63,000	0

7-03. Overall Plan for Water Control.

a. General Plan. The navigation channel of Pool No. 9 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. 9, 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 32,000 cfs, the pool is fairly flat. To meet depth requirements in the upper pool requires the pool elevation at Lansing, Iowa to be at elevation 620.0 feet (1912 adjustment). Therefore, "project pool" elevation for Lock and Dam No. 9 is 620.0 feet, and Lansing acts as the "primary control point" for maintaining this elevation. As discharges increase, gates are opened at the dam to maintain project pool at Lansing. This results in a drawdown of the water surface elevation at the dam. Maximum allowable drawdown is one foot below the project pool level or elevation 619.0 feet. At higher flows, the gates are opened to maintain the pool elevation of 619.0 feet at the dam. The lock and dam is now in "secondary control". As discharges continue to rise to around 63,000 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 the 1973 Gate Regulation Schedule and historical data from 1972 through 2001.

Table 7-3
Control Conditions at Lock and Dam No. 9

Control Conditions	Approximate Discharge	Lansing Gage Elevation	Lock and Dam 9 Pool Elevation
Primary	< 32,000 cfs	620.0 ft	≤ 620.0 ft
Primary and Secondary	32,000 to 34,000 cfs	620.0 ft	619.0 ft
Secondary	34,000 to 63,000 cfs	> 620.0 ft	619.0 ft
Open-River	> 63,000 cfs	> 620.0 ft	> 619.0 ft

b. **Computed Discharge.** Discharge measurements were taken at the dam for various gate openings at various differential heads. These data were used to develop discharge curves based on a per foot gate opening. Flows through the dam can then be computed based on the differential head and the gate settings. Discharge over the fixed crest spillway can be determined from the rating curve shown **Plate 7-2**. At high discharges when the gates are out of the water, discharges can be determined from a tailwater-rating curve. To prevent a jump from computed outflows to the tailwater rating curve, outflows are transitioned to the tailwater rating. Discharges are automatically computed every four hours as part of the "River Program".

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 1973, 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 with a slight change to the tailwater rating. These changes were presented in a new Gate Regulation Schedule (August 1973). Included with the new scheduler 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. With the placement of the additional riprap the maximum outflow velocity was raised from 4.5 fps to 6.0 fps and the maximum gate openings were correspondingly changed on the Gate Regulation Schedule.

In 1998, the St Paul District contracted with Barr Engineering to verify the measurements taken in 1973. The discharge measurements were made using an Acoustic Doppler Current Profiler (ADCP). Flows were measured at both the tainter gates and the roller gates. The data are plotted on **Plate 7-3**. As part of the quality control plan, full-river discharge measurements were made downstream of the dam on two separate days. The following table shows a comparison of computed flows and the total river measurement.

Table 7-4
Comparison of 1998 Computed Gate Discharge to Full-River Discharge (cfs)

Date	Tainter Gate Opening	Roller Gate Opening	Tainter Discharge Per foot	Roller Discharge Per foot	Computed Discharge	Measured Discharge	Percent Diff
6 May 98	24.0 ft	30.0 ft	530	1,100	45,720	40,730	12.3 %
7 Oct 98	6.0 ft	7.0 ft	900	1,660	17,020	14,970	13.7 %

Because of the poor comparison shown in **Table 7-4**, another comparison was made using the 1973 gate ratings. The differential heads on 5 May and 7 October were 3.58 feet and 7.76 feet respectively. Per foot discharges were determined from the curves presented on **Plate 7-3**. The following table shows the comparison with the full-river discharge.

Table 7-5
Comparison of 1973 Computed Gate Discharge to Full-River Discharge (cfs)

Date	Tainter Gate Opening	Roller Gate Opening	Tainter Discharge Per foot	Roller Discharge Per foot	Computed Discharge	Measured Discharge	Percent Diff
6 May 98	24.0 ft	30.0 ft	470	895	38,130	40,730	-6.4 %
7 Oct 98	6.0 ft	7.0 ft	820	1,375	14,545	14,970	-2.8 %

Assuming the full-river discharge measurements are accurate, the 1973 gate rating produced better results than the 1998 gate rating. Based on this, the 1973 gate rating was selected for continued use pending further measurements in the prototype. Therefore, the current Gate Regulation Schedule should not need to be revised; however, as part of the update for the manual, the flow distribution and the maximum allowable gate openings were investigated. In 1973, the distribution of flow was based on equalizing the outflow velocities. As a check, a flow of 40,000 cfs was selected for investigation. The head across the dam at this discharge is 3.55 feet with a tailwater elevation of 615.45 feet. The discharge per foot opening for roller and tainter gates are 893 cfs and 470 cfs respectively. By setting the roller gates at a total opening of 30.0 feet (30 x 893 = 26,800 cfs) and the tainter gates at 28 feet (28 x 470 = 13,200 cfs) gives a total discharge of 40,000 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 15 feet. Tainter gates are 35 feet long with a pier width of 8 feet. The respective end sill elevations for roller and tainter gates are 598 feet and 603 feet. Therefore, the flow velocities are;

Roller Gate
$Q = VA$
(30 ft/5 roller gates) 893 cfs = V (80 ft + 15 ft) (615.45 ft – 598.0 ft)
V = 3.23 ft/sec

Tainter Gate
$Q = VA$
(28 ft/8 tainter gates) 470 cfs = V (35 ft + 8 ft) (615.45 ft – 603.0 ft)
V = 3.07 ft/sec

Based on this, there was no need to change the flow distribution presented in the 1973 Gate Regulation Schedule. To complete the investigation, verification of the computations for maximum allowable gate openings was needed. Again, let's consider a discharge of 40,000 cfs and a differential head of 3.55 feet with a tailwater elevation of 615.45 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
$Q = VA$
893 cfs (max gate opening in ft) = 6.0 fps (80 ft + 15ft) (615.45 ft – 598.0 ft)
Max Gate Opening = 11.1 ft

Tainter Gate
$Q = VA$
470 cfs (max gate opening in ft) = 6.0 fps (35 ft + 8 ft) (615.45 ft – 603.0 ft)
Max Gate Opening = 6.8 ft

The respective computed maximum gate openings in 1973 were 9.5 feet and 5.8 feet. Because of this, all maximum gate openings were recomputed. The revised Gate Regulation Schedule is presented in **Table 7-6**.

Table 7-6
Gate Regulation Schedule
5 Roller Gates and 8 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
7,000	3.0	3.0	619.90	611.33	8.57	1,470	878	4,400	2,600	5.2	2.5
10,000	5.0	3.5	619.88	611.60	8.28	1,437	858	7,200	3,000	5.4	2.6
11,000	5.5	3.5	619.86	611.70	8.16	1,423	848	7,800	3,000	5.5	2.6
12,000	6.0	4.0	619.84	611.80	8.04	1,410	838	8,500	3,400	5.6	2.7
13,000	6.0	5.5	619.81	611.90	7.91	1,395	828	8,400	4,600	5.7	2.8
14,000	7.0	5.5	619.78	612.07	7.71	1,372	811	9,600	4,500	5.8	2.9
15,000	7.0	7.0	619.76	612.25	7.51	1,349	795	9,400	5,600	6.0	3.0
16,000	8.0	7.0	619.73	612.35	7.38	1,333	784	10,700	5,500	6.1	3.1
17,000	8.0	8.5	619.70	612.50	7.20	1,313	769	10,500	6,500	6.3	3.2
18,000	9.0	8.5	619.68	612.60	7.08	1,299	759	11,700	6,500	6.4	3.3
19,000	10.0	8.5	619.64	612.75	6.89	1,278	744	12,800	6,300	6.6	3.4
20,000	10.0	10.0	619.60	612.90	6.70	1,256	728	12,600	7,300	6.8	3.5
21,000	11.0	10.0	619.58	613.00	6.58	1,241	718	13,700	7,200	6.9	3.6
22,000	12.0	10.0	619.54	613.10	6.44	1,226	707	14,700	7,100	7.0	3.7
23,000	13.0	10.5	619.50	613.25	6.25	1,204	692	15,700	7,300	7.2	3.8
24,000	13.0	13.0	619.48	613.40	6.08	1,184	677	15,400	8,800	7.4	4.0
25,000	14.0	13.0	619.44	613.50	5.94	1,169	666	16,400	8,700	7.6	4.1
26,000	15.0	14.0	619.35	613.65	5.70	1,141	646	17,100	9,000	7.8	4.3
27,000	16.0	14.5	619.30	613.80	5.50	1,118	630	17,900	9,100	8.1	4.4
28,000	17.0	15.5	619.20	613.95	5.25	1,089	610	18,500	9,500	8.3	4.6
29,000	18.0	16.5	619.15	614.10	5.05	1,066	593	19,200	9,800	8.6	4.8
30,000	19.0	17.5	619.10	614.21	4.89	1,048	580	19,900	10,200	8.8	5.0

Table 7-6 – Continued
Gate Regulation Schedule
5 Roller Gates and 8 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	20.0	18.5	619.05	614.30	4.75	1,031	569	20,600	10,500	9.0	5.1
32,000	21.0	20.0	619.00	614.48	4.52	1,005	550	21,100	11,100	9.3	5.4
33,000	22.0	20.0	619.00	614.55	4.45	997	544	21,900	10,900	9.5	5.5
34,000	23.0	22.0	619.00	614.70	4.30	980	532	22,500	11,700	9.7	5.7
35,000	24.0	23.0	619.00	614.80	4.20	968	523	23,200	12,000	9.9	5.8
36,000	25.0	24.0	619.00	614.97	4.03	948	509	23,700	12,200	10.2	6.1
37,000	26.0	25.5	619.00	615.10	3.90	934	499	24,300	12,700	10.4	6.3
38,000	27.0	27.0	619.00	615.20	3.80	922	491	24,900	13,300	10.6	6.4
39,000	28.0	28.0	619.00	615.30	3.70	911	482	25,500	13,500	10.8	6.6
40,000	30.0	28.0	619.00	615.45	3.55	893	470	26,800	13,200	11.1	6.8
41,000	31.0	30.0	619.00	615.60	3.40	876	458	27,200	13,700	11.5	7.1
42,000	32.0	32.0	619.00	615.68	3.32	867	452	27,700	14,500	11.6	7.2
43,000	33.0	34.0	619.00	615.80	3.20	853	441	28,100	15,000	11.9	7.5
44,000	35.0	34.0	619.00	615.90	3.10	842	433	29,500	14,700	12.1	7.7
45,000	36.0	36.0	619.00	616.03	2.97	826	423	29,700	15,200	12.4	7.9
46,000	38.0	37.5	619.00	616.20	2.80	807	409	30,700	15,300	12.9	8.3
47,000	39.0	40.0	619.00	616.30	2.70	796	400	31,000	16,000	13.1	8.6
48,000	41.0	41.5	619.00	616.45	2.55	778	388	31,900	16,100	13.5	8.9
49,000	42.0	44.0	619.00	616.55	2.45	767	380	32,200	16,700	13.8	9.2
50,000	44.0	46.0	619.00	616.70	2.30	750	368	33,000	16,900	14.2	9.6
51,000	46.0	48.0	619.00	616.80	2.20	738	359	33,900	17,200	14.5	9.9
52,000	47.0	51.0	619.00	616.90	2.10	727	351	34,200	17,900	14.8	10.2

Table 7-6 – Continued
Gate Regulation Schedule
5 Roller Gates and 8 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
53,000	50.0	52.0	619.00	617.05	1.95	710	339	35,500	17,600	15.3	10.7
54,000	51.0	54.0	619.00	617.10	1.90	704	335	35,900	18,100	15.5	10.9
55,000	53.0	57.0	619.00	617.22	1.78	691	324	36,600	18,500	15.9	11.3
56,000	55.0	59.0	619.00	617.32	1.68	680	316	37,400	18,600	16.2	11.7
57,000	57.0	62.0	619.00	617.45	1.55	666	305	38,000	18,900	16.6	12.2
58,000	59.0	65.0	619.00	617.60	1.40	648	293	38,200	19,900	17.2	12.9
59,000	62.0	68.0	619.00	617.68	1.32	638	287	39,600	19,500	17.6	13.2
60,000	64.0	72.0	619.00	617.78	1.22	626	279	40,000	20,100	18.0	13.7
61,000	66.0	77.0	619.00	617.90	1.10	610	268	40,300	20,600	18.6	14.3
62,000	70.0	82.0	619.00	618.02	0.98	586	257	41,000	21,000	19.5	15.1
63,000	75.0	85.0	619.00	618.13	0.87	561	245	42,100	20,800	20.5	15.9
64,000	Out of control - All gates out of the water. Gates put back in at 75 ft Roller Gates and 85 ft Tainter Gates.										

c. Regulation Procedure. Each morning at 0640-hours, the River Regulator prints the Regulation Sheets containing all the input from the lock and dam sites. Regulation for Lock and Dam No. 9 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, and so on down to Lock and Dam No. 9. After regulating Lock and Dam 8, inflow to Pool No. 9 is determined. Inflow consists of outflow from Lock and Dam No. 8, inflow from the Upper Iowa River, and any miscellaneous inflow. Inflow from Lock and Dam 8 is computed as part of the daily regulation. Inflow from the Upper Iowa River will appear on the Regulation Sheet from input by site personnel (see Standing Instructions to Lockmaster). Miscellaneous inflow will vary seasonally but for simplicity it is assumed to be a constant 800 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 1,300 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 1,600 cfs over a 24-hr period of time will result in about a one tenth of a foot change in the overall pool elevation. This value was computed based on the effective project pool area of 29,125 acres. Once the needed change in discharge is determined, the Gate Regulation Schedule is used to distribute flow and hence set gate changes. The gate change information is e-mailed to the lock site and the St. Paul District's intranet at approximately 0800-hours each day. The orders are typically one of four types; (1) no change, (2) no change at present, (3) open a given amount, or (4) cut a given amount. A "no change at present" order is followed by an "if statement". For example, "if the pool falls to elevation 619.9 feet, cut 2 feet on roller gates". All "open" and "cut" orders include the anticipated change in flow. All four types of orders are followed by a "pool band" to be maintained at the dam. For example, "hold 620.0 ± 0.2 feet". As a final note, the orders may also include "allow for wind on the high side" or "allow for wind on the low side", if appropriate. Sometimes it is necessary to check back with the lock site in the afternoon. If this were the case, the site would be informed, via the morning's orders, that Water Control will be contacting them at a given time (typically 1400-hours). At that time, site personnel would provide present, noon pool and tailwater elevations, and present wind conditions. Water Control would then provide any gate change verbally over the telephone or via e-mail. The following is a sample of a morning's regulation of Dam No. 9. The portion printed in black represents the daily regulation sheet while that printed in blue represents regulation notes.

Regulation of Lock and Dam No. 9 for 18 September 2001

```
        Orders to LD 8:  No change.
        Note:  Roller gates opened 3 ft in the past 24-hours.

                                                 5-RG   8-TG   [primary = 620.00
gates in/out:  70/72 @ 64,000                    Total  Total   for flow<33,000]
              | sec: |                           Roller Tainter      CP-9
LOCK 9        |619.00|  Tail    Flow             Gate   Gate        Lansing
        ----------------------------------------------------------    TM9
22SEP01 0800   619.66  612.82  16700              8.0    8.0        620.00
        1200   619.70  612.83  16700              8.0    8.0
        1600   619.73  612.81  16800              8.0    8.0
        2000   619.75  612.82  16800              8.0    8.0
        2400   619.79  612.89  18000              9.0    8.0 ←—— Opened 1 ft
23SEP01 0400   619.82  612.92  18000              9.0    8.0
        0630   619.83  612.91  18100              9.0    8.0        620.18
             up 0.17        up 1400                                 up 0.18
phone   HEAD      6.9                          Dorchester:           7.24
##034   Q/foot   1319/750                           TM9
        temp.          58                          Flow:              192
        precip.    0.06
        wind (dir&speed)        @    0
        INFLOW:
          L/D 8 -       21500            Orders:
          Upper Iowa.     200            Open 2.0 ft RG and 3.0 ft TG
          1600 CFS -                     Inc. Flow 4,400 to 22,500 cfs
          Misc. -         800            Hold 19.70 ± 0.2 ft
                     ------
                      22500 up 3100
```

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 9.
Computed inflow from LD 8 was 21,500 cfs.
LD 8 orders were no change at present.
The Upper Iowa River is at 200 cfs.
Miscellaneous inflow is 800 cfs.
Rainfall was 0.06 inches (insignificant).
Total Inflow = 22,600 cfs (up 3,100 cfs from yesterday).

Step 2. Note change in outflow.
Up 1,400 cfs, mostly due to the 1.0 ft RG opening.

Step 3. Note change in pool elevation.
Pool is up 0.17 feet at the dam.
Pool is up 0.18 feet at Lansing.
Wind is minimal.

Step 4. Primary or Secondary Control?
Flow is less than 33,000 cfs; therefore, Primary Control.
For Primary Control, maintain Lansing at 620.0 ± 0.2 ft.

Step 5. Estimate needed change in discharge.
Total Inflow = 22,500 cfs
Increase outflow by 4,400 cfs to 22,500 cfs. OR
Inflow is up 3,100 cfs from yesterday (3 ft opening at LD 8).
However, there was a 1,200 cfs opening during the night.
Needed Change for Inflow = (3,100 – 1,200) = 1,900 cfs
The pool is 0.17 ft to 0.18 ft on the high side.
Needed Change for Pool = (1.75 x 1,600) = 2,400 cfs
Total Change Needed = (2,400 + 1,900) = 4,300 cfs
Gate Regulation Schedule ideal gate settings: 12 RG & 10 TG
Therefore,
"Open 2.0 ft on RG and 3.0 ft on TG."
" Increase flow 4,400 to 22,500."

Step 6. Set the pool band.
The pool is on the high side (i.e. target at Lansing is 620.00 ft).
We want an opening if the pool goes up; therefore,
"Hold elevation 619.70 ± 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 Control makes an estimate of the anticipated minimum base flow for the winter months. The estimate is based on the average flow from 1 October through 15 November and the minimum winter flow rate curve. The curve was developed using historic discharge information for the gage site at

McGregor, Iowa. “Average October Flow” and “Average November Flow” were plotted against the “Minimum Winter Flow”. Curves were drawn through the lowest data points. A composite curve was then developed. By entering the average flow for the period 1 October through 15 November, the anticipated minimum base flow can be selected from the curve. To determine where 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 are typically not submerged less than 1.0 foot due to ice interference. Therefore, Roller Gates can be submerged from a minimum of 1.0 foot to a maximum of 5.0 feet. Discharges for half-foot increments are shown in **Table 7-7**. Because the minimum submergence is one-foot, the total discharge for all roller gates at one-foot submergence must be deducted from the estimated minimum base flow. This flow is then used to determine tainter gate settings. While two of the tainter gates can be submerged to 2.0 feet below project pool elevation, they are operated only in the raised position due to icing problems. The recommended tainter gate settings are sent to the Lockmaster for evaluation. The Lockmaster assesses the Water Control recommendations and makes the final decision on tainter gate settings before freeze up. Before ice begins to form on the pool, the roller gates are placed in a submerged position. Adjusting roller gates in the submerged position makes the necessary changes in discharge. When the roller gates are at an extreme setting and additional change in outflow is needed, a tainter gate, or tainter gates, must be freed up. Usually considerable time is spent steaming and chopping before an ice bound tainter gate becomes moveable.

Throughout the winter, the tainter valves in the lock walls are kept open a total of ten feet so that the lock chamber will remain ice free. It is estimated that the discharge is equal to one-tenth the discharge under a normal roller gate with the same head. Lock personnel enter the gate opening and the River Program computes the flow and posts it to the electronic log sheet.

Table 7-7 Discharge Through Submerged Roller Gate – cfs										
Pool Elevation	**Head Feet**	**Depth of Submerged Gate**								
		1.0 ft	1.5 ft	2.0 ft	2.5 ft	3.0 ft	3.5 ft	4.0 ft	4.5 ft	5.0 ft
620.0	8.0	800	1010	1270	1570	1910	2300	2690	3110	3460
	7.0	770	980	1240	1540	1880	2270	2660	3080	3430
619.9	8.0	770	970	1210	1510	1850	2220	2610	3040	3390
	7.0	740	940	1180	1480	1820	2190	2580	3010	3360
619.8	8.0	740	920	1160	1450	1770	2140	2520	2950	3320
	7.0	710	890	1130	1420	1740	2110	2490	2920	3290
619.7	8.0	710	880	1110	1390	1710	2060	2450	2870	3250
	7.0	680	850	1080	1360	1680	2030	2420	2840	3220
619.6	8.0	680	840	1050	1330	1640	1980	2370	2780	3180
	7.0	650	810	1020	1300	1610	1960	2340	2750	3150
619.5	8.0	650	800	1010	1270	1570	1910	2300	2690	3110
	7.0	620	770	980	1240	1540	1880	2270	2660	3080
619.4	8.0	620	770	970	1210	1510	1850	2220	2610	3040
	7.0	600	740	940	1180	1480	1820	2190	2580	3010
619.3	8.0	600	740	920	1160	1450	1770	2140	2520	2950
	7.0	580	710	890	1130	1420	1740	2110	2490	2920
619.2	8.0	580	710	880	1110	1390	1710	2060	2450	2870
	7.0	560	680	850	1080	1360	1680	2030	2420	2840
619.1	8.0	560	680	840	1050	1330	1640	1990	2370	2780
	7.0	540	650	810	1020	1300	1610	1960	2340	2750
619.0	8.0	540	650	800	1010	1270	1570	1910	2300	2690
	7.0	510	620	770	980	1240	1540	1880	2270	2660
619.0	7.0	510	620	770	980	1240	1540	1880	2270	2660
	6.0	480	590	740	950	1210	1510	1850	2240	2620
619.0	6.0	480	590	740	950	1210	1510	1850	2240	2620
	5.0	440	550	700	910	1170	1470	1800	2200	2580
619.0	5.0	440	550	700	910	1170	1470	1800	2200	2580
	4.0	390	500	650	860	1120	1420	1760	2150	2540

On the weekends and holidays, the second and third shifts are limited to one person at the dam site. There is a one half hour over lap in the morning between the 0730 and 0800-hours. Therefore, Water Control 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 Lansing gage is to be maintained at elevation 620.0 ± 0.3 feet. A high pool level during the winter reduces oxygen depletion in the backwater areas, which benefits fish habitat. Therefore, Water Control operates on the high side of the band during winter months.

7-04. Standing Instructions to Lock and Dam No. 9 Staff. Lock and dam personnel are to maintain daily log sheets (**Appendix C**). The log sheet begins at 0400-hours. The data entry interval varies from once a day to every four hours. Four-hour intervals begin at 0400-hours and end at 2400-hours with the exception of 0800-hour data which are taken at 0600-hours and entered as such. Eight-hour data are taken at 0600, 1600, and 2400-hours. Four-hour interval data include pool and tailwater elevations. Gate openings, total discharge, air temperature, and wind speed and direction are recorded on eight-hour intervals. Discharges at the dam are calculated by Water Control on 4-hour intervals and can be obtained from the Water Control web site at www.mvp-wc.usace.army.mil. Daily records include water surface stage/elevations, precipitation, water temperature, and maximum and minimum air temperature. All daily data are recorded at 0600-hours with the exception of max-min air temperature which is recorded at 1900-hours. River elevations are recorded for the Lansing and McGregor gage sites on the Mississippi River. River stages are recorded for the Dorchester gage on the Upper Iowa River, the Muscada gage on the Wisconsin River, and the Steuben gage on the Kickapoo River. It should be noted that the McGregor, Muscada, and Steuben information is used to regulate Lock and Dam No. 10; however, because the telephone calls to the voice modems of these gages are all local calls, Lock No. 9 personnel make the calls and enter the data. 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 Observing Handbook No. 2.

In addition to the log sheets, site personnel also enter data via a remote computer to a program called “sig-na-term”. These data are the same as the daily log sheet with minor exceptions. Gate settings are input on four-hour intervals and during the winter months, tainter valve openings are to be entered. As with the log sheet, all 0800-hour data are collected at 0600-hours and are entered to the computer no later than 0630-hours.

The Stevens PAV-C strip charts containing the continuous record pool and tailwater elevations are to be mailed to Water Control at least once a year.

At 0645-hours everyday, the river regulator analyzes the field data and at around 0800-hours, the daily orders for gate movements are sent to the site via e-mail. On weekends and holidays, during winter operations, orders are sent by 0730-hours due to limited staffing at the site. Gate changes are to be made as soon as possible. If Water Control has notified the site that they will contact them later in the day (typically 1400-hrs), site personnel will have the noon and present pool and tailwater elevations as well any other pertinent information (e.g. wind speed and direction, precipitation, etc.).

Normal duty hours for Water Control are 0630 to 1500-hours during the week and 0630 to 0930-hours on weekends and holidays. During the course of non-duty hours, site personnel may make gate changes as necessary to stay within the pool band prescribed. The site is limited however to changes up to ten percent of the 1600-hour discharge. If a gate change greater than this is necessary, site personnel should contact the river regulator at home. If the need for a gate change becomes necessary after 0400-hours, no gate change is to be made. Water Control will provide the necessary gate change and band limit with the morning's orders. 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 7-8**. The weekend pager number is 612-660-8053. Lock personnel contacting Water Control personnel at home should have pool and tailwater readings, wind speed and direction, amount of precipitation since last report, and all gate changes following the morning's orders. If lock personnel have any questions regarding the Water Control order, they are to contact the regulator via telephone (651-290-

5624) and the question will be resolved. During computer outages, log sheets will be faxed to Water Control Section (651-290-5841) and orders will be given via telephone or FM radio.

Table 7-8 Water Control Personnel Telephone Numbers		
Name	Non-Duty Telephone	Office Telephone
Scott Bratten	651-436-6135	651-290-5624
Farley Haase	715-235-1928	651-290-5633
Ferris Chamberlin	651-653-7981	651-290-5619
Robert Engelstad	651-459-6343	651-290-5610

In the event of a gate failure or any occurrence that will require the installation of the bulkheads, communications must be established as quickly as possible with Water Control Section and Construction and Operations (Con-Ops) Division. Under full head conditions at the dam, the force is too great to allow the installation of the bulkheads. Therefore, the operating head must be reduced. Water Control will coordinate gate movements with site personnel in preparation for installation and removal of the bulkheads.

7-05. Flood Control. Lock and Dam No. 9 has no flood control benefits. It is operated strictly for navigation. While it may seem possible that the pools be drawdown over the winter months to provide storage for spring runoff, this plan has no merit for two reasons. First, the Anti-Drawdown Law (Public Law 697) of June 1948 prevents the drawdown of the pools during the winter months. 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. 9 is fishing, hunting, and boating. Construction of the lock and dam inundated the numerous wing dams that were constructed as part of the six-foot channel project. The wing dams as well as some of the backwater areas provide excellent fish and waterfowl habitat. As for recreational boating, there is typically around 6,000 recreation boats locked through each year (5,715 in 2002). **Table 7-9** shows a comparison of recreational to towboat lockages.

Table 7-9
Commercial & Recreational Lockages at Lock No. 9

Year	Commercial Lockages	Recreation Lockages*	Other Lockages	Total Lockages	Percent Recreation
1991	2,560	2,230	126	4,916	45 %
1992	2,875	2,190	105	5,170	42 %
1993	1,771	1,206	59	3,036	40 %
1994	2,375	2,324	61	4,760	49 %
1995	2,601	2,086	136	4,823	43 %
1996	2,709	1,903	99	4,711	40 %
1997	2,548	2,052	90	4,690	44 %
1998	2,784	2,120	87	4,991	42 %
1999	2,957	2,098	105	5,160	41 %
2000	2,627	2,002	68	4,697	43 %
2001	2,064	1,742	143	3,949	44 %
2002	2,510	1,972	162	4,644	42 %

* Note that many recreation boats are locked through with each lockage.

7-07. Water Quality. The Corps of Engineers does not perform any water quality analysis in Pool No. 9. 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 sates of Illinois, Iowa, Minnesota, Missouri, and Wisconsin with guidance and overall program responsibility by the Corps of Engineers.

7-08. Fish and Wildlife. By letter dated 20 May 1964, the regional director of the Bureau of Sport Fisheries and Wildlife (now the US Fish and Wildlife Service) recommended that St. Paul District install aeration culverts through the embankments at many of the locks and dams. An arched, flat-bottomed, corrugated metal culvert, 65-inches wide and 40-inches high was installed through the submersible dam at Harpers Slough. The culvert provides a constant flow of 110 cfs when the pool is at project level (**Paragraph 3-02**). The culvert provides aeration to Harpers Slough throughout the year. It is particularly beneficial during the winter when the slough is covered with ice.

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

Several Habitat Rehabilitation and Enhancement Projects have been constructed within the pool. They include, channel excavation (Blackhawk Park), side channel modifications (Lansing Big Lake), island construction (Pool No. 9 Island), and a diversion weir (Cold Springs). For a more complete description of these projects see **Section 2.04. Related Control Facilities**.

7-09. Water Supply. The cities of New Albin and Lansing, Iowa and Genoa, Victory, De Soto, Ferryville, and Lynxville, Wisconsin obtain their water from wells. Pool No. 9 does not provide water supply.

7-10. Hydroelectric Power. There is no hydroelectric power at Lock and Dam No. 9.

7-11. Navigation. The primary purpose of Lock and Dam No. 9 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 off 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 a head of nine feet is approximately seven minutes. Under normal conditions it is about eight and ten minutes. Lockage time for a double lockage depends on the experience of the deck hands breaking and making couplings, number of loaded and empty barges, wind speed and direction, flow conditions, and whether it is an up bound or down bound tow. On average, a single lockage takes approximately 30 minutes, while a double lockage takes about 1.5 hours.

7-12. Flood Emergency Action Plans. The Emergency Action Plan is a stand-alone document entitled *Emergency Plan for Lock and Dam 9, Lynxville, Wisconsin*, August 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. Potential causes of an emergency affecting the operation or safety of Lock and Dam No. 9 include excess seepage, sabotage, extreme storm, failure of earthen dike, and failure due to scouring.

There are several protective measures taken at Lock and Dam No. 9 when a flood occurs. The following table gives a brief summary of the steps to be taken as water levels rise.

Table 7-10
Emergency Flood Actions

Pool Elevation	Action Taken
622.0 feet	Protect dike slough areas. Seal drains & install pump. In transformer pit: Install cross over pump. Install plugs in drains to valve bulkhead slots.
623.5 feet	Control seepage in CCS.
625.0 feet	Protect diesel fuel storage tank.
631.0 feet	Remove miter gate over travel limit. Remove hand rails. Secure gratings and sand bag CCS.
632.0 feet	Sand bag shop, comfort station and pump house. Protect storage yard. Remove water heaters & burners.
632.5 feet	Protect comfort station holding tank.
633.0 feet	Protect above ground gasoline storage and two LP tanks.

7-13. Other. During a flood event, debris is passed beneath the gates as they are typically raised clear of the water. Debris that hangs up around the tainter gates may require assistance. This is handled after the peak has passed. During ice breakup, ice is passed over the submerged roller gates.

7-14. Deviation from Normal Regulation. Project pool elevation is mandated by Congress. When in primary control, the pool is to be maintained at elevation 620.0 ± 0.2 feet at the Lansing gage as best as possible. During low flows, the pool is not to be intentionally raised above or lowered below this elevation; however, temporary deviations are permitted. Because these deviations are unplanned and are only temporary, while actions are being taken to correct the situation, these exceptions do not require notification to be sent to the Division Office. The Division Office (MVD) must be notified when deviation outside the limits set by primary and secondary control is intentional and for a prolonged period of time. Planned deviations will be coordinated with MVD. A written request describing cause and effect will be sent to the Division Water Control Manager for approval. The District Commander or Chief of Engineering Division may deviate from the approved plan in an emergency situation. The District will inform MVD as soon as possible. This will include a written confirmation of the deviation and description of the cause.

7-15. Rate of Release Change. The only guideline for rate of release change is the "ten percent rule" (**Section 7-04**). During Water Control's non-duty hours, lock and dam personnel may only make a gate change to remain within the prescribed band such that it does not exceed ten percent of the total flow at 1600-hrs. 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. 9 is to maintain a nine-foot depth in the navigation channel of Pool No. 9. Lock and Dam No. 9 is just one piece of the lock and dam system that provides navigation from St. Louis, Missouri to Minneapolis, Minnesota. Navigation on the Upper Mississippi River progressed from a four-foot deep channel in 1866, to a four and one-half foot channel in 1878, to a six-foot channel in 1907, and finally, to a nine-foot channel in the 1930's. A more complete description of this development is available in the Master Water Control Manual for the Locks and Dams.

8-02. Flood Control. The locks and dams provide no flood control benefits. They were constructed strictly for navigation purposes. The dam operates on a run-of-the-river principal. As discharge increases, the gates are opened. At around 64,000 cfs the gates are raised clear of the water surface. Therefore, for flood events, the only impact on the flow line is the swellhead at the dam, which is less than one foot.

8-03. Recreation. The project is not regulated for recreation purposes; however, it does provide recreational benefits. The three recreation qualities associated with Pool No. 9 are fishing, hunting, and boating. Project pool inundated the wing dams, constructed as part of the six-foot navigation project, and created backwater areas, which provide good fish and waterfowl habitat. While Lock and Dam No. 9 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 1,972 recreation boat lockages in 2002 in which 5,715 recreation boats locked through.

8-04. Fish and Wildlife. The McGregor District of the Upper Mississippi River National Wildlife and Fish Refuge includes Pool Numbers 9, 10, and 11. The refuge was established in 1924 to preserve the Upper Mississippi River for fish, migratory birds, other wildlife, and people. The Refuge includes acreage acquired during the 1930's by the US Army Corps of Engineers for the construction of the 9-foot navigation channel. The McGregor District consists of 78,224 acres of wooded islands, forest, prairie, marsh, and water from Genoa, Wisconsin to Dubuque, Iowa. Of this, 24,808 acres are located in Pool No. 9 (see **2-05. Real Estate Acquisition**).

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. 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 over 17 million in 2002. **Table 8-1** shows the recent history of tonnage commodities at Lock and Dam No. 9. Commodity codes used to track product types were changed in 1991. 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. 9 Tonnage – Commodities

Year	Coal	Petrol Product	Chemical Products	Metallic Ores and Products	Non Metallic Minerals	Stone Clay Cement	Farm Products	Misc Product	Total Tonnage
1980	2,758,000	1,532,000	1,051,000	1,191,000	313,000	231,000	9,668,000	195,000	15,939,000
1981	2,540,000	1,948,000	1,032,000	231,000	317,000	208,000	10,230,000	181,000	16,677,000
1982	2,509,000	1,211,000	1,029,000	96,000	336,000	189,000	9,315,000	110,000	14,795,000
1983	2,457,000	1,034,000	1,246,000	151,000	497,000	210,000	13,768,000	109,000	19,472,000
1984	2,186,000	1,068,000	1,729,000	154,000	501,000	299,000	11,736,000	87,000	17,760,000
1985	2,034,000	1,042,000	1,644,000	146,000	636,000	314,000	7,919,000	66,000	13,801,000
1986	2,357,000	933,000	1,669,000	162,000	608,000	298,000	6,769,000	65,000	12,861,000
1987	2,023,000	1,233,000	1,431,000	233,000	461,000	404,000	8,128,000	76,000	13,989,000
1988	2,116,000	1,158,000	1,417,000	203,000	561,000	461,000	9,315,000	123,000	15,354,000
1989	2,136,000	1,158,000	1,428,000	221,000	691,000	535,000	9,337,000	86,000	15,592,000
1990	2,184,000	1,464,000	1,405,000	256,000	765,000	620,000	11,560,000	86,000	18,340,000
Year	Coal	Petrol Product	Chemical Products	Crude Materials	Manuf Goods	Farm Products	Eqip Mach	Misc Product	Total Tonnage
1991	2,136,000	634,300	1,484,700	781,600	642,300	10,465,500	16,500	69,000	16,229,900
1992	2,110,100	459,800	1,901,300	1,023,200	608,900	11,375,900	10,000	25,500	17,514,700
1993	2,030,300	196,300	1,916,300	877,900	411,200	5,519,700	15,000	18,500	10,985,200
1994	2,318,800	234,600	2,254,100	1,014,700	618,200	6,952,700	10,700	40,900	13,454,700
1995	2,305,200	538,000	1,822,100	1,064,500	626,900	8,717,300	23,400	159,200	15,256,600
1996	2,365,700	437,700	1,822,200	1,053,100	430,000	10,028,500	7,400	83,100	16,227,700
1997	2,286,600	531,000	1,659,900	1,403,600	576,000	8,829,700	10,300	144,900	15,442,000
1998	2,988,700	843,200	1,896,000	1,214,600	854,800	9,162,900	10,200	58,000	17,028,400
1999	3,131,200	575,200	1,639,800	1,111,800	1,026,600	11,172,400	12,400	151,500	18,820,900
2000	2,797,914	635,830	1,954,702	1,212,106	833,234	9,968,130	3,200	335,411	17,740,527
2001	2,532,238	196,636	1,626,329	1,571,783	660,562	7,683,527	7,228	271,451	14,549,356
2002	2,744,583	415,017	1,789,510	1,582,458	848,195	9,673,242	17,180	281,936	17,352,121

8-06. Frequencies. The St. Paul District developed a discharge-frequency relationship in 2002 for the Mississippi River at the Upper Iowa River confluence. The Upper Iowa River enters Pool No. 9 at river mile 671.0, which is 8 miles below Lock No. 8 and is 23 miles upstream of Lock No. 9. The frequency curve displayed in **Figure 8-1** represents peak flow relationships for the Mississippi River at river mile 671.0. The frequency curve is derived from regionalized statistics for the mean and standard deviation, based on drainage area relationships at this location.

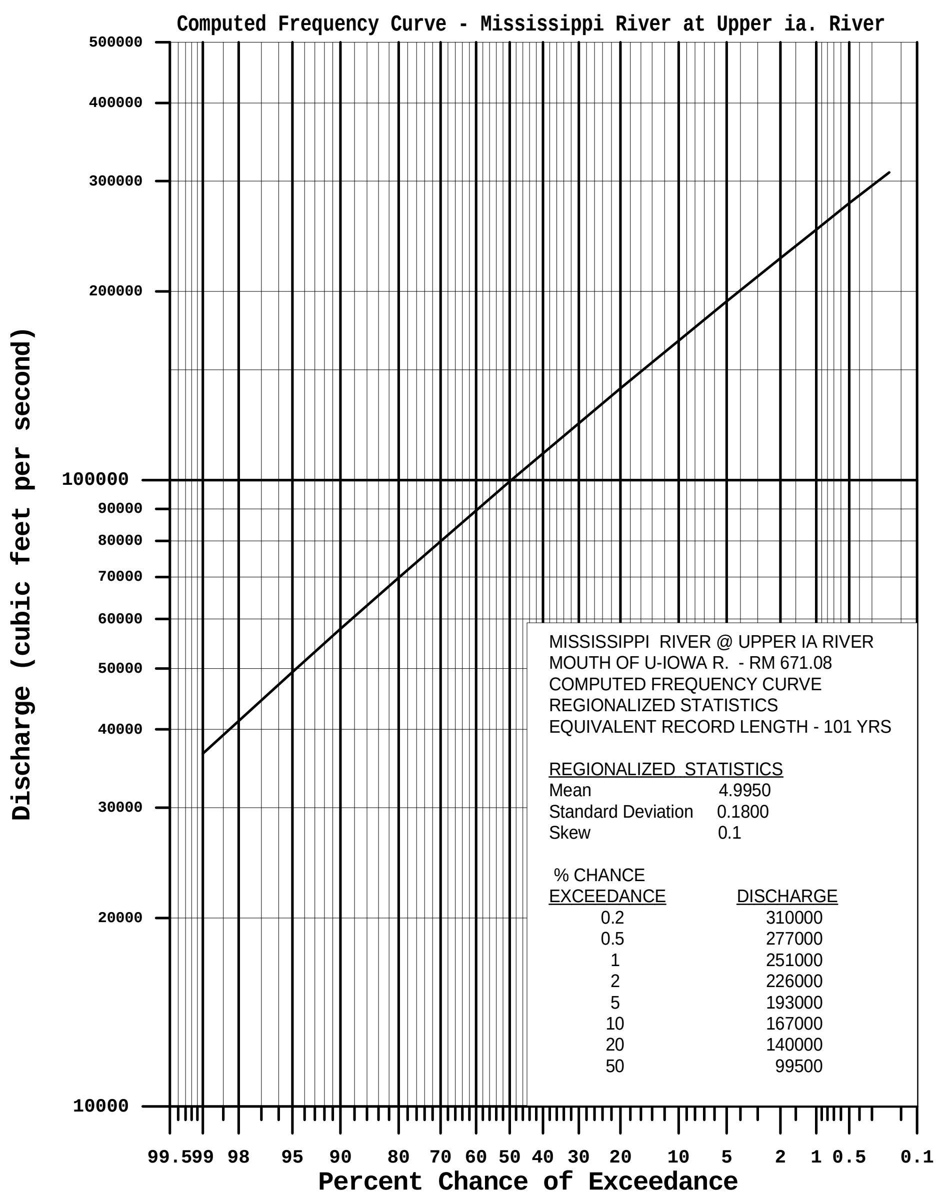


Figure 8-1. Mississippi River at Upper Iowa River – Discharge/Frequency

Construction of the dam was completed in April 1937. By November, project pool elevation was achieved. **Figure 8-2** 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 617.5 feet (1912 adjustment). In the spring of 1971, drawdown of the pool was reduced to one foot thus making the secondary control elevation 619.0 feet. Prior to the Anti-Drawdown Law, passed by Congress in 1948, the pools were sometimes drawn down below primary and secondary elevations during the winter months. The greatest drawdown occurred on 23 January 1944 when the pool was draw down to elevation 612.28 feet.

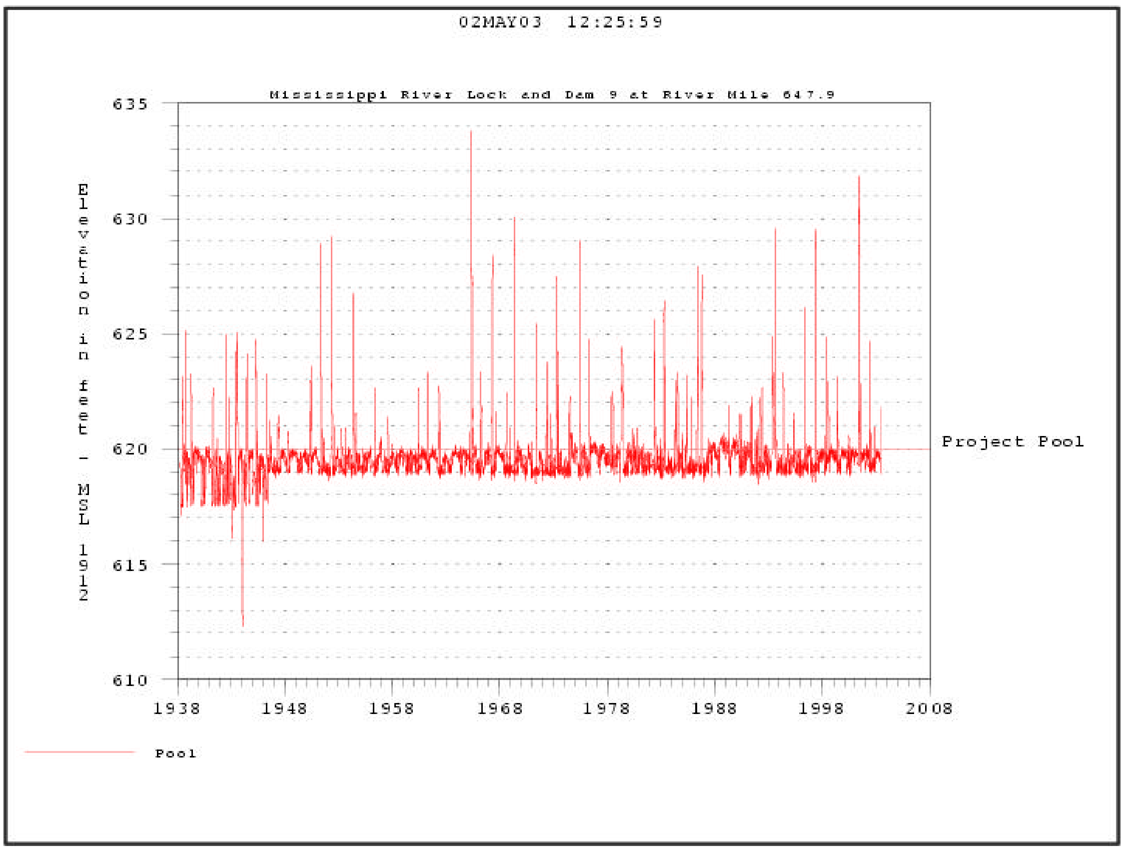


Figure 8-2. History of Pool Elevation

Water surface profile frequencies were developed in 1979 for Pool No. 9. The following figure shows how these profiles compare with historic floods. Note that the flood of 2001 was not documented at the time of this report.

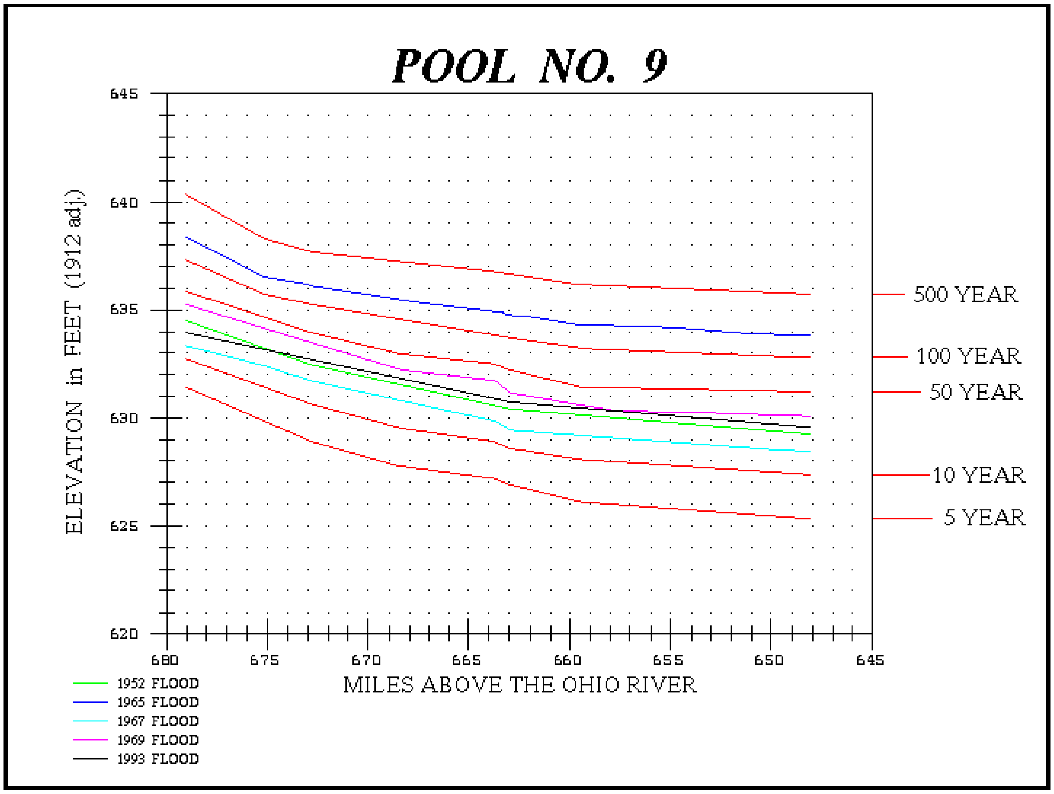


Figure 8-3. Water Surface Profiles
Flood frequencies and Historic Floods

IX – WATER CONTROL MANAGEMENT

9-01. Responsibilities and Organization.

a. Corps of Engineers. The Corps of Engineers is the owner, operator, and regulator for Lock and Dam No. 9. The St. Paul District, Water Control Section has direct day-to-day responsibility for gate adjustments at the dam. Construction and Operations Division is responsible for operation and maintenance of the lock and the dam. The following shows the working relationship for the locks and dams within the St. Paul District.

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

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

Water Control Manager → → → → → **Lock Leader**

b. Other Federal Agencies. During high water, the National Weather Service (NWS) forecasts stage heights for the control point at Lansing, Iowa. Water Control Section provides the NWS with the daily output from the Mississippi Basin Modeling System to aid them in making their forecast. The US Geological Survey (USGS) maintains the gage site at Dorchester. Daily discharge values can also be obtained from their web site at ia.water.usgs.gov. The US Fish and Wildlife Service (USFWS) operates and maintains the Upper Mississippi River National Wildlife and Fish Refuge, part of which is located in Pool 9.

9-02. Interagency Coordination.

a. Local Press and Corps Bulletins. Information concerning regulation of Lock and Dam No. 9 is provided by the St. Paul District's Public Affairs

Office (PAO) to the local news media in response to their requests. In addition, Construction and Operations Division coordinates with PAO to provide News Releases regarding the opening or closing of the lock to navigation.

b. **National Weather Service.** The National Weather Service (NWS) provides the St. Paul District a "Work 10" file daily by 0830-hours. The file contains the five-day forecast for tributaries to the Mississippi River lock and dam system. The five-day forecast includes the 24-hour quantitative precipitation forecast (QPF). These stage hydrographs are input to Mississippi Basin Modeling System, which is an unsteady flow model utilizing the computer program UNET. After the model is run, the output is sent to the NWS by 0930-hours. The NWS uses this information to forecast stages along the Mississippi River, which includes Lansing, Iowa in Pool No. 9. During flood events the NWS will sometimes include additional forecast locations at he locks and dams including Lock and Dam No. 9 (Lynxville).

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.9, this includes the Upper Iowa River at Dorchester. The USGS publishes the daily discharges for this site annually as part of the *Water Resources Data, Iowa*. Data are also available from their web site at ia.water.usgs.gov.

d. **US Fish and Wildlife Service.** The St. Paul District, in coordination with the US Fish and Wildlife Service, constructed Habitat Rehabilitation and Enhancement Project on the Upper Mississippi River System under the Upper Mississippi River System Environmental Management Program (EMP) authorized by the Water Resources Development Act of 1986. Most of the monitoring for project evaluation is performed by the US Fish and Wildlife Service and by the States of Iowa and Wisconsin. The Corps of Engineers developed the scope of work and schedule for the environmental monitoring, including water quality testing, needed for the performance evaluations. Additional information concerning the project can be viewed at the website: http://www.mvp.usace.army.mil/enviro_protection/umrs_program/.

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

9-03. Reports. A "Daily Log Sheet" contains a record of river and dam conditions. These are kept at the site. Nation Weather Service (NWS) Form B-91 contains pertinent weather information at the lock site. These are mailed to the NWS on the first of each month. The "Stevens Strip Charts" are sent to Water Control at a minimum of once a year.

EXHIBIT A
SUPPLEMENTARY PERTINENT DATA

General Information

Location:	Mississippi River Mile 647.9 Lat 43° 12' 42" N Long 91° 05' 42" W Lynxville, Wisconsin 31.3 miles below Lock and Dam No. 8 32.8 miles above Lock and Dam No. 10
Type of Project:	Lock and Dam for Navigation Purposes
Project Owner:	US Army Corps of Engineers
Operating Agency:	St. Paul District; Construction-Operations Division 24 hrs a day, 7 days a week
Regulating Agency:	St. Paul District; Water Control Section
Completion Date:	Lock: 4 March 1935 Moveable Dam: 30 April 1937 Earthen Dike: 22 December 1936

Hydrology

Drainage Area:	66,610 square miles
Design Flood:	Flood of 1880 Design High Water: Elevation 635.8 ft Design Discharge: 193,000 cfs
Minimum Flow:	Of Record: 1933 Discharge 3,300 cfs (stage 606.99) Post Const: August 1977 Discharge 5,400 cfs
Maximum Instantaneous Flow:	21 April 1965: Discharge 275,500 cfs
Average Annual Flow:	Years 1959-1993: 37, 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. 8 Upper Iowa River @ Dorchester, Iowa

Data Recorded at Dam Site:	Pool & Tailwater Elevations (4-hr) Gate Settings (8-hr) Discharge (8-hr) Wind Speed & Direction (8-hr) Air Temperature (8-hr) Control Pt Elevation at Lansing (daily) Mississippi River Stage at McGregor (daily) Upper Iowa River Stage at Dorchester (daily) Wisconsin River Stage at Muscada (daily) Kickapoo River Stage at Steuben (daily) Water Temperature (daily) Precipitation (daily) Max-Min Air Temperature (daily) Snow Depth & Water Content (weekly) Pool & Tailwater Ice Coverage (weekly) Pool & Tailwater Ice Thickness (weekly)
Precipitation Gages:	Lock & Dam No. 8 and 9
Snow Survey:	At Lock & Dam No. 9 (weekly by site personnel) Viroqua, Wisconsin (late Feb by Gage Crew)

Physical Features

Moveable Dam:	Roller Gates: 5 Gates	80 feet by 20 feet
	Tainter Gates: 8 Gates	35 feet by 15 feet
	Roller Gate Sill:	Elevation 600.0 ft
	Tainter Gate Sill:	Elevation 605.0 ft
	Roller Gate End Sill:	Elevation 598.0 ft
	Tainter Gate End Sill:	Elevation 603.0 ft
	Roller Gate Submergence:	5 feet below PP
	Bulkheads: Roller Gates: 5 @	4’-2” by 85’- 0.5”
	Tainter Gates: 4 @	4’-2” by 37’- 6.0”
	Top of Bridge Deck:	Elevation 651.5 ft
Pool:	Normal (Project) Upper Pool:	Elevation 620.0 ft
	Normal (Project) Lower Pool:	Elevation 611.0 ft
	Primary Control Point (Lansing):	Elevation 620.0 ft
	Secondary Control Point:	Elevation 619.0 ft
	Pool Area (at Project Pool):	29,125 ac
	Length in River Miles:	31.3 miles
	Navigation Channel Width;	
	Straight Reaches:	300 feet
	Curved Reaches:	300-550 feet
	Most Frequent Dredge Sites:	Lansing Upper Light Indian Camp Light

Lock:	Main Lock Chamber:	110 ft by 600 ft
	Top of Lock Walls:	Elevation 633.0 ft
	Top of Upper Gate Sill (main):	Elevation 604.0 ft
	Top of Upper Gate Sill (aux):	Elevation 601.0 ft
	Top of Lower Gate Sill:	Elevation 598.0 ft
	Lock Chamber Floor:	Elevation 597.0 ft
	Height of Upper Miter Gates (main):	27.0 feet
	Height of Upper Miter Gates (aux):	30.0 feet
	Height of Lower Miter Gates:	33.0 feet
	Lift:	9 feet
	Upper Guidewall Length:	521 feet
	Lower Guidewall Length:	504 feet
	Freeboard @ Project Pool:	13 feet
	Normal Filling/Emptying Time:	8 -10 minutes
	Average Single Lock Time:	30 minutes
	Average Double Lockage Time:	1.5 hours

Earthen Dam:	Length:	9,100 feet
	Crest Elevation:	633.0 ft (1912)
	Top Width:	20 feet
	Maximum Height:	27 feet
	Pool Side Slope:	1V:3H
	Tailwater Slope:	1V:5.5 H
	Slope Protection:	12 inch riprap
	To crest on pool side.	
	To elevation 614.0 ft on tailwater side.	

Fixed Crest Spillway:	Length:	1,350 feet
(within earthen dam)	Crest Elevation:	620.0 feet (1912)
	Culvert in Spillway:	65 inches by 40-inches
	Flow @ Project Pool:	125 cfs

STATION NUMBER 05388250 Upper Iowa River near Dorchester, IA; SOURCE AGENCY USGS; LATITUDE 432516 LONGITUDE 0913031
DRAINAGE AREA 770 CONTRIBUTING DRAINAGE AREA 770 DATUM 660.00 NGVD29 Date Processed: 2003-01-23 14:44 By vemiller
RATING ID: 4.0 Remarks: EXTENDED LOWER END OF RATING FROM 6.8 TO 6.6

GAGE HEIGHT (FEET)	DISCHARGE IN CFS .00	.01	.02	.03	.04	(STANDARD PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
6.60	56.0*	57.7	59.4	61.2	62.9	64.7	66.5	68.4	70.2	72.1	18.0
6.70	74.0*	76.1	78.2	80.3	82.5	84.7	86.9	89.1	91.4	93.7	22.0
6.80	96.0*	98.3	101	103	105	108	110	113	115	117	24.0
6.90	120*	122	125	128	130	133	135	138	141	143	26.0
7.00	146*	149	151	154	157	160	163	165	168	171	28.0
7.10	174*	177	180	183	186	190	193	196	199	203	32.0
7.20	206*	209	213	216	220	224	227	231	235	238	36.0
7.30	242*	246	249	253	257	261	264	268	272	276	38.0
7.40	280*	284	287	291	295	299	302	306	310	314	38.0
7.50	318	322	326	330	334	338	342	346	350	354	40.0
7.60	358	362	366	370	374	379	383	387	391	396	42.0
7.70	400*	405	409	414	419	423	428	433	438	443	47.0
7.80	447	452	457	462	467	472	477	482	487	492	50.0
7.90	497	503	508	513	518	523	529	534	539	545	53.0
8.00	550*	555	561	566	572	577	583	588	594	599	55.0
8.10	605*	611	617	622	628	634	640	646	652	658	59.0
8.20	664	670	676	682	688	694	700	706	713	719	61.0
8.30	725*	732	738	745	751	758	765	772	778	785	67.0
8.40	792	799	806	813	820	827	834	841	848	855	70.0
8.50	862	869	876	884	891	898	905	913	920	928	73.0
8.60	935*	942	948	955	961	968	974	981	988	994	65.0
8.70	1000	1010	1010	1020	1030	1030	1040	1050	1060	1060	70.0
8.80	1070	1080	1080	1090	1100	1100	1110	1120	1130	1130	70.0
8.90	1140	1150	1150	1160	1170	1180	1180	1190	1200	1200	70.0
9.00	1210	1220	1230	1230	1240	1250	1260	1260	1270	1280	80.0
9.10	1290	1290	1300	1310	1320	1320	1330	1340	1350	1350	70.0
9.20	1360	1370	1380	1380	1390	1400	1410	1420	1420	1430	80.0
9.30	1440	1450	1460	1460	1470	1480	1490	1500	1500	1510	80.0
9.40	1520	1530	1540	1540	1550	1560	1570	1580	1580	1590	80.0
9.50	1600	1610	1620	1630	1630	1640	1650	1660	1670	1680	90.0

EXHIBIT B

GAGE HEIGHT (FEET)	DISCHARGE IN CFS .00	.01	.02	.03	.04	(STANDARD PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
9.60	1690*	1690	1700	1710	1720	1720	1730	1740	1750	1760	70.0
9.70	1760	1770	1780	1790	1800	1800	1810	1820	1830	1840	80.0
9.80	1840	1850	1860	1870	1880	1890	1890	1900	1910	1920	90.0
9.90	1930	1940	1940	1950	1960	1970	1980	1990	1990	2000	80.0
10.00	2010	2020	2030	2040	2040	2050	2060	2070	2080	2090	90.0
10.10	2100	2100	2110	2120	2130	2140	2150	2160	2160	2170	80.0
10.20	2180	2190	2200	2210	2220	2230	2230	2240	2250	2260	90.0
10.30	2270	2280	2290	2300	2310	2310	2320	2330	2340	2350	90.0
10.40	2360	2370	2380	2390	2400	2400	2410	2420	2430	2440	90.0
10.50	2450*	2460	2470	2480	2490	2500	2510	2520	2530	2540	100
10.60	2550	2560	2570	2580	2590	2600	2610	2620	2630	2640	100
10.70	2650	2660	2670	2680	2680	2690	2700	2720	2730	2740	100
10.80	2750	2760	2770	2780	2790	2800	2810	2820	2830	2840	100
10.90	2850	2860	2870	2880	2890	2900	2910	2920	2930	2940	100
11.00	2950*	2960	2970	2980	2990	3000	3010	3020	3030	3040	100
11.10	3050	3060	3070	3080	3100	3110	3120	3130	3140	3150	110
11.20	3160	3170	3180	3190	3200	3210	3220	3230	3240	3250	100
11.30	3260	3280	3290	3300	3310	3320	3330	3340	3350	3360	110
11.40	3370	3380	3390	3400	3420	3430	3440	3450	3460	3470	110
11.50	3480	3490	3500	3510	3530	3540	3550	3560	3570	3580	110
11.60	3590	3600	3610	3630	3640	3650	3660	3670	3680	3690	110
11.70	3700	3720	3730	3740	3750	3760	3770	3780	3800	3810	120
11.80	3820	3830	3840	3850	3860	3880	3890	3900	3910	3920	110
11.90	3930	3940	3960	3970	3980	3990	4000	4010	4030	4040	120
12.00	4050*	4060	4070	4090	4100	4110	4120	4130	4140	4160	120
12.10	4170	4180	4190	4200	4210	4230	4240	4250	4260	4270	120
12.20	4290	4300	4310	4320	4330	4350	4360	4370	4380	4390	120
12.30	4410	4420	4430	4440	4450	4470	4480	4490	4500	4520	120
12.40	4530	4540	4550	4560	4580	4590	4600	4610	4630	4640	120
12.50	4650*	4660	4680	4690	4700	4720	4730	4740	4760	4770	130
12.60	4780	4800	4810	4820	4840	4850	4860	4880	4890	4900	140
12.70	4920	4930	4940	4960	4970	4980	5000	5010	5030	5040	130
12.80	5050	5070	5080	5090	5110	5120	5130	5150	5160	5180	140
12.90	5190	5200	5220	5230	5250	5260	5270	5290	5300	5320	140
13.00	5330	5340	5360	5370	5390	5400	5410	5430	5440	5460	140

GAGE HEIGHT (FEET)	DISCHARGE IN CFS .00	.01	.02	.03	.04	(STANDARD PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
13.10	5470	5480	5500	5510	5530	5540	5560	5570	5580	5600	140
13.20	5610	5630	5640	5660	5670	5680	5700	5710	5730	5740	150
13.30	5760	5770	5790	5800	5810	5830	5840	5860	5870	5890	140
13.40	5900	5920	5930	5950	5960	5980	5990	6010	6020	6040	150
13.50	6050*	6070	6080	6100	6110	6130	6140	6160	6170	6190	160
13.60	6210	6220	6240	6250	6270	6290	6300	6320	6330	6350	150
13.70	6360	6380	6400	6410	6430	6440	6460	6480	6490	6510	160
13.80	6520	6540	6560	6570	6590	6610	6620	6640	6650	6670	170
13.90	6690	6700	6720	6740	6750	6770	6780	6800	6820	6830	160
14.00	6850*	6870	6880	6900	6920	6930	6950	6970	6980	7000	170
14.10	7020	7030	7050	7070	7080	7100	7120	7130	7150	7170	160
14.20	7180	7200	7220	7240	7250	7270	7290	7300	7320	7340	170
14.30	7350	7370	7390	7410	7420	7440	7460	7470	7490	7510	180
14.40	7530	7540	7560	7580	7600	7610	7630	7650	7670	7680	170
14.50	7700*	7720	7740	7750	7770	7790	7810	7820	7840	7860	180
14.60	7880	7890	7910	7930	7950	7960	7980	8000	8020	8040	170
14.70	8050	8070	8090	8110	8130	8140	8160	8180	8200	8220	180
14.80	8230	8250	8270	8290	8310	8320	8340	8360	8380	8400	190
14.90	8420	8430	8450	8470	8490	8510	8530	8540	8560	8580	180
15.00	8600*	8620	8640	8660	8680	8700	8710	8730	8750	8770	190
15.10	8790	8810	8830	8850	8870	8890	8910	8930	8940	8960	190
15.20	8980	9000	9020	9040	9060	9080	9100	9120	9140	9160	200
15.30	9180	9200	9220	9240	9260	9280	9300	9320	9340	9360	200
15.40	9380	9390	9410	9430	9450	9470	9490	9510	9530	9550	190
15.50	9570	9590	9610	9630	9650	9670	9690	9710	9730	9750	210
15.60	9780	9800	9820	9840	9860	9880	9900	9920	9940	9960	200
15.70	9980	10000	10000	10000	10100	10100	10100	10100	10100	10200	220
15.80	10200	10200	10200	10200	10300	10300	10300	10300	10300	10400	200
15.90	10400	10400	10400	10500	10500	10500	10500	10500	10600	10600	200
16.00	10600*	10600	10600	10700	10700	10700	10700	10800	10800	10800	200
16.10	10800	10800	10900	10900	10900	10900	10900	11000	11000	11000	200
16.20	11000	11100	11100	11100	11100	11100	11200	11200	11200	11200	300
16.30	11300	11300	11300	11300	11300	11400	11400	11400	11400	11500	200
16.40	11500	11500	11500	11500	11600	11600	11600	11600	11700	11700	200
16.50	11700*	11700	11700	11800	11800	11800	11800	11900	11900	11900	200

GAGE HEIGHT (FEET)	DISCHARGE IN CFS .00	.01	.02	.03	.04	(STANDARD PRECISION) .05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
16.60	11900	12000	12000	12000	12000	12100	12100	12100	12100	12100	300
16.70	12200	12200	12200	12200	12300	12300	12300	12300	12400	12400	200
16.80	12400	12400	12500	12500	12500	12500	12600	12600	12600	12600	300
16.90	12700	12700	12700	12700	12800	12800	12800	12800	12900	12900	200
17.00	12900*	12900	13000	13000	13000	13000	13100	13100	13100	13100	300
17.10	13200	13200	13200	13200	13300	13300	13300	13300	13400	13400	200
17.20	13400	13400	13500	13500	13500	13500	13600	13600	13600	13600	300
17.30	13700	13700	13700	13800	13800	13800	13800	13900	13900	13900	200
17.40	13900	14000	14000	14000	14000	14100	14100	14100	14100	14200	300
17.50	14200*	14200	14300	14300	14300	14300	14400	14400	14400	14400	300
17.60	14500	14500	14500	14600	14600	14600	14600	14700	14700	14700	300
17.70	14800	14800	14800	14800	14900	14900	14900	14900	15000	15000	200
17.80	15000	15100	15100	15100	15100	15200	15200	15200	15300	15300	300
17.90	15300	15300	15400	15400	15400	15500	15500	15500	15500	15600	300
18.00	15600*	15600	15700	15700	15700	15700	15800	15800	15800	15900	300
18.10	15900	15900	16000	16000	16000	16000	16100	16100	16100	16200	300
18.20	16200	16200	16300	16300	16300	16300	16400	16400	16400	16500	300
18.30	16500	16500	16600	16600	16600	16600	16700	16700	16700	16800	300
18.40	16800	16800	16900	16900	16900	16900	17000	17000	17000	17100	300
18.50	17100*	17100	17200	17200	17200	17300	17300	17300	17300	17400	300
18.60	17400	17400	17500	17500	17500	17600	17600	17600	17700	17700	300
18.70	17700	17700	17800	17800	17800	17900	17900	17900	18000	18000	300
18.80	18000	18100	18100	18100	18200	18200	18200	18200	18300	18300	300
18.90	18300	18400	18400	18400	18500	18500	18500	18600	18600	18600	400
19.00	18700	18700	18700	18800	18800	18800	18900	18900	18900	19000	300
19.10	19000	19000	19000	19100	19100	19100	19200	19200	19200	19300	300
19.20	19300	19300	19400	19400	19400	19500	19500	19500	19600	19600	300
19.30	19600	19700	19700	19700	19800	19800	19800	19900	19900	19900	400
19.40	20000	20000	20000	20100	20100	20100	20200	20200	20200	20300	300
19.50	20300*	20300	20400	20400	20400	20500	20500	20500	20600	20600	300
19.60	20600	20700	20700	20700	20800	20800	20800	20900	20900	20900	400
19.70	21000	21000	21000	21100	21100	21100	21200	21200	21200	21300	300
19.80	21300	21300	21400	21400	21400	21500	21500	21600	21600	21600	400
19.90	21700	21700	21700	21800	21800	21800	21900	21900	21900	22000	300
20.00	22000*	22000	22100	22100	22200	22200	22200	22300	22300	22400	400

GAGE HEIGHT (FEET)	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER .1 UNITS
			DISCHARGE IN CFS			(STANDARD PRECISION)					
20.10	22400	22400	22500	22500	22500	22600	22600	22700	22700	22700	400
20.20	22800	22800	22900	22900	22900	23000	23000	23100	23100	23100	400
20.30	23200	23200	23300	23300	23300	23400	23400	23500	23500	23600	400
20.40	23600	23600	23700	23700	23800	23800	23800	23900	23900	24000	400
20.50	24000*	24000	24100	24100	24200	24200	24300	24300	24400	24400	500
20.60	24500	24500	24600	24600	24700	24700	24700	24800	24800	24900	400
20.70	24900	25000	25000	25100	25100	25200	25200	25300	25300	25400	500
20.80	25400	25500	25500	25600	25600	25700	25700	25700	25800	25800	500
20.90	25900	25900	26000	26000	26100	26100	26200	26200	26300	26300	500
21.00	26400	26400	26500	26500	26600	26600	26700	26700	26800	26800	500
21.10	26900	26900	27000	27000	27100	27100	27200	27200	27300	27300	500
21.20	27400	27400	27500	27500	27600	27600	27700	27700	27800	27800	500
21.30	27900	27900	28000	28000	28100	28100	28200	28200	28300	28300	500
21.40	28400	28400	28500	28500	28600	28700	28700	28800	28800	28900	500
21.50	28900	29000	29000	29100	29100	29200	29200	29300	29300	29400	500
21.60	29400	29500	29500	29600	29600	29700	29800	29800	29900	29900	600
21.70	30000	30000	30100	30100	30200	30200	30300	30300	30400	30400	500
21.80	30500*										

"*" indicates a rating descriptor point

DAILY LOG SHEET LOCK AND DAM #9

DATE: *2 March 2005*

GATE NO.	GATE OPENING IN FEET 0600	1600	2400	GATE CHANGES AND REMARKS
RG 1	-3.0'	-3.0	-3.0	
2	"	"	"	
3	-4.0'	-4.0	-4.0	
4	|	"	"	
5	|	"	"	
Total	-18.0'	-18.0		
TG 6	2.0'	2.0	2.0	
7	|	"	|	
8	|	"	|	
9	|	"	|	
10	|	"	|	
11	|	"	|	
S-12	|	"	|	
S-13	|	"	|	
Total	16.0'	16.0	16.0	
Dis RG	12,618	12452	12,324	COMMENTS:
TG	11,135	11,135	11,157	
Tv@10'+ spillway	1,428	1,428	1430	
Total Discharge	25,181	25015	24,961	03F06H10

WATER SURFACE ELEVATIONS

TIME	0400	0600	1200	1600	2000	2400
POOL	19.77	19.76	19.73	19.72	1971	1970
TAIL	13.78	13.79	13.78	13.75	1373	1971
HEAD	5.99	5.97	5.95	5.97	598	599
WIND	\\\\\\\\\\	—	\\\\\\\\\\	N-3	\\\\\\\\\\	—
TEMP	//////////	11°	//////////	27°	//////////	17

TEMP.	MAX	MIN	1900
STATS.	08	10	24

GAUGES/WATER/PRECIP.	
LANSING	20.23
McGREGOR (NEED FOR NEW PAPER)	12.05
MUSCODA	1.44
DORCHESTER	7.31
STEUBEN	6.65
WATER TEMP.	—
PRECIPITATION	—

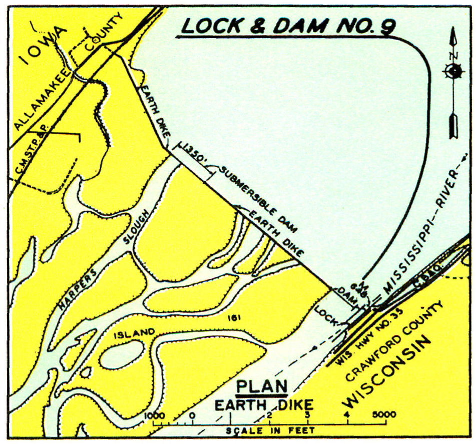
ICE/SNOW REPORT	
ICE THICKNESS-POOL	6.0"
RIVER COND.-POOL	30%
ICE THICKNESS-T.W.	4.0"
RIVER COND.-T.W.	30%
ICE THICKNESS-LOCK	-
SNOW DEPTH	3"
WATER CONTENT	.75"

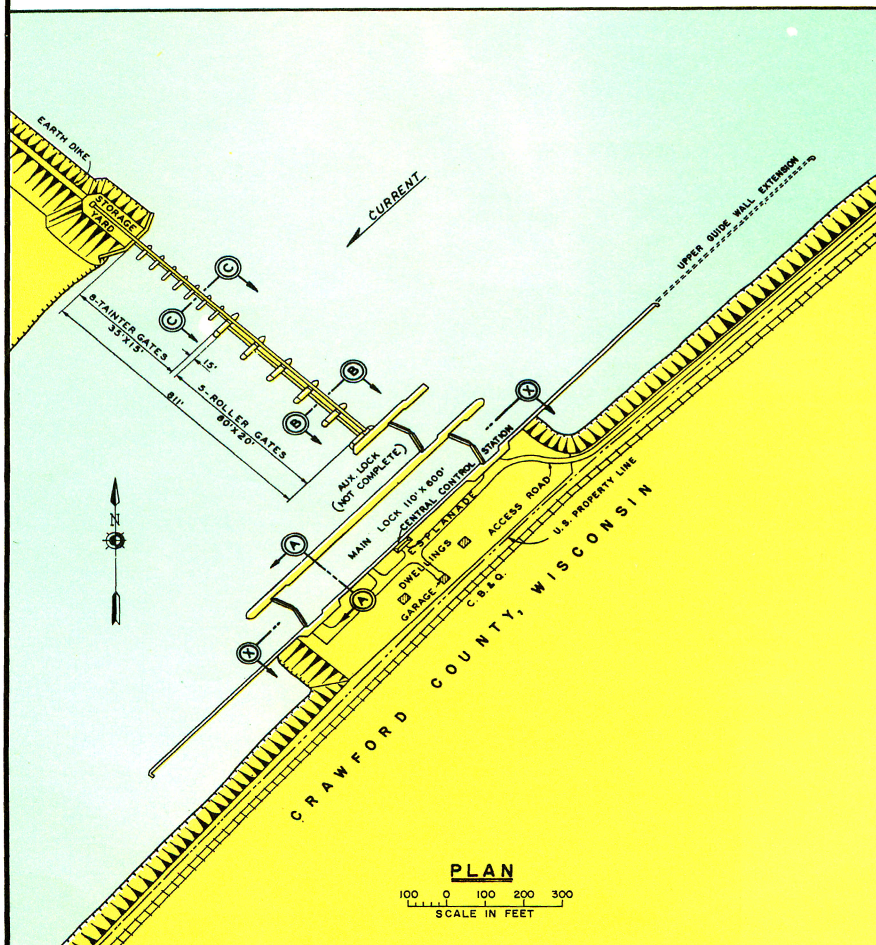
[signature] Operator 2400-0800

[signature] Operator 0800-1600

Operator 1600-2400

34

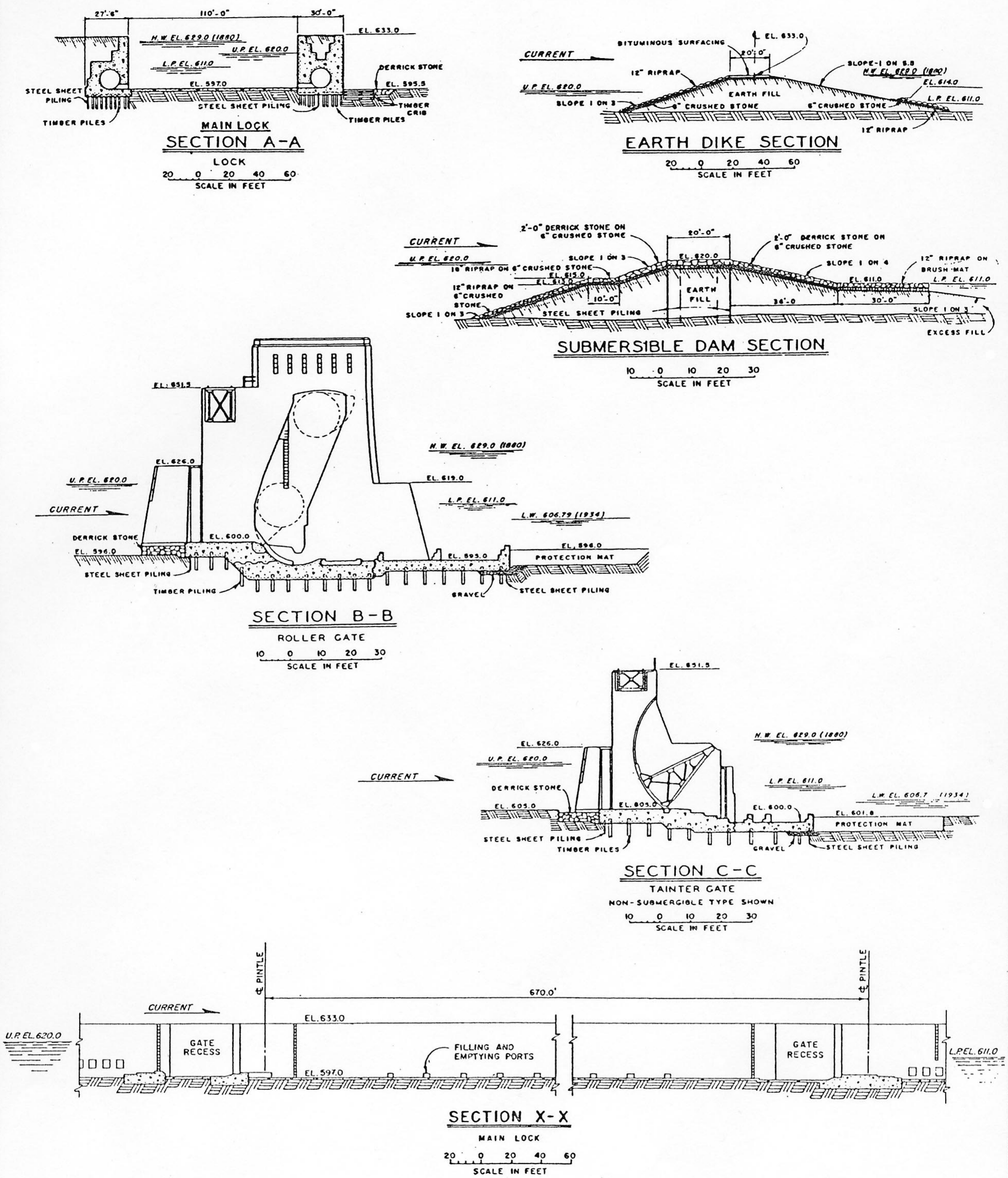




TOTAL LENGTH OF EARTH DIKE - 8004.0 FT.
DEPTH ON UPPER GATE SILL - 16.0 FT. (U.P. EL. 620.0)
DEPTH ON LOWER GATE SILL - 13.0 FT. (L.P. EL. 611.0)
ELEVATION UPPER GATE SILL - 604.0
ELEVATION LOWER GATE SILL - 598.0

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

Upper Mssissippi River
Nine-Foot Navigation Project
Lock and Dam No. 9
Project Location Map
US Army Corps of Engineers
St. Paul District - June 1961

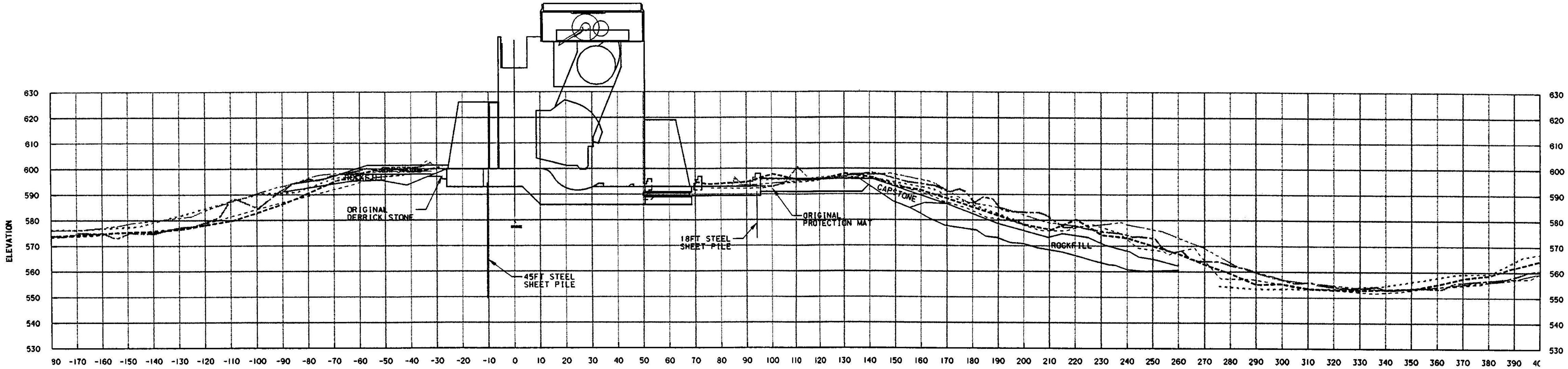


ELEVATIONS ARE REFERRED TO M.S.L. (1912 ADJ.)

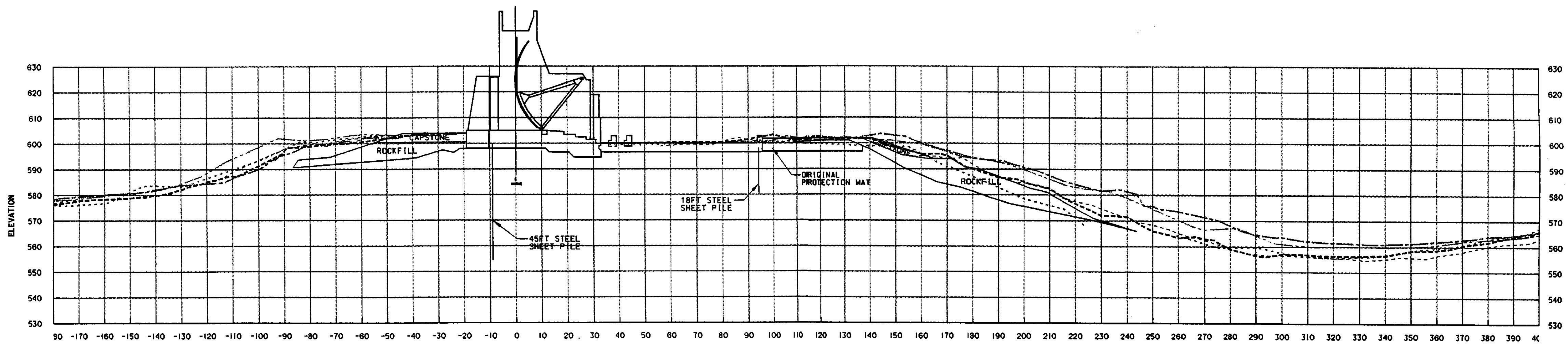
Upper Mississippi River
Nine-Foot Channel Navigation Project

Lock and Dam No. 9
Cross-Sections

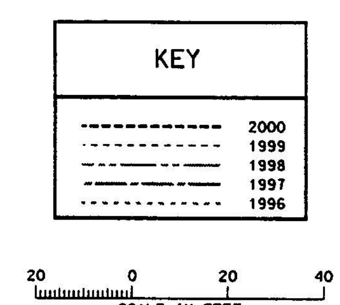
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN



P-6



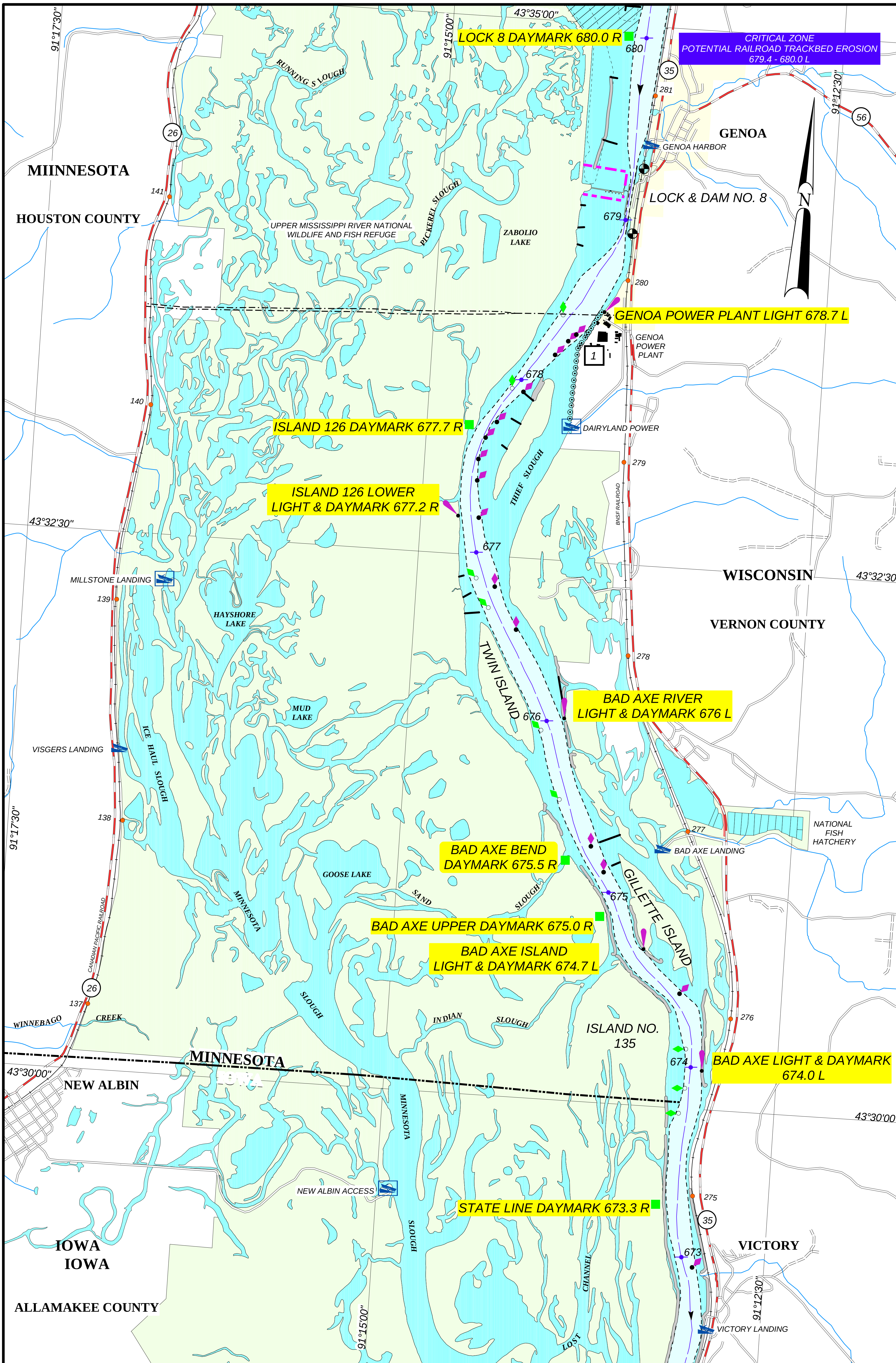
P-7



Upper Mssissippi River
Nine-Foot Navigation Project

Scour Protection
Upstream and Downstream of Dam
Capstone and Rockfill Placed in 1982-83

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



2001

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

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

1 0.5 0 1 MILES

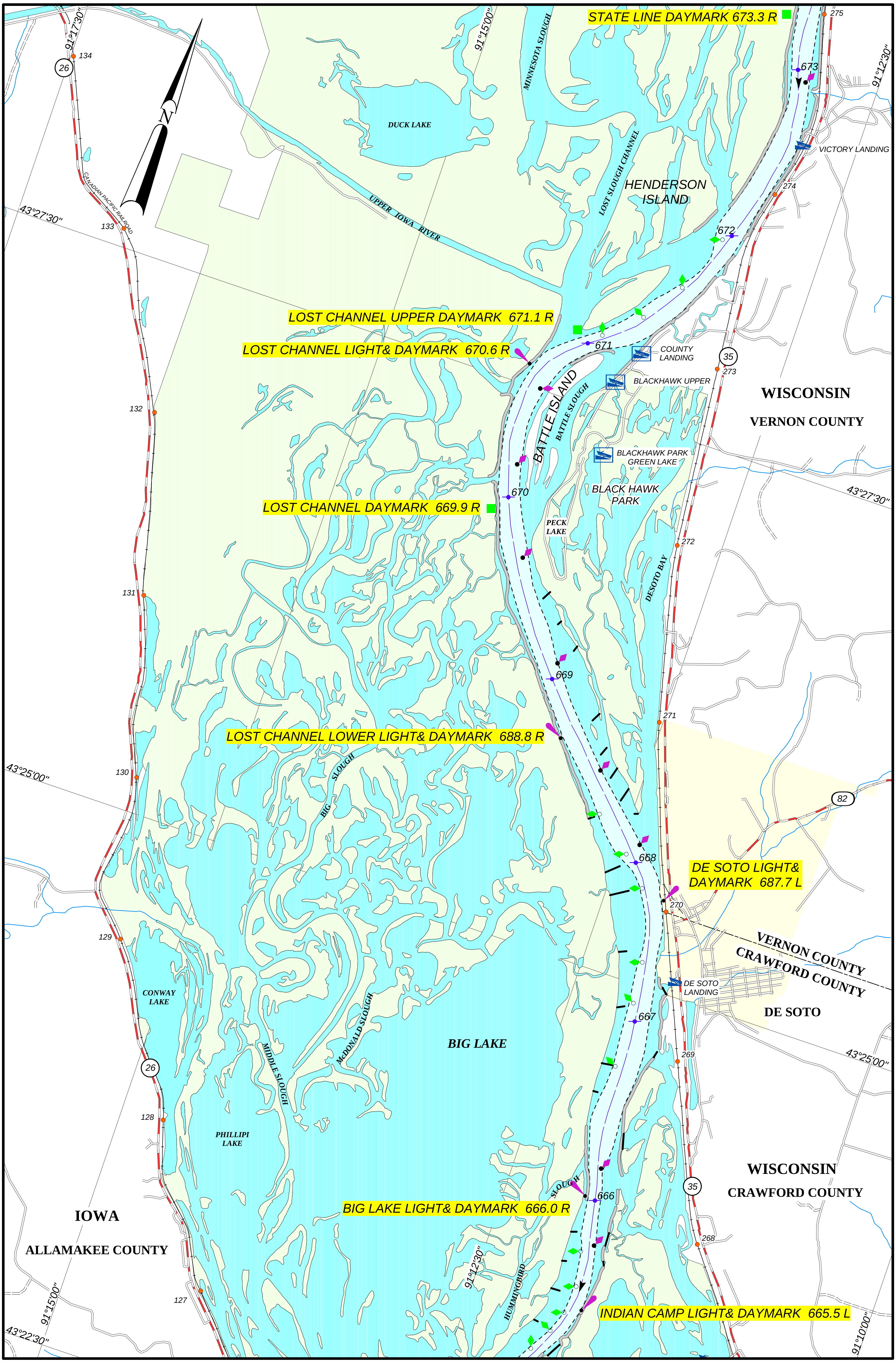
1 0.5 0 1 KILOMETERS

Upper Mississippi River
Nine-Foot Channel Navigation Project

Navigation Chart

River Mile 673 to 680

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



2001

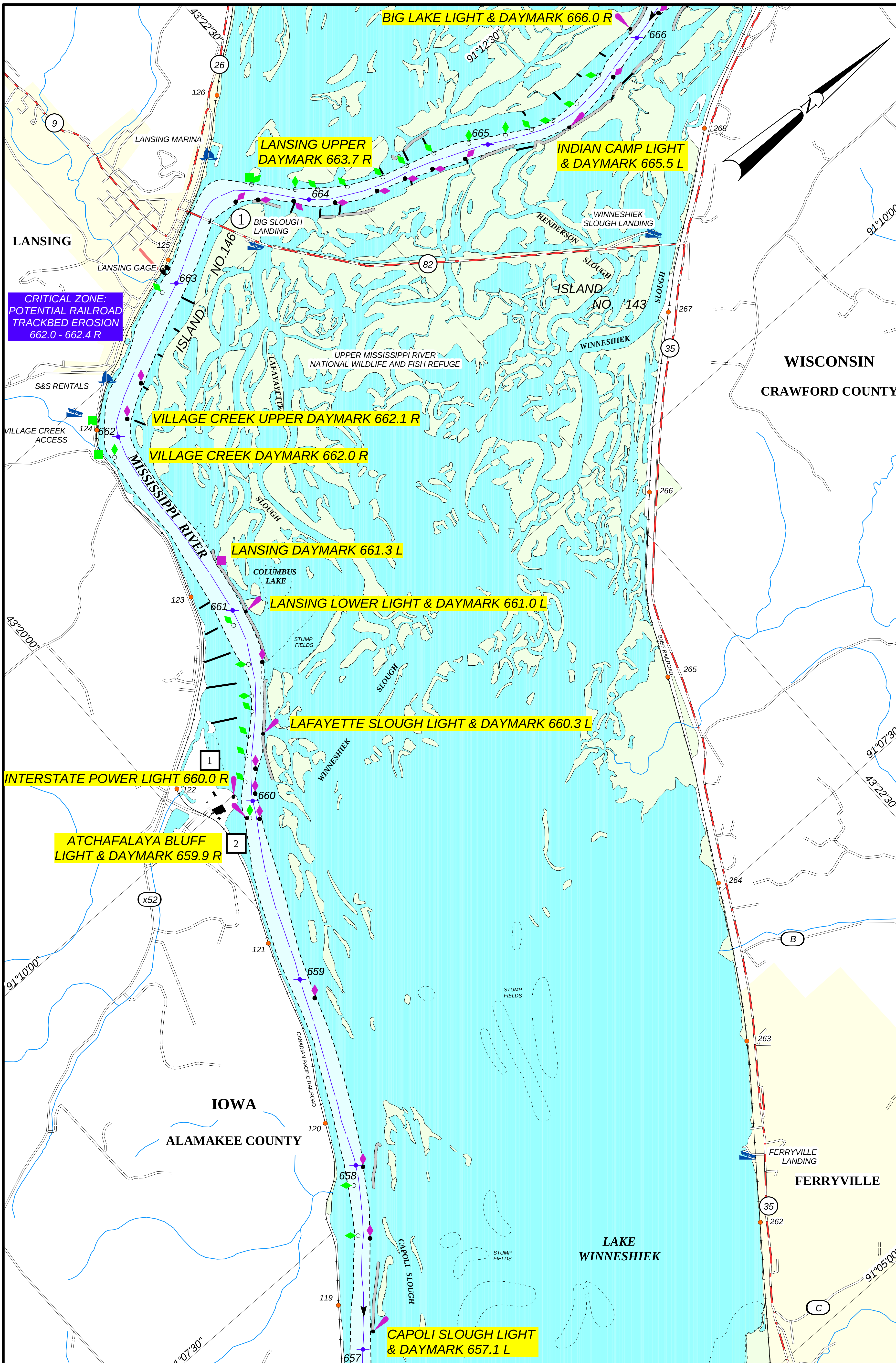
BUOY POSITIONS ON CHARTS ARE APPROXIMATE, SEE NOTICE ON LEGEND NO. 1

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

1 0.5 0 1 MILES

1 0.5 0 1 KILOMETERS

Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 666 to 673
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN

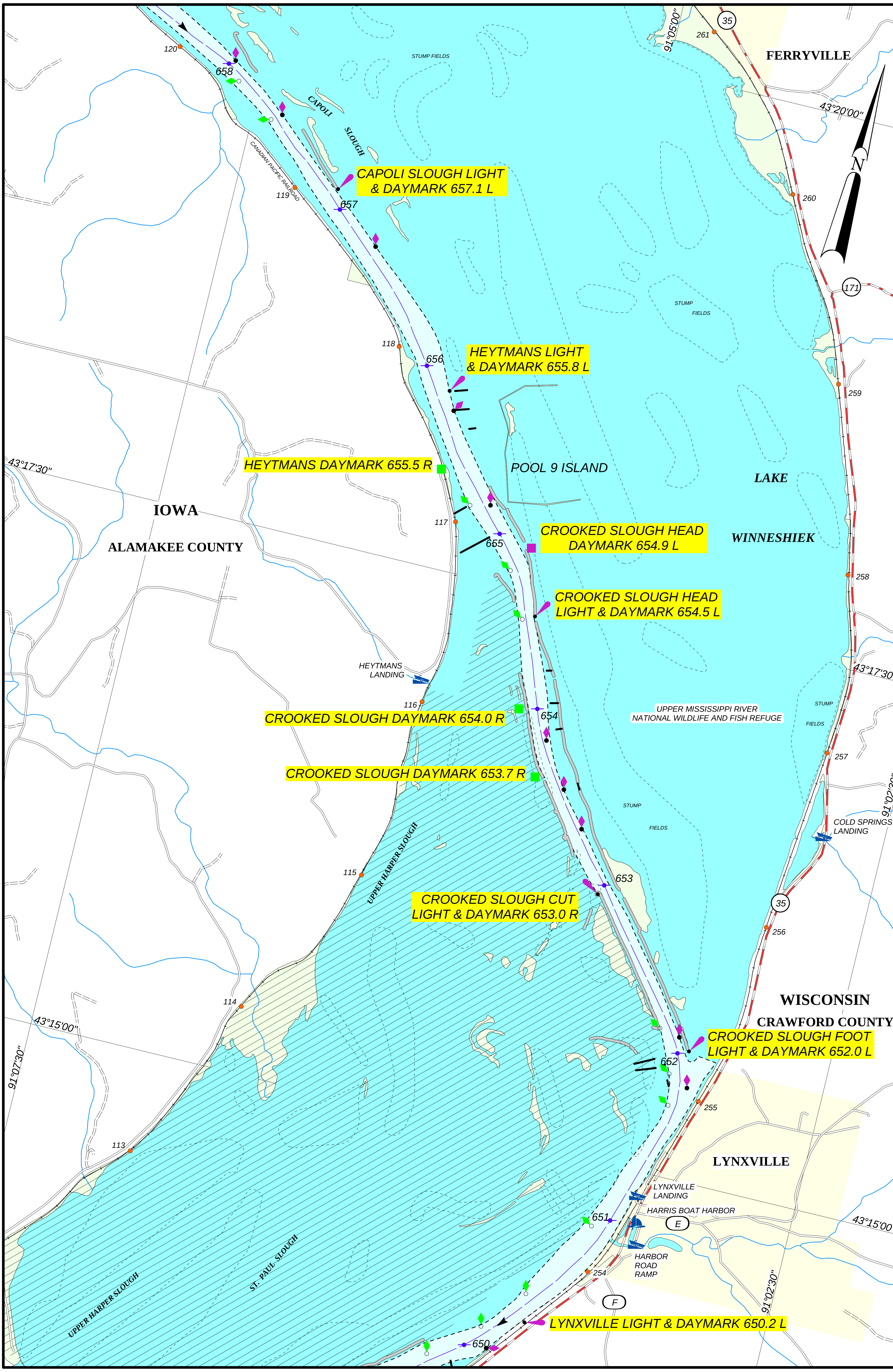


2001

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

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

Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 657 to 666
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN

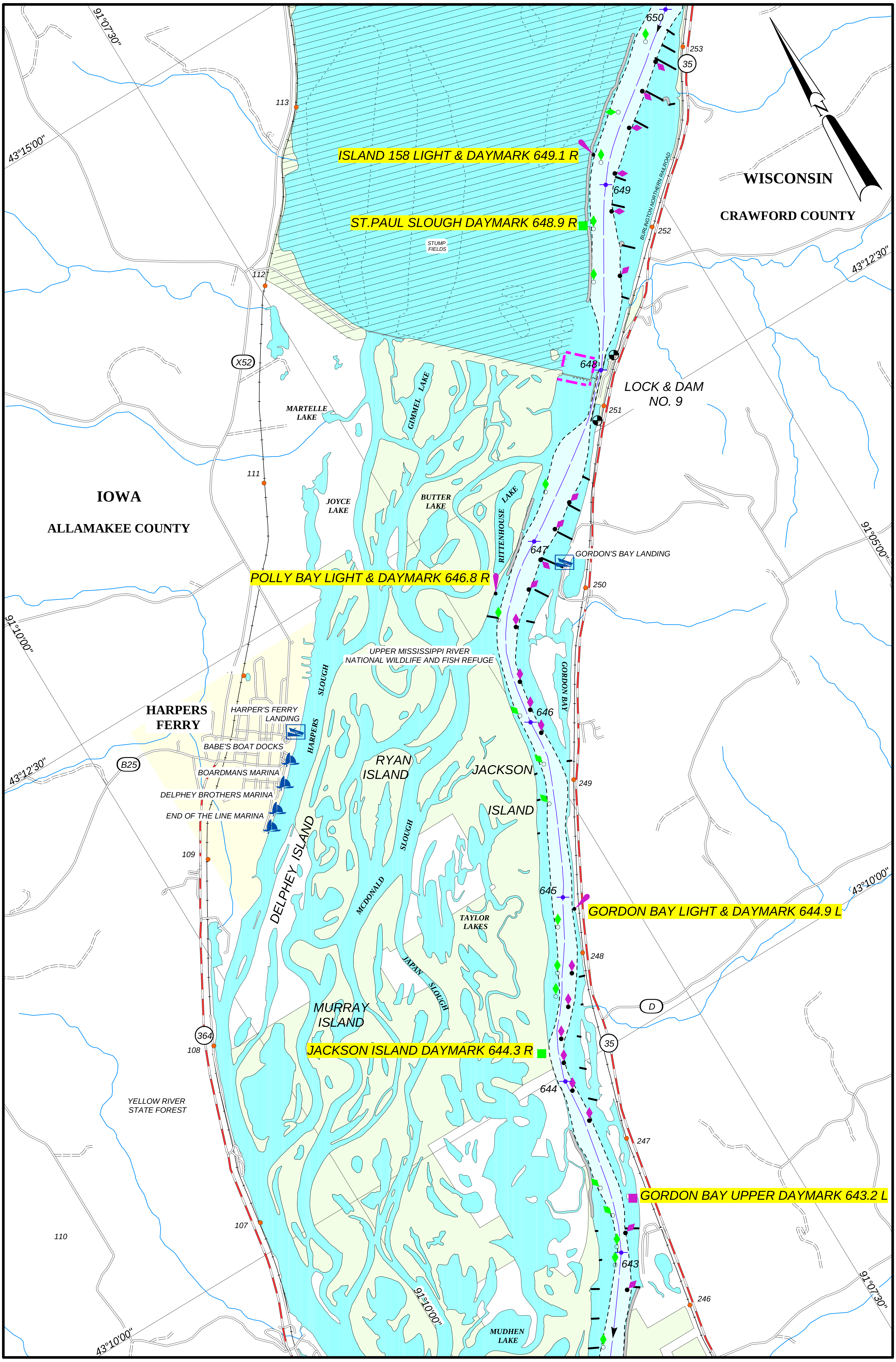


2001

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

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

Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 650 to 658
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN



2001

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

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

1 0.5 0 1 MILES

1 0.5 0 1 KILOMETERS

Upper Mississippi River
Nine-Foot Channel Navigation Project
Navigation Chart
River Mile 643 to 650
U.S. Army Corps of Engineers
St. Paul District - St. Paul, MN

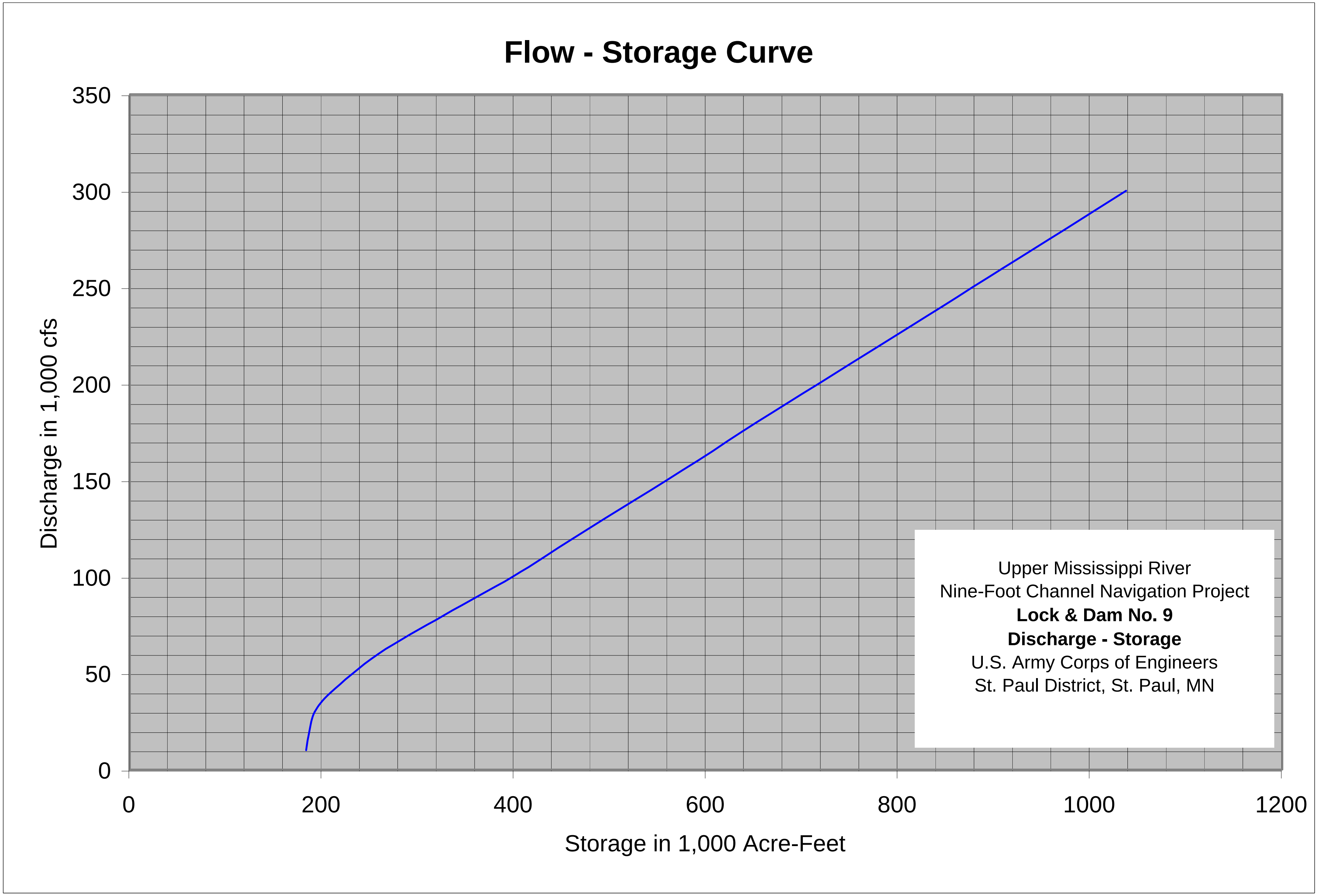
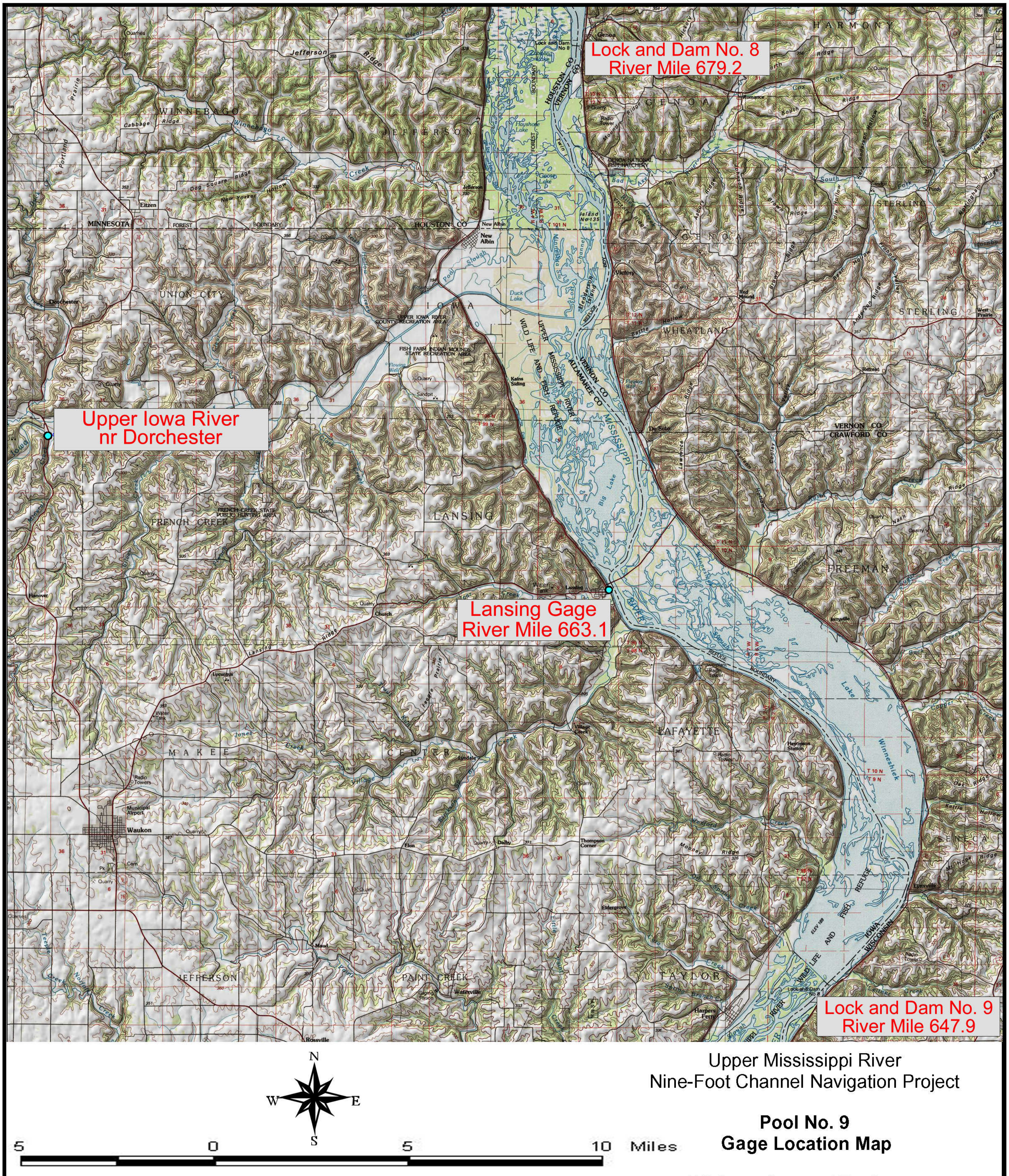

Flow - Storage Curve
Discharge in 1,000 cfs
350
300
250
200
150
100
50
0
0
200
400
600
800
1000
1200
Storage in 1,000 Acre-Feet
Upper Mississippi River
Nine-Foot Channel Navigation Project
Lock & Dam No. 9
Discharge - Storage
U.S. Army Corps of Engineers
St. Paul District, St. Paul, MN

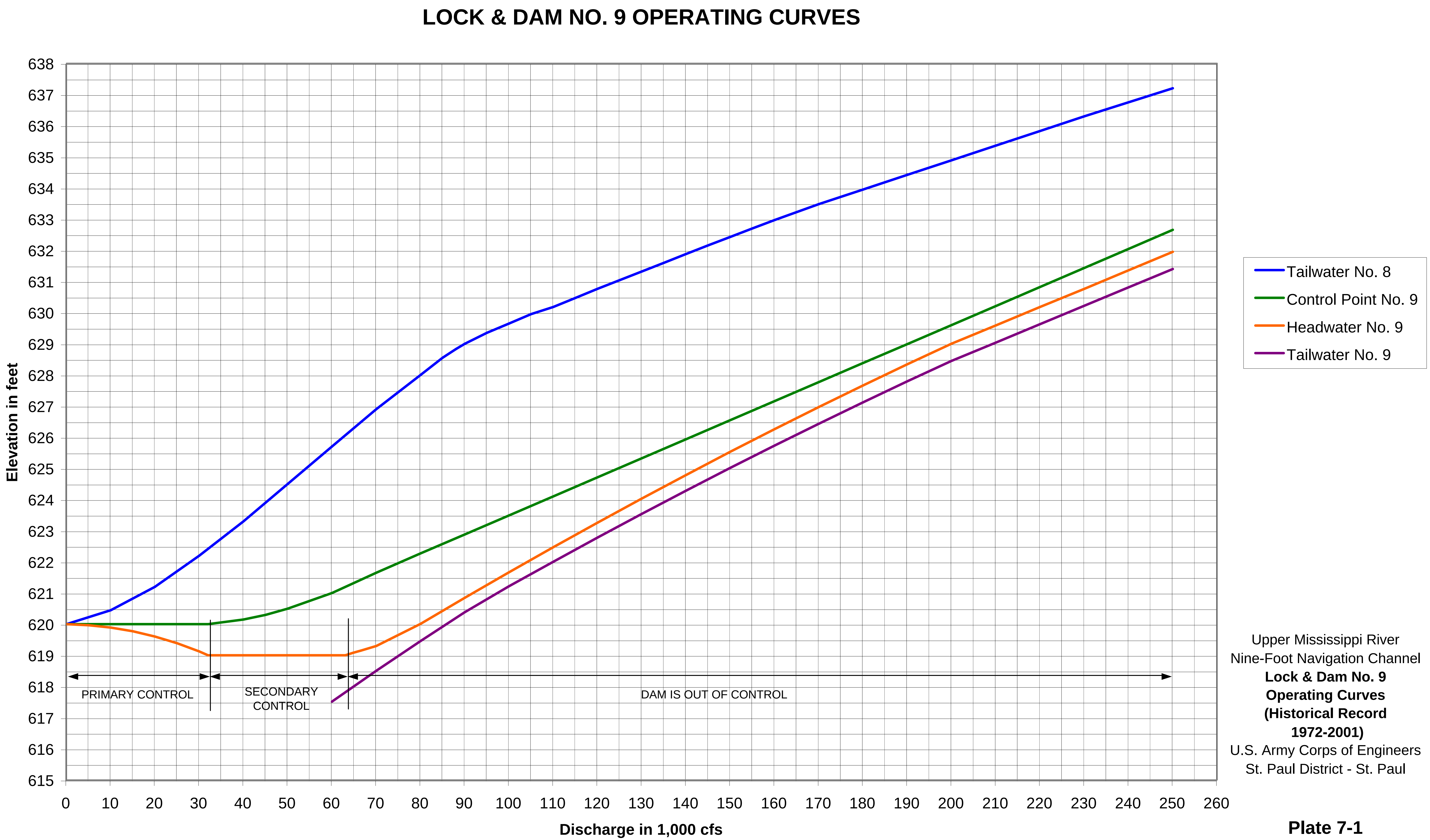
Plate 4-1



Upper Mississippi River
Nine-Foot Channel Navigation Project

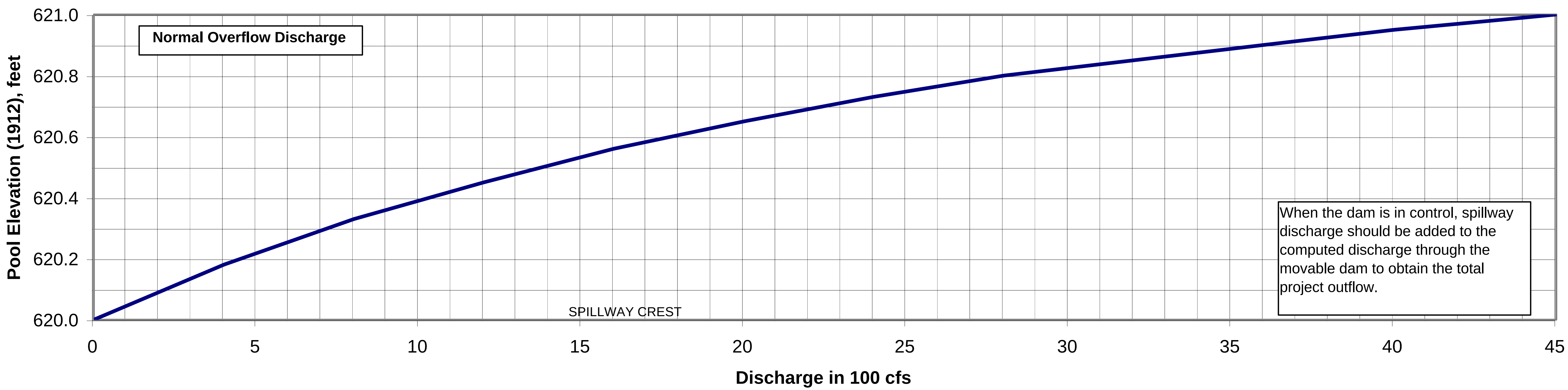
Pool No. 9
Gage Location Map

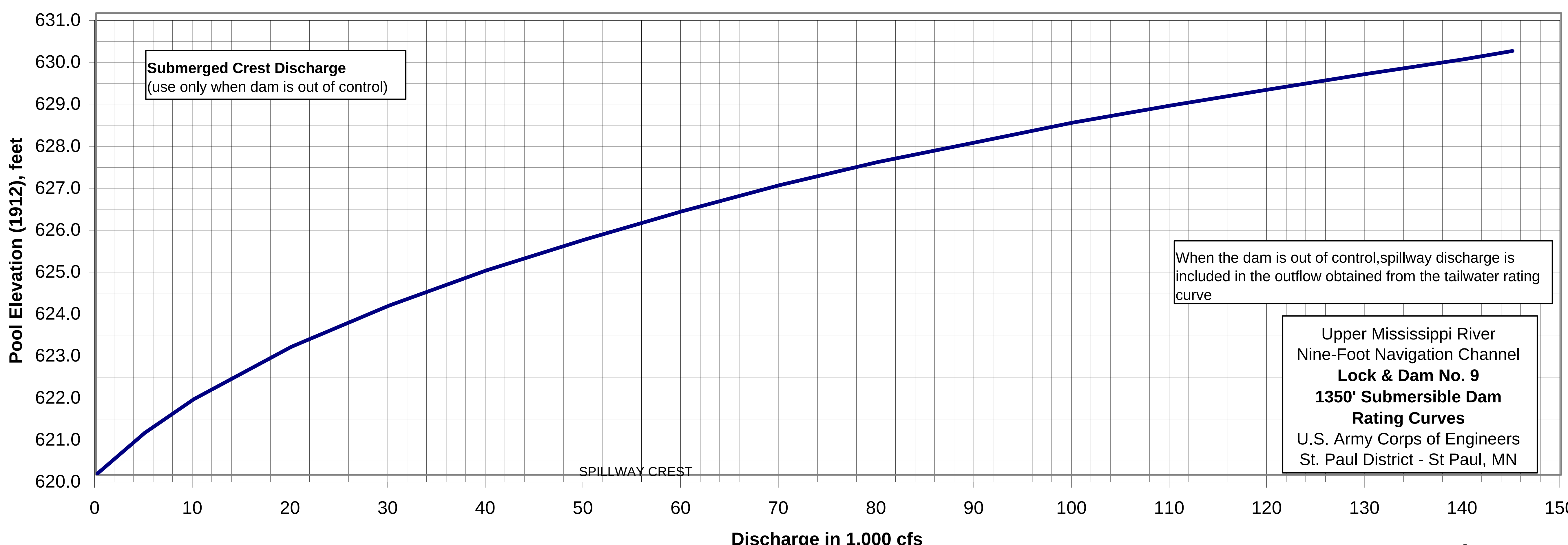
US Army Corps of Engineers
St. Paul District - St. Paul, MN

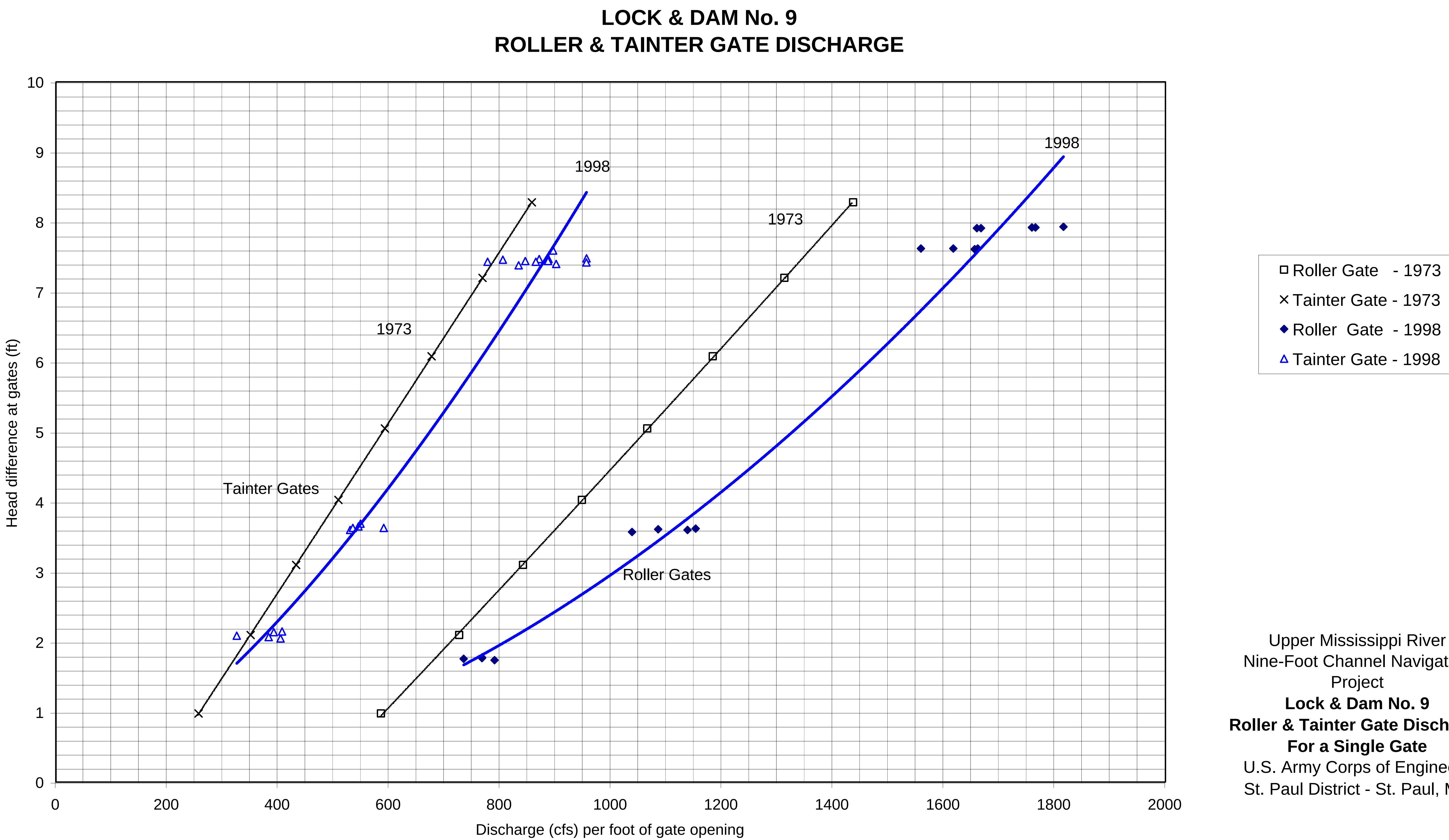


Upper Mississippi River
Nine-Foot Navigation Channel
Lock & Dam No. 9
Operating Curves
(Historical Record
1972-2001)
U.S. Army Corps of Engineers
St. Paul District - St. Paul

Plate 7-1


Normal Overflow Discharge
Pool Elevation (1912), feet
621.0
620.8
620.6
620.4
620.2
620.0
SPILLWAY CREST
When the dam is in control, spillway discharge should be added to the computed discharge through the movable dam to obtain the total project outflow.
0
5
10
15
20
25
30
35
40
45
Discharge in 100 cfs


Submerged Crest Discharge
(use only when dam is out of control)
Pool Elevation (1912), feet
631.0
630.0
629.0
628.0
627.0
626.0
625.0
624.0
623.0
622.0
621.0
620.0
SPILLWAY CREST
When the dam is out of control,spillway discharge is included in the outflow obtained from the tailwater rating curve
Upper Mississippi River
Nine-Foot Navigation Channel
Lock & Dam No. 9
1350' Submersible Dam
Rating Curves
U.S. Army Corps of Engineers
St. Paul District - St Paul, MN
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Discharge in 1,000 cfs



Upper Mississippi River
Nine-Foot Channel Navigation Project

Lock & Dam No. 9
Roller & Tainter Gate Discharge
For a Single Gate

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

Plate 7-3