US Army Corps
of Engineers
St. Paul District

WATER CONTROL MANUAL
FLOOD CONTROL
OTTER TAIL RIVER, MINNESOTA

ORWELL RESERVOIR
OTTER TAIL RIVER FLOOD CONTROL RESERVOIR
AND CHANNEL IMPROVEMENT PROJECT
FERGUS FALLS, MINNESOTA

REVISED AUGUST 2001

DEPARTMENT OF THE ARMY
MISSISSIPPI VALLEY DIVISION, CORPS OF ENGINEERS
P.O. BOX 80
VICKSBURG, MISSISSIPPI 39181-0080
http://www.mvd.usace.army.mil/

REPLY TO
ATTENTION OF:

CEMVD-TD-TW (1110-2-240) 13 September 2001

MEMORANDUM FOR Commander, St. Paul District, ATTN: CEMVP-ED-H

SUBJECT: Draft Water Control Manual, Orwell Dam and Reservoir

1. Reference, memorandum, CEMVP-ED-H, 23 May 2001, subject as above. This is the fourth document in the referenced chain of correspondence.

2. The Water Control Manual for Orwell Dam and Reservoir is approved.

3. The MVD point of contact for this action is Mr. Bob Occhipinti (601)634-5915.

MICHAEL P. FALLON, P. E.
Chief, Technical Engineering and
Construction Division

WATER CONTROL MANUAL

ORWELL PROJECT

ORWELL DAM AND RESERVOIR

Otter Tail River Basin
Minnesota

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

AUGUST 2001

Revised from
Reservoir Regulation Manual, August 1963
Reservoir Regulation Manual, April 1954

ORWELL RESERVOIR

Orwell Dam - Year 1995

Orwell Dam and Tailwater Structure - Year 2000

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 completed the water control manual for Orwell Dam and Reservoir in April 1954. The manual was revised August 1963 and was updated in August 2001.

This manual was 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 during normal business (duty) hours, contact can be made to Water Control by telephone (651-290-5617), fax (651-290-5841), or VHF-FM radio, call signal WUG-613 (St. Paul, MN). During nonduty hours, assistance can be obtained by contacting one of the following persons, in the order listed below.

Name	Title/Internet Address	Number
Edward Eaton	Chief, Water Control Section edward.j.eaton@usace.army.mil	Work: 651-290-5617 [redacted]
Kenton Spading	Hydraulic Engineer kenton.e.spading@usace.army.mil	Work: 651-290-5623 [redacted]
Ferris Chamberlin	Hydraulic Engineer ferris.w.chamberlin@usace.army.mil	Work: 651-290-5619 [redacted]
Michael Knoff	Chief, Hydraulics & Hydrology Branch michael.r.knoff@usace.army.mil	Work: 651-290-5602 [redacted]
John Bailen	Chief, Engineering Division john.j.bailen@usace.army.mil	Work: 612-290-5303

Orwell Project
Otter Tail River

U.S. Army Corps of Engineers
St. Paul District
Revised March 2001

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Mean Sea Level Reference Datum

All elevations in this manual use the 1912 Mean Sea Level adjustment (1912 MSL) unless otherwise stated.

Metric Equivalents and Conversions

Length:

1 Centimeter = 0.394 inches
1 meter = 3.28 feet
1 kilometer = 0.621 miles

Area:

1 meter^2 = 10.764 feet^2
1 kilometer^2 = 0.386 miles^2
1 hectare = 2.,471 acres

Volume:

1 meter^3 = 35.31 feet^3
1 meter^3 = 1.308 yards^3
1 meter^3 = 0.81 x 10^{-3} acre-feet

Flow:

1 meter^3/second = 35.31 feet^3/second

Temperature:

(Fahrenheit - 32)/1.8 = Degrees Celsius

World Wide Web Sites

St. Paul District	http://www.usace.army.mil
Water Control Section	http://www.mvp-wc.usace.army.mil

ORWELL DAM AND RESERVOIR
PERTINENT DATA (Also see Exhibit A)

Location: Orwell Dam is located on the Otter Tail River, 38.6 river miles upstream of Breckenridge, Minnesota, where the Otter Tail and Bois de Sioux Rivers combine to form the Red River of the North. The dam is situated in the southwestern part of Otter Tail County, approximately 6 miles southwest of Fergus Falls, Minnesota, 55 miles southwest of Fargo, North Dakota, and 170 miles northwest of the Minneapolis-St. Paul, Minnesota, metropolitan area, in Section 26, T132N, R44W, near Latitude 46°13'0"N, Longitude 96°10'40"W.

Total Drainage Area: 1,820 Square Miles

Real Estate Taking Guide Line Contour for Title in Fee: Contour Elevation 1073.0 feet

Dam

Type:	Rolled Earth Fill	Maximum Height:	47 feet
Total Length:	1,355 feet	Top Width:	20 feet
Crest Elevation:	1080.0 feet	Side Slopes:	1V:3H

Control Structures

Type:	One-Tainter Gate	Type :	Two- Low Flow Conduits
Gate Width:	33.0 feet	Shape/Location	Circular/Abutments
Gate Height:	27.5 feet	Diameter:	2 feet
Gate Radius:	30.0 feet	Inlet Invert Elevation:	1040.0 feet
Weir Crest Elevation:	1044.0 feet	Control:	24 inch Slide Gates
Top of Gate (closed):	1071.5 feet		
Gate Seat Elevation:	1043.5 feet		

Spillway and Chute Outlet

Type Spillway:	Flared Concrete Ogee	Type Chute:	Flared Concrete
Crest Elevation:	1044.0 feet	Width at Spillway Toe:	41.8 feet
Crest Width:	33.0 feet	Width at Stilling Basin:	54.5 feet
Width at Toe:	41.8 feet	Length:	38.2 feet
		Slope:	1V:10H

Stilling Basin

Type:	Flared with Baffles	Rows of Baffle Blocks:	2
Width at Chute:	54.5 feet	Baffle Block Height:	8.0 feet
Width at End Sill:	78.5 feet	End Sill Height:	8.0 feet
Floor Elevation:	1024.5 feet	End Sill Elevation:	1032.5 feet
		Length:	72.0 feet

Elevation - Area - Storage

	Elevation (ft)	Area (acres)	Storage (acre-ft)
Deign Flood (PMF)	1078.8	1,700	26,320
Top of Surcharge Pool	1073.0	1,300	17,750
Flood Control Pool	1070.0	1,110	14,000
Conservation Pool	1064.0	782	8,300
Intermediate Drawdown	1060.0	598	5,500
Maximum Drawdown (pg 3-6)	1050.0	264	1,200
Dead Storage (weir crest elev)	1044.0	104	150

I - INTRODUCTION

1-01. Authorization for the Manual. Authority to prepare a Reservoir Regulation Manual (Water Control Manual) for Orwell Dam and Reservoir was given by letter, 800.2 (Reservoirs) UMVGW, Upper Mississippi Valley Division, subject: "Manual of Regulation for Flood Control and Multiple Purpose Reservoirs", dated 30 August 1948. The interim Reservoir Regulation Manual was submitted as requested by first indorsement, UMVGB, Upper Mississippi Valley Division, dated 8 October 1952, to letter, UMPRH 800.2 (Reservoirs), St. Paul District, subject: "Operation of Flood Control Reservoirs", dated 30 September 1952.

This manual supersedes the Reservoir Regulation Manual, dated April 1954 and revised August 1963, and incorporates changes to the water control plan as recommended in the *Operation Plan Evaluation and Environmental Assessment, Lake Traverse, Bois de Sioux River, and Orwell Reservoir*, dated April 1994. This manual was prepared in compliance with the following guidelines:

Civil Works Document	Number	Document Title	Date
Engineering Regulation	1110-2-240	*Water Control Management*	30 Apr 1987
Engineering Manual	1110-2-3600	*Management of Water Control Systems*	30 Nov 1987
Engineering Regulation	1110-2-8156	*Preparation of Water Control Manuals*	31 Aug 1995

1-02. Purpose and Scope of the Manual. 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 scope of this manual covers all water control management activities as they relate to the hydraulic and hydrologic aspects of the project.

1-03. Related Manuals and Reports. Prior reports on flood control and navigation in the region date from 1850. The annual reports of the Chief of Engineers are a good source of pre-project information. Reports and documents concerning the basin prior to 1949 are listed in **Exhibit B**. The following is a list of more recent reports.

a. *Flood Control Definite Project Report on Orwell Reservoir, Otter Tail River, Minnesota*, U.S. Army Corps of Engineers, St. Paul District, February 1949 (revised August 1950).

b. *Final Report, Laboratory Tests on Hydraulic Models of Orwell Reservoir Conduit Outlet and Spillway Structures for Otter Tail River, Minnesota*, U.S. Army Corps of Engineers, St. Paul District, December 1953.

c. *Flood Control and Water Conservation, Otter Tail River, Minnesota Red River of the North Watershed, Orwell Dam and Reservoir, Reservoir Regulation Manual*, U.S. Army Corps of Engineers, St. Paul District, April 1954 (Revised August 1963).

d. *Finding of Fact and Negative Declaration for Operation and Maintenance, Orwell Lake and Dam, Ottertail County, Minnesota*, Finding of Fact signed May 1975.

e. *Flood Control, Orwell Dam, Otter Tail River, Minnesota, Letter Report No. 2 Seepage and Uplift Investigation*, U.S. Army Corps of Engineers, St. Paul District, May 1979.

f. *Probable Maximum Flood and Standard Project Flood Discharge Hydrographs for the Otter Tail River at Orwell Dam near Fergus Falls, Minnesota*, - Prepared for U.S. Army Corps of Engineers, St. Paul District by Enviroscience Inc., November 1981.

g. *Shoreline Erosion Process, Orwell Lake, Minnesota*, John R. Reid, University of North Dakota, January 1983.

h. *Orwell Reservoir Operation Plan Evaluation (ROPE) and Environmental Assessment*, U.S. Army Engineer District, St. Paul, Corps of Engineers, St. Paul, Minnesota, January 1986. Finding of No Significant Impact (FONSI) signed February 1986.

i. *Risk Assessment Report, Orwell Dam, Otter Tail River, Minnesota*, U.S. Army Corps of Engineers, St. Paul District, July, 1987.

j. *Flood Control Project, Orwell Dam & Reservoir Emergency Plan*, U.S. Army Corps of Engineers, St. Paul District, April 1990.

k. *Ice Influenced Flood Stage Frequency Analysis - Red River of the North and Bois de Sioux River at Wahpeton, North Dakota, and Breckenridge, Minnesota*, U.S. Army Corps of Engineers, St. Paul District, October, 1990.

l. *Drought Contingency Plan, Orwell Reservoir Water Control Appendix DCP* (draft), U.S. Army Corps of Engineers, St. Paul District, September 1992.

m. *St. Paul District Designs Wetlands Restoration Project at Orwell Lake*, U.S. Army Corps of Engineers, Waterways Experiment Station, The Wetlands Research Program Bulletin, Volume 3, Number 3, October 1993.

n. *Operation Plan Evaluation and Environmental Assessment (ROPE), Lake Traverse, Bois de Sioux River, and Orwell Reservoir*, U.S. Army Corps of Engineers, St. Paul District, In-House Draft dated June 1988. Final report issued April 1994. Finding of No Significant Impact (FONSI) signed July 1994.

o. *Design Memorandum, Dam Safety Assurance Program, Orwell Dam, Otter Tail River, Minnesota*, U.S. Army Corps of Engineers, St. Paul District, June 1994.

p. *Lake Traverse Reservoir, Bois de Sioux River, Water Control Manual*, U.S. Army Corps of Engineers, St. Paul District, Revised December 1994.

q. *Supplement to Design Memorandum, Dam Safety Assurance Program, Orwell Dam, Otter Tail River, Minnesota*, U.S. Army Corps of Engineers, St. Paul District, January 1996. Structural Rehabilitation and Downstream Channel Modifications for Orwell Dam, Environmental Assessment and Finding of No Significant Impact (FONSI) signed June 1996. Drawdown for Construction, Environmental Assessment and Finding of No Significant Impact (FONSI) signed December 1997.

r. *Operation and Maintenance Manual, Section 1135 Habitat Restoration Project, Orwell Lake, Otter Tail County, Minnesota*, U.S. Army Corps of Engineers, St. Paul District, May 1996.

s. *Feasibility Study and Environmental Assessment, Wahpeton, North Dakota* and *Breckenridge, Minnesota*, Section 205 Local Flood Reduction Project, Red River of the North, U.S. Army Corps of Engineers, St. Paul District, September 2000.

1-04. Project Owner. The United States Government is the owner of Orwell Dam. The U.S. Army Corps of Engineers, St. Paul District is responsible for the regulation of the Orwell Project.

1-05. Operating Agency. Regulation instructions for the project are provided by the St. Paul District, Engineering Division, Hydraulics and Hydrology (H&H) Branch, Water Control Section. Operation and maintenance of the Orwell Project is the responsibility of Construction-Operations (Con-Ops) Division, Western Flood Control Office.

The project is attended full time. Site personnel are responsible for project maintenance as well was as performing gate adjustments as directed by Water Control. The following table gives the names, addresses and phone numbers for the Orwell Project related personnel.

Table 1-1 Project Office Points of Contact	
Names and Addresses	**Numbers**
David Salberg, Project Resource Manager Lake Traverse Project, U.S. Army Corps of Engineers Route 2, Box 59 Wheaton, MN 56296-9630 David Doll, Assistant	Work: 320-563-4586 Home: 320-563-4691 VHF-FM: WUG638 Cellular: 888-955-9046 Work: 320-563-4586 Home: 320-563-4075
Robert Schimming, Maintenance Worker Orwell Dam, U.S. Army Corps of Engineers RFD 4, Box 116 Fergus Falls, MN 56537-9352	Work: 218-736-6463 Home: 218-736-6510 VHF-FM: WUG637
Project Fax Numbers	Lake Traverse Project: 320-563-8662 Orwell Dam: 218-736-2652
24-Hour Project Information Recording	Lake Traverse Project and Orwell Dam: 320-563-8681
Timothy Bertschi, Operations Project Manager Western Flood Control Project Office Federal Building 15 South 21st Street, Suite 103 Fargo, ND 58103-1435	Work: 701-232-1894 Home: 701-232-5967 Cellular: 701-238-1680 Fax: 701-232-1789 VHF-FM: WUG642

1-06. Regulating Agency. Regulation of the Orwell Project is under the supervision of the Water Control Section, within the Hydraulics and Hydrologic Branch, Planning and Engineering Division, of the St. Paul District, Corps of Engineers.

II - DESCRIPTION OF PROJECT

2-01. Location of Project. Orwell Dam is located in the state of Minnesota on the Otter Tail River at River Mile 38.6. The reservoir occupies a portion of southwestern Otter Tail County, approximately six miles southwest of Fergus Falls, Minnesota. It is approximately 170 miles northwest of the Minneapolis-St. Paul, Minnesota, metropolitan area and about 55 miles southeast of Fargo, North Dakota. Project location is shown on **Plate 2-1**.

2-02. Purpose of the Project. Orwell Dam and Reservoir was originally a dual-purpose project designed to impound water during flood periods and to release stored water for water supply and pollution abatement during low-flow periods. Releases for pollution abatement were primarily due to beet processing. Improvements in the industry have made this function no longer necessary; however, when water is released for flood control drawdown, the water does help dilute the water released from the Lake Traverse Project. As for water supply, when Wahpeton, North Dakota and Breckenridge, Minnesota switched to groundwater systems, the need for water supply diminished. Also, the completion of the Fargo Diversion on the Sheyenne River, eliminated the need for water supply from Orwell Reservoir except for drought conditions (see **Paragraph 7-09 and 8-06**). The authorized purposes and the public laws pertaining to the project are given in **Table 2-1**.

Table 2-1
Authorized Purposes Assigned by Congress

Authorized Purpose	Public Law	Name
Surplus Water, Recreation	PL 89-72	Flood Control Act of 1944
Flood Control, Water Supply	PL 81-516	Flood Control Acts of 1948 and 1950
Fish and Wildlife	PL 85-624	Fish and Wildlife Coordination Act of 1958
Water Supply	PL 85-500	Water Supply Act of 1958
Recreation	PL 78-534	Federal Water Project Recreation Act of 1965
Water Quality	PL 92-500	Federal Water Pollution Control Act of 1972
Fish and Wildlife	PL 93-205	Conservation, Protection, and Propagation of Endangered Species Law of 1973

Therefore, while changes in the Red River of the North basin have diminished the water supply and pollution abatement role of the reservoir, flood control remains a major purpose of the project.

2-03. Physical Components.

a. Embankment and Dikes. Orwell Reservoir is contained by one main embankment and two perimeter dikes. The dam elevation was determined by routing the spillway design flood hydrograph through the reservoir filled to elevation 1070.0 feet. A safety factor was introduced by limiting the discharge to not more than 90 percent of the peak inflow. The maximum reservoir pool elevation reached for this routing was 1075.0 feet. Established Corps of Engineeers criteria at the time called for five feet of freeboard. Therefore a dam crest elevation of 1080.0 feet was established. Based on updated estimates of the Probable Maximum Precipitation, a revised PMF hydrograph was developed in November 1981. Routing of the PMF through the reservoir resulted in a computed peak pool elevation of 1078.8 feet. Therefore, as part of the dam safety features constructed in 1999, a parapet wall with a top elevation of 1083.8 feet (i.e. 1078.8 ft + freeboard) was constructed along the top of the main embankment. The top elevation is in accordance with ER 1110-8-2, which requires five feet of freeboard. The following gives physical descriptions of the main embankment and the perimeter dikes.

(1) Main Embankment. The main embankment consists of compacted earth fill. The upstream side is protected from scour activity (e.g. wave attack) by an 18 inch layer of riprap. Vegetation protects the downstream side slope from erosion by local runoff. Seepage beneath the structure is limited by a foundation of impervious material. Relief wells were installed along the right bank of the outlet channel in 1979. The embankment has side slopes of 1V:3H, is 1,355 feet long, has a crest elevation of 1080.0 feet, and a maximum height of 47 feet (see As-Built on **Plate 2-2**). The top width is 20 feet and accommodates a gravel service road 16 feet in width and a concrete parapet wall (I-wall) with a top elevation of 1083.8 feet. The parapet wall is tied to high ground to south by a parapet wall dike (see Dam Safety General Plan on **Plate 2-11**).

(2) Perimeter Dikes. The two small perimeter dikes consist of compacted earth fill and are located on the southwest perimeter of the reservoir (**Plates 2-2 and 4-1**). Their function is to prevent overflow during high reservoir stages. One dike is located 500 feet southeast of the dam, has a length of about 720 feet, and a maximum height of 8 feet. The other dike is located about a mile south of the dam, has an approximate length of 420 feet, and a maximum height of 10 feet. Both dikes have a crest elevation of 1080.0 feet, a top width of 10 feet, and side slopes of 1V:3H on the landward side and 1V:2H on the reservoir side. Erosion protection for the side slopes consists of vegetation on the landward side and 12 inches of riprap on the reservoir side.

b. Approach Channel. The approach channel to the outlet structure is trapezoidal in shape and is approximately 400 feet in length. It has a bottom width of 33 feet, an invert elevation of 1037.0 feet, and 1V:3H side slopes. Curved concrete wing walls direct flow towards the outlet structure. Scour protection along the channel bottom and side slopes extends upstream of the outlet structure about 100 feet and consists of a 24 inch layer of riprap. See **Plate 2-2.**

c. Outlet Structure. The outlet structure consists of an ogee spillway, surmounted by a Tainter gate, followed by a spillway chute and a stilling basin. The outlet is constructed of concrete and flares in the downstream direction at a constant rate from a point about midway down the ogee spillway. Two low-flow conduits are formed within the spillway abutments (**Plate 2-3**).

(1) Tainter Gate. The Tainter gate is 33 feet wide, 27.5 feet high, and has a radius of 30 feet. It is supported on trunnions at the two spillway abutments (**Plate 2-3**). The gate seat is located on the ogee spillway just downstream of the spillway crest (elevation 1044.0 feet) at elevation 1043.5 feet. With the gate in the closed position, the top of gate elevation is 1071.5 feet. A set of aluminum bulkheads are stored on site for dewatering of the Tainter gate. The primary Tainter gate operating machinery is located on the left abutment (looking downstream). It is connected to a speed reducer through a shaft to a gear and chain sprocket on the right abutment. An auxiliary electric motor is located on the right abutment. The Tainter gate is housed and equipped for heating for winter operation.

As part of a major rehab project in 1996, all the mechanical equipment was replaced. New sill and side sill heaters were installed on the Tainter gate. Changes were made to the hoist chains to increase the maximum gate opening by 3.0 feet to obtain a 5.0 foot clearance for debris passage during the Probable Maximum Flood (PMF). Prior to the rehab, gate settings were determined by markings on the chain links. This was replaced by a gate height indicator scale. The counter number from the gage height indicator was correlated to a specific gage opening as shown in **Table 2-2.**

(2) Spillway. The spillway has an ogee shape with a crest elevation of 1044.0 feet. The abutment walls extend upward to the top of the earthen embankment (elevation 1080.0 feet). A foot bridge spans the abutments providing access across the spillway. The spillway remains at a constant width of 33 feet from the spillway crest to a point midway down the ogee slope, where it then flares at a constant rate of about 9.5 degrees to a width of 41.8 feet at the toe (see **Plate 2-3**). Spillway rating curves for full and partial Tainter gate openings are shown on **Plate 2-4.**

(3) Spillway Chute. The spillway chute begins at the toe of the ogee spillway and extends to the stilling basin. It has a length of 38.18 feet and a uniform slope of 1V:10H. The chute flares from 41.8 feet at the upstream end to 54.5 feet at the downstream end. The training walls slope from an elevation of 1070.0 feet at the upstream end to 1055.0 feet at the stilling basin. See **Plate 2-3.**

(4) Stilling Basin. The stilling basin is located at the downstream end of the spillway chute and is designed to force the formation of a hydraulic jump for dissipation of energy. It is 72 feet in length, and flares from a width of 54.5 feet at the upstream end, to 78.5 feet at the end sill. The floor of the stilling basin is at elevation 1024.5 feet. The stilling basin contains two rows of baffle blocks 8 feet in height (elevation 1032.5 feet). The baffle blocks are staggered, 6 feet apart in each row, and extend across the entire width of the stilling basin. There is a stepped end sill with a top elevation of 1032.5 feet at the downstream end of the stilling basin. The training walls have a top elevation of 1055.0 feet which is 3.8 feet above the maximum design tailwater elevation of 1051.2 feet. Flared wing walls extend downstream of the stilling basin. See **Plate 2-3.**

Table 2-2
Gate Height Indicator Scale Readings - Orwell Dam
Gate Opening in Tenths of Feet

COUNTER READING AT DAM	GATE OPENING (FEET)	COUNTER READING AT DAM	GATE OPENING (FEET)	COUNTER READING AT DAM	GATE OPENING (FEET)	COUNTER READING AT DAM	GATE OPENING (FEET)	COUNTER READING AT DAM	GATE OPENING (FEET)
0	0.0	504	4.5	997	8.9	1502	13.4	1995	17.8
11	0.1	516	4.6	1009	9.0	1513	13.5	2006	17.9
22	0.2	527	4.7	1020	9.1	1524	13.6	2017	18.0
34	0.3	538	4.8	1031	9.2	1535	13.7	2028	18.1
45	0.4	549	4.9	1042	9.3	1547	13.8	2040	18.2
56	0.5	560	5.0	1053	9.4	1558	13.9	2051	18.3
67	0.6	572	5.1	1065	9.5	1569	14.0	2062	18.4
78	0.7	583	5.2	1076	9.6	1569	14.0	2073	18.5
90	0.8	594	5.3	1087	9.7	1580	14.1	2084	18.6
101	0.9	605	5.4	1098	9.8	1591	14.2	2096	18.7
112	1.0	616	5.5	1109	9.9	1603	14.3	2107	18.8
123	1.1	628	5.6	1121	10.0	1614	14.4	2118	18.9
134	1.2	639	5.7	1132	10.1	1625	14.5	2129	19.0
146	1.3	650	5.8	1143	10.2	1636	14.6	2140	19.1
157	1.4	661	5.9	1154	10.3	1647	14.7	2152	19.2
168	1.5	672	6.0	1165	10.4	1659	14.8	2163	19.3
179	1.6	684	6.1	1177	10.5	1670	14.9	2174	19.4
191	1.7	695	6.2	1188	10.6	1681	15.0	2185	19.5
202	1.8	706	6.3	1199	10.7	1692	15.1	2196	19.6
213	1.9	717	6.4	1210	10.8	1703	15.2	2208	19.7
224	2.0	728	6.5	1222	10.9	1715	15.3	2219	19.8
235	2.1	740	6.6	1233	11.0	1726	15.4	2230	19.9
247	2.2	751	6.7	1244	11.1	1737	15.5	2241	20.0
258	2.3	762	6.8	1255	11.2	1748	15.6	2253	20.1
269	2.4	773	6.9	1266	11.3	1759	15.7	2264	20.2
280	2.5	784	7.0	1278	11.4	1771	15.8	2275	20.3
291	2.6	784	7.0	1289	11.5	1782	15.9	2286	20.4
303	2.7	796	7.1	1300	11.6	1793	16.0	2297	20.5
314	2.8	807	7.2	1311	11.7	1804	16.1	2309	20.6
325	2.9	818	7.3	1322	11.8	1815	16.2	2320	20.7
336	3.0	829	7.4	1334	11.9	1827	16.3	2331	20.8
347	3.1	840	7.5	1345	12.0	1838	16.4	2342	20.9
358	3.2	852	7.6	1356	12.1	1849	16.5	2353	21.0
370	3.3	863	7.7	1367	12.2	1860	16.6	2365	21.1
381	3.4	874	7.8	1378	12.3	1871	16.7	2376	21.2
392	3.5	885	7.9	1390	12.4	1883	16.8	2387	21.3
403	3.6	897	8.0	1401	12.5	1894	16.9	2398	21.4
415	3.7	908	8.1	1412	12.6	1905	17.0	2409	21.5
426	3.8	919	8.2	1423	12.7	1916	17.1	2421	21.6
437	3.9	930	8.3	1434	12.8	1928	17.2	2432	21.7
448	4.0	941	8.4	1446	12.9	1939	17.3	2443	21.8
459	4.1	953	8.5	1457	13.0	1950	17.4	2454	21.9
471	4.2	964	8.6	1468	13.1	1961	17.5	2465	22.0
482	4.3	975	8.7	1479	13.2	1972	17.6	2477	22.1
493	4.4	986	8.8	1490	13.3	1984	17.7	2488	22.2

(5) Low-Flow Conduits. Low water releases are accomplished by means of two 2-foot diameter conduits formed into each of the spillway abutments (see **Plate 2-3**). The invert elevation at the inlet of the conduits is 1040.0 feet. These extend through the spillway abutments and discharge onto the ogee section. The double disc gate values used to control flow through these conduits were replaced in 1988 with two hand-operated 24 inch cast iron slide gates. The discharge rating curve for the conduits is shown on **Plate 2-5**.

d. Discharge Channel. The discharge channel conveys water from the stilling basin end sill to a point 495 feet downstream where the channel joins the natural river. The channel bottom width expands from 78.5 feet at the end sill to 100 feet at the downstream end of the wing walls. The channel remains at this width until it terminates at natural ground. Channel side slopes are 1V:3H. As part of the Dam Safety Project, the discharge channel was modified in 2000. The following summarizes the riprap protection and channel slope:

End Sill	80" Layer	Wing Walls	63" Layer		45" Layer		24" Layer		18" Layer	Natural Channel
0'	48" Riprap	35'	42" Riprap	90'	30" Riprap	135'	18" Riprap	305'	12" Riprap	495'
1030.1'		Elevation Slopes To				1032.5'	Elevation Remains Constant			1032.5'

There are two fish enhancement depressions, three feet deep, located within the final reach of riprap.

e. Tailwater Control Structure. To meet dam safety requirements for the Probable Maximum Flood (PMF), construction of a tailwater structure began in 1998 and was completed in 1999. The purpose of the structure is to provide the required tailwater to contain the hydraulic jump within the existing stilling basin for extreme events. The structure is located approximately 1,000 feet downstream of Orwell Dam (see **Plate 2-11**). It consists of a 765 foot long earthen embankment with five concrete box culvert openings designed to ensure adequate tailwater elevations for all discharges passing over the spillway of Orwell Dam. The earthen embankment has a maximum height of 20 feet with 1V:3H side slopes and a crest width of 15 feet at elevation 1052.5 feet. The crest and downstream slope of the embankment is protected from erosion during overtopping by an articulated concrete mattress system. The approach channel is protected by an 18 inch layer of 12

inch riprap and the outlet channel is protected by a 63 inch layer of 42 inch riprap. The five box culverts are 15.5 feet by 15.5 feet and about 40 feet in length. The culverts have an invert elevation of 1032.5 feet. The structure is designed to be overtopped with an effective overflow length of 564 feet. See **Plate 2-10.**

f. Downstream Channel. In 1954 and 1955, the Otter Tail River was modified between river miles 9.7 and 21.4. The purpose of the modifications was to mitigate flooding between river miles 10.0 and 22.0. See **Paragraphs 3-01 and 4-09** and **Plates 2-1 and 4-7**.

g. Reservoir. Orwell reservoir is regulated between a minimum elevation of 1050.0 feet (maximum drawdown) and 1073.0 feet (top of surcharge pool). The top of flood control pool is elevation 1070.0 feet. At this elevation, the reservoir has a length of 4.0 miles and a maximum width of 1.0 mile. Conservation pool is 1064.0 feet $\pm$ 0.5 feet. When snow surveys reveal a high potential for flooding in the basin, a winter drawdown of the reservoir is performed. The drawdown elevation varies between 1060.0 and 1050.0 feet, depending on hydrologic conditions. Complete information on the operation of the reservoir is given in **Chapter VII - Water Control Plan**. **Table 2-3** gives area-storage values at key pool elevations. Reservoir area and capacity curves are shown graphically on **Plates 2-6 and 2-7** and in tabular form in **Exhibit F**.

Table 2-3
Orwell Reservoir - Area/Volume

Pool Condition	Pool Elevation	Surface Area	Total Volume	Available Flood Storage
Top of Flood Control	1070.0 ft	1,100 acres	14,000 ac-ft	Surcharge
Conservation Pool	1064.0 ft	782 acres	8,300 ac-ft	5,700 ac-ft
Intermediate Drawdown	1060.0 ft	598 acres	5,500 ac-ft	8,500 ac-ft
Maximum Drawdown	1050.0 ft	264 acres	1,200 ac-ft	12,800 ac-ft

2-04. Related Control Facilities. Related control facilities include the perimeter dikes, the tailwater control structure, and the sub-impoundments. The sub-impoundment features are presented here. The locations of the sub-impoundments are shown on **Plate 4-9**. Additional details concerning the sub-impoundments can be found in the *Operation and Maintenance Manual* for the Habitat Restoration Project at Orwell Lake, dated May 1996.

Within the boundaries of the Orwell Reservoir there are four controlled sub-impoundment areas (**Plate 4-9**). These sub-impoundments were created to provide fall staging and feeding areas for migrating waterfowl and to increase the overall value of Orwell Reservoir and the surrounding area for fish and wildlife. The first controlled sub-impoundment area was constructed by the Minnesota Department of Natural Resources (MDNR). Construction of additional sub-impoundment areas was initiated by the *Orwell Reservoir Operation Plan Evaluation and Environmental Assessment* (1986 ROPE Study). While nine impoundment areas were identified, the Corps of Engineers developed plans for six and three have been constructed. Upon completion of the sub-impoundments, operation and maintenance was turned over to the MDNR Division of Fish and Wildlife to manage as required for the stated purpose.

MDNR Sub-impoundment. The first project was a 144 acre impoundment constructed by the MDNR Division of Fish and Wildlife on the south arm of the reservoir. Construction cost was reduced by utilizing the County Road 2 crossing as an embankment. The outlet consists of a 78-inch CMP with stop log control. Although the water levels in the impoundment area were managed independently from the reservoir, its effectiveness was limited due to the steep gradient of the area (i.e. bottom elevation between ends of the impoundment is about 4 feet).

Sub-impoundment 9. The effectiveness of the MDNR Sub-impoundment was improved in 1993 by the construction of Sub-impoundment 9. The project was constructed by the Corps of Engineers in cooperation with the MDNR under Section 1135 Authority. The structure consists of a sheet pile weir located upstream of County Road 2 within the upper reach of the MDNR Sub-impoundment. Therefore, there is a northern impoundment, 0.5 miles in length, and a southern impoundment, 0.8

miles in length. The elevation difference within both impoundments is about 2 feet. The sheet pile weir is about 100 feet in length and features conveyance channels upstream and downstream.

Sub-impoundment 7. In 1994, the Corps of Engineers constructed Sub-impoundment 7 under Section 1135 Authority with MDNR as the local sponsor. The outlet for this 9 acre impoundment consists of an earthen dike with a standpipe control structure. To accommodate outflows during flooding, a spillway, 20 feet in length, was incorporated into the embankment. Conveyance channels are provided upstream and downstream of the structure.

Sub-impoundment 2. Sub-impoundment 2 was constructed in 1999 as part of the Orwell Dam Safety Project. To compensate for the approximately 2 acres of wetland filled by the tailwater control structure, Sub-impoundment 2 was constructed. It is located on the northern perimeter of the reservoir and has an area of 11.5 acres. The structure consist of a sheet pile weir with two stop log bays, 5 feet in width.

Table 2-4
Sub-impoundment Control Structures

Sub-Impoundment	Type Retention	Length	Crest Elevation	Design Pool	Outlet Control	Outlet Invert	Impoundment Area
No. 2	Sheet Pile Weir	73 ft	1070.0 ft	1068.0 ft	Two 5-ft Stop Log Bays	1062.0 ft	11.5 ac
No. 7	Earthen Berm	85 ft	1073.0 ft	1072.0 ft	Stand Pipe 20 ft Spillway	1068.0 ft	8.9 ac
No. 9	Sheet Pile Weir	94 ft	1069.0 ft	1068.0 ft	Two Stop Log Bays	1063.0 ft	82.2 ac
MDNR	County Road 2	-----	~1075 ft	------	78 inch CMP Stop Logs	1060.5 ft	~80 ac

2-05. Real Estate Acquisition. The Federal Government owns about 2,000 acres of land in connection with the Orwell Project. The taking line guide contour was elevation 1073.0 feet (**Plates 2-8 and 2-9**). Bank erosion in the upper pool in 1988 resulted in the purchase of an additional 30 acres. In 1980, 1,957.6 acres of project land and water areas were leased to the Minnesota

Department of Natural Resources (MDNR) for wildlife management. This area was expanded to 1992.6 acres in 1989. This area is known as the Orwell Wildlife Management Area. The license is shown in **Exhibit D-5**. The lease expires in 2004. In the event that the MDNR does not renew the lease for wildlife management, the Corps of Engineers (COE) would need to revise the Orwell Master Plan and Operational Management Plan (last full revision was in 1993). If the COE does reassume management, St. Paul District would conduct resource inventories, establish wildlife management objectives and goals, and develop and implement management prescriptions.

2-06. Public Facilities. There are two recreation areas maintained by the St. Paul District at the Orwell Project site. **Orwell Dam Recreation Area** is located downstream of the dam. This area covers approximately 3 acres, and includes a paved 15-car parking area, picnic shelter with tables, an information kiosk, playground equipment, and rest rooms (new in year 2000). There is also river access for tailwater fishing at this site. **Overlook Recreation Area** is above the dam. It covers approximately 2 acres, and includes a 20-car gravel parking area, a picnic shelter with tables, and an information kiosk.

III - HISTORY OF THE PROJECT

3-01. Authorization. House Document No. 185, 81st Congress, dated 24 May 1948, contained a comprehensive plan for flood control for the Red River of the North basin. Included in this document was a recommendation for the construction of a reservoir on the Otter Tail River and channel modifications downstream of the reservoir, between river miles 24.8 and 9.7 (**Plates 2-1 and 4-7**). Partial completion of the comprehensive plan was authorized by the 1948 Flood Control Act (approved 30 June 1948). Completion of the plan was authorized by the Flood Control Act approved on 17 May 1950.

3-02. Planning and Design. Numerous attempts have been made to alleviate flooding in the lower Otter Tail River area. The first project (in 1895) was sponsored by the Red River Valley Drainage Commission. The Commission constructed a ditch to divert overflow from the Otter Tail River (near river mile 23.0) into the Doran Slough. In 1910, another attempt was made to control the overflow in the same vicinity by constructing a high flow cutoff ditch (floodway) linking river miles 25.9 and 18.8. This cutoff was constructed through the joint efforts of the Wilkin County Board and the Minnesota State Drainage Commission. Later, several cutoffs and ditches between river miles 16 and 22 were constructed, but none effectively solved the flooding problems.

Following the drought of the 1930's, water supply became an issue in the region. As a result, 31 low head dams were constructed in the lake region of the Otter Tail River basin to restore the lakes to levels deemed necessary for recreational activities and water conservation. These dams were sponsored by the Water Resources Branch of the Minnesota Department of Conservation and were constructed by the Works Progress Administration. The dams were completed in 1938.

In the 1940's, a basin-wide study of the Red River of the North was made by the Corps of Engineers. The Corps developed a comprehensive plan for flood control and associated purposes and presented its results in a report entitled "Survey Report on the Red River of the North". The plan included two features; (1) a reservoir on the Otter Tail River to control floods and to supplement low flows for water supply and pollution abatement, and (2) channel modifications downstream of the reservoir,

between river miles 24.8 (later changed to river mile 21.4) and 9.7, for increased channel capacity. The report was submitted to congress on 24 May 1948 and construction of the project was authorized by the Flood Control Acts approved 30 June 1948 and 17 May 1950. The 1948 act authorized partial accomplishment of the Red River of the North comprehensive plan for flood control and the 1950 act authorized completion of the plan.

3-03. Construction. Construction of the Orwell Dam and Reservoir Project began in May 1951 and was placed into operation during the spring of 1953. The downstream channel modification was started in January 1953 and completed in June 1954.

3-04. Related Projects. The Otter Tail River and the Bois de Sioux River combine at Wahpeton, North Dakota/Breckenridge, Minnesota to form the Red River of the North. The Lake Traverse Project on the Bois de Sioux River is operated in conjunction with Orwell Dam to provide flood control for the two cities. Detailed information on the Orwell Dam operation plan is given in **Chapter 7**. The Lake Traverse Project consists of White Rock Dam and a low-head structure (upstream) called Reservation Dam. Refer to the Lake Traverse Project, Water Control Manual for additional information.

There are numerous small dams upstream of Orwell Dam. Dayton Hollow Dam, located about five miles upstream of Orwell Dam, is the only dam that can affect regulation of Orwell Reservoir. However, under normal operating procedure, Dayton Hollow Dam does not store or release large volumes of water and therefore, has minor impacts on the operation of Orwell Dam. See **Paragraph 4-10** for more information regarding upstream dams.

3-05. Modification to Regulations. The Water Control Plan was formally presented in the *Interim Reservoir Regulation Manual* dated April 1954. This section begins by describing portions of the regulation manual, as presented in 1954, that were later changed. Following this, in chronological order, are modifications to the regulation plan.

a. 1954 Regulations (That Were Later Modified). The Water Control Plan of 1954 established a "normal full pool" elevation of 1070.0 feet and a minimum pool elevation of 1048.0 feet. Winter drawdown was to begin on 1 November to assure that elevation 1048.0 feet would be reached by 1 March. During flood runoff, discharges were not to exceed 900 cfs until elevation 1070.0 feet was achieved. At this point, the gate was to be adjusted to discharge 90 percent of the reservoir inflow rate (based on the average inflow rate for the previous 3 hours), thus changing to an induced surcharge operation. When the maximum pool elevation of 1075.0 feet was reached, the gate was opened as necessary to pass inflow. Upon recession, the gate remained unchanged until the pool had lowered to elevation 1070.0 feet.

Minimum release from Orwell Dam was not to be less than 5 cfs. During drought conditions, releases from Orwell Dam were to be coordinated with Baldhill Dam to meet water supply needs above the confluence of Red Lake River. Minimum releases from Orwell Dam for water supply, pollution abatement, and sugar beet processing was approximately 40 cfs.

b. 1963 Modifications. In August of 1963, the Water Control Manual was revised. Changes were made to the Water Control Plan to augment low-flow conditions and control downstream flooding during winter drawdown. Under this plan, winter drawdown began on 20 September and was to be completed by 15 March. Also, so as not to exceed channel capacity during winter drawdown, a maximum discharge of 900 cfs was established. See **Exhibit D-3**.

c. 1972 Modifications. Due to the reduced need to augment low flows downstream, delaying the start of the winter drawdown was investigated. In 1969, winter drawdown began on 15 October, and in 1970 it began on 1 November. After completion of the Fargo low-flow diversion dam on the Sheyenne River in July 1972, augmentation of low-flow conditions was deemed less critical; therefore, the date to begin winter drawdown was officially changed back to 1 November. See **Exhibit D-4**.

d. 1977-79 Modifications. Several boils were discovered in the bottom of the discharge channel in late May 1977 with a pool elevation 1069.5 feet and a differential head of 35.5 feet. Boils

also occurred in late September 1978 under similar conditions. Because of these seepage problems, there were safety concerns regarding the allowable surcharge to be placed on the pool; therefore, surcharging of the pool above top of flood control (1070.0 feet) was avoided, thus minimizing surcharge pressures on the dam. For example, the peak pool elevation in the spring of 1979 was 1070.06 feet (**Table 4-7**). Relief wells were put in place in the summer of 1979 and thereby allowed surcharging pool to revert back to elevation 1075.0 feet.

e. 1986 Modifications. In January 1986, the *Orwell Reservoir Operation Plan Evaluation (ROPE) and Environmental Assessment* was released. The Finding of No Significant Impact (FONSI) was signed in February 1986. The ROPE study indicated that the annual fluctuations of the pool between elevations 1070.0 and 1048.0 feet caused environmental problems for the reservoir area. The report presented an alternative operating plan to mitigate these problems. As a result, the operating plan was amended such that a normal pool elevation of 1068.0 feet and a normal winter drawdown elevation of 1064.0 feet was established. Drawdown would begin on 1 February and be completed by 15 March. The intent was to minimize pool fluctuations so as to improve habitat conditions in the wetlands and shallow aquatic areas around the reservoir. In addition, studies indicated that a discharge of 1,200 cfs from the dam did not interfere with agricultural operations downstream. Therefore, the channel capacity discharge was increased from 900 cfs to 1,200 cfs. Essentially, this change in operation eliminated freeboard in the channel improvement reach.

An agreement between the Corps of Engineers (COE) and the Minnesota Department of Natural Resources (MDNR), regarding low flow releases, was established in 1986 (**Exhibit D-6**). Prior to this agreement, the low flow minimum was 5 cfs with an exception for water supply, pollution abatement, and sugar beet processing whereby the minimum flow was approximately 40 cfs. The new agreement raised the minimum outflow to a year-round minimum release of 80 cfs. This was based on the need for (1) pollution abatement during the summer when wastewater treatment plants have higher biochemical oxygen demand constraint, (2) water supply, (3) recreational boating, and (4) instream aquatic wildlife and fish habitat.

While improvements to the dam were made in 1979 to address seepage problems, boils were again discovered in May 1986 when the pool peaked at elevation 1072.14 feet. After that, surcharging of the pool more that a couple tenths of a foot above the top of flood control (1070.0 feet) was avoided. For example, during the floods of 1993 and 1997, the pool reached elevations of 1070.73 feet and 1070.30 feet respectively.

f. 1988 Modifications. Problems associated with pool fluctuations were addressed in the *Operation Plan Evaluation and Environmental Assessment, Lake Traverse, Bois de Sioux River, and Orwell Reservoir, In-House Draft Report* (1988). While the final report was not issued until April 1994, some recommendations were adopted in 1988. The report proved that a normal pool elevation of 1068.0 feet with a winter drawdown to elevation 1064.0 feet, established in 1986, was ineffective in improving habitat conditions. Therefore, the following recommendation was adopted: A year-round conservation pool elevation of 1064.0 feet will be maintained with an allowance for a drawdown to as low as 1048.0 feet, by 31 March, if the water content of the winter snow pack indicated a potential for significant spring flooding (i.e. three inches or more snow-water content).

g. 1994 Modifications. The *Operation Plan Evaluation and Environmental Assessment, Lake Traverse, Bois de Sioux River, and Orwell Reservoir Report* was completed in April 1994. The Finding of No Significant Impact (FONSI) was signed July 1994. While some of the reports recommendations were adopted in 1988 (see above paragraph), additional modifications were made in 1994. Two Minnesota Department of Natural Resources (MDNR) recommended changes to the operating plan were adopted to further enhance habitat conditions. One was to allow for a temporary pool raise to about 1066 feet during the fall waterfowl migration season to provide waterfowl staging and feeding areas. The other was to draw down the reservoir to about 1061 feet following the spring runoff every few years to allow the MDNR to drain their sub-impoundments located in the south arm of the reservoir. See **Exhibit D-7**.

The city of Moorhead, Minnesota draws water supply from the Red River of the North and therefore has concerns regarding water quality (**Exhibit D-8**). Outflows from the Lake Traverse Project are of poor water quality while outflows from Orwell Reservoir are of much higher quality. Therefore,

when the appropriate conditions exist for an Orwell drawdown, Orwell Reservoir will be drawn down concurrently with the drawdown of Lake Traverse. Drawdown will begin on 1 March and be completed by 31 March.

h. 1999 Modifications. To meet dam safety requirements for the Probable Maximum Flood (PMF), construction of a tailwater structure to raise tailwater elevations began in 1998 and was completed in 1999. The Finding of No Significant Impact (FONSI) for construction was signed in June 1996. The FONSI for drawdown to meet construction needs was signed in December 1997. Improvements to the scour protection downstream of the dam were completed in fall 2000. The tailwater structure, along with the channel improvements, safely allows for a surcharge pool elevation of 1075.0 feet. However, the taking line guide for the reservoir is the 1073.0 feet contour (**Plates 2-8 and 2-9**) and no arrangements have been made for flood easements to elevation 1075.0 feet. Therefore, top of surcharge pool for the current operating plan is constrained to an elevation of 1073.0 feet. (Note: Under this operating plan, a record pool elevation of 1072.47 feet occurred on 9 June 1999; **Table 4-7**).

As per agreement with the US Fish and Wildlife Service, maximum drawdown was established to provide 1,000 acre-feet of storage for fish habitat. The elevation associated with this capacity was elevation 1048.0 feet based the survey of 1943-1944 (**Table 4-1**). The survey of 1985 indicated sedimentation had reduced the storage volume at this elevation to 700 acre-feet. Based on this survey, 1,000 acre-feet of storage would exist at elevation 1049.2 feet. Assuming a linear rate of sedimentation, the elevation that would presently (year 2000) provide 1,000 acre-feet of storage is 1049.6 feet. To eliminate the need for adjusting the maximum drawdown elevation on an annual basis, maximum drawdown was established at elevation 1050.0 feet. This elevation will remain in effect until the next sedimentation survey is performed.

When the basin-average snow-water equivalent was exceptionally high, drawdown was allowed to begin before 1 March. For example, excessive snowfall during the winter of 1996-97 resulted in a concurrent drawdown of Lake Traverse and Orwell Reservoir beginning on 16 February. On 13 June 1997, the Minnesota Department of Natural Resources became aware of a turtle kill on Orwell

Reservoir. Based on a survey of the shoreline, the turtle kill consisted of 69 snapping turtles and 23 painted turtles. It was theorized by the St. Paul District, Environmental Unit that early drawdown during cold temperatures was the likely cause for the turtle kill. This brought about consideration of the following two items: (1) Drawdown of Orwell Reservoir can be achieved much faster than drawdown of Lake Traverse, and (2) Recent improvements to water supply plants on the Red River of the North make the diluting of Lake Traverse water less critical. Therefore, when there is potential for high runoff volume, drawdown of Lake Traverse may begin before 1 March; however, drawdown of Orwell Reservoir will begin on or after 1 March and be completed by 31 March. To reduce shoreline erosion, a general guide rule for maximum drawdown rate was established at 0.5 feet per day.

3-06. Principal Regulation Problems.

a. Gate Icing. As part of the original gate structure, electric base and side seal heaters were installed to address potential gate icing problems. During the first winter of operation (1953-54), this heater system was proven to be inadequate. Icing was sufficient to freeze the Tainter gate in a partially opened position, resulting in loss of reservoir regulation. The icing problem was corrected in 1957 by supplementing the base and side seal heaters with a corrugated aluminum Tainter gate housing connected to two liquefied petroleum-gas-fired, forced hot-air heating systems. The original forced air system had the base and side seal heaters replaced in 1996. In 1999 the forced air system was replaced with electric heaters.

b. Artesian Pressure. Artesian pressures became a cause for concern during the 1970 periodic inspection. At this time, a general wet condition was noted along the downstream toe of the embankment. Clearing was recommended, along with construction of a drainage ditch and installation of piezometers. This work, performed in 1973, was only partially effective. In 1976, a 15-inch perforated polyvinyl chloride (PVC) toe drain was installed, and a 150-foot-wide berm, up to 5 feet in depth, was constructed along the entire dam toe adjacent to the existing road. The berm width was extended to 250 feet over the old river channel.

c. Boils. In May 1977, boils of significant size with some displacement of material (sand cones) were detected in the bottom of the spillway discharge channel. To relieve the pressure and provide adequate safety, 10 relief wells were installed along the right bank of the outlet channel in 1979. In addition to the relief wells, 21 piezometers, 20 observation wells, and 2 inclinometers were installed between 1971 and 1978. In spite of these improvements, boils were again discovered in May 1986. Downstream channel improvements were made in 1999 and 2000 as part of design measures to meet dam safety requirements. As a result of these improvements, boils are no longer expected to be a problem.

d. Shoreline Erosion. A considerable amount of shore erosion has occurred since Orwell Lake was first impounded. Steep banks have developed on about 35 percent of the high water shoreline of the main lake, making many of the banks nearly vertical. The effects of the erosion have been serious. For example, erosion of private land along the south shore resulted in the purchase of 30 acres of land by the Federal Government. A 2½-year study was conducted by John R. Reid, University of North Dakota, to determine the causes of bank erosion and ways to slow down its rate and magnitude. The results of the study were published in January 1983 in a report entitled *Shoreline Erosion Process, Orwell Lake, Minnesota.* The report identified wave action accompanying high pool levels and, to a lesser extent, freeze-thaw and rainfall as the primary causes of erosion.

The effects of bank erosion on storage capacity and the useful life of the reservoir were analyzed in the *Orwell Reservoir Operation Plan Evaluation and Environmental Assessment* (ROPE) study of 1986. Also analyzed in the ROPE study were the environmental impacts of the plan of operation in effect at that time. This plan allowed for an annual fluctuation of the pool elevation between 1048.0 and 1070.0 feet. This wide annual fluctuation and the resulting repeated changes in the conditions to which the shoreline was exposed prevented the formation of a stable vegetative cover. Recommendations from the ROPE study changed the operation of the pool from wide annual fluctuations to a near constant elevation of 1064.0 feet, which has allowed the shoreline to establish vegetation in the littoral zone. This for the most part has eliminated the serious bank erosion that

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had been taking place and has provided stable habitat for the invertebrates which make up part of the food supply for game fish and waterfowl.

e. Low-Flow Conduits. The two existing 24-inch low-flow conduits were originally controlled by double disc gate valves. When the gate valves were in a partially open position, vibration would occur. Vibration resulted in excessive wear of the valves; therefore, the valves were kept either fully open or fully closed. The Tainter gate was used to control low-flow releases for those conditions when partially open valves would normally have been used. However, because of the Tainter gate's large size, it was not an adequate substitute for the valves and could not be operated with sufficient accuracy. In addition, vibration and erosion of the lip occurred during very small gate openings. In 1988, the double disk gate valves were replaced with slide gates to allow the conduits to be operated over their full range. These have functioned effectively since their installation.

IV - WATERSHED CHARACTERISTICS

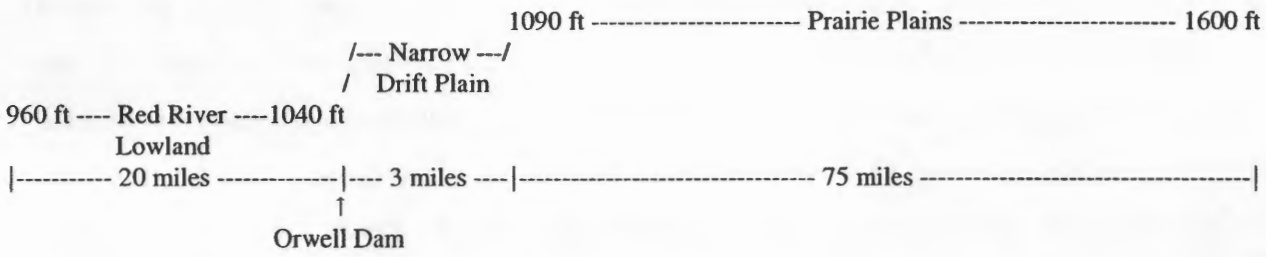
4-01. General Characteristics. The Otter Tail River basin lies in west central Minnesota about 150 miles south of the Candian border and is part of the Red River of the North drainage basin. The watershed is shown on **Plate 2-1**. The drainage area above the Orwell Project covers about 1,820 square miles. The headwaters are in the morainic hills of southwestern Clearwater County approximately 90 miles northeast of the project site, at about elevation 1600 feet. The river flows from its source in a southerly direction through an extensive network of lakes and depressions until it reaches Otter Tail Lake located upstream of Fergus Falls. It then flows in a westerly direction, past Fergus Falls, through Orwell Reservoir, and ends at Breckenridge, Minnesota where it joins with the Bois de Sioux River to form the Red River of the North. Above river mile 40.0 the river runs through rolling hills as noted above, whereas below river mile 22.0 the area is nearly devoid of relief. Between these two distinct areas lies a transition section of a series of ridges, which is where the dam is located.

The largest tributary to the Otter Tail River is the Pelican River, which joins the main stem at mile 49.6 and drains an area of about 518 square miles. There are two other tributaries of significance. These are the Dead River, which drains an area of about 148 square miles and enters the Otter Tail River in Otter Tail Lake at approximately mile 102.0, and the Toad River, which drains about 122 square miles and enters the Otter Tail River in Pine Lake at approximately mile 125.0.

The average fall of the Otter Tail River over its 200 miles of length is about three feet per mile. The maximum fall of 12 feet per mile occurs in a five mile reach below Height Of Land Lake in T139N, R39-40W. The minimum fall is less than one half foot per mile occurring in the reach between Pine Lake and Otter Tail Lake, T135-136N, R38-39W.

4-02. Topography. The Otter Tail River embraces two well defined subdivisions of the central lowland province of the great interior plains region of North America. These are the prairie plains in the upper part of the drainage basin and the Red River lowland in the lower reaches. These two regions are separated by small sections of beaches lying in a narrow drift plain. These beach sections

were formed when Lake Agassiz occupied the area. The Red River Valley plain is remarkably flat, ascending gradually toward the east from an elevation of about 960 feet at the Red River to elevation 1040 feet at the base of the lake beaches, a distance of about 20 miles. The drift plain containing these lake beaches is about three miles wide and gradually blends into the morainic knolls and ridges of the prairie plains. The drift plain affects a rise of about 50 feet in a distance of about three miles to the prairie plains which continues a gradual ascent in a northeasterly direction reaching an elevation of about 1600 feet at the upper limit of the basin.



The prairie plains are characterized by a complex combination of rugged morainic knolls and ridges with interspersed hollows. On the east and south sides of the basin lie the most massive morainic accumulation in the State of Minnesota. These hills are known as the Leaf Hills and rise 200 to 350 feet above the adjoining county. The summit of this range is about 15 miles south-southeast of Otter Tail Lake at an elevation of 1700 feet. Along the Otter Tail River and its tributaries, the natural fall and volume of water from the overflow of the numerous lakes is sufficient to permit the development of hydropower.

4-03. Geology and Soils. The surface of the basin is a thick cover of glacial drift composed of a heterogeneous mass of clay, sand, gravel, and boulders which range in depths up to 500 feet. The thinnest covering is in the vicinity of Pine Lake near Perham, Minnesota, where the Archean bedrock is about 200 feet below the existing surface. There are no rock outcrops anywhere in the basin.

In the Red River Valley plain, the ancient Lake Agassiz was responsible for the lacustrine deposit. Sediment brought in by the large glacier-fed streams spread over the bottom covering the drift or till in most places to depths of 50 feet or more.

4-04. Sediment. There were 24 sediment ranges established in 1955 as shown on **Plate 4-1**. Range lines 1 through 3 are below the dam, while the remaining range lines are located in the pool area. Repeat soundings were taken at the same ranges in January 1964 and January 1985. The 1985 survey was performed as part of the *Orwell Reservoir Operation Plan Evaluation Environmental Assessment* (1986 ROPE Study). Inflow of sediment from upstream is restricted by the presence of the Dayton Hollow Dam and the numerous lakes in the upper portions of the basin; however, the sedimentation surveys indicate there is continuing shoreline erosion. While bank erosion has caused agradation of the deeper areas of the reservoir, sedimentation is occurring at a slow rate. The establishment of the lower, more stable conservation pool in 1986 and the resulting vegetation near the shore, has reduced shoreline erosion and thereby the sedimentation rate. A more detailed discussion of shoreline erosion is given in the 1986 ROPE report.

Reservoir area and capacity curves presented in the 1954 regulation manual were determined by planimetering the contour areas on a topographic map developed from surveys taken between October 1943 and January 1944. The scale of the map was 200 feet to the inch and the contour interval was five feet. While bank erosion has certainly changed the elevation-area curve, the change in area is very small in comparison with the total area. Therefore, elevation-area data has remained unchanged.

In 1984, reservoir volumes were recomputed by applying the conic method to the 1954 elevation-area curve. The results showed little change in reservoir capacity above elevation 1048 feet (maximum drawdown). Reservoir volumes were computed again in 1986. This analysis involved a comparison of average-end-area volumes using the 1954 and 1985 surveys, with the original planimetered values. In general, the 1986 computed reservoir volumes are basically average-end-area volumes calibrated to the 1954 planimetered values. The reduction in storage due to sedimentation can be derived from the elevation-volume data presented in **Table 4-1**. The table indicates that, over the project life, there has been a 30 percent reduction in storage volume below elevation 1048 feet; whereas, storage at top of flood control (1070.0 feet) remains essentially unchanged. Area-capacity curves are shown on **Plates 2-6 and 2-7**.

Table 4-1 Orwell Reservoir - Area/Capacity				
	1954 Regulation Manual Survey Date: 1943-44		1984 Conic Method 1943-44 Survey	1986 ROPE Study 1985 Survey
Elevation (ft)	Area (acres)	Volume (ac-ft)	Volume (ac-ft)	Volume (ac-ft)
1033	0	0	0	0
1040	35	210	97	4
1048	210	1000	973	700
1060	598	5750	5656	5500
1064	782	8600	8414	8300
1070	1110	14100	14057	14000

4-05. Climate. The climate in the region is variable. The area is subject to cold winters and warm summers, typical of continental conditions in the temperate zone. The climate is generally favorable for agricultural activity. The growing season ranges from 96 days in the headwaters area to 135 days in the lower reaches. The average is about 130 days in the main farming area.

a. Temperature. The mean annual temperature for the basin is about 41°F with extremes ranging from -53 °F to 114° F. Normal monthly temperatures for the National Weather Service stations at Wheaton, Minnesota and Fargo, North Dakota are listed in **Table 4-2**. On average, the first killing frost occurs on 22 September.

Table 4-2 Normal Temperatures at National Weather Service Stations - Degrees Fahrenheit													
Location/Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Wheaton, MN 1951-80 & 1988-90	10.6	16.8	28.7	45.4	58.6	68.0	73.2	71.3	61.4	49.6	31.9	16.6	44.3
Fargo, ND 1942-91	6.3	11.8	25.2	42.8	55.6	65.0	71.0	69.0	57.8	46.2	28.0	12.3	40.9

b. Precipitation. The mean annual precipitation is about 22.5 inches. About 85 percent of this total occurs during the months of April through October and about one half occurs during April through July. Most of the precipitation during the period November through March accumulates in the form of snow, which constitutes about 15 percent of the annual total. Average monthly precipitation for the National Weather Service stations at Wheaton, Minnesota and Fargo, North Dakota are listed in **Table 4-3**.

Table 4-3
Average Precipitation at National Weather Service Stations - in Inches

Location/Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
Wheaton, MN 1949-56, 1958-86 1988-90	0.66	0.55	1.22	2.08	2.70	3.85	2.99	2.55	1.92	1.53	0.91	0.56	21.4
Fargo, ND 1949-90	0.33	0.33	0.80	1.88	2.37	3.80	2.92	2.83	1.93	1.32	0.76	0.50	19.8

c. Evaporation. Evaporation represents a major portion of the water lost from the reservoir during the period April-October. The *Climatic Atlas of the United States* (June, 1968), estimates the mean annual lake evaporation to be about 30 inches. Average monthly pan evaporation for open water months at the National Weather Service station at Fargo, North Dakota, is listed in **Table 4-4**. Evaporation from lakes is less than pan evaporation due to cooler water temperatures. Assuming a pan coefficient of 0.7 provides a convenient means of estimating reservoir evaporation (*Hydrology for Engineers*, McGraw-Hill, 1958).

Table 4-4
Average Pan Evaporation at Fargo, North Dakota and Estimated Average Reservoir Evaporation - in Inches

	Apr	May	Jun	Jul	Aug	Sep	Oct	Record
Fargo, ND	3.64	7.15	7.41	8.43	7.31	4.95	3.29	1963-80
Orwell Reservoir	2.55	5.01	5.19	5.90	5.12	3.47	2.30	------

d. Wind. The average wind speed in this area is about 10 miles per hour. The prevailing winds are from the northwest, but southeast winds are very common during the summer months. **Table 4-5** shows the highest monthly wind speeds at Fargo, North Dakota over a 41 year period of record. Fastest-mile wind-speeds as shown in the table are defined as the fastest speed at which wind travels one mile measured over the month indicated. Fastest-mile wind speed values are obtained from a short period generally less than 2-minutes in duration. Very high fastest-mile wind speeds are usually the result of short duration thunderstorms. The fastest-mile wind speeds were modified to a time-dependent (1-hour) average wind speed using procedures presented in the US Army Corps of Engineers' *Shore Protection Manual* (1984).

Table 4-5
Highest Monthly Wind-Speeds in MPH at Fargo, North Dakota

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direction	W	W	N	N	NW	NW	SE	NW	N	NW	N	N
Fastest Mile	57	56	56	65	72	115	60	71	88	57	66	58
1 - Hour	46	45	45	52	57	87	48	56	68	46	53	47

The Soil Conservation Service (SCS) developed wind-stress factors to be used in the design of shore protection. The results are presented in Minnesota Technical Release No. 2, *Slope Protection for Dams and Lakeshores* dated April 1988 and in the 1997 updated version by National Resources Conservation Service (NCRS). Wind-stress factors were computed from the wind-speed which equaled or exceeded 95 percent of the recorded readings at Fargo, North Dakota for each of 16 compass points. For presentation here, the wind-stress factors were back-calculated to obtain wind-speeds at a height of 10 meters (33-ft).

Table 4-6
Wind-Stress Factors (WSF) and Wind-Speeds (WS) in MPH at Fargo, ND

	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
WSF	41	43	33	33	32	34	39	40	33	33	32	32	41	53	52	48
WS	31	33	26	26	26	27	30	31	26	26	26	26	31	39	38	36

Wind blowing over the reservoir 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 piling up of water is referred to as wind setup. It is expressed as a height above the undisturbed water level and can be determined from the following equation (EM 1110-2-1414; 1989).

$$S = \frac{U^2 F}{1400 h}$$

S = setup above still-water level (ft)
U = over-water wind speed at 33 ft (mph)
F = fetch length (miles)
h = average water depth along fetch line (ft)

Wind setup can have a significant impact on the water surface elevation. For example, a sustained wind blowing at 30 mph from the east would produce about 0.3 feet rise above the still-water elevation at the dam.

4-06. Storms and Floods. The Otter Tail River is one of the best naturally regulated rivers in the State of Minnesota because of the more than 1,400 lakes in the drainage basin. High flows occur during the spring breakup and from heavy spring rains; however, extensive flooding is largely confined to the flat low land area of the Red River Valley where the Otter Tail River joins the Bois de Sioux River to form the Red River of the North. The following is a brief description of floods that have occurred in the basin. A summary of stages and discharges is presented in **Table 4-7**.

a. Spring 1897. Prior to the year 1900, information on floods and flood damage in the Otter Tail Basin is very limited. A large flood is known to have occurred in 1897 resulting from a rapid snow melt. While there are no estimates of the flow on the Otter Tail River, the peak stage and discharge at Wahpeton, North Dakota was estimated by the US Geological Survey (USGS) to be 17.0 feet and 10,500 cfs respectively. Following this event, the Corps of Engineers established a station at the outlet of Otter Tail Lake in May 1899. Daily discharge measurements were taken at this station until 1904 when the USGS established a station about 15 miles downstream in May of that year. From May 1904 to September 1917, the USGS published monthly discharge data for this site under the name 'Otter Tail River at German Church near Fergus Falls'.

b. Late Spring/Early Summer 1906. In June 1906, a flood occurred which produced high flows into July. A maximum discharge of 1,350 cfs was measured on 26 June 1906 at a point one mile below the mouth of the Pelican River. The USGS gage located several miles upstream of the Pelican River confluence (German Church near Fergus Falls) recorded a constant discharge of 1,100 cfs from 25 June to 9 July. This maximum discharge stood as a record flow until 1953.

c. 1930's-1940's. The Dayton Hollow Dam and Hydroelectric Plant was constructed in 1908. It is located approximately five miles downstream from the mouth of the Pelican River. On 18 November 1933, the USGS established the gaging site 'Otter Tail river below Pelican River', below the Dayton Hollow Dam. This site was maintained until 21 March 1953. Maximum flood flows recorded at this station in April 1943 and June 1944 were 1,150 cfs and 1,200 cfs respectively. In June 1947 a maximum daily discharge of 1,200 cfs was recorded.

d. Late Spring 1953. With the construction of the Orwell Project in 1953, the gaging station downstream of Dayton Hollow Dam was moved 6.1 miles downstream to its present location, 0.7 miles downstream of the Orwell Dam. Soon after the reservoir was placed in operation during the spring of 1953, heavy rains followed the spring breakup and produced an outflow of 1,710 cfs on 17 June. While this event did not cause flooding at Wahpeton, North Dakota, it produced the discharge of record for Orwell Reservoir.

e. Summer 1962. During the spring of 1962 runoff conditions in the basin were normal. In May a period of frequent heavy rains began that extended into July. These rains caused extensive flooding along the Red River of the North with considerable local damage. The river rose above flood stage at Wahpeton three times; in late May, early June, and early July. The peak discharge at Wahpeton was 5,650 cfs, with an accompanying stage of 16.34 feet, on 11 June. Flood stage at Wahpeton is 10 feet. While inflow to Orwell Reservoir was not as high as in 1953, it had a constant high rate of flow over a much longer period of time. The modification of the downstream channel and the regulated flows from the reservoir greatly reduced flood damages in the lower reaches of the Otter Tail River. The modified channel was designed for a maximum flood capacity of 900 cfs plus freeboard. However, outflows during the 1962 flood were above 900 cfs from 10 June through 16

August 1962 with little damage. The peak discharge was 1,260 cfs on 26 June and the maximum reservoir elevation was 1072.35 feet on 17 June.

f. Spring 1966. Five antecedent factors led to early spring flooding in the Red River of the North basin in 1966. These were: (1) the coldest September of record in 1965; (2) heavy autumn precipitation and resultant soil saturation; (3) an early freeze and deep winter frost penetration; (4) a severe early March snowstorm with high water content following heavy winter-long snowfall over most of the basin; and (5) unseasonably warm early spring temperatures. The Red River of the North at Wahpeton rose above flood stage on 14 March, and crested at 13.93 feet on 16 March. Downstream ice jams contributed to this early crest. The peak discharge occurred two days later, on 18 March, at 4,760 cfs. Ideal spring melt conditions after these peaks prevented a more serious flood. At Orwell Reservoir, the peak discharge was 1,490 cfs on 1 June, and the maximum reservoir elevation was 1072.37 feet on 23 May. Discharge was at or above 1,000 cfs from 22 March to 23 June. An effective flood fight prevented significant damage in the agricultural area downstream of the project and in the urban areas of Wahpeton-Breckenridge.

g. Spring 1969. The combination of a dense snow-pack, an early April warm spell, and heavy rain during the period 7-10 April caused a major spring flood event in the Red River of the North basin, including the Otter Tail basin. On 10 April, this event produced a peak stage of 16.34 feet at Wahpeton, equaling the stage achieved during the flood of 1962; however, with a significantly higher discharge of 9,200 cfs. Orwell Dam had a peak discharge of 1,000 cfs on 16 April and a maximum reservoir elevation of 1070.71 feet on 14 April. The Orwell Project prevented an estimated two million dollars in downstream damages.

h. Spring and Summer 1975. There were two flood events in the Red River of the North basin in 1975. There was a snowmelt event in April due to late-season snowfall, resulting in moderate flooding, and a series of heavy rainfall events in late June and early July resulting in significant flooding. In both cases, the Otter Tail basin was less seriously affected than areas downstream. For the spring event, the peak discharge at Orwell Dam was 1,060 cfs on 19 April and the reservoir remained within the flood control pool range. For the summer event, the peak

discharge at Orwell Dam was 1,125 cfs on 25 June, and the maximum reservoir elevation was 1070.52 feet on 7 July. For both events, the impacts at Wahpeton were minimal.

i. Spring 1979. A major spring snowmelt event occurred in the Red River of the North basin in the Spring of 1979. It was caused by a combination of above normal snow water content and heavy rain occurring at the time of the greatest melting of the snow-pack. On 14 April, a peak discharge of 7,050 cfs and accompanying stage of 15.44 feet was recorded at the Wahpeton gage. At Orwell Dam, the peak discharge was 1,100 cfs on 17 April, and the maximum reservoir elevation was 1070.06 feet on 19 April.

j. Spring 1986. Above normal spring precipitation following an abrupt warm-up at the end of March resulted in high flows in the Otter Tail River from the end of March through early July. The initial rapid snow melt caused the highest flows to occur early in the period at Wahpeton, where a peak discharge of 6,140 cfs and an accompanying stage of 14.31 feet were observed on 30 March. High discharges and pool elevations at Orwell Dam came later, in response to the above normal precipitation. On 19 May, Orwell Reservoir reached a peak elevation of 1072.14 feet. The peak discharge of 1,600 cfs was observed on 27 May. The spring rains also caused a secondary peak flow period in excess of 5,000 cfs at Wahpeton on 10-12 May. Orwell Reservoir discharges exceeded 1,000 cfs continuously from 19 April through 1 July, and the reservoir elevation was near or above the top of the flood control pool from the beginning of April until early June.

k. Spring 1989. After above normal winter snowfall and below normal temperatures for most of March, an abrupt warm-up at month's end, accompanied by a widespread rain event lasting 4 days, set off a major spring flood event. On 5 April, a discharge of 8,370 cfs was measured at the Wahpeton gage. While this was the second highest discharge of record, an ice jam at Wahpeton resulted in the stage of record of 17.95 feet on the same day. It was estimated that, without the ice jam, the stage would have been 16.14 feet. Orwell Reservoir rose to 1070.23 feet on 7 April. The peak discharge of 1,180 cfs occurred on 10 April.

l. Spring/Summer 1993. There were two periods of flooding in the Red River of the North basin in 1993, a spring snowmelt event and a heavy rainfall event in July. The greater of the two events at Wahpeton was the spring event, in which a peak discharge of 6,080 cfs and accompanying stage of 14.33 feet occurred on 31 March. While runoff from the Otter Tail basin did not contribute significantly to this event, it had a great impact on the summer event. At Wahpeton, a peak summer discharge of 4,850 cfs and accompanying stage of 12.67 feet occurred on 27 July. The heavy summer rainfall events resulted in a peak discharge of 1,290 cfs from Orwell Dam on 24 July. The pool achieved its peak elevation of 1070.73 feet on 1 August. Except for reductions in outflow to reduce downstream impacts, discharges were near or above 1,000 cfs from late June to mid-August.

m. Spring 1997. By early January, record snowfall levels had occurred over much of the Red River of the North basin. In mid-March, snow depths of two to three feet were recorded over the entire Otter Tail Basin. Snow water equivalents determined in late March by the National Weather Service indicated water content over the basin was about six inches. Because of this, drawdown of the pool was started one month sooner than normal operating procedures to avoid large releases and ensure maximum drawdown before spring snow-melt and runoff. Drawdown of the pool began on 1 February and on 30 March, the pool reached its minimum allowable elevation of 1048.0 feet. In late March, initial snowmelt of the Otter Tail and Bois de Sioux River basins began. On 6 April, a record stage of 19.42 feet was recorded at Wahpeton. The day prior to this peak stage (5 April), a powerful storm produced over two inches of precipitation, in the form of snow and freezing rain, over the southern and eastern portion of the Red River basin, including the Otter Tail basin. The storm was followed by several days of abnormally low temperatures, thus retarding runoff. The cool period was followed by warm weather. The snow melt, combined with increased releases from White Rock Dam, resulted in a second crest at Wahpeton of 19.37 feet on 16 April. On 15 April, the USGS measured a discharge of 12,800 cfs at the Wahpeton gage site and estimated overland flow to the Wild Rice River basin, about seven miles upstream of the gage, to be 2,200 cfs. The Orwell Reservoir reached a maximum pool elevation of 1070.30 feet on 15 April with a peak discharge of 1,520 cfs occurring on the following day (16 April). Orwell Reservoir discharges exceeded 1,000 cfs continuously from 12 April through 25 June.

n. Summer 1999. Continuous heavy rainfall events during the summer of 1999 produced a record high pool elevation at Orwell Reservoir. Over the period of 4 May through 6 May, Orwell Dam recorded 1.4 inches of rainfall. While flows were increased to bank full capacity (1,200 cfs), the pool rose to one foot above conservation pool (1065.0 ft) on 9 May. An additional 0.8 inches of rainfall occurred over the next two days. With outflows still at channel capacity, the pool reached top of flood control (1070.0 ft) on 29 May and the dam went into surcharge operations (i.e. discharging 90 percent of the three-hour inflow or channel capacity flow, which ever is greatest). Two days later on 31 May, an additional 1.1 inches of rainfall was recorded at the dam. As channel capacity discharges continued, the pool rose to elevation 1072.0 on 6 June. The next day, 2.8 inches of rainfall was recorded at the dam. As discharges were ramped up to discharge 90 percent of inflow, the pool reached a peak elevation of 1072.47 feet on 9 June with a peak outflow of 1,350 cfs. Continuous minor rainfall events hampered the return to channel capacity outflows. The pool fell below top of flood control on 25 June with outflows near channel capacity. Conservation pool was achieved on 11 July.

m. Spring/Summer 2001. The late February snow survey indicated a basin average snow-water equivalent of 3.1 inches. Based on this information, a drawdown was initiated on 1 March. On 31 March, the target drawdown elevation of 1053.0 feet was achieved. Spring runoff began on 6 April with inflows rising to over 1500 cfs by 8 April. Outflow was maintained at channel capacity discharge of 1200 cfs. By 22 April, inflow had fallen to 1170 cfs, when 1.3 inches of rainfall was recorded at the dam. Inflows again rose above 1500 cfs while outflows remained at 1200 cfs. Over the next two months, inflows were supplemented with intermitent rainfall events, thus keeping inflows on the high side. On 16 May, the pool reached elevation 1070.0 feet, at which time outflow was set at 90 percent of inflow. With the sustained high inflow, top of surcharge (elevation 1073.0 feet) was reached on 29 May and outflow was set equal to inflow. Over the next month, intermittent rainfall events resulted in a very slow fall in inflow rates. The pool did not fall below top of flood control (elevation 1070.0 feet) until 1 July. Conservation pool level was reached on 20 July.

Table 4-7
Summary of Peak Discharges (cfs) and Elevations/Stages (feet) at Orwell Reservoir, and Wahpeton, ND

Orwell Pool[1]		Orwell Tailwater[2]		Wahpeton, ND Gage[3]		
Date	Pool Elevation	Date	Peak Discharge	Date	Peak Discharge	Peak Stage
---	---	---	---	Spring 1897	10,500[4]	17.0[4]
---	---	26 Jun 1906	1,350	---	---	---
---	---	---	---	Apr 1916	---	14.80
---	---	---	---	27 Apr 1952	7,130	14.99
---	---	17 Jun 1953[5]	1,710[6]	21 Jun 1953	3,150	9.87
17 Jun 1962	1072.35	26 Jun 1962	1,260	11 Jun 1962	5,650	16.34
23 May 1966	1072.37	1 Jun 1966	1,490	18 Mar 1966	4,760	13.93
14 Apr 1969	1070.71	17 Apr 1969	1,000	10 Apr 1969	9,200	16.34
7 Jul 1975	1070.52	25 Jun 1975	1,125	5 Jul 1975	3,850	10.84
19 Apr 1979	1070.06	16 Apr 1979	1,110	14 Apr 1979	7,050	15.44
19 May 1986	1072.14	27 May 1986	1,600	30 Mar 1986	6,140	14.31
7 Apr 1989	1070.23	10 Apr 1989	1,180	5 Apr 1989	8,370	17.95[7]
3 Apr 1993 1 Aug 1993	1064.98 1070.73	3 Apr 1993 24 Jul 1993	1,008 1,290	31 Mar 1993 27 Jul 1993	6,080 4,850	14.33 12.67
15 Apr 1997	1070.30	16 Apr 1997	1,520	6 Apr 1997 16 Apr 1997	12,800[8]	19.42[9] 19.37
9 Jun 1999	1072.47	8 Jun 1999	1,350	7 Jun 1999	4,000	11.05
29 May 2001	1072.93[10]	29 May 2001	1,703	9 Apr 2001	9,220	16.96

1. COE Gage. Datum 1912 Adjustment.
2. USGS gage located 0.7 mile below Orwell Dam. The 1906 gaging was taken 10.1 miles upstream.
3. USGS gage on Red River of the North. Gage Datum = 942.97 feet 1929 NGVD.
4. Estimated by USGS.
5. Reserevoir put into operation spring of 1953.
6. Discharge of record for Orwell Reservoir.
7. Stage influenced by ice jam.
8. Discharge of record at Wahpeton.
9. Stage of record at Wahpeton.
10. Elevation of record for Orwell Reservoir.

4-07. Runoff Characteristics. US Department of Agriculture Bulletin No. 1017 includes a comprehensive study of floods and flooding in the Red River Valley for the period 1893-1920. This study showed that snow has an important effect on runoff during March and April. Snow accumulates in varying quantities during the period of November through March. The runoff resulting from this stored precipitation was studied for the above period. It was found that when a considerable portion of the watershed was covered with snow to a depth exceeding 15 inches, and when, on or near 1 March, 12 inches or more of the winter accumulation of snow was still on the watershed, high stages would result in the principal streams.

Historically, high flows in the Otter Tail River basin have been caused by the combination of spring snowmelt and rainfall events or by intense summer rainfall events. The basin has a generally east-west orientation. Therefore, the factors that can aggravate spring snowmelt flooding in the greater Red River of the North basin are absent from the Otter Tail River basin except for backwater and ice jam effects at the lowermost end just upstream of the confluence with the Bois de Sioux River. Local ice jams can occur at bridges and constrictions elsewhere along the Otter Tail River as well. A mitigating factor to any flood situation in the basin is the previously noted highly effective natural regulation of the river.

The USGS maintains a gage located 0.7 miles downstream of the dam (i.e. *Otter Tail River Below Orwell Dam*). Since completion of the project in 1953, daily reservoir outflows have been recorded using the latest USGS rating curve, with the appropriate shift applied. Because of changes in the reservoir operating plan (**Paragraph 3-05**), the outflow record is not homogeneous. While the impact on flow duration computations is minor, the change in drawdown dates over the period of record can be evident when making inflow/outflow comparisons. Reservoir inflows are also recorded daily. Inflows are computed, based on the 24-hour change in pool elevation, the associated change in storage volume, and a 24-hour discharge. While recorded outflows are instantaneous, inflows are averaged over a 24-hour period. Therefore, a good comparison of inflows to outflows is not possible. In addition, the computation for inflow does not provide adjustment for wind (e.g. wind setup at the pool gage) or changes in discharge from the 0800-hour reported discharge (e.g. mid-day gate changes, change in head, etc.); therefore, smoothing of the data is sometimes required. Based on the Corps data records for the period August 1953 through 1995, the percent of time a given annual inflow or outflow is equaled or exceeded (annual flow duration) is shown on **Plates 4-2 and 4-3**. The mean monthly and annual inflow and outflow rates, are presented on **Plates 4-4 and 4-5**.

Plate 4-6 shows the variation in monthly streamflow rates at the project control point at Wahpeton, North Dakota. Monthly inflow and outflow duration is shown in **Tables 4-8 and 4-9**. Average monthly and annual reservoir inflow and outflow rates are listed in **Tables 4-10 and 4-11**.

Table 4-8
Orwell Reservoir - Inflow Duration (cfs) - Years 1953 - 1995

Percent of Time at or Above Indicated Reservoir Inflow (rounded to nearest whole number)

Flow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Nov	Dec	Jan	Year
1500					1								
1400					2	2							
1300					5	4							1
1200				1	6	7	1						1
1100			1	3	9	12	2	1					2
1000			2	4	17	17	4	2	1	1			4
900			3	8	24	24	8	5	4	2			7
800			5	17	34	31	13	5	5	4	4		10
700			7	26	44	40	20	7	6	7	6	4	14
600	2	3	12	36	54	51	27	14	9	7	8	7	19
500	9	8	21	54	65	63	41	23	18	12	11	13	28
400	16	16	36	76	77	73	59	34	28	25	23	18	40
300	28	31	58	89	88	82	77	51	39	37	33	32	54
200	51	57	78	96	95	93	86	76	65	59	56	51	72
100	84	92	97	99	98	97	95	92	89	85	84	77	91

Table 4-9
Orwell Reservoir - Tailwater Outflow Duration (cfs) - Years 1953 - 1995

Percent of Time at or Above Indicated Reservoir Outflow (rounded to nearest whole number)

Flow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Nov	Dec	Jan	Year
1500					1	1							
1400					2	2							
1300					3	3							
1200					5	7							1
1100				2	9	12	2	3					2
1000			1	6	14	17	5	4	2	1			4
900			1	10	23	25	10	5	5	2			7
800			3	18	35	32	15	7	5	4	3	1	10
700		1	5	26	45	40	20	8	5	7	7	5	14
600	3	4	9	36	55	53	28	15	8	7	9	9	20
500	12	8	20	51	65	62	42	22	12	10	14	14	28
400	21	17	37	72	76	73	57	29	24	20	24	23	39
300	31	36	60	86	89	80	73	44	37	39	41	36	54
200	66	65	85	94	94	91	82	63	54	61	61	60	73
100	86	93	95	97	98	98	93	81	76	81	89	88	90

Table 4-10
Average Monthly and Annual Inflow Rates (cfs) - Years 1953 - 1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1953								628	598	528	457	379	518
1954	305	293	444	621	853	907	520	263	258	227	151	154	417
1955	128	152	231	471	394	350	480	447	502	459	270	135	336
1956	177	181	211	637	814	648	300	221	115	80	129	96	301
1957	82	73	222	423	628	594	548	505	487	445	410	316	396
1958	227	241	355	382	236	219	354	254	255	170	158	144	250
1959	166	182	282	302	331	514	412	280	212	194	157	189	269
1960	204	219	228	512	768	648	402	222	180	145	130	116	315
1961	144	132	194	282	334	371	202	225	107	74	57	55	182
1962	61	112	207	434	675	1025	912	638	543	490	360	252	477
1963	185	174	271	444	442	586	353	244	240	231	150	78	283
1964	130	151	185	475	765	514	298	219	229	203	182	159	293
1965	169	145	178	690	940	1129	765	473	447	512	482	503	538
1966	415	333	751	1034	1329	993	562	595	472	470	469	399	653
1967	361	338	464	780	1038	962	637	334	199	174	142	93	461
1968	89	135	251	397	594	578	462	326	245	242	241	225	316
1969	226	350	446	874	1075	813	461	265	117	108	92	133	413
1970	147	167	220	392	675	714	473	209	94	102	132	105	286
1971	121	149	247	452	344	301	413	225	241	233	418	544	308
1972	501	464	684	771	1102	1022	668	569	490	412	364	316	614
1973	335	338	494	438	372	287	230	181	209	374	573	566	367
1974	468	440	482	606	1015	1172	671	429	322	266	197	153	518
1975	178	245	389	738	1006	1078	832	551	411	321	257	207	519
1976	217	284	406	514	324	197	136	27	20	19	12	15	180
1977	13	17	67	105	73	71	57	57	114	180	250	338	112
1978	356	318	510	753	768	492	407	239	157	86	90	76	354
1979	72	110	261	750	939	937	776	695	545	348	359	325	512
1980	326	360	476	640	470	336	174	128	110	90	85	69	271
1981	95	136	179	218	167	145	124	203	132	128	166	205	158
1982	185	246	411	616	738	714	532	367	250	267	253	259	404
1983	248	260	339	371	318	258	364	407	402	298	242	217	311
1984	269	308	452	544	578	672	469	291	177	216	227	243	371
1985	246	258	413	559	873	1215	1104	1039	895	832	785	714	747
1986	594	566	684	1004	1449	1349	885	618	692	756	784	722	843
1987	596	569	682	703	534	442	310	308	282	227	228	247	426
1988	242	235	357	405	414	309	110	59	66	67	78	68	200
1989	92	148	237	692	616	580	366	160	175	133	97	75	281
1990	123	137	307	428	506	532	408	237	166	130	99	85	264
1991	90	142	239	388	681	722	675	454	368	272	168	165	365
1992	192	222	350	437	434	383	373	343	306	234	231	223	311
1993	240	279	386	572	633	931	995	944	1022	979	805	643	704
1994	553	634	701	794	972	684	537	384	284	322	303	392	546
1995	403	418	625	875	915	643	522	323	275	370	463	415	521
Period Mean	237	254	369	560	670	644	483	362	312	289	272	251	400

Period (1953-1995) Monthly Maximums and Minimums

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MINIMUM	2	3	4	24	3	11	6	10	3	10	4	10
YEAR	1977	1977	1977	1977	1977	1977	1977	1976	1976	1976	1976	1976
MAXIMUM	672	723	1227	1692	1563	1514	1622	1165	1122	1048	929	861
YEAR	1987	1994	1966	1969	1986	1986	1993	1985	1993	1993	1993	1985

Table 4-11
Average Monthly and Annual Outflow Rates (cfs) - Years 1953 - 1995

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1953								747	507	395	466	444	512
1954	400	312	482	614	856	903	522	189	229	117	146	211	415
1955	230	190	240	410	355	319	467	466	502	390	322	185	340
1956	235	194	235	642	808	652	247	192	109	69	44	69	291
1957	111	113	275	427	634	592	578	498	436	351	395	382	401
1958	282	272	401	382	218	143	332	226	196	153	163	155	244
1959	166	182	282	302	331	514	412	280	212	194	157	189	269
1960	236	254	234	484	785	703	426	171	116	103	131	136	315
1961	161	168	235	281	346	379	187	95	81	99	110	89	186
1962	82	94	234	433	489	1035	939	777	443	400	366	317	469
1963	286	197	285	450	443	555	360	141	156	218	181	174	287
1964	172	155	150	474	802	564	297	79	129	228	215	231	292
1965	217	176	214	566	961	1156	731	420	398	520	488	519	532
1966	489	433	605	1033	1273	1149	564	521	412	467	506	476	661
1967	416	367	406	821	1040	866	727	244	118	201	184	156	463
1968	137	148	265	397	598	575	431	234	167	283	309	276	319
1969	248	374	461	738	1104	910	413	201	60	113	151	150	410
1970	194	215	229	385	680	716	440	122	29	90	184	175	288
1971	150	166	263	458	340	296	352	152	166	248	488	593	307
1972	564	473	510	865	970	1181	692	492	425	438	391	397	617
1973	359	358	518	433	371	274	157	131	137	381	634	641	366
1974	506	461	484	608	984	1156	666	337	253	299	267	187	517
1975	200	269	413	643	957	1023	846	597	369	334	321	241	519
1976	248	306	433	519	318	171	110	57	9	9	8	8	182
1977	20	22	30	46	14	55	60	50	128	201	299	363	108
1978	403	357	385	814	812	519	402	137	96	140	109	104	356
1979	98	132	296	621	972	918	804	702	551	343	356	325	512
1980	363	393	489	549	505	346	167	103	41	70	119	114	271
1981	101	132	207	213	170	125	142	152	59	139	221	247	159
1982	240	256	407	612	748	720	503	277	172	300	331	297	406
1983	281	263	354	374	330	236	288	366	354	330	292	258	311
1984	289	328	322	619	627	637	512	290	154	188	199	269	369
1985	270	272	447	544	842	1047	1136	1087	907	811	832	752	749
1986	623	571	521	1015	1419	1419	874	618	674	771	788	724	835
1987	586	630	697	639	533	466	351	253	276	236	232	240	427
1988	251	291	380	406	418	303	95	79	74	67	55	52	205
1989	82	157	302	639	591	608	364	158	181	123	132	107	287
1990	104	128	277	417	508	552	406	237	164	129	95	86	259
1991	85	147	243	388	690	714	686	446	388	253	173	161	366
1992	195	222	354	440	427	391	374	334	313	230	239	223	312
1993	236	280	391	569	633	950	884	1045	1029	984	822	614	705
1994	552	644	704	781	985	676	536	380	279	327	300	392	546
1995	407	418	607	909	914	641	521	317	276	370	462	417	522
Period Mean	270	276	364	547	662	647	477	333	273	281	295	283	392

Period (1953-1995) Monthly Maximums and Minimums

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MINIMUM	8	22	19	22	8	13	36	5	7	8	7	8
YEAR	1977	1977	1977	1977	1977	1977	1977	1970	1976	1976	1976	1976
MAXIMUM	675	771	1260	1198	1600	1590	1234	1208	1103	1048	949	820
YEAR	1986	1994	1995	1986	1986	1986	1985	1993	1993	1993	1993	1985

4-08. Water Quality. Orwell Reservoir is an eutrophic lake located on the Otter Tail River in west central Minnesota in the Central Hardwood Forest (CHF) ecoregion. Land use in the Otter Tail basin is largely agricultural with 43 percent of the watershed cultivated. The remainder of the basin consists of 7 percent grassland/prairie, 14 percent open water, 13 percent wetland, 20 percent forest, 2 percent urban/residential, and 1 percent unknown. The upper portion of the basin, above Orwell reservoir, contains most of the forest, open water, and wetland areas. Average summer total phosphorus, chlorophyll 'a', and Secchi transparency is 58 μg/l, 30 μg/l, and 1 meter, respectively. The reservoir contributes the largest amount and best quality water to the Upper Red River of the North. From the standpoint of municipal and industrial use it is good quality water because it is low in dissolved minerals such as sulfate (avg. 12 mg/l), calcium, and magnesium which must be removed to soften the water. In contrast, the Bois de Sioux watershed which combines with the Otter Tail River to form the Red River, is high in sulfate (200-600 mg/l), calcium, magnesium, and total dissolved minerals and is considered poor for municipal and industrial use.

Though suitable for industrial use, Orwell Reservoir water quality is considered to be impaired as stated by the Minnesota Pollution Control Agency (MPCA) in the 1994 Minnesota Water Quality - Report to the Congress of the United States. Orwell reservoir does not support swimming use during the summer months due to low secchi transparency and high algae concentrations. Impaired swimming conditions, based on the frequency of severe nuisance algal blooms, may occur over 40 percent of the summer.

4-09. Channel and Floodway Characteristics. The Otter Tail River continues for approximately 33 miles downstream from Orwell Dam to the river's confluence with the Bois de Sioux River at Wahpeton-Breckenridge. In 1954 and 1955 the channel was modified by the Corps of Engineers between River Miles 9.7 and 21.1 (**Plates 2-1 and 4-7**). The modifications consisted of cleaning, enlarging, and straightening the channel. The modified channel reach was designed for a discharge of 900 cfs plus freeboard. Studies have indicated that the freeboard will allow 1,200 cfs outflow at the dam with no damages. The design channel bottom width is 30 feet between River Miles 21.1 and 16.0, and 50 feet between River Miles 16.0 and 9.7 (**Plate 4-7**). The material removed from the channel was placed adjacent to the river in spoil banks no more than 8 feet high. These banks are discontinuous at intersections with the old channel and at inlets of natural watercourses to allow for side drainage into

the channel. The non-Federal sponsor and contact for the project is the Wilkin County Drainage and Conservancy District No. 1 in Breckenridge, Minnesota.

The principal flood damage reach is between River Miles 10 and 22, with minor flood damages occurring in the reach from the mouth to River Mile 7.7. During flood periods, a high percentage of the area flooded is fertile crop land with farmsteads in the area generally well improved. Flood waters also cause damage in the cities of Breckenridge and Wahpeton, particularly when combined with flood waters of the Bois de Sioux River. The control point for the Orwell Project is at Wahpeton-Breckenridge. The reservoir, along with Lake Traverse Project, is regulated for this urban damage center when the stage on the Red River of the North at Wahpeton exceeds 10 or 12 feet, depending on runoff conditions (**Chapter 7**). The travel time from Orwell Dam to Wahpeton varies between 12 and 24 hours, depending on flow rate.

A general plan and a typical cross section of the channel are shown on **Plate 4-7**. Rating tables for the USGS gages on the Otter Tail River near Fergus Falls, Minnesota and near Foxhome, Minnesota, and for the Red River of the North at Wahpeton, North Dakota, and Fargo, North Dakota, are listed in **Exhibit E**. An elevation-discharge curve for the USGS gage at Wahpeton is shown on **Plate 4-8**.

4-10. Upstream Structures.

a. Dayton Hollow Dam. The Dayton Hollow Dam and Hydroelectric Plant is located about 5 river miles upstream of Orwell Dam (**Plate 2-1**). It is owned and operated by the Otter Tail Power Company. The dam was constructed in 1908 and began producing electricity in 1909. The powerhouse is equipped with two generating units, with ratings of 520 and 450 kilowatts. The dam spillway is 80 feet wide across the top and 39 feet high. Flow through the dam is controlled by stoplogs. The normal reservoir capacity at elevation 1107.5 feet is 3,500 acre-feet, and the maximum discharge capacity at the top of the dam is 2,600 cfs. Recreational use of Dayton Lake upstream of the dam is mainly fishing. Under normal operating procedure, Dayton Hollow Dam does not store or release large volumes and therefore, has minor impacts on the operation of Orwell Dam.

b. Other Hydropower Dams. The Otter Tail Power Company owns and operates four other dams on the Otter Tail River, all upstream of the Dayton Hollow Dam. These are: Pisgah Dam, about 12 river miles upstream of Orwell Dam; Central Dam, about 14 miles upstream; Hoot Lake Diversion, about 28 miles upstream; and Friberg Dam, about 36 miles upstream. None of these dams have any impact on the regulation of the Orwell Project.

c. Upstream Low-Head Dams. During the drought of the 1930's, 31 low-head dams were constructed in the lakes region of the Otter Tail River Basin to raise the lakes to levels deemed necessary for recreational activities and water conservation. These dams were sponsored by what was then known as the Water Resources Branch of the Minnesota Department of Conservation (now known as the MDNR Division of Waters). They were constructed by the Works Progress Administration (WPA) and completed in 1938. They are now owned by the MDNR except for those in the Tamarac National Wildlife Refuge (TNWR), which are owned by the U.S. Fish and Wildlife Service (USFWS). All of the MDNR owned dams are fixed crest structures, whereas the dams in the TNWR have some control. None of these dams have any effect on the operation of Orwell Dam. The Soil Conservation Service (now known as Natural Resources Conservation Service), in cooperation with the White Earth Indian Reservation, performed a computer model study of the Otter Tail River basin upstream of the dam at Hubbel Pond (River Mile 161), near Rochert, Minnesota, using the SSARR (Streamflow Synthesis and Reservoir Regulation) program. The purpose of the study was to evaluate the hydrologic impacts of lake level management alternatives on wild rice growth.

4-11. Downstream Structures. There are no structures on the Otter Tail River between Orwell Dam and the river's confluence where the Otter Tail and Bois de Sioux Rivers meet to form the Red River of the North at Wahpeton, North Dakota and Breckenridge, Minnesota. However, upstream of the confluence on the Bois de Sioux River, the Corps of Engineer's Lake Traverse Project (Reservation and White Rock Dams), controls a drainage area of 1,160 square miles. The travel time from White Rock dam, the lowermost of the two dams, to Wahpeton, varies between 24 and 48 hours, depending on flow rates. Operation of Orwell Dam is coordinated with releases from White Rock Dam (**see Chapter 7**).

4-12. Economic Data.

a. Population. The watershed area of the Otter Tail River lies in portions of five counties: Wilkin, Otter Tail, Becker, Clearwater and a very small portion of Mahnomen, with the major portion being in Otter Tail County. Population statistics for these five counties, and for the cities of Fergus Falls, Breckenridge, and Wahpeton, are given in **Table 4-12**.

Table 4-12
Otter Tail River Basin - Population by County and City

County/City	1990 Census	2000 Census	% Change
Becker	27,881	30,000	7.6
Clearwater	8,309	8,423	1.4
Mahnomen	5,044	5,190	2.9
Otter Tail	50,714	57,159	12.7
Wilkin	7,516	7,138	-5.0
Fergus Falls, MN	12,362	N/A	---
Breckenridge, MN	3,708	N/A	---
Wahpeton, ND	9,135[1]	N/A	---

1. Special 1994 census

b. Agriculture. Grain farming is the dominant agricultural activity in the basin although diversified farming including dairying is becoming more important. Timber stands of commercial value exist in the headwaters region northeast of Detroit Lakes, Minnesota.

c. Industry. Industries in the watershed include dairy product processing, meat packing, sand and gravel production, wood products manufacturing and beverage bottling. There are more then 700 meandered lakes and 700 non-meandered lakes within the watershed with many resorts forming a recreational industry. Transportation facilities include seven state and federal highways and a good secondary road system with rail service from three major railroads. Hydroelectric power is developed at five sites on the Otter Tail River by the Otter Tail Power Company. Steam plants are also used to meet the power demand within and adjacent to the area.

Total employment in the Fergus Falls area (for zip code 56537) in 1993 amounted to 6,641. Of this total, manufacturing accounted for 1,045 (15.7%), retail trade - 1,790 (27.0%), finance, insurance and real estate - 234 (3.5%), and services - 2,383 (35.9%). The unemployment rate was measured at 4.4 percent.

Major employers are found within the medical services, manufacturing, and government sectors of the local economy. Agriculture is also a major industry in the area. Employment figures by industry and by county for the Otter Tail River basin area are listed in **Table 4-13**.

Table 4-13
Otter Tail River Basin
1993 Employment by Industry - County & State

Industry	County										State	
	Becker		Clearwater		Mahnomen		Otter Tail		Wilkin			
	No.	%	No.	%	No.	%	No.	%	No.	%	Number	%
Ag & Forestry	40	0.5	<20	—	<20	—	107	0.7	0	0	7,633	0.4
Mining	0	0	<20	—	0	0	10	0.1	0	0	7,188	0.4
Construction	296	4.0	101	7.0	69	3.6	686	4.8	102	5.9	7,780	0.4
Manufacturing	890	12.0	117	8.1	75	3.9	2,481	17.4	10	0.6	393,043	20.2
Trans & Utilities	467	6.3	51	3.5	<10	---	1,167	8.2	152	8.8	106,217	5.5
Wholesale Trade	309	4.2	104	7.2	67	3.5	677	4.7	232	13.4	135,261	7.0
Retail Trade	1,862	25.1	311	21.5	266	13.9	3,634	25.5	515	29.8	409,042	21.0
Emergency Services	319	4.3	74	5.1	55	2.9	661	4.6	77	4.5	133,603	6.9
Other Services	3,216	43.3	660	45.6	1,317	68.8	4,821	33.8	640	37.0	673,315	34.6
Unclassified	24	0.3	17	1.2	<20	---	13	0.1	0	0	1,598	0.1
Total	7,423		1,446		1,914		14,267		1,728		1,944,630	

Source: County Business Patterns - 1993 (Minnesota), U.S. Department of Commerce, Bureau of Census

d. Flood Damages. Flood damage in the Otter Tail River Basin is largely confined to a reach between River Mile 10 and 22 (**Plate 2-1**). The area affected covers about 38,000 acres and is susceptible mostly to agricultural and crop damage. This reach of the Otter Tail River was modified by dredging and realignment between January 1953 and June 1954. The capacity of the modified channel was designed for a flow of 900 cfs, plus freeboard. With one foot of freeboard the new channel was estimated to have a capacity ranging from 1,205 to 1,270 cfs (Definite Project Report, page C-3, Channel Modification). This was supported by the spring and summer event of 1963, when the freeboard allowed flows exceeding 1,100 cfs to pass without any appreciable flooding or damage. Later studies indicated that outflows from Orwell Dam up 1,200 cfs caused little to no damage. The discharge-area flooded relation for the downstream agricultural area is shown on **Plate 4-10**. Flood damage can range from $10 to $200 per acre depending upon the date of flooding. Early season floods occurring before planting may

have relatively minor impact. Fertilizer applied in the fall may have to be replaced or additional herbicide may need to be applied to fight flood-induced weed infestation. Floods during the growing season can wipe out a crop resulting in a total loss of income from the affected acres.

The cities of Breckenridge, Minnesota, and Wahpeton, North Dakota, are located at the mouth of the Otter Tail River where it joins the Bois de Sioux River to form the Red River of the North. Flooding in these cities has been alleviated by the operation of the Orwell and Lake Traverse Projects. The urban areas of Fargo, North Dakota, and Moorhead, Minnesota, are also affected by the project, but to a lesser extent than the Wahpeton-Breckenridge area. The National Weather Service flood stage at Wahpeton and Breckenridge is 10 feet as measured by the USGS (gage #05051500) on the Red River of the North at Wahpeton, North Dakota. At a stage of 9.5 feet, sewers begin to flood and emergency pumping is necessary. Damage at Breckenridge starts at a stage of about 10 feet. As river stages increase in Breckenridge, floodwater seeps from storm sewers into nearby sanitary sewers. Both cities have constructed levees which prevent most residential flooding up to the 15 foot stage in Wahpeton and about the 16 foot stage in Breckenridge. Discharge-damage curves for Wahpeton, Breckenridge, Fargo and Moorhead, in 1995 dollars, are shown on **Plates 4-11** through **4-14**.

e. Damage Due to Low Water. There have been two significant drought periods which have affected the Otter Tail River basin since the reservoir began operation. The 1976-77 drought was widespread across Minnesota. The drought had an impact on municipal water supplies causing some wells to go dry. The major drought event of 1988 affected the entire Midwestern United States. Orwell Reservoir releases were as low as 55 cfs, but no additional releases for water supply were requested. Details on historic drought conditions and drought planning in the basin can be found in the *Drought Contingency Plan, Appendix DCP to the Orwell Dam and Reservoir, Reservoir Regulation Manual*, September 1992.

V - DATA COLLECTION AND COMMUNICATION NETWORK

5-01. Hydro-Meteorological Stations.

a. Facilities. Several agencies including the Corps of Engineers (COE), U.S. Geological Survey (USGS), National Weather Service (NWS), and Soil and Water Conservation Districts (SWCD) own various gages in the Otter Tail River basin. The COE and USGS operate their respective gages, whereas most of the NWS and SWCD gages rely on volunteers for gage readings. The USGS data gathering is related primarily to streamflow information (e.g. stage, discharge). The NWS and SWCD collect climatological data (e.g. precip, temp) throughout the basin. The COE collects both streamflow and climatologic data in a coordinated effort with the USGS and NWS. **Tables 5-1 and 5-2** give a brief description of stream gages and climatological gages located in the basin. **Plate 5-1** shows the locations of these gages.

Table 5-1
Stream Gages in the Otter Tail River Basin

Gage Owner	Drainage Area (sq. mi.)	Gage Name	Notes
USGS	1,230	Otter Tail River near Elizabeth, MN	Daily stage and discharge, Jul 1992 to current year. Monthly discharge only May 1904 to Sep 1917, published as German Church near Fergus Falls. Staff gage. Voice modem. Datum 1929.
COE	1,830	Orwell Lake near Fergus Falls, MN (Orwell Pool)	Daily stage and reservoir outflow, Aug 1953 to current year. Hourly DCP stages, Feb 1994 to present. Well with staff gage & tape. Staff gage on wing wall. Voice modem. Datum 1912.
USGS	1,830	Otter Tail River below Orwell Dam, near Fergus Falls, MN	Daily stage and discharge, Aug 1953 to current year. Hourly DCP stages, Feb 1994 to present. Staff gage. Voice modem. Datum 1912.
USGS MDNR	N/A	Otter Tail River near Foxhome, MN	USGS: crest-stage partial record est. Sep 89. MDNR: wire weight at Hwy 19.
USGS	4,010	Red River of the North at Wahpeton, ND	Daily stage and discharge, Mar 1943 to current year. Staff gage. Voice modem. Datum 1929.

Table 5-2 Climatological Gages in the Otter Tail Basin				
Station	**Data Type**	**Equipment**	**Freq.**	**Owner**
Orwell Dam	Precipitation	Fischer/Porter Recording Tipping Bucket Standard Rain Gage - 8 in	15 min hourly daily	NWS Corps NWS
	Air Temperature	Max/Min Temperature System	daily	NWS
	Wind Speed & Direction	Anemometer & Wind Vane	daily	Corps
	Snow Depth & Water Content	Snow Tube	weekly	Corps
	Ice Depth	Ice Auger	weekly	Corps
	Frost Depth	Frost Tube	weekly	Corps
Pelican Rapids	Precipitation	Standard Rain Gage - 8 in	daily	NWS
Ottertail	Precipitation	Standard Rain Gage - 8 in	daily	NWS
	Air Temperature	Max/Min Thermometers	daily	NWS
New York Mills	Precipitation	Standard Rain Gage - 8 in	daily	NWS
Upper Cormorant Lake	Precipitation	Standard Rain Gage - 8 in	daily	NWS
	Air Temperature	Max/Min Temperature System	daily	NWS
Detroit Lakes	Precipitation	Standard Rain Gage - 8 in	daily	NWS
	Air Temperature	Max/Min Thermometers	daily	NWS
Pernham	Precipitation	Tipping Bucket	hourly	SWCD
	Air Temperature	Max/Min Thermometer	daily	SWCD
	Wind Speed & Direction	Anemometer & Wind Vane	daily	SWCD
Fergus Falls	Precipitation	Rain Gage	monthly	SWCD
Tamarac Lake	Precipitation	Rain Gage	monthly	SWCD

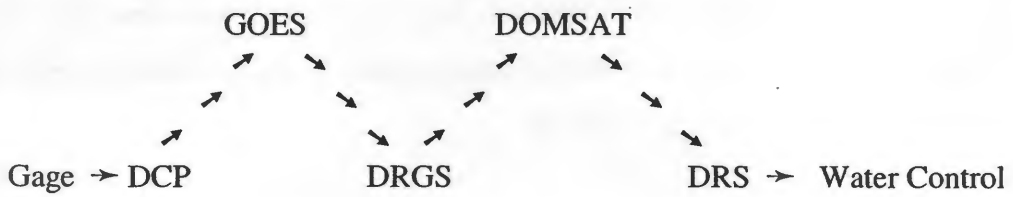
All the gage information collected within the basin is useful to the regulation of Orwell Dam; however, not all data are key to dam operation and not all data are needed on a daily basis. Gage data and information considered key to normal operation, regarding regulation of the dam, consist of pool and tailwater stage recordings, local precipitation, wind speed and direction, snow-water content over the basin, and the stage at Wahpeton, North Dakota. Secondary data requirements would include local air temperature, frost depth, ice thickness, spacial rainfall data, and forecasted rainfall events. **Table 5-3** lists the key stations and the primary purpose of the gage data.

Table 5-3 Key Stations - Operation of Orwell Dam		
Station	**Data Type**	**Primary Purpose**
Orwell Dam	Orwell Pool Elevation	Monitor pool levels and fluctuations. Used to compute inflow.
	Orwell Tailwater Elevation	Gives outflow based on rating table.
	Precipitation	Indicator of anticipated reservoir inflow.
	Wind Speed and Direction	Adjustment of pool elevation readings.
	Snow Water Content	Indicator of potential for severe runoff.
Wahpeton, ND	River Red of North Stage	Control point for operation of dam.
Snow Survey Sites	Snow-Water Content	Establish severity of basin runoff potential.

b. Reporting.

1. Water Elevations. Daily pool and tailwater readings are made by site personnel at Orwell Dam. Stages are converted to elevation, recorded on a weekly log sheet (CEMVP Form 416A) and reported to Water Control via a remote terminal. Water elevations can also be obtained from Data Collection Platforms (DCP's) which are located at the following key locations: (1) Orwell pool, (2) Orwell tailwater, and (3) Wahpeton, North Dakota. Stage information at these three locations is transmitted from the DCP to the US Geostationary Operational Environment Satellite (GOES). The GOES system transmits the data to a Direct Readout Ground Station (DRGS) in Wallops, Virginia. The DRGS transmits the data to the Domestic Communications Satellite (DOMSAT) which transmits the data to a DOMSAT Receive Sation (DRS) located at the St. Paul District Office. Data transmissions are made hourly. The following sketch shows the flow of data.

Transmission of Data via Satellite



If transmission is lost, current information can be obtained at each of the three sites via voice modem. When voice modems are malfunctioning or out of service, stage information can be obtained from field personnel observing staff gages. During flood conditions, reconnaissance teams are dispatched to the Red River of the North basin to gather information that is reported to Water Control by fax and phone on a daily basis or more frequently depending upon need.

2. Discharges and Inflows. Site personnel report the Orwell Dam discharge daily to Water Control via a remote terminal. While discharges could be computed using the gate setting and differential head, outflows are determined using the tailwater stage and applying the latest shift to the USGS rating table for *Otter Tail River below Orwell Dam.* Discharge information at this location, as well as the Wahpeton station, are available from the Minnesota and North Dakota USGS web sites which can be accessed through *Agency Links* on the Water Control web site at *http://www.mvp-wc.usace.army.mil.* During flood events the USGS performs stream gaging operations at the tailwater gage site and at Wahpeton, and updates the rating curves periodically as deemed necessary.

Reservoir inflows are also recorded daily. Inflows are computed, based on the 24-hour change in pool elevation, the associated change in storage volume, and the assumed 24-hour discharge (i.e. the 0800-hour discharge is assumed constant for the 24-hour period). While recorded outflows are instantaneous, inflows have been averaged over a 24-hour period. Therefore, a good comparison of inflows to outflows is not possible. In addition, the computation for inflow does not provide adjustment for wind (e.g. wind setup at the pool gage) or changes in discharge from the 0800-hour reported discharge (e.g. mid-day gate changes, change in head, etc.); therefore, smoothing of the data is sometimes required.

3. Air Temperature. On workdays, current air temperature and the 24-hour maximum and minimum air temperature are observed at approximately 0800 hours by site personnel at Orwell Dam and entered on the weekly log sheet.

4. Precipitation. Precipitation is measured hourly by a tipping bucket located near the pool gage site. The data, in cumulative format, is available from the Water Control web site (*http://www.mvp-wc.usace.army.mil*) by clicking on *Real Time* data. In addition, site personnel at Orwell Dam record the 24-hour precipitation every workday at 0800 hours. This is entered on the weekly log sheet and reported to Water Control via a remote terminal and the DWINDO program. Following weekends and holidays, the DCP record is used as an aid in determining the distribution of the total rainfall in the gage. Water Control also obtains precipitation information from the National Weather Service (NWS). The NWS receives observed rainfall data from Soil and Water Conservation Districts (SWCD), the State of Minnesota Climatology Office, and the Corps of Engineers. The NWS utilizes this information, along with observations of the numerous NWS rain gages in the basin, to produce many weather service products (e.g. mean areal precipitation maps). These products are available on NWS web sites and can be accessed through *NWS Products* on the Water Control web site (*http://www.mvp-wc.usace.army.mil*). Products include the latest regional 6, 12 and 24-hour quantitative precipitation forecast (QPF), NEXRAD Stage III radar images, 24-hour observed and radar mean areal precipitation maps, and weather forecasts.

5. Snow, Frost, and Ice. During the winter months, site personnel at Orwell Dam measure frost depth, ice thickness, snow depth, and snow-water content on a weekly basis. Frost depth readings provide information on the amount of infiltration to be expected. Ice thickness is an indicator of when spring breakup may occur. Snow-water equivalent indictes the snowmelt potential for runoff. Addtional measurements may be made at the request of Water Control. All information is relayed to Water Control via remote terminal, telephone, or fax.

While snow-water content measurements taken at the dam are a good indicator of the snow-melt potential for the general area of the dam, it is too great of an extrapolation to project total basin coverage. Therefore, snow surveys are pereformed at various sites throughout the basin. The start date for snow surveys is established by Water Control but is typically performed the last week of February or the first week of March. Site personnel perform the survey and work is completed in less than a week. If an appreciable amount of snow should fall after the survey has been completed, another survey may be required. **Table 5-4** lists the snow survey stations used each time a snow

survey is requested. The location of the snow survey sites are shown on **Plate 5-2**. At least four samples are taken at each station. In addition to the snow samples, notes are recorded on the general conditions of snow cover in fields, timbered areas, river channels, and ditches. Reports are faxed to the Water Control office for analysis upon completion of the survey.

Table 5-4
Snow Survey Sites in the Otter Tail River Basin

Number and Name	Location
1. Orwell Dam	Approximately 1,000 ft southwest of Corps office.
2. Foxhome	Foxhome Park.
3. Fergus Falls	Fergus Falls High School athletic field.
4. Pelican Rapids	1 mile south of Pelican Rapids on MN 59, ¼ mile east on County 3.
5. Detroit Lakes	East of Detroit Lakes on MN 210, northeast on County 116.
6. Perham	1.3 miles south of Perham on east side of MN 78.
7. Dent	South of Dent on south side of County 35.
8. Ottertail	West side of MN 78, 0.2 mile south of MN 108.
9. Battle Lake	South of Battle Lake on Chittenhall Lake Rd, 1.5 miles east of MN 78.

The Corps of Engineers (COE) snow survey information is provided to the National Weather Service (NWS) which uses the information to ground truth NWS snow surveys that use airborne gamma ray remote sensing technology. The NWS snow surveys are available to Water Control via NWS web sites and are used to supplement the COE surveys and identify potential trouble areas.

6. Normal Day Activities. Every work day at approximately 0800 hours, site personnel at Orwell Dam call the tailwater voice modem and read the float gage located in the pool side gage house. The tailwater stage is used to determine Orwell Dam outflow using the current USGS rating table **(Exhibit E, Table E-1)** and applying the latest shift. The stage information is converted to elevation and entered on the weekly log sheet. Also recorded on the log sheet is the current gate setting, 24-hour precipitation total, wind speed and direction, and any pertinent comments. By 0900 hours, site personnel enter Orwell Project information into an independent DWINDO program using a remote terminal thus making this information readily available to Water Control staff. By invoking the inflow program "*IN*", reservoir inflow is computed based on the 24-hour change in reservoir storage and the known outflow. Following weekends and holidays, missing

values are input into DWINDO with the workdays regular data entry. Missing pool elevations and tailwater stages are obtained from the DCP record. The DCP pool gage reading is checked against the staff gage a minimum of once a week to verify the record. During flood events, the dam is staffed seven days a week and data are input daily.

c. Maintenance. Tables 5-1 and 5-2 list the owners of the gages located throughout the basin. As such, each oganiztation is responsible for maintenace of their gages. The tailwater gage below Orwell Dam however, is presently part of the co-operative stream gaging network between the Corps of Engineers (COE) and the US Geological Survey (USGS). The gage is owned by the USGS. Repairs, while typically performed by the USGS, may be made by the COE.

5-02. Water Quality Stations.

a. Facilities. Historically there have been seven water quality data collection stations on or near Orwell Reservoir. Data collected are used to define baseline water quality conditions, identify water quality trends, support locally sponsored lake management programs, and to analyze water quality problems and concerns as they relate to natural conditions and to reservoir operations. Sampling in the past was accomplished by contract with the University of Minnesota (1978-1979) and the USGS (1985-1986). From 1989 to the present, data collection has been limited to sites 2, 3, 4, and 6 as shown on **Plate 5-3**. Sampling is performed by the St. Paul District, Water Quality Unit staff with assistance from site personnel. Samples are taken at these four sites, about four times a year.

Funding constraints, monitoring priorities, and staffing limitations have inhibited data collection activities on Orwell Reservoir. When possible, data collection activities are concentrated during the open water period from May through October. Vertical profiles of water temperature, dissolved oxygen, pH, and specific conductance are electronically monitored at each station. In addition, 2-meter integrated surface water samples are collected and analyzed for total phosphorus, total kjeldahl nitrogen, nitrate-nitrite nitrogen, ammonia nitrogen, and chlorophyll "*a*". Additional depth specific samples and parameters are obtained at sporadic intervals to further define water quality relationships. Laboratory analyses are performed by COE inspected and approved laboratories.

b. Reporting. Water quality data are recorded on data sheets and mailed to the Water Quality Unit in the District Office. Raw water samples analyzed for nutrients and chlorophyll are processed at the field site and shipped to a Corps-approved laboratory for analysis. All chemical analysis follow recommended Environmental Protection Agency (EPA) or equivalent procedures. Lab results are then forwarded to the COE Water Quality Unit. The data are reviewed and entered into DBASE and the EPA's STORET data storage system. Project Water Quality Reports are generated on a yearly basis for the project site. The information is used to assess current trophic conditions in the reservoir and to evaluate the effects of operational changes and watershed management options on reservoir water quality and quality of releases from the project. All water quality data are available in hard copy or on magnetic media upon request.

c. Maintenance. There is presently no water quality equipment at Orwell Reservoir and therefore, there is no maintenance.

5-03. Sediment Stations. The tailwater gage below Orwell Dam is a National Water Quality Assessment (NAWQA) Station and as such, periodic information regarding suspended solids is available through USGS Water Resources Data, Minnesota, publications.

To monitor lake sedimentation, the COE established 24 sediment ranges in 1955 (**Plate 4-1**). Repeat soundings were taken in 1964 and 1985. See **Paragraph 4-04**.

5-04. Recording Hydrologic Data. Water Control presently has four forms of recording and storing hydrologic data; weekly log sheets, DCP tracking charts, micro-film, and the COE Data Storage System (DSS). In addition to the COE, there is hydrologic data collected by others.

a. Weekly Log Sheets. Site personnel at Orwell Dam record the daily pool elevation, tailwater elevation, Tainter gate opening, low flow opening, discharge from dam, 24-hour precipitation, current air temperature, 24-hour maximum and minimum air temperature, and wind speed and direction on a weekly log sheet (CEMVP Form 416A). The log sheet is prepared in duplicate and the original is mailed directly to Water Control after the last entry has been recorded

at the end of the week. See **Table 9-2**. The log sheets are used by Water Control staff to verify or correct daily DSS data entries. The originals are stored at the District Office.

b. DCP Tracking Charts. Before DCP tracking charts, a strip chart was used to track the pool gage. Strip charts record up to six months of continuous data. They were used by Water Control to verify, correct, or fill in missing data in the DSS file. For its period of use, the strip charts served as the official pool record and are stored at the District Office. The strip chart was replaced by DCP tracking charts in fall of 1999. The hourly DCP record acts as the official pool record. To verify record accuracy, the DCP stage is checked every workday with the tape in the well which is checked weekly with the staff gage. All readings are entered on the DCP tracking chart which is mailed to Water Control at the end of each month. When the difference between gage readings is 0.03 feet or more, the gage crew is notified and the DCP is adjusted as soon as possible. **Exhibit C** shows an example of an DCP tracking chart.

c. Micro-Film. The log sheets, strip charts, and DCP tracking charts are stored in Water Control. They are periodically transferred to micro-film and stored with the originals. A copy of the micro-film is stored at an off-site facility. The originals are stored in Water Control as long as space allows. When the storage bins become filled, the older originals records are sent to an off-site storage facility.

d. COE Data Storage System (DSS). The daily pool elevation, tailwater elevation, 24-hour precipitation, Tainter gate opening, reservoir outflow, wind speed and direction, and reservoir inflow are entered by site personnel at Orwell Dam, via a remote terminal, into a DWINDO program which stores the data in a DSS file. Hourly stage data from the DCP's, including the cumulative precipitation data at Orwell Dam, are entered directly from the DCP sites into the DSS data base in Water Control. Two types of DSS files are retained: raw data and adjusted data. The following is an example of some of the Orwell Project DSS path names in *RES.dss*:

Water Control - Data Storage System (DSS)
DSS Path Names in RSS.dss

A	B	C	D	E	F
ORWELL	ORWM5	PRECIP-CUM	01MAY1998	1HOUR	ORWELL_DAM-DCP
ORWELL-POOL	ORWM5	ELEV	01MAY1998	1HOUR	ORWELL_DAM-POOL
ORWELL-TAIL	OTRM5	STAGE	01MAY1998	1HOUR	ORWELL_DAM-TW
ORWELL	ORWM5	FLOWRES-IN	01JAN1998	1DAY	COMPUTED
ORWELL	ORWM5	FLOWRES-OUT	01JAN1998	1DAY	COMPUTED
ORWELL	ORWM5	GATE	01JAN1998	1DAY	OBS
ORWELL	ORWM5	PRECIP	01JAN1998	1DAY	OBS
ORWELL	ORWM5	WIND-DIR	01JAN1998	1DAY	OBS
ORWELL	ORWM5	WIND-SPEED	01JAN1998	1DAY	OBS
ORWELL-POOL	ORWM5	ELEV	01JAN1998	1DAY	OBS
ORWELL-TAIL	OTRM5	ELEV	01JAN1998	1DAY	OBS

Weekly measurements of snow depth, ice thickness, frost depth, and snow-water equivalent, taken during the winter months, are stored in the Water Control data base (*WINTER.dss*).

e. Data Recordings by Others. The NWS records incremental rainfall (15 minutes) at Orwell Dam on a punch tape that is collected monthly and archived by the National Climatic Data Center in Asheville, North Carolina. Data from USGS and co-op stations are available from the USGS web sites which can be accessed through agency links from the Water Control web site.

5-05. Communication Network. The communication network consists of telephone, fax machine, computer terminal, voice modem, 56k modem telephone line, T1 line, and satellite. The computer terminals allow communication between the office and field sites by e-mail and the DWINDO program. The three pertinent gage sites (pool, tailwater, and Wahpeton) have voice modems for current water level conditions. Water Control receives DCP hourly data from the pool, tailwater, and Wahpeton via satellite. To ensure communications between Water Control and the National Weather Service, a dedicated line was installed (56k modem leased telephone line). A T1 line ensures communication between Water Control and the Division Office (MVD) in Vicksburg, Mississippi. Stage/Elevation information is available from the Water Control web site (*http://www.mvp-wc.usace.army.mil*). The following summarizes the communications network. Note: WC=Water Control; NWS=National Weather Service; MVD=Mississippi Valley Division

Type	Information/Data Transfer	Backup
Telephone	WC ↔ Orwell & Traverse	FM Radio
Fax	WC ↔ Orwell & Traverse	Computer
Computer	WC ↔ Orwell & Traverse	Fax
Voice Modem	WC & Project → Gage Sites	DCP
56k Modem	WC ↔ NWS	Radio
T1 Line	WC ↔ MVD	Computer
Satellite	DCP → WC → Project	MVS & RI
Web Links	WWW → WC & Project	Telephone
US Mail	Orwell → WC	Fax

Telephone communication serves as a backup to the remote terminal (DWINDO). Rock Island (MVR) or St. Louis District (MVS) provide backup satellite (DOMSAT) data. Field personnel can be deployed to make observations of staff gages to provide backup for the DCP's and voice modems. During flood events, reconnaissance teams communicate field information to Water Control by cellular phone and fax machine.

5-06. Communication with Project.

a. Regulating Office with Project Office. Upon review of daily stages and climatologic data, Water Control determines if any changes to Tainter gate or low flow openings are necessary. At approximately 1000 hours, the regulating office (Water Control) communicates any changes in operation by telephone with the project office (Orwell or Lake Traverse). Flood events or downstream activities may require additional gate movements during the day. During flood events, stages are monitored at Water Control for additional changes that may be required.

During floods or other emergencies, the Project Resource Manager located at the Lake Traverse Project Office reports by telephone every morning to Water Control. Requests for additional readings are made by Water Control at this time. Special reports are transmitted by telephone (651-290-5620) as soon as possible, by fax (651-290-5841), or by mail as directed by Water Control. If a telephone call must be made after regular office hours or non-duty days, first call Water Control staff using the office phone numbers listed on page iii at the front of the manual. If Water Control cannot be contacted, call one of the regulators at home, in order of preference as shown.

In the event of communication failure, operation of the dam should follow the procedures outlined in **Chapter 7** as far as practicable until communications are reestablished.

b. Between Project Office and Others.

1. National Weather Service. National Weather Service (NWS) Form B-91 is used to record river and climatological observations. The form is to be filled out in quadruplicate for each month of record. The original and two copies are to be mailed to the NWS, North Central River Forecast Center, 1733 Lake Drive West, Chanhassen, Minnesota, 55317-8581 at the end of the month and one copy is to be retained at the dam. In addition, charts from the Fischer/Porter recording rain gage at Orwell Dam are also mailed the NWS every month.

2. Local Residents. Local residents have access to lake level and discharge information from the Project Resource Manager at Lake Traverse Project office or site personnel at Orwell Dam by telephone or in person. In addition, project information can be obtained from the 24-hour project information recording for Lake Traverse and Orwell Projects at 320-563-8681 (see **Table 1-1**). Notifications of severe weather or impending unusual conditions are dealt with by local law enforcement and civil defense authorities.

5-07. Project Reporting Instructions. Field staff report hydrologic and climatic conditions to Water Control each Monday, Wednesday, and Friday. Water Control may request more frequent reports, if warranted by flooding situations, or less frequent reports under relatively quiescent conditions. Also, in the event that local 24-hour rainfall exceeds 1.5 inches, field personnel at Orwell Dam or Lake Traverse Project Offices should notify Water Control as soon as possible.

5-08. Warnings. In the event of impending emergency conditions, or advisories requiring interim gate changes, Water Control will call the Project Resource Manager at the Lake Traverse Project office or site personnel at Orwell Dam. Should project staff in the field become aware of any emergency conditions, the District Office should be notified as soon as possible. The introduction to this manual contains phone numbers for Water Control and various District Office personnel. In

the event of other emergencies affecting project regulation and concerns downstream, the officials listed in **Table 5-5** will be contacted.

Table 5-5
Points of Contact for Emergency Notification

Point of Contact	Telephone Numbers	
	Work	Home
Otter Tail Cty: MN Emergency Services Director County Sheriff (24-Hour)	218-739-2271 218-736-5421	 218-739-6237
Wilkin County: Civil Defense Director County Sheriff (24-Hour)	218-643-4234 218-643-8544	218-643-5467 -------
Richland Cty: ND Civil Defense Coordinator County Sheriff	701-642-7788 701-642-7711	701-642-9369 -------
Wahpeton, ND: Disaster Emergency Services Coordinator	701-642-7788	701-642-9363
Breckenridge, MN: Disaster Emergency Services Coordinator (24-hour)	218-643-5506	-------
Fargo, ND: Water Utility; Ron Hendrickson	701-241.1469	-------
Moorhead, MN: Water Utility; Cliff McLain	218-299-5470	-------
Minnesota Division of Emergency Management Minnesota Statewide Emergency	612-649-5451 1-800-422-0798	24 Hours 24 Hours
North Dakota Disaster Emergency Management	701-224-2111	-------

Note: Phone numbers for Water Control and District personnel are listed on **Page iii**.
Phone numbers for Project Office personnel are listed in **Table 1-1.**

VI - HYDROLOGIC FORECASTS

6-01. General. Forecasting of river-stage information for public release rests with the National Weather Service as mandated by Congress. The Corps of Engineers, St. Paul District provides present reservoir conditions and advisory forecasts of reservoir operations. The Water Quality Division of the State of Minnesota, Pollution Control Agency, forecasts water quality conditions when warranted. The St. Paul District may provide data through its Water Quality Unit.

a. Role of Corps. The present role of the Corps of Engineers (COE) is to assist the National Weather Service (NWS) in their forecasting efforts. These efforts include providing the NWS with the following;

(1) Current reservoir data, including rainfall and the daily operating plans (i.e. planned changes in reservoir releases) for Orwell and Lake Traverse Projects,

(2) During winter months, weekly snow depth, frost depth, ice thickness, and snow water equivalents at the Orwell and Lake Traverse Projects,

(3) Snow survey data collected in the upper basins of the Ottertail and Bois de Sioux by Orwell and Lake Traverse reservoir site personnel (performed in mid to late February),

(4) Snow survey data of the Red River of the North basin collected by Water Control personnel (typically performed the last week of February or the first week of March),

(5) River ice thickness data collected around mid-February (available from the "River Ice Network" site on the Water Control home page (*http://www.mvp-wc.usace.army.mil*),

(6) The results of any additional snow surveys taken due to unusually heavy snowfall that may have occurred since the last survey.

The COE does not provide any forecast information for public release; however; Water Control does keep the public informed of changes in reservoir operation during flood events by providing advisory forecasts of reservoir inflow/outflow and pool elevation changes through the COE Public Affairs office. Any COE forecast that may arise from either wet or dry conditions, is for internal use only and acts as a tool for Water Control staff and the Project Resource Manager to perform their duties.

b. Role of Other Agencies. The National Weather Service (NWS), North Central River Forecast Center (NCRFC) is responsible for river forecasts. In the spring of 2001, the NWS switched to the Advanced Hydrologic Prediction Service (AHPS) for the Red River Valley. AHPS enables the NWS to provide long-range probabilistic river outlooks. Under this scenario, a minimum of one Flood Outlook is generated once a month. Because the outlook includes the climatological forecast, which comes out around the middle of every month, the Flood Outlook comes out shortly there after. Therefore, the Flood Outlook includes current conditions as well as the long-range climatological forecast. The outlook is presented in text, as well as color graphics, for each forecast site along the Red River of the North. The nearest forecast site to Orwell Dam is Wahpeton, North Dakota.

When runoff is under way and river levels are approaching Flood Stage, the NWS issues a River Forecast that has a five day forecast. The five-day forecast is based on current river data and the 24-hour quantitative precipitation forecast (QPF). Forecasts can be accessed from the Water Control web site (*http://www.mvp-wc.usace.army.mil*) through *NWS Products*.

6-02. Flood Condition Forecasts. Snow surveys of the Ottertail basin above Orwell Dam are taken annually. The snow-water content provides an indicator of the potential volume of spring runoff. Runoff from snow melt ordinarily commences the latter part of March and crests about 15 April. Due to the regulatory effect of the numerous inter-connected lakes upstream of Orwell Dam, recession is gradual, extending over a period of at least 30 days. Previous studies developed a relationship between accumulated snowfall and the resulting total runoff and the peak inflow. This relationship is shown in Plate 44A of the 1963 revised Orwell Regulation Manual. To investigate the usefulness of this relationship as a tool for predicting peak reservoir inflow, snow survey data for the period 1993 to 1997 was used. **Table 6-1** shows the results of the investigation. The table shows that while accumulated snowfall is a good indicator of the volumetric runoff potential, the pattern of the snow melt can have a significant impact on peak inflow.

Table 6-1 Accumulated Snowfall and Reservoir Inflow				
Snow Year	Accumulated Precipitation (1 Nov-31 Mar)	Peak Snow Water Content (near the Dam)	Peak Inflow Forecast (1963 Plate 44A)	24-Hour Average Reservoir Inflow (computed avg.)
1992 - 1993	4.54 in	2.15 in	450 cfs	870 cfs
1993 - 1994	4.64 in	3.80 in	740 cfs	1,060 cfs
1994 - 1995	4.58 in	2.37 in	500 cfs	1,070 cfs
1995 - 1996	3.74 in	3.15 in	540 cfs	965 cfs
1996 - 1997	7.53 in	7.87 in	1,370 cfs	2,400 cfs

Based on the results presented in Table 6-1, Plate 44A of the of the 1963 revised Orwell Regulation Manual is not included in this manual revision. Snow surveys will continue to be performed in the future and will serve as an indicator of the flood potential from spring runoff.

6-03. Conservation Purpose Forecasts. Forecasts for water conservation purposes are not required for the Orwell Project.

6-04. Long Range Forecasts. Long-range forecasts of reservoir inflows and levels are not normally required for flood periods or conservation purposes. Long range forecasts for drought conditions might be required, depending on the severity of the drought, as discussed in **Paragraph 6-05**.

6-05. Drought Forecast. The South Dakota Game Fish and Parks Department, the North Dakota Game and Fish Department, the Minnesota Department of Natural Resources and the National Weather Service routinely monitor and report drought indicators. Consult the *Draft Drought Contingency Plan* (1992) for the project for additional information.

VII - WATER CONTROL PLAN

7-01. General Objectives. Orwell Reservoir is operated primarily for flood control and water conservation. Other authorized uses include recreation, water quality/pollution abatement, and fish and wildlife enhancement. The water control plan meets flood control needs by providing storage volume within the reservoir. In the spring, when there is significant snow-water equivalent, the pool is drawn down to accommodate high runoff volumes. When drawdown of the pool is performed, it is coordinated with releases from the Lake Traverse Project to dilute the poor water quality from Mud Lake.

The conservation pool elevation for Orwell Reservoir is 1064 ± 0.5 feet. This is maintained year-round, except for flood control and two special conditions: (1) temporary fall pool raise to benefit migrating waterfowl; (2) drawdown once every few years for Minnesota Department of Natural Resources sub-impoundment drainage.

7-02. Constraints.

a. Conservation Pool. From when the dam was put into operation in spring of 1953, until spring runoff of 1986, the "normal full pool" elevation was 1070.0 feet and the "normal low pool" was 1048.0 feet. The pool fluctuated between these elevations annually. In an effort to get a band of vegetation initiated, a more consistent pool level was desired. From 1986 to spring runoff of 1988, a normal pool elevation of 1068.0 feet was established with a normal drawdown to elevation 1064.0 feet. Continued problems with pool fluctuations resulted in the formation of a "conservation pool" level set equal to the normal drawdown elevation. Drawdown of the pool would only be performed if the basin average snow-water content was greater than three inches. Therefore, following spring runoff of 1988, a conservation pool elevation of 1064.0 ± 0.5 feet was established.

b. Top of Flood Control. The maximum pool elevation that will not affect the tailwater rating curve at the Dayton Hollow power dam is 1070.0 feet. This constraint established the top of flood control pool at 1070.0 feet.

c. Top of Surcharge Pool. The spillway design flood hydrograph was routed through the reservoir with a pool elevation of 1070.0 feet. A safety factor was introduced by limiting the discharge to no more than 90 percent of the peak inflow, thus surcharging the pool. The maximum reservoir pool elevation reached by this routing was 1075.0 feet. Therefore, a top of surcharge pool was established at elevation 1075.0 feet. In the spring of 1979, boils were discovered in the discharge channel and thus limited the top of surcharge pool to elevation 1070.0 feet. After construction of relief wells that summer, top of surcharge pool returned to elevation 1075.0 feet, until the spring of 1986 when boils were again discovered. After that, surcharging much above the top of flood control pool was avoided until improvements were made in 2000. These improvements would allow surcharging to elevation 1075.0 feet; however, the taking line-guide for the reservoir was the 1073.0 foot contour (**Plates 2-8 and 2-9**) and no arrangements were made for flood easements to elevation 1075.0 feet. Therefore, top of surcharge pool for the current operating plan is constrained to an elevation of 1073.0 feet.

d. Drawdown.

1. Drawdown Period. Since the project was put into operation in 1953, until 1963, winter drawdown began on 1 November and was completed by 1 March. In an effort to control downstream flooding during drawdown, in 1963 drawdown was changed such that it was to begin on 20 September and be completed by 15 March. Then, due to reduced need to augment low flows downstream, different drawdown starting dates were tried. In 1969, winter drawdown began on 15 October and in 1970, it began on 1 November. Drawdown continued to start on 1 November until the fall of 1986, when it was changed to begin on 1 February. In 1988, in an effort to establish a more permanent pool level, drawdown was extended to 31 March; however, it was not to be initiated unless there was three inches or more of snow-water equivalent over the basin. Then in 1994, to dilute releases from White Rock Dam on the Bois de Sioux River, the drawdown period of 1 March to 31 March was established.

2. Maximum Drawdown. Drawdown of the reservoir is limited to the invert elevation of the low flow conduits which is 1040.0 feet; however, by agreement with the US Fish and Wildlife Service, drawdown was limited to 1,000 acre-feet of storage to maintain fish life. At

the time of construction, that elevation was around 1048.0 feet. This elevation has remained the maximum drawdown elevation until 2000. Based on the survey of 1985, a storage volume of 1,000 acre-feet exists at elevation 1049.2 feet. To account for past and near future sedimentation, the maximum drawdown is now established at elevation 1050.0 feet. This elevation will remain in effect until the next sedimentation survey is performed.

3. Rate of Drawdown. To reduce shoreline erosion, the rate of drawdown is limited to a maximum rate of 0.5 feet per day.

e. Discharge: From the spring of 1953 until 1986, during normal operations, maximum discharge was 900 cfs (plus freeboard) and minimum discharge was 5 cfs with an exception for water supply whereby minimum flow was 40 cfs. In 1986 it was discovered that a discharge of 1,200 cfs from the dam did not disrupt agriculture operations downstream of the dam. Also in the same year, an agreement was reached between the Corps of Engineers and the Minnesota Department of Natural Resources regarding low flow releases. A minimum outflow of a year-round minimum of 80 cfs was established. Therefore, during normal operations, minimum and maximum outflows are constrained to 80 cfs and 1,200 cfs respectively.

See **Paragraphs 7-14 and 7-16** for constraints regarding rate of release changes.

7-03. Overall Plan for Water Control. Orwell Reservoir is regulated between a minimum elevation of 1050.0 feet (maximum drawdown) and a maximum elevation of 1073.0 feet (top of surcharge pool). To the greatest extent possible, the conservation pool of 1064.0 $\pm$ 0.5 feet is maintained throughout the year, except for flood control and two periods of specialized regulation: (1) a temporary fall pool raise to accommodate migrating waterfowl; and (2) occasional drawdown to drain the MDNR sub-impoundments. Under normal conditions, the discharge from Orwell Reservoir will not be less than 80 cfs, nor will the discharge be greater than 1,200 cfs. The low flow conduits will be used for discharges as long as their capacity is adequate. See **Plate 2-5** for conduit rating curves. When the desired outflow exceeds the conduit capacity, the total discharge will be achieved by the Tainter gate. When operation of the Tainter gate is only required for a short period

of time (i.e. one to two days), operation of the low flow culverts in conjunction with the Tainter gate will be allowed. See **Plate 2-4** for Tainter gate rating curves.

a. Flood Control. If the late February basin-average snow-water content is less than three inches, there is no drawdown and the conservation pool elevation of 1064.0 ± 0.5 feet is maintained. If the late February basin-average snow-water content is three inches or more, the pool may be drawn down to between elevations 1050.0 and 1060.0 feet. The drawdown target elevation will be determined by Water Control. Drawdown begins on or after 1 March and is to be completed by 31 March. Maximum discharge will not exceed 1,200 cfs nor will the rate of fall exceed 0.5 feet/day.

As spring runoff begins, the storage capacity of the reservoir is utilized as needed to assist in preventing or reducing flood damages at Wahpeton-Breckenridge. If the pool elevation rises above the flood control pool elevation of 1070.0 feet, the discharge will be set to 90 percent of the inflow (based on the average inflow rate for the previous 3 hours), but not less than 1,200 cfs. If the pool elevation rises to the top of surcharge pool elevation of 1073.0 feet, the discharge is to be set equal to the inflow, but not less than 1,200 cfs. After the peak passes, the gate remains unchanged until the pool falls to elevation 1070.0 feet.

During summer and fall floods, outflow is not to exceed 1,200 cfs (bank full capacity) until the pool rises to elevation 1070.0 feet. At that time, the same procedure as a spring event is followed.

b. Temporary Fall Pool Raise. Upon request from Minnesota Department of Natural Resources, a temporary pool raise to elevation 1066.0 feet may be performed in the fall to provide waterfowl staging and feeding areas. The pool is returned to elevation 1064.0 feet before freeze-up.

c. Temporary Pool Drawdown. Upon request from the Minnesota Department of Natural Resources (MDNR), a drawdown after spring runoff to about elevation 1061 feet will be performed (every few years) to drain MDNR sub-impoundments located in the south arm of the reservoir (**Plate 4-9**). Details concerning the sub-impoundments are given in **Paragraph 2-04**.

7-04. Standing Instructions to Project Staff. This Chapter, *Water Control Plan*, along with Chapter 5, *Data Collection and Communication Network*, act as the "Standing Instructions to Project Staff". In the event of failure of normal (telephone) communications, field staff will maintain contact with the District Office by any other means available (e.g. radio, cellular telephone service). If necessary, a messenger with be sent to the dam with instructions. In the mean time, the primary objective of field staff will be to ensure the safety of the structures and to provide the most effective operation of the project by following the guidance in this chapter. During emergency operation, the appropriate schedule in this chapter will be followed until contact with the District Office is re-established. Field staff should make an effort to keep informed concerning effects of any reservoir releases on downstream damage centers. If Water Control Section cannot be contacted at the District Office, one of the Water Control managers should be contacted at home, in order of preference as shown in the introduction to this manual.

7-05. Flood Control. Flood control is typically required for two types of flooding: (1) spring floods as a result of snowmelt, often with rainfall, and (2) summer or fall floods which are the result of heavy or prolonged rainfall. During a spring flood event, operation of Orwell Dam is performed in conjunction with the Lake Traverse Project (see Lake Traverse Project, Water Control Manual) to eliminate or reduce flood damages for cities of Wahpeton, North Dakota and Breckenridge, Minnesota. While operation for a summer flood event may be performed in conjunction with Lake Traverse Project, Orwell Dam is typically operated to prevent or reduce agricultural damages downstream of the dam. See **Exhibit F** and **Plates 2-6 and 2-7** for elevation-area and elevation-storage relationships.

a. Spring Floods. In preparation of spring breakup, Orwell Reservoir may be drawn down to provide additional storage capacity to assist in preventing or reducing flood damages at Wahpeton and Breckenridge. There are two categories of drawdown:

1. Category I Drawdown. Category I drawdown conditions exist when the late February basin-average snow-water content is less than three inches. Only Lake Traverse is drawn down in a Category I drawdown. The pool level at Orwell Reservoir will be maintained at the

conservation pool elevation of 1064.0 ± 0.5 feet. Additional precipitation during the flood runoff period (i.e. after 1 March) will be evaluated by Water Control Section. If the precipitation is in the form of snow and the outflow is less than channel capacity, a drawdown may be performed. Under Category I drawdown conditions, the target stage on the Red River of the North at Wahpeton, North Dakota, is 10 feet (see Lake Traverse Project, Water Control Manual).

2. Category II Drawdown. Category II drawdown conditions exist when the late February basin-average snow-water content is three inches or more. Typically in a Category II drawdown, Orwell Reservoir and Lake Traverse are drawn down concurrently with drawdown beginning on 1 March and being completed by 31 March. The drawdown rate for Orwell Reservoir will not exceed 0.5 feet per day. The target drawdown elevation is between 1050.0 and 1060.0 feet. The actual drawdown target elevation will be determined by the Water Control Section based upon hydrologic conditions for the specific event. Under Category II drawdown conditions, the target stage on the Red River of the North at Wahpeton, North Dakota, is 12 feet (see Lake Traverse Project, Water Control Manual).

Table 7-1
Orwell Reservoir Drawdown

Drawdown Category & Runoff Condition	Drawdown Dates	Target Pool Elevation	Wahpeton Target Stage
Category I Normal Runoff Conditions	No Drawdown	Maintain Conservation Pool 1064.0 ± 0.5 feet	10.0 feet
Category II Moderate to Heavy Runoff Conditions[1]	1 March to 31 March	1060.0 feet to 1050.0 feet[2]	12.0 feet

1. Snow cover with 3 inches or more of water equivalent.
2. Final drawdown target determined by Water Control based on field conditions. Maximum fall rate = 0.5 ft/day.

Following a Category I or II drawdown, storage of the inflows from the spring breakup continue as necessary until the flood control pool elevation of 1070.0 feet is reached. If conditions at Wahpeton-Breckenridge still require storage of inflow, a surcharge may be placed on the pool by discharging

90 percent of inflow, based on average inflow over the previous 3 hours (when practical), but not less than 1,200 cfs, and storing the balance. Surcharge continues, if necessary, until the pool reaches elevation 1073.0 feet (top of surcharge). At this point, the stage at Wahpeton is no longer a consideration. Discharge is set equal to inflow to prevent flooding of private property around the reservoir and to ensure safety of the dam. After the peak passes, the gate will remain unchanged until the surcharge has been disposed and the pool elevation has dropped to 1070.0 feet (top of flood control). Once the pool elevation drops below 1070.0 feet, outflow is set equal to inflow, but not less than 1,200 cfs. When inflow falls below 1,200 cfs, outflow is maintained at the channel capacity discharge of 1,200 cfs until the pool falls to conservation level (elevation 1064.0 feet).

b. Late Spring, Summer, and Fall Floods. Following spring runoff, the pool is maintained at elevation 1064.0 $\pm$ 0.5 feet. Releases are not to exceed the downstream channel design capacity of 1,200 cfs nor cause the Red River of the North at Wahpeton to exceed the target stage of 10 feet. Should the pool rise to elevation 1070.0 feet (top of flood control) regulation is the same as an early spring flood situation.

7-06. Recreation. Day-use recreation facilities are located at the dam site. Hunting, fishing, sightseeing, nature study, and picnicking are among the recreational opportunities available at the project. Parking near the dam is available. There is some canoeing and inner-tube rafting on the Otter Tail River downstream of the dam.

7-07. Water Quality. Orwell Reservoir contributes some of the best quality water to the Upper Red River of the North. From the standpoint of municipal and industrial use, it is good quality water because it is low in dissolved minerals. Though suitable for industrial use, Orwell Reservoir water quality is considered to be impaired as stated by the Minnesota Pollution Control Agency (MPCA) in the 1994 *Minnesota Water Quality-Report to the Congress of the United States*. Orwell Reservoir does not support swimming use during the summer months due to low Secchi transparency and high algae concentrations. Impaired swimming conditions, based on the frequency of severe nuisance algal blooms, may occur over 40 percent of the summer. See **Paragraphs 4-08, 5-02, and 8-04**.

7-08. Fish and Wildlife. There is a great diversity of wildlife at and near the Orwell Project. This is due in part to the variety of vegetation types in the area and the presence of grasslands, forest, shrub, wetland, and open-water areas at the reservoir. The Minnesota Department of Natural Resources (MDNR) has observed 83 species of birds and 14 species of mammals in the Otter Tail River valley. Many additional species are known to be present as well. Orwell Reservoir and the connected and adjacent wetland areas provide waterfowl habitat. Numerous waterfowl species use the reservoir during migration, and a number of non-game bird species inhabit the area. The MDNR has designated about one-quarter of the reservoir as wildlife sanctuary, primarily to protect migrating waterfowl. The MDNR also leases 1,957 acres of project land from the Corps of Engineers for wildlife management, primarily for pheasants and white-tail deer.

The reservoir harbors good populations of several gamefish species. Substantial numbers of black crappies and yellow perch are present, as well as populations of walleye and northern pike. A high quality smallmouth bass population utilizes the reservoir during the fall and winter months. In the tailwater area and river reach downstream of the dam, there is an excellent cool-water fishery which includes smallmouth bass, walleye, channel catfish, northern pike, and black crappie. The river reach above the reservoir harbors a high quality smallmouth bass fishery and good populations of walleye and northern pike.

Under previous operating plans, reservoir regulation had a significant adverse impact on fish populations and water-oriented wildlife. Impacts included prevention of development of emergent and submerged vegetation; flooding of waterfowl and game-bird nests; isolation of nests, broods, game-fish eggs, and larvae from the pool during drawdowns; prevention of the development of a littoral zone and accompanying vegetation and invertebrate habitat; and bank erosion which increased turbidity and siltation in the reservoir. The new plan of operation, based on the results of the ROPE studies completed in 1986 and 1994, is intended to improve these adverse impacts.

7-09. Water Supply. Orwell Dam and Reservoir was originally a dual-purpose project designed to impound water during flood periods and to release stored water for water supply and pollution abatement during low-flow periods. For years after the completion of the Orwell Project, the cities

of Wahpeton, North Dakota, Breckenridge, Minnesota, Fargo, North Dakota and Moorhead, Minnesota relied the Red River for water supply. In 1987, the cities of Wahpeton and Breckenridge switched to groundwater systems, thus diminishing the need for water supply. The City of Fargo relies on surface water and ground water for its water supply needs. However, completion of the Fargo Diversion on the Sheyenne River in 1988 greatly reduced the city's reliance on the Red River. Orwell Reservoir does however aid water supply needs at Fargo by diluting Lake Traverse Project releases during spring drawdown. Reliance on the Red River for water supply by the City of Moorhead was reduced with the construction of a new water plant in 1993. With the exception of minimum release requirements, improvements in basin have essentially eliminated water supply as one of the purposes for operating Orwell Reservoir.

7-10. Hydroelectric Power. The Dayton Hollow Dam and Hydroelectric Plant is located about five river miles upstream of Orwell Dam. It is owned and operated by the Otter Tail Power Company. The dam was constructed in 1908 and began producing electricity in 1909. There are a number of cabins along the lake shore of Dayton Lake. The main recreational use is fishing. Operation of the Dayton Hollow Dam can have an effect the operation of Orwell Dam; however, under normal operations, the impacts are minimal. The Otter Tail Power Company owns and operates four other dams on the Otter Tail River, all upstream of Dayton Hollow Dam. None of these dams have any impact on the operation of the Orwell Project.

7-11. Navigation. Navigation is not an authorized use of the Orwell Project.

7-12. Drought Contingency Plans. In 1986, the Corps of Engineers and Minnesota Department of Natural Resources reached an informal agreement to increase the minimum flow below Orwell Reservoir to 80 cfs year-round (**Exhibit D-6**). A step function to reduce flows further if reservoir inflow falls below 80 cfs is presented in the *Draft Drought Contingency Plan (DCP) for Orwell Reservoir,* September 1992. The draft DCP is a stand-alone document at this time. The guidelines of the agreement are summarized below:

When inflows are above 80 cfs, release a minimum of 80 cfs. If inflows are less than 80 cfs;

1. Release for the first 30 days:
    a. Pool Elev. > 1060.0 ft; Min Flow = 80 cfs
    b. Pool Elev. < 1060.0 ft; Min Flow = Inflow (1-week to ramp to inflow)
2. Release for second 30 days:
    a. Pool Elev. < 1060.0 ft and Inflow > 70 cfs; Min Flow = 80 cfs
    b. Pool Elev. < 1060.0 ft and Inflow < 70 cfs; Min Flow = Inflow
    c. Pool Elev. > 1060.0 ft and Inflow < 70 cfs; Min Flow = 50 or Inflow +10 cfs
    d. Pool Elev. < 1060.0 ft and Inflow < 70 cfs; Min Flow = Inflow (1-week ramp)
3. Release for next 60 days plus:
    a. Same as #2 above and implement drought contingency plan.

7-13. Flood Emergency Action Plans. The *Flood Control Project, Orwell Dam & Reservoir Emergency Plan* (1990) outlines procedures to be followed under various emergency conditions. The report includes: an emergency identification plan, an emergency operations and repair plan, an emergency notification list, and an inundation map. The plan is dated April 1990 and is a stand-alone document. See also **Paragraphs 5-08, and 8-10**.

7-14. Releases to Aid Construction. It is sometimes necessary to deviate from standard changes in the release rate to accommodate construction downstream of the dam. Rapid changes in discharge can have a significant impact on fish life downstream. Therefore, a recommended ramping schedule (actually a step function) for changes in discharge was developed in cooperation with the District's Environmental Section. Ramping down of discharges should occur over an extended period of time (less chance of stranding fish), while the ramping up of discharges may occur slightly faster. Decreasing flows to 80 cfs during spawning season (i.e. April - May) should be avoided if at all possible. While the following table was developed for construction of the tailwater control structure, it may be used as a reference for future construction purposes.

Table 7-2
Ramping Discharges (cfs) to Aid Construction

Decreasing Flow	8-Hour Increments								
	1250	1050	850	650	450	300	200	125	80
Increasing Flow	5-Hour Increments								
	80	125	200	300	450	650	850	1050	1250

7-15. Deviation from Normal Regulation. Unusual circumstances that require deviations from the normal regulation must have the official concurrence of the District Engineer and the Division Commander. Water Control Section will coordinate with Environmental Section who in turn will coordinate with cooperating agencies. For deviations that become necessary with little advance notice, Water Control Section will obtain verbal approval from the District Engineer, or his designated representative, and the Division Commander, with supporting documentation provided as soon as possible after the fact. Water Control Section personnel may authorize necessary short-term changes under extreme emergency conditions until approval from higher authority is obtained.

7-16. Rate of Release Change. The maximum 24-hour rate of release change at the dam was established to be limited to 300 cfs for both increases and decreases, in so far as practicable, in order to avoid damage to real property, livestock, and fish in the area downstream (**Exhibit D-2**). This restriction to the rate of release change applies at all times **except** for the following two situations: (1) change to higher releases are required to reduce an imminent threat to life, property, or the structural integrity of the dam and (2) change to lower releases are required to accomplish downstream construction (**Paragraph 7-14**). The Corps will notify the City of Breckenridge whenever there is a daily release change that is likely to cause the flow in the Otter Tail River to exceed channel capacity.

VIII - EFFECT OF WATER CONTROL PLAN

8-01. General. The primary benefits from the project are derived from flood control and water conservation. Agricultural and urban flood control benefits are provided below Orwell Dam along the Otter Tail River and at the towns of Wahpeton, North Dakota and Breckenridge, Minnesota. Secondary benefits include fish and wildlife enhancements and recreation.

8-02. Flood Control.

a. Spillway Design Flood. As part of the Orwell Dam design (*Definite Project Report on Orwell Reservoir, 1949*), a Probable Maximum Flood (PMF) hydrograph was developed. The spillway design flood hydrograph was computed by applying the run-off value used for the maximum probable flood to the peaked unit hydrograph. A base flow was added which varied from 270 cfs to a maximum of 1,750 cfs in accordance with the expected outflow from the upstream lakes. The final hydrograph peak was 20,400 cfs. This hydrograph was routed through the structure with a starting pool elevation of 1070.0 feet. A safety factor was introduced by limiting the discharge to not more than 90 percent of the peak inflow. The maximum reservoir pool elevation reached for this routing was 1075.0 feet. Therefore, with the Tainter gate fully open and the pool elevation at 1075.0 feet (maximum design pool), the capacity of the spillway, is 20,400 cfs. Spillway rating curves for full and partial Tainter gate openings are shown on **Plate 2-4**. The PMF was revised in 1981 and the resulting hydrograph was routed through the reservoir. See the following paragraph.

b. Probable Maximum Flood. A PMF hydrograph was developed in 1949 as part of the Orwell Dam design (*Definite Project Report on Orwell Reservoir*) with a peak inflow of 16,500 cfs and a peak outflow of 14,800 cfs. A revised PMF hydrograph was developed in November 1981 as a part of the preliminary work for the Orwell Dam, Risk Assessment Study. The revised hydrograph was based on the latest PMF development methodology and the updated generalized estimates of Probable Maximum Precipitation for areas east of the 105th meridian. The all season PMF was routed through the structure with the pool at top of food control (1070.0 feet) in accordance with EC 1110-2-163, August 1975. The routing resulted in a computed peak inflow of 26,200 cfs, a peak

outflow of 20,400 cfs, and a peak pool elevation of 1078.8 feet (**Plate 8-1**). For more detailed information, see the reference shown in **Paragraph 1-03.n.**

c. Standard Project Flood. A Standard Project Flood (SPF) analysis was performed as part of the 1949 *Definite Project Report on Orwell Reservoir*. The peak discharge was 8,250 cfs. A revised SPF was developed in November 1981 as part of the preliminary work for the Orwell Dam, Risk Assessment Study. The SPF hydrograph was assumed to be 45 percent of the Probable Maximum Flood (PMF) hydrograph. The peak SPF discharge based on this analysis was 11,800 cfs.

8-03. Recreation. The current water control plan for the Orwell Project provides dependable and stable summer lake levels for recreational use. Hunting, fishing, canoeing, and picnicking are some of the recreational opportunities at or near Orwell Project.

8-04. Water Quality. Releases from Orwell Reservoir affect the quantity and quality of water available for municipal water supply in the Red River of the North. The St. Paul District monitors the quality of water released from the Orwell and Lake Traverse Reservoir Projects, in conjunction with the municipal water utilities at Fargo and Moorhead. The monitoring program is used to evaluate the effects of releases from the projects on water quality. The Cities of Fargo, North Dakota and Moorhead, Minnesota use the Red River for water supply when it is available in sufficient quality and quantity. The cities have requested Orwell Reservoir releases to supplement flows in the Red River to (1) help flush algal blooms in the river, (2) dilute poor quality releases from Lake Traverse, (3) allow for larger treatment plant effluent dilution, and (4) improve the aesthetic appeal of the Red River of the North. Releases from Orwell Reservoir dilute Lake Traverse releases to the extent allowable by the operational plan. Releases from Orwell Reservoir are most important for dilution during the winter. During this time, treatment of Bois de Sioux River (Lake Traverse) water is much more difficult since biotic activity in the stream and chemical reaction rates in the softening process are much slower and less efficient due to cold water temperatures. Therefore, when a drawdown of Orwell Reservoir is performed, it is coordinated with the drawdown of Lake Traverse.

8-05. Fish and Wildlife. The water control plan provides benefits to fish and wildlife. For example, the plan allows for temporary changes in pool levels to aid in the management of the Minnesota Department of Natural Resources (MDNR) sub-impoundments which benefit migrating waterfowl. The stable summer pool levels promote favorable aquatic habitat conditions during the growing season and sufficient lake volume to support fish habitat. Drawdown of the reservoir prior to spring runoff is limited to provide a minimum of 1,000 acre-feet of storage for fish habitat. Also, no early drawdown (i.e. prior to 1 March) is permitted to minimize the chance of a turtle kill. To benefit downstream fish habitat, the minimum release from the dam is 80 cfs, as per agreement with the MDNR (see **Exhibit D-6**).

8-06. Water Supply. One of the original purposes for Orwell Reservoir was water supply; however, improvements by cities downstream of the reservoir have essentially eliminated water supply as an operating purpose for the Orwell Project. While water supply needs have been reduced, some reliance on the river still remains. For example, the City of Breckenridge, Minnesota maintains its intake in the Otter Tail River for an emergency source of supply. It should be noted that while the reservoir is not operated to provide water supply, the minimum release requirements (**Paragraph 7-12**) inadvertently provide water to the system.

8-07. Hydroelectric Power. The Dayton Hollow Dam and Hydroelectric Plant is located about 5 river miles upstream of Orwell Dam. It is located a sufficient distance upstream of the dam so as to not be affected by reservoir operation. There are four other hydropower dams on the Otter Tail River, all significantly upstream of Orwell Dam.

8-08. Navigation. Navigation is not an authorized purpose of the project.

8-09. Drought Contingency Plans. The Drought Contingency Plan (DCP) provides a basic reference for water management decisions and responses to a water shortage in the Otter Tail basin induced by climatological droughts. The DCP includes a plan formulation process for the release of low flows and an interagency coordination matrix. The drought contingency plan is in draft form (dated September 1992) and is a stand-alone document (see **Paragraph 7-12**).

8-10. Flood Emergency Action Plans. The *Flood Control Project, Orwell Dam & Reservoir Emergency Plan* (1990) outlines procedures to be followed under various emergency conditions. The report includes: an emergency identification plan, an emergency operations and repair plan, an emergency notification list, and an inundation map. The plan is dated April 1990 and is a stand-alone document.

8-11. Frequencies.

a. Peak Inflow Probability. Plate 8-2 shows the probability of a given daily-average inflow into the Orwell Project, based on the period of record 1931-1993. For the period 1931-1952, prior to the construction of the project, inflows were taken to be the discharge at the gage site, Otter Tail River below Pelican River, near Fergus Falls, Minnesota. For the period 1953-1993, daily-average inflows were based on the storage equation [$I = O + \Delta S$] using project pool elevations and outflows.

b. Pool Elevation Frequency and Discharge Frequency. The operating plan for Orwell Reservoir has under gone significant changes over the years **(Paragraph 3-05)**. Some of these changes had a big impact on pool levels and reservoir outflows. The following summarizes some examples:

(1) In 1986 the "normal full pool" elevation of 1070 feet was abandoned and a normal pool elevation of 1068.0 feet was established. In 1988 a conservation pool elevation of 1064 ± 0.5 feet was established.

(2) Drawdown dates were changed in 1963, 1969, 1970, 1986, 1988, and 1994. In addition, drawdown elevations varied from mandatory drawdown to elevation 1048.0 feet (1953 - 1986) to present day where drawdown may or may not occur dependant on the snow-water equivalent in the basin.

(3) After seepage problems were discovered in 1977, surcharging of the pool was limited to the top of flood control (i.e. elevation 1070.0 feet) until improvements were made in 1979. Boils were again discovered during high water in 1986. Surcharging of the pool more than a couple of tenths of a foot above top of flood control was avoided until improvements were made in 1999.

Because a consistent operating plan over a sustained period of time does not exist, it is not possible to generate a useful graphical relation for pool elevation/frequency. A listing of maximum pool elevations by year since Orwell Reservoir began operations is given in **Table 8-1**.

Table 8-1
Maximum Pool Elevations by Year

Calendar Year	Elevation (1912 MSL)	Date	Notes
1953	1070.54	21 Nov	Operation began this spring. Discharge of record, 1710 cfs, on 6/17.
1954	1070.01	25 Nov	
1955	1069.27	14 Nov	
1956	1068.82	31 Dec	
1957	1069.94	08 Nov	
1958	1070.19	28 Oct	
1959	1070.06	04 Nov	
1960	1068.37	08 Nov	
1961	1067.43	09 Jan	
1962	1072.35	17 Jun	Summer flooding in Red River of the North basin.
1963	1070.68	14 Oct	
1964	1071.33	02 Oct	
1965	1070.47	02 Oct	
1966	1072.37	23 May	Early spring flooding around Wahpeton. Discharge 1490 cfs on 6/1.
1967	1069.83	22 Sep	
1968	1069.94	25 Sep	
1969	1070.71	14 Apr	Major spring flooding in Red River of the North basin.
1970	1069.28	03 Nov	
1971	1070.23	20 Oct	
1972	1071.71	01 Jun	
1973	1070.06	11 Oct	
1974	1070.51	07 Oct	
1975	1070.51	07 Jul	
1976	1060.60	02 Jan	Severe drought. Excluding drawdown, minimum elevation of record.
1977	1070.10	28 Aug	
1978	1069.50	24 Sep	
1979	1069.98	19 Apr	Major spring flooding in Red River of the North basin.
1980	1068.75	09 Apr	
1981	1069.96	14 Oct	
1982	1070.54	07 Oct	
1983	1069.60	08 Oct	
1984	1067.10	01 Apr	
1985	1071.54	09 Jul	
1986	1072.14	19 May	Highest discharge since 1953, 1600 cfs on 5/27.
1987	1068.77	26 May	
1988	1068.61	29 Jan	Severe drought.
1989	1070.23	18 Apr	Spring flooding in Red River of the North basin.
1990	1065.55	29 May	
1991	1065.50	06 May	
1992	1065.03	08 Aug	
1993	1070.73	01 Aug	Major summer flooding throughout the midwest.
1994	1065.43	25 Mar	
1995	1068.79	20 Mar	
1996	1068.33	28 May	
1997	1070.30	15 Apr	Record flooding on the Red River of the North.
1998	1066.19	24 Jul	
1999	1072.47	09 Jun	Heavy rainfall event of 2.8 inches on 7 June
2000	1065.52	29 Feb	
2001	1072.93	29 May	Rainfall events following spring runoff. Record pool elevation.

An inflow-frequency analysis was performed as part of the *Dam Safety Assurance Program* in 1994. The adopted annual instantaneous peak discharge-frequency curve is shown on **Plate 8-2**.

A discharge/frequency curve was developed for the Otter Tail River below Orwell Dam near Fergus Falls, Minnesota for a period of record from 1953 to 1993 (see **Plate 8-3**). The gage is located 0.7 river miles downstream of Orwell Dam and is operated and maintained as part of the USGS cooperative stream gage network.

Ice jams often have had a significant impact on stages on the Red River of the North at Wahpeton, North Dakota. Therefore, elevation-frequency is of greater importance than discharge-frequency. As part of the Wahpeton, North Dakota, Section 205 Study of September 2000, an elevation-frequency curve was developed for "open-water", "ice affected", and "combined population". Of the 56 years of available gaged stream flow records (1942-1997), 28 years of annual peak stages were ice-affected and 28 years of annual peak stages were associated with open-water discharges. Due to the high number of ice-affected flood stages, flood frequency analysis based on peak annual instantaneous discharges was not appropriate. Therefore, the analysis considered the mixed populations of annual peak ice-affected stages and annual peak open-water stages. A combined-population frequency analysis was conducted by deriving an annual elevation-frequency curve from two frequency curves developed from separate subpopulations. These two subpopulations were separated according to season. A combined-population frequency curve was then developed by combining independent annual frequency curves for the two separate subpopulations. The elevation-frequency curve is shown on **Plate 8-4**.

c. Key Control Points. The only control point below the project is the USGS gage located on the Red River of the North at Wahpeton, North Dakota (**Table 5-1**). There are two target elevations based on the late February basin-average snow-water content. Category I conditions exist when the snow-water content is less than three inches and Category II conditions exist when the snow water content is three inches or more. Under Category I conditions, the target stage at Wahpeton is 10 feet. Under Category II drawdown conditions, the target stage is 12 feet. The stage-frequency curve for

Wahpeton is shown on **Plate 8-4**. Discharge-damage curves for Wahpeton and Breckenridge are shown on **Plates 4-11 and 12** respectively.

8-12. Other Studies.

a. Examples of Regulation. Several studies have been completed to determine the effectiveness of the present regulation plan for the Orwell Project. These studies include:

(1) *Orwell Reservoir Operation Plan Evaluation and Environmental Assessment,* U.S. Army Corps of Engineers, St. Paul District, January 1986.

(2) *Operation Plan Evaluation and Environmental Assessment, Lake Traverse, Bois de Sioux River, and Orwell Reservoir,* U.S. Army Corps of Engineers, St. Paul District, April 1994.

(3) *Operation and Maintenance Manual, Section 1135 Habitat Restoration Project, Orwell Lake, Otter Tail County, Minnesota,* U.S. Army Corps of Engineers, St. Paul District, May 1996.

Other related studies, manuals, and reports are listed in **Paragraph 1-03**.

b. Channel and Floodway Improvements. In 1954 and 1955 the Otter Tail River Channel was modified between river miles 9.7 and 21.1. The channel was modified to have a capacity of 900 cfs plus freeboard in this reach. The channelization project was found to be in generally good condition during the last inspection, which took place in 1991. Prior checks of the condition of the Otter Tail River channel upstream of river mile 21.1 and downstream of the dam by site staff found a few downed trees or other similar snags in a few reaches of the river, but the channel was generally in good condition.

During the spring and summer of 1963 flows exceeding 1,100 cfs were passed without any appreciable flooding or damage (Orwell Regulation Manual, revised 1963). The elevation-area flooded curve indicated that, for a discharge of up to 1,200 cfs, no agricultural land would be flooded, but that flood damages would begin to occur at discharges greater than 1,200 cfs. During the spring and early summer of 1985, several heavy rainfall events provided an opportunity to

investigate channel capacity. The rainfall provided significant inflows to the reservoir as well as higher than normal inflows to the river channel between the reservoir and Breckenridge. Discharge from the reservoir was 900 cfs in mid-May and was over 1,000 cfs by the first week of June. The discharge peaked at 1,240 cfs the 28th of June, but continued to remained over 1,000 cfs until the 28th of August. During that time, the downstream reaches of the Otter Tail River were inspected by a reconnaissance hydraulic engineer who found that a discharge of 1,000 cfs was remaining within the banks. When the discharge reached 1,200 cfs, Orwell site personnel interviewed downstream farmers located along the channel. They indicated that the flows were not interfering with their agricultural operations. The Water Control Section, the Minnesota Department of Natural Resources area hydrologist, and the Breckenridge City Engineer indicated that they had not received any complaints about the 1,200 cfs discharge.

The discharge value of 1,200 cfs is now established as the maximum discharge that can be released and contained in the downstream river channel without causing any damages.

IX - WATER CONTROL MANAGEMENT

9-01. Responsibilities and Organization.

a. Corps of Engineers. The Corps of Engineers is the owner, operator, and regulator of the Orwell Project. The St. Paul District, Water Control Section has direct day-to-day responsibility for the regulation of flows from Orwell Dam. Operation and maintenance of the project is the responsibility of Construction-Operations Division, Western Flood Control Project Office.

b. Other Federal Agencies. The National Weather Service (NWS) has the responsibility for all hydrologic forecasts within the Red River of the North Basin. The St. Paul District provides the NWS with daily operation information at Orwell Dam to aid in the development of flood forecasts. The US Geological Survey collects data on discharges at various stations within the basin. **Plate 5-1** shows the stations in the Otter Tail River basin. Federal agencies that have an on-going interest in the regulation of the Orwell Project are listed in **Table 9-1**.

c. State and County Agencies. The state and county agencies that have an interest in the regulation of the Orwell Project are listed in **Table 9-1**.

9-02. Interagency Coordination.

a. Local Press and Corps Bulletins. Information concerning the regulation of the Orwell Project is provided by the St. Paul District's Public Affairs Office (PAO) to the local news media in response to their requests. Additionally, the PAO provides news releases of an advisory nature to the local media regarding important aspects of project regulation. All news bulletins regarding regulation of Orwell Dam is reviewed by Water Control Section before release. These releases may include forecasts at the project site (e.g. expected pool crest) but do not provide public forecasts of river stages downstream because such forecasts are a Congressionally mandated responsibility of the National Weather Service.

Table 9-1 Organizations With an Interest in Orwell Reservoir Water Control Activities	
FEDERAL AGENCIES	U.S. Army Corps of Engineers U.S. Fish and Wildlife Service U.S. Environmental Protection Agency U.S. Geological Survey National Weather Service Federal Emergency Management Agency
STATE OF MINNESOTA	Department of Natural Resources Pollution Control Agency Board of Water and Soil Resources Becker, Clearwater, Mahnomen, Otter Tail, & Wilkin County County Soil and Water Conservation Districts County Drain Conservation Districts
STATE OF NORTH DAKOTA	State Water Commission Game and Fish Department State Conservationist Richland County Richland County Water Management District
INTERSTATE	Tri-State Waters Commission Red River Watershed Management Board
INTERNATIONAL	International Joint Commission

b. National Weather Service. The St. Paul District provides operational information regarding Orwell Reservoir to the National Weather Service (NWS) through the World Wide Web, e-mail, fax, and telephone. The Water Control (WC) web site at *www.mvp-wc.usace.army.mil* has simplified much of the data transfer. Hourly data available from the WC web site includes pool and tailwater levels. Daily data includes average daily inflow, 24 hour precipitation, and the morning (0800 hrs) discharge. Weekly data includes, frost depth, lake ice thickness, snow depth, and snow water equivalent. The NWS uses this information in developing their spring runoff outlook and flood forecasts. During a flood, contact with the NWS North Central River Forecast Center may occur several times (e.g. telephone the latest change in outflow, fax the latest field conditions, etc.).

c. U.S. Geological Survey. To maintain the vast network of stream gages needed for operation of the Corps of Engineers (COE) reservoirs located in the Red River of the North basin, would be a costly undertaking. Because of the existing infrastructure of the US Geological Survey (USGS), the St. Paul District enters into a co-operative agreement with the USGS on an annual basis to maintain several gages throughout the Red River basin (**Table 5-1**). While the Orwell pool gage

is owned and operated by the COE, the USGS co-ops with the COE to maintain the data collection platforms (DCP) at the Orwell Dam tailwater and at the Orwell Reservoir control point on the Red River of the North at Wahpeton, North Dakota. Part of the co-op agreement includes updating the rating table at Orwell tailwater and Wahpeton by performing periodic stream gaging. The COE typically retrieves the latest stream information from the USGS web site.

d. Minnesota Department of Natural Resources. The Minnesota Department of Natural Resources (MDNR) coordinates with the St. Paul District in the operation of sub-impoundments on the Orwell Reservoir for waterfowl and other wildlife management. See **Paragraphs 4-10 and 7-03**.

e. Other Federal, State or Local Agencies. Local interests include recreationists and the Cities of Breckenridge and Moorhead, Minnesota, and Wahpeton and Fargo, North Dakota. Interests by Wahpeton/Breckenridge are typically flood related, whereas interest by Moorhead and Fargo are typically related to water supply.

9-03. Interagency Agreements. There is an interagency agreement between the St. Paul District and the Minnesota Department of Natural Resources (MDNR) regarding the management of project lands for wildlife. A copy of this agreement can be found in **Exhibit D-5**. Otherwise, there is an understanding between the St. Paul District and the MDNR that, in all river regulation matters affecting state interests, issues will be resolved through consultation.

9-04. Commissions, River Authorities, Compacts & Committees.

a. Tri-State Waters Commission. There is a compact among the states of Minnesota, South Dakota, and North Dakota regarding the management of the waters of the Red River of the North. This compact is spelled out in a Congressional Act dated 2 April 1938, which established the Tri-State Waters Commission. The text of the act can be found in **Exhibit D-1**. By this compact, each of the three states agrees to cooperate with the other two for the most advantageous utilization of the waters of the river for the control of floods and the prevention of pollution.

b. Red River Watershed Management Board. The Red River Watershed Management Board was created by legislative act in 1976. Its purpose is to institute, coordinate, and finance projects to alleviate flooding and to assure the beneficial uses of water in the Red River of the North and its tributaries. It consists of eight watershed districts in Red River of the North basin. The Otter Tail River basin is not represented on this board.

9-05. Reports. Table 9-2 presents a listing of reports complied by Water Control regarding the regulation of the Orwell Project.

Table 9-2
Reports

Report Name	Compiled	Form
Compiled by Water Control Section		
Reservoir Bulletin	Daily	Water Control Web Site
Gage Records	As Needed	Computer Archived
Flood Damage Report	Annually	Memorandum/Table
Water Quality Report	Annually	Memorandum
Compiled by Field Offices for Water Control Section		
Weekly Log Sheet	Weekly	CEMVP-416 A
DCP Tracking Chart	Monthly	DCP Tracking Chart
Snow Reports and Frost Reports	Weekly During the Season	CEMVP-430 CEMVP-58
Emergency Reports (when requested)	Daily, 0800 hr	By Phone or Fax
Compiled by Field Office for National Weather Service		
Record of River and Climatological Observations	Monthly	Form B-91

A

EXHIBIT A
SUPPLEMENTARY PERTINENT DATA
ORWELL RESERVOIR

General Information:

Location:	Red River of the North Basin Otter Tail River, Mile 38.6
Type of Project:	Dam and Reservoir
Objectives of Regulation:	Flood Control, Water Conservation
Owner/Regulating & Operating Agency:	Corps of Engineers (COE)/St. Paul District
Low Flow Agreement with MDNR:	Minimum Flow = 80 cfs
Project Cost to Date 1977:	$1,916,753
Estimated Cost of Tailwater Structure:	$5 Million
Special Project Feature:	Tailwater Structure for Dam Safety

Reservoir Pool:

Real Estate Taking Guide-Line Contour for Fee Title:	Elevation 1073.0 feet
Length and Width of Reservoir at Top of Flood Control:	4.0 miles by 1.0 mile
Reservoir Land Cleared:	175 acres @ Elev.1071.0 ft

	Elevation	Area	Storage
Top of Dam	1080.0 ft	1,625 ac	28,300 ac-ft
Tailwater Control Design Flood	1078.8 ft	1,700 ac	26,320 ac-ft
Spillway Design Flood	1075.0 ft	1,400 ac	20,500 ac-ft
Top of Surcharge Pool	1073.0 ft	1,300 ac	17,750 ac-ft
Top of Flood Control Pool	1070.0 ft	1,110 ac	14,000 ac-ft
Conservation Pool	1064.0 ft	782 ac	8,300 ac-ft
Intermediate Drawdown	1060.0 ft	598 ac	5,500 ac-ft
Maximum Drawdown	1050.0 ft	264 ac	1,200 ac-ft
Dead Storage	1044.0 ft	104 ac	150 ac-ft

Maximum Pool Elevation:	1072.47 ft 8 Jun 1999
Control Point for Flood Operations:	Wahpeton, ND on Red River
Target Stage at Control Point;	
Category I (Normal Runoff):	10 feet
Category II (Moderate to Heavy Runoff):	12 feet
No Damage Channel Capacity:	1,200 cfs
Drawdown:	Begin 1 March; Complete 30 March Category I: No drawdown Category II: 1060 ft to 1050 ft Maximum Rate of Fall: 0.5 ft/day

Hydrology:

Total Drainage Area:	1,820 sq mi
Local Drainage Area (i.e. directly into the reservoir):	245 sq mi
Probable Maximum Flood (Tailwater Control Design Flood)	
Maximum Water Surface Elevation:	1078.8 ft
Peak Inflow:	26,200 cfs
Peak Outflow:	24,400 cfs
Total Flood Volume:	26,320 ac-ft
Climate:	Temperate
Flood Season:	Early Spring
Travel Time to Control Point (Wahpeton, ND):	12 to 24-hours
Minimum Daily Flow:	Pre-Project: 5 cfs
	Post-Project: 5 cfs
	As of 1988: 80 cfs
Key Streamflow Locations:	Orwell Tailwater
	Wahpeton, ND
Hydrometeorologic Data Recorded at the Dam Site:	Pool & Tailwater Elevation
	24-hour Precipitation
	Periodic Water Quality
Snow Surveys:	1 Weekly at Dam Site
	1 Basin Surveys (9 locations)
Sediment Ranges:	24 Ranges, Last Survey 1985

Dam:

Type:	Rolled Earth Fill
Volume of Earth Fill:	168,165 cubic yards
Embankment Side Slopes:	1V:3H
Side Slope Protection (upstream/downstream):	18" Riprap/Vegetation
Total Length:	1,355 feet
Crest Elevation:	1080.0 feet
Maximum Height:	47 feet
Top Width:	20 feet
Parapet Wall (I-wall) Elevation:	1083.8 feet
Design Flood (PMF) Elevation:	1078.8 feet

Perimeter Dikes:

Number:	2
Crest Elevation:	1080.0 feet
Maximum Height:	10 feet
Total Length:	1,140 feet
Total Volume of Earth Fill:	9,521 cubic yards

Spillway and Chute Outlet:

Type Spillway:	Flared Concrete Ogee
Crest Elevation:	1044.0 feet
Length of Spillway Crest:	33.0 feet
Width at Toe:	41.8 feet
Type Chute:	Flared Concrete
Width at Spillway Toe:	41.8 feet
Width at Stilling Basin:	54.5 feet
Length:	38.2 feet
Slope:	1V:10H
Gate:	Single Tainter Gate
Size:	33.0 ft Wide by 27.5 ft High
Top of Tainter Gate Elevation (closed):	1071.5 feet
Gate Seat Elevation:	1043.5 feet
Design Discharge (PMF):	24,400 cfs
Maximum Recorded Discharge:	1,710 cfs on 17 June 1953
Volume of Concrete in Structure:	9,310 cubic yards

Low Flow Control:

Type and Number:	Two Circular Culverts
Diameter:	24-inch
Upstream Invert Elevation:	1040.0 feet
Gates:	Hand-operated 24-inch cast iron slide gates

Total Discharge Capacity (both gates wide open):

Elevation	Discharge
1070.0 ft	150 cfs
1064.0 ft	135 cfs
1060.0 ft	120 cfs

Stilling Basin:

Type:	Concrete Flared Chute
Length:	72.0 feet
Width at Chute:	54.5 feet
Width at End Sill:	78.5 feet
Floor Elevation:	1024.5 feet
Rows of Baffle Blocks:	2
Baffle Block Height:	8.0 feet
End Sill Height:	8.0 feet
End Sill Elevation:	1032.5 feet

Tailwater Control Structure

Location:	1,000 feet downstream of dam
Earthen Embankment:	
Total Length:	765 feet
Effective Overflow Length:	564 feet
Maximum Height:	20 feet
Side Slopes:	1V:3H
Side Slope Protection:	Articulated Concrete Mattress
Crest Width:	15 feet
Concrete Box Culverts	
Number:	5
Dimensions:	15.5 feet x 15.5 feet x 40 feet
Invert:	1032.5 feet
Channel Protection	
Approach Channel:	18 inches of 12 inch Riprap
Outlet Channel:	63 inch layer of 42 inch Riprap

B

EXHIBIT B

RELATED MANUALS AND REPORTS

1. Early Reports. Prior reports for flood control and navigation aids date from about 1850 and include a number of printed documents and annual reports of the Chief of Engineers. These reports deal with investigations into the advisability of dredging, removal of obstructions, and construction of locks and dams on the Red River of the North and its tributaries, including the Otter Tail River. In general, these reports were favorable to dredging and removal of obstructions but were unfavorable to the construction of reservoirs with locks and dams as aids to navigation.

2. *Report of an exploration of the Territory of Minnesota in 1849*, Ex. Document #42, 31st Congress, Captain John Pope, Corps of Topographical Engineers, 1850.

3. *Examination and Survey of the Red River of the North and its Headwaters in Minnesota and North Dakota*, House Document No. 616, 62nd Congress, 2nd Session, 1912. This report studied the use of storage reservoirs to improve navigation.

4. *Report on Drainage and the Prevention of Overflow in the Valley of the Red River of the North*, P.T. Simons, F.V. King, U.S. Department of Agriculture, Bulletin No. 1017, 1922. This is a comprehensive report on the Red River of the North Basin summarizing flood conditions and recommending modifications for flood control and drainage.

5. *Report on the Comprehensive Water Plan Proposed in the Report of the Interstate Committee on the Red River of the North Drainage Basin*, Prepared by the Corps of Engineers at the request of the Works Progress Administration (WPA), 1937. The report includes a modified plan to solve water problems in the basin, outlines certain projects suitable for inclusion in the WPA program, and prioritizes individual reports.

6. *Red River of the North Research Investigation*, North Dakota State Department of Health, 1938-1941. This report covers a joint investigation by the North Dakota State Department of Health, the Minnesota State Board of Health, and the U.S. Public Health Service into a variety of water quality characteristics of the Red River of the North and its tributaries.

7. *Flood Control Act of 1944, Section 6.* This act provides the authority for the Secretary of the Army to make contracts with others for domestic and industrial uses of surplus water that may be available at any reservoir under the control of the Department of the Army.

8. *Report on Survey of Red River of the North Drainage Basin in Minnesota, South Dakota, and North Dakota for Flood Control and Other Purposes*, U.S. Army Engineer District, St. Paul, Corps of Engineers, St. Paul, Minnesota, September 1947.

C

ORWELL DAM POOL ELEVATIONS MONTH / YEAR JULY 99

DATE	INDICATOR	TIME	INITIALS	DCP	LOGGER	REMARKS
1	68.63	0800	DB	68.53	68.52	OK TP
2				↑		
3	LONG WEEKEND					
4						
5				↓		
6	66.94	08:00	RS	66.94	66.94	✓
7	66.41	08:00	DB	66.41	66.40	✓
8	65.96	08:00	DB	65.96	65.95	✓
9	65.46	08:00	DB	65.46	65.46	✓
10	WEEKEND					
11						
12	63.76	0800	DB	63.76	63.76	✓
13	63.09	0800	DB	63.09	63.09	✓
14	62.52	0800	DB	62.52	62.52	✓
15	62.03	0800	DB	62.03	62.03	✓
16	61.39	0800	DB	61.39	61.38	✓
17	WEEKEND					
18						
19	59.71	08:00	RS	59.71	59.71	✓
20	59.30	08:00	DB	59.30	59.29	✓
21	58.97	08:00	DB	58.97	58.97	✓
22	58.64	08:00	DB	58.64	58.63	✓
23	58.13	08:00	DB	58.13	58.13	✓
24	WEEKEND					
25						
26	56.87	0800	DB	56.87	56.85	✓
27	56.32	0800	DB	56.32	56.31	✓
28	55.73	0800	DB	55.73	55.72	✓
29	55.40	0800	DB	55.40	55.40	✓
30	55.18	0800	DB	55.18	55.17	✓
31	WEEKEND					

DCP = Sutron 8210 Goes / Sp. Mod. LOGGER = Sutron 8200 Datalogger

The above pool gauge readings were checked against a plot of the hourly DCP data in the water control data base. Any significant deveations are noted in the remarks column above.

SIGNED :

D

EXHIBIT D
LETTERS, AGREEMENTS, AND RESOLUTIONS

TABLE OF CONTENTS

EXHIBIT D-1

Laws of the United States Relating to the Improvement of Rivers and Harbors, House Document No. 379, 76th Congress, Chapter 59, 2 April 1938.

This Act of Congress established the Tri-State Waters Commission, by which the States of Minnesota, South Dakota, and North Dakota agree to cooperate with each other for the most advantageous utilization of the waters of the Red River of the North.

wagons), at a cost, completely equipped for operation, and including the value of any vehicle exchanged, in excess of $750, unless otherwise specifically provided for in the appropriation.

Maintenance, etc., automobiles not used for official purposes.
"Official purposes" construed.

(b) For the maintenance, operation, and repair of any Government-owned motor-propelled passenger-carrying vehicle not used exclusively for official purposes; and "official purposes" shall not include the transportation of officers and employees between their domiciles and places of employment, except in cases of medical officers on outpatient medical services and except in cases of officers and employees engaged in field work the character of whose duties makes such transportation necessary and then only as to such latter cases when the same is approved by the head of the department or establishment concerned. The limitations of this subsection (b) shall not apply to any motor vehicles for official use of the President, or of the heads of the executive departments.

Exceptions.

Maintenance, upkeep, etc., limitation.

(c) For the maintenance, upkeep, and repair (exclusive of garage rent, pay of operators, tires, fuel, and lubricants) on any one motor-propelled passenger-carrying vehicle, except busses and ambulances, in excess of one-third of the market price of a new vehicle of the same make and class and in no case in excess of $400.

Approved, March 28, 1938.

April 2, 1938
[S. 1570]
[Public, No. 456]
Vol. 52, p. 150.

CHAP. 59.—An Act Consenting to an interstate compact between the States of Minnesota, South Dakota, and North Dakote relating to the utilization of, the control of the floods of, and the prevention of the pollution of the waters of the Red River of the North and streams tributary thereto.

Compact between Minnesota, South Dakota, and North Dakota with respect to Red River of the North.
Consent of Congress granted to.
Proviso.
Federal jurisdiction

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the consent of Congress is hereby given to the compact and agreement set forth below: *Provided*, That nothing therein contained shall be construed as impairing or in any manner affecting any right or jurisdiction of the United States in and over the Red River of the North and streams tributary thereto, or in regard to any of the matters covered by the said compact:

Text..

"A COMPACT BETWEEN THE STATE OF SOUTH DAKOTA, THE STATE OF NORTH DAKOTA AND THE STATE OF MINNESOTA

"This compact made and entered into by and between the State of South Dakota, the State of North Dakota and the State of Minnesota, Witnesseth:

"Whereas, the Red River of the North, which has its source in the State of South Dakota, and which flows northward, forming the boundary line between the State of Minnesota and the State of North Dakota, has a

drainage area which includes a portion of all three states; and,

"Whereas, the surface waters in said drainage area, if properly conserved and regulated, will produce benefits common to all three of said states; and,

"Whereas, the interests of the people of said three states will be best served by the organization of an interstate authority vested with sufficient power; and,

"Whereas, all three states have mutual interests in the regulation and administration of said surface waters in said drainage area; and

"Whereas, it is highly desirable that there be a single agency of all three of said states empowered to further the aforesaid regulation and administration of said surface waters in the interests of all of said states,

"Now, Therefore, the State of South Dakota, the State of North Dakota and the State of Minnesota, do hereby solemnly covenant and agree, each with the other, as follows:

"ARTICLE I

"The following terms, whenever used in this agreement, shall have the following meanings, unless a different meaning. clearly appears in the context:

"(a) The term 'commission' shall mean the Tri-State Waters Commission, the corporation created by this agreement and the acts authorizing the same.

"(b) The term 'acquire' shall mean and include construct, acquire by purchase, lease, devise, gift or the exercise of the rights of eminent domain, or any other mode of acquisition whatsoever.

"(c) The term 'federal agency' shall mean and include the United States of America, the President of the United States of America, the Public Works Administration, the Works Progress Administration, and any and every other authority, agency, or instrumentality of the United States of America heretofore or hereafter created or established.

"(d) The term 'real property' shall mean and include lands, structures, franchises, and interests in land, including waters and riparian rights, and any and all things and rights usually included within the said term, and includes not only fees simple absolute but also any and all lesser interests, such as easements, rights of way, uses, leases, licenses, and all other incorporeal hereditaments, and every estate, interest or right, legal or equitable, including terms of years and liens thereon by way of judgments, mortgages or otherwise, and also claims for damages to real estate.

"(e) The term 'drainage area' shall mean the area from which surface waters drain from the States of South Dakota, Minnesota and North Dakota into the Red River of the North.

"ARTICLE II

"Each of the States of North Dakota, South Dakota and Minnesota undertake to cooperate with the other two states for the most advantageous utilization of the waters of the Red River of the North, for the control of the flood waters of this river and for the prevention of the pollution of such waters.

"ARTICLE III

"To that end the said three states do hereby create a district to be known as the Tri-State Waters Area, which shall comprise that portion of the drainage basin of the Red River of the North lying within the boundaries of the said states.

"ARTICLE IV

"The said three states do hereby create the Tri-State Waters Commission, which shall be a body corporate and shall have the powers, duties and jurisdiction herein set forth and such other powers, duties and jurisdiction as shall hereafter be conferred upon it by acts of the legislatures of each of said three states concurred in, when of a character to require such concurrence, by act of Congress.

"ARTICLE V

"The Tri-State Waters Commission, hereafter in this compact called the Commission, shall consist of nine Commissioners, three from each state, appointed by each state in such manner and for such length of term as may be determined by the legislature thereof. Each Commissioner shall be a citizen of the state from which he is appointed, and at least one Commissioner from each state shall be a resident of the drainage area of the Red River of the North. Each Commissioner may be removed or suspended from office in such manner as shall be provided by the law of the state from which he shall be appointed. Each Commissioner shall receive such compensation as may be provided by the legislature of the state he represents, which compensation shall be paid by such state. Each Commissioner shall be paid actual expenses necessarily incurred in the performance of his duties as such Commissioner.

"ARTICLE VI

"The Commission shall elect from its number a chairman and vice-chairman and shall appoint and at its pleasure remove an executive secretary and such other officers and assistants as may be required to carry the provisions of this compact into effect, and shall fix and determine their duties, qualifications and compensation.

"It shall adopt a seal and suitable by-laws and shall promulgate rules and regulations for its management and control.

"A majority of the members from each state shall constitute a quorum for the transaction of business, the exercise of any powers, or the performance of any duties, but no action of the Commission shall be binding unless at least two of the members from each state shall vote in favor thereof.

"The Commission shall keep accurate accounts of all receipts and disbursements and shall make an annual report to the Governor of each state setting forth in detail the operations and transactions conducted by it pursuant to this compact, and shall make recommendations for any legislative action deemed by it advisable, including amendments to the statutes of the said states which may be necessary to carry out the intent and purpose of this compact, and such changes in the area of the district as may seem desirable.

"The Commission shall not incur any obligations for salaries, office, or other administrative expenses prior to the making of appropriation adequate to meet the same; nor shall the Commission pledge the credit of any of the said states except by and with the authority of the legislatures thereof. Each state reserves the right to provide hereafter by law for the examination and audit of the accounts of the Commission by its comptroller or other official.

"The Commissioner shall meet and organize within thirty days after the effective date of this compact.

"ARTICLE VII

"It shall be the duty of the Commission to study the various water problems relating to water supply with the Tri-State Waters Area.

"ARTICLE VIII

"Plans for works on boundary waters in said drainage area prepared by the state, municipal or industrial agencies shall receive the approval of the Commission before construction is begun.

"It shall be the duty of the Commission to maintain and control lake levels and stream flow on boundary waters within the area, but such action shall be taken only with the approval of the authorized county or state agencies, in which such lake or stream is located, but said Commission shall have no power or jurisdiction over water levels or stream flow in the Otter Tail River which is known as that portion of the Red River originating in Becker and Otter Tail counties extending and flowing through in a southerly and southwesterly direction through the counties of Becker, Otter Tail and Wilkin,

and emptying into the Red River of the North at the junction of the Boise de Sioux at Breckenridge, Minnesota and its chain of lakes and its tributaries.

"The Commission shall have power to cooperate with any duly authorized federal, state or municipal agency in studies and surveys, construction, maintenance and operation of water projects within the scope of its jurisdiction.

"The Commission shall be authorized to exercise the power of eminent domain, to acquire such real and personal property as may be reasonably necessary to effectuate the purposes of this compact, and to exercise all other powers not inconsistent with the constitutions of the States of North Dakota, South Dakota and Minnesota, or with the Constitution of the United States, which may be reasonably necessary or appropriate for or incidental to the effectuation of its authorized purposes, and generally to exercise in connection with the property and affairs and in connection with property within its control any and all powers which may be exercised by a private corporation in connection with similar property and affairs.

"ARTICLE IX

"The Commission shall study the methods of financing the construction, control, maintenance and operation of projects and shall recommend for enactment to the legislatures of the states concerned such legislation as will effectuate the purposes and ends of the Commission.

"ARTICLE X

"Each state shall bear its proportionate share of the expense of the Commission based on the pro rata value to such state of the activities of the Commission, which expense shall be provided for by appropriation by the legislature.

"ARTICLE XI

"Should any part of this compact be held to be contrary to the constitution of any of said states or of the United States such part of said compact shall become inoperative as to each state but all other severable provisions of this compact shall continue in full force and effect.

"ARTICLE XII

"This compact shall become operative immediately after it has been signed by the Governor of the State of South Dakota, the Governor of the State of North Dakota and the Governor of the State of Minnesota.

"In testimony whereof the Governor of the State of South Dakota, the Governor of the State of North Dakota and the Governor of the State of Minnesota

have signed this compact in triplicate and the seals of said states have been thereunto affixed.

"Done this 23rd day of June, in the year of our Lord One Thousand Nine Hundred Thirty-seven.

"LESLIE JENSON
"*Governor of the State of South Dakota*
"WILLIAM LANGER
"*Governor of the State of North Dakota*
"ELMER A. BENSON
"*Governor of the State of Minnesota.*"

SEC. 2. That the right to alter, amend, or repeal this Act is hereby expressly reserved. Amendment, etc.

Approved, April 2, 1938.

CHAP. 67.—An Act Authorizing the completion of the existing project for the protection of the sea wall at Galveston Harbor, Texas.

April 4, 1938
[H. R. 8524]
[Public, No. 463]
Vol. 52, p. 196.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of War is hereby authorized to complete the project, adopted in the River and Harbor Act approved August 30, 1935, for the construction of groins to protect the sea wall at Galveston Harbor, Texas, in accordance with the plans submitted in House Document Numbered 400, Seventy-third Congress.

Galveston Harbor, Tex.
Completion of project for protecting the sea wall, authorized.
49 Stat. 1034.

Approved, April 4, 1938.

CHAP. 69.—An Act To amend section 35 of the Criminal Code, as amended (U. S. C., title 18, sec. 82), relating to purloining, stealing, or injuring property of the United States.

April 4, 1938
[H. R. 9826]
[Public, No. 465]
Vol. 52, p. 197.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 35 of the Criminal Code of the United States, as amended (U. S. C., title 18, secs. 80, 82, 83, 84, 85, and 86), be, and the same is hereby, amended to read as follows:

Criminal Code amendments.
18 U. S. C. §§80, 82–86.

"SEC. 35. (A) Whoever shall make or cause to be made or present or cause to be presented, for payment or approval, to or by any person or officer in the civil, military, or naval service of the United States, or any department thereof, or any corporation in which the United States of America is a stockholder, any claim upon or against the Government of the United States, or any department or officer thereof, or any corporation in which the United States of America is a stockholder, knowing such claim to be false, fictitious, or fraudulent; or whoever shall knowingly and willfully falsify or

Presenting false claims.

EXHIBIT D-2

Documentation of "Standard Operating Procedure, Orwell Reservoir" and "Reservoir Regulation Schedule", circa. 1954.

States that as part of the standard operating procedure, "changes in discharge from the reservoir are limited to 300 cfs per day, in-so-far as practical, in order to avoid damage to real property, livestock, and fish in the area downstream."

Also includes the Reservoir Regulation Scedule which shows drawdown to begin on 1 November.

Standard Operating Procedure

Orwell Reservoir

The entire capacity of Orwell Reservoir is available each spring for flood control storage because of being emptied before spring break-up. Subsequent to the spring runoff the reservoir is again emptied and held empty or partially so depending upon existing inflow to the reservoir and the amount of water in the feeder lakes upstream. This type of operation is possible in this reservoir because the stream has a very slow rate of flow recession due to the natural regulation by lakes upstream and consequently the reservoir can be filled in a relatively short time for water supply use.

During late summer and fall, when the danger of floods is virtually nonexistent, the reservoir is filled for release during the winter months to augment natural flows during the period of ice cover. The discharge during the winter is regulated so as to maintain a relatively uniform flow downstream while emptying the reservoir in time to store the spring runoff.

Changes in discharge from the reservoir are limited to 300 second-feet per day, insofar as practicable, in order to avoid damage to real property, livestock, and fish in the area downstream.

A resumé of the regulation schedule is attached.

Reservoir regulation schedule - Orwell Dam

Regulation schedule	Reservoir stage	Condition	Operations
Routine operation	1048 - 1070	Normal reservoir inflow anticipated	Beginning 1 November schedule winter releases to meet downstream water requirements and to assure draw-down to elevation 1048 by 1 March. During spring runoff, discharge flows up to 900 second-feet. After the crest has been reached lower the pool to predetermined elevations dependent on the base flow which will assure filling of pool to elevation 1070 by 31 October. Minumum releases from reservoir will not be less than 5 second-feet. Notify Breckenridge of substantial changes in discharge.
Flood control	1048 - 1070	Large runoff predicted	Beginning 1 November, schedule winter releases to assure draw-down to elevation 1048 by 1 March. During flood runoff, discharge up to 900 second-feet until pool reaches elevation 1070. Above 1070 increase storage by an induced surcharge based on the rate of inflow. Insofar as practicable, limit increase or decrease to 300 second--feet per day. Notify city of Breckenridge when changes will equal or exceed 100 second--feet.
Induced surcharge	Above 1070	Pool continues to rise above 1070 or large flood occurs with reservoir at elevation 1070.	Raise gate to discharge 90 percent of reservoir inflow rate for previous 3-hour period. After the maximum pool has been reached maintain maximum gate opening until pool level is lowered to elevation 1070.

EXHIBIT D-3

Reservoir Regulation Schedule taken from the Reservoir Regulation Manual for Orwell Reservoir, August 1963.

This documents the change in the date of the beginning of the fall drawdown from 1 November to 20 September.

Table A-2 - Regulation Schedule - Orwell Dam and Reservoir

Regulation Schedule	Stage	Condition	Operations
	1075.0 to 1070.0	Disposing of Surcharge	If the pool reaches elevation 1075.0, discharge inflow but not less than 900 c.f.s. Once surcharging has begun, do not decrease Tainter gate opening until pool has dropped to elevation 1070.0, and the surcharge is disposed of.
	1070.0 to 1048.0	Spring Drawdown	When the pool is below elevation 1070.0 and the stage at Wahpeton - Breckenridge permits, the spring drawdown shall begin by discharging up to 900 c.f.s. until the pool is lowered to minimum pool, elevation 1048.0, if possible. Minimum pool shall be maintained by discharging inflow until it becomes necessary to begin storing inflow for flood prevention or to begin filling the pool.
Routine Operation			
About 15 June to 20 September	1048.0 to 1070.0	Filling Reservoir	Before 1 June, Plates 13 and 13A shall be used to obtain data required to fill pool to elevation 1070.0 by 20 September.
Water Supply and Conservation			
Low water period in Red River	1048.0 to 1070.0	Releasing storage to aid in water supply and pollution abatement	If the flow in the Red River from Fargo to Grand Forks is less than that required for water supply and pollution abatement, the deficiency shall be corrected by drawing upon the storage capacity of Orwell Reservoir and Baldhill Reservoir. See Par. 25 b.

Table A-2 - Regulation Schedule - Orwell Dam and Reservoir

Regulation Schedule	Stage	Condition	Operations
Routine Operation			
Freezeup to spring breakup	1070.0 to 1048.0	Winter Drawdown	Each year on 20 September begin winter drawdown from full pool, elevation 1070.0, at rate determined by Reservoir Regulating Section to lower pool to minimum pool, elevation 1048.0, by 15 March. If elevation 1048.0 is reached before spring breakup begins, maintain minimum pool by discharging inflow. Water requirements for sugar beet processing may require altering rate of discharge. Maximum discharge shall not exceed 900 c.f.s. channel capacity.
Flood Control			
Spring breakup to about 15 June	1048.0 to 1070.0	Flood Prevention	When spring breakup begins, store inflow as necessary to assist in preventing or reducing flood damages at Wahpeton - Breckenridge. Minimum discharge shall not be less than 40 c.f.s. Storing of inflow shall continue if necessary until full pool, elevation 1070.0, is reached.
	1070.0 to 1075.0	Surcharging Pool	If conditions at Wahpeton - Breckenridge still require the storing of inflow, surcharge pool (see Par. 17c) by discharging 90% of inflow but not less than 900 c.f.s. and store balance. Surcharging shall continue if necessary until pool reaches elevation 1075.0

EXHIBIT D-4

Memorandum to North Central Division Engineer, Dated 22 February 1971,
Subject: Orwell Lake Regulation.

This memorandum states that, upon construction of the Fargo low-flow diversion structure on the Sheyenne River, the date of the beginning of the fall drawdown "is anticipated" to revert to 1 November. The structure was completed in July 1972. The "original plan" of Paragraph 4 of the memorandum refers to to the 1954 Reservoir Regulation Manual (see Exhibit D-3).

NCSED-H (22 Feb 71) 2d Ind
SUBJECT: Orwell Lake Regulation HWHarich/smk/7598

DA, St. Paul District, Corps of Engineers, 1210 USPO & Custom House, St. Paul, Minnesota 55101 4 May 1971

TO: Division Engineer, North Central, ATTN: NCDED-H

1. The regulation plan for Orwell Reservoir has been reviewed as requested.

2. The original plan of operation of Orwell Reservoir as presented in our Interim Reservoir Regulation Manual dated April 1954 was predicated upon utilizing storages from Baldhill Reservoir in conjunction with releases from Orwell. This plan involved a low water diversion from the Sheyenne River to the Red River of the North, immediately upstream from Fargo-Moorhead. The construction of the low water diversion was the responsibility of the City of Fargo, who provided assurance prior to the construction of the Baldhill Dam in 1950 that they would build the diversion.

3. Since 1950, the St. Paul District has been in a wet cycle and there has been no need for the Sheyenne water at Fargo-Moorhead. As a result, Fargo has delayed construction of the diversion channel. In lieu of the diversion, the present plan of operation of Orwell, as outlined in the August 1963 manual, was developed as an interim measure which will continue in effect until the low water diversion is actually constructed. Throughout the above period, there have been sufficient releases from the Orwell Reservoir for the requirements downstream. However, a change had to be made in the plan for filling Orwell Reservoir. The original plan required the reservoir to be filled by 1 November, whereas the new plan requires that the reservoir be filled by 20 September. The rate of filling Orwell Reservoir had to be increased and the downstream flows decreased somewhat, since it was not feasible to commence filling prior to 1 July because the reservoir is a dual purpose reservoir for flood control and water conservation. As a flood control reservoir, it cannot be filled until the threat of summer rains is over. Last September, for the first time since 1950, it was necessary to reduce the discharge from Orwell Reservoir to about 10 second-feet to assure filling the reservoir by 20 September. Due to a lack of communications, the American Crystal Sugar Company at Moorhead commenced pumping operations from the river prior to the arrival of necessary waters from Orwell Reservoir. This situation was further aggravated by additional pumping for water supply needs at Fargo, plus the pumping for water for a municipal golf course in Fargo. The above pumping dried up the river downstream from the water plant and resulted in the fish kill.

NCSED-H (22 Feb 71) 2d Ind 4 May 1971
SUBJECT: Orwell Lake Regulation

4. To prevent another occurrence of events that led to the fish kill, this office will require the American Crystal Sugar Company to advise us not less than two weeks prior to commencing their sugar processing so that adequate releases can be made prior to the actual need. Ordinarily, the travel time from Orwell to Fargo-Moorhead is approximately five to six days. This would allow a factor of safety of over a week for the water to reach Moorhead. The City of Fargo has also been contacted and Mayor Herschel Lashkowitz has assured us of their intent to construct the Sheyenne low water diversion. However, no actual date for the construction has been indicated. Following the completion of the diversion, it is anticipated that the plan of operation will revert to the original plan, a copy of which is inclosed along with Table A-1, Reservoir Regulation Schedule.

FOR THE DISTRICT ENGINEER:

2 Incl
1. Plan of Operation
2. Table A-1

RICHARD W. LEONARD
Chief, Engineering Division

EXHIBIT D-5

License for Wildlife Conservation and Management Purposes at Orwell Reservoir, May 1980 (including Amendment dated July 1989).

This document authorizes the Minnesota Department of Natural Resources (MDNR) to utilize approximately 1,957 acres of land purchased in fee title as part of the Orwell Project. The MDNR manages the land for wildlife purposes.

DEPARTMENT OF THE ARMY

License

FOR Wildlife Conservation and Management PURPOSES, Orwell Reservoir, Minnesota,

THE SECRETARY OF THE ARMY, under authority of Section 4 of the Act of Congress approved 22 December 1944, as amended (76 Stat. 1195; 16 U.S.C. 460d) and Section 3 of the Fish and Wildlife Coordination Act (48 Stat. as amended; 16 U.S.C. 661 et seq) and in accordance with a General Plan for Use of Lands Acquired for the Orwell Reservoir Project approved by the Secretary of the Army, the Secretary of the Interior and the Commissioner of the Department of Conservation of the State of Minnesota, hereby grants to the State of Minnesota, Department of Natural Resources, thereafter referred to as the licensee, a license for the period of twenty-five (25) years commencing on 1 January 1980 and ending on 31 December 2004 to use and occupy approximately 1957.6 acres of land and water areas under the primary jurisdiction of the Department of the Army in the Orwell Reservoir Project Area as shown in red on Exhibit A, numbered R28-R-3/1, and dated February 1953, attached hereto and made a part hereof, for wildlife conservation and management purposes.

THIS LICENSE is granted subject to the following conditions:

1. That the licensee, in the exercise of the privileges hereby granted, shall conform to such rules and regulations as may be prescribed by the Secretary of the Army to govern the public use of the said project area, and with the provisions of Section 4 of the Act of Congress approved 22 December 1944, as amended (76 Stat. 1195; 16 U.S.C. 460d).

2. That the licensee may construct upon said land such as buildings, improvements, facilities, accommodations, fences, signs and other structures as may be necessary for the purposes of this license, and may plant seeds, shrubs and trees, provided that all such structures shall be constructed and the landscaping accomplished in accordance with plans approved by the District Engineer, U.S. Army Corps of Engineers, in charge of the administration of the property.

3. That the licensee shall administer and maintain the said property, for the purposes of this license, in accordance with the master plan for the sais project area and with an annual management program to be mutually agreed upon between the licensee and the said District Engineer, which program will be prepared and submitted to the said District Engineer each year on or before 1 March and may be amended from time to time as may be necessary. Such annual management program shall include, but is not limited to, the following:

a. Plans for mangement and development activities to be undertaken by the licensee or jointly by the Corps of Engineers and the licensee.

b. Budget of the licensee for carrying out the management and development activities.

c. Personnel to be used in the management of the area.

d. Plans for supervising, patrolling and policing the licensed areas, including the water areas.

4. That the licensee shall protect the property from fire, vandalism and soil erosion, and may make and enforce such rules and regulations as are necessary, and within its legal authority, in exercising the privileges granted in this license, provided that such rules and regulations are not inconsistent with those prescribed by the Secretary of the Army to govern the public use of the area. The licensee shall patrol the project boundaries on a regular basis and report to the District Engineer any real estate encroachments and boundary monument damage. Noxious weeds shall be controlled by the licensee in accordance with the State Law.

5. a. That the licensee, in exercising its governmental or proprietary functions, may plant or harvest crops, either directly, by service contract, by sharecrop agreements with local farmers, or by agricultural agreements to provide food and/or habitat for wildlife and for the development and conservation of fish and wildlife, forests, and other natural resources. Where feasible, contracts and agreements with third parties shall be by competitive bid procedures.

b. The proceeds derived from the sale of crops, and timber required to be cleared, may be used in furtherance of the above uses at this project in accordance with the approved managment plan. The balance of the proceeds not so used shall be paid to the United States of America at the expiration of each five-year period. The first five-year period is to begin on the date of the execution of this license by the Government. Payment of direct expenses are authorized for planning and development of optimum wildlife habitat including planting or wildlife food plots, necessary timber clearing, erosion control or habitat improvements such as shelter, restocking of fish and wildlife, and protection of endangered species. Payment of licensee's employees who are directly engaged in such activities at the project is also authorized. However, proceeds will not be used for the payment of general administrative expenses.

c. Proceeds derived from the sale of fishing and hunting licenses are not subject to this condition.

d. Any lands not being managed by the licensee for wildlife habitat will be made available for lease by the District Engineer for agricultural or grazing purposes under conditions which would not be incompatible with the licensee's use of the licensed property.

e. The licensee will establish and maintain adequate records and accounts and render annual statements of receipts and expenditures in furtherance of its management program, and as otherwise may be reasonably required by the said District Engineer. The District Engineer shall have the right to perform audits of the licensee's records and accounts.

6. That the licensee may take, trap, remove, stock or otherwise control all forms of fish and wildlife within the said area, and may place therein such additional forms of fish and wildlife as it may desire from time to time, and shall have the right to close the area, or any parts thereof from time to time, to fishing, hunting or trapping, provided that the closing of any area to such use for fishing, hunting or trapping shall be consistent with the state laws for the protection of fish and wildlife; also, the licensee shall enforce the fish and game laws and such orders and regulations as may be ussued by the Division of Game and Fish, and/or its Director, which laws, orders and regulations are consistent with its state-wide program.

7. That the water areas of the project shall be open to public use generally, without charge, for recreational purposes, and that ready access to and exit from such water areas along the shores of the project shall be maintained for general public use, when such use is determined by the Secretary of the Army not to be contrary to the public interest. However, no use or any area shall be permitted which is inconsistent with the state laws for the protection of fish and game.

8. That this license is subject to all existing and future easements, leases, licenses and permits heretofore grnated, or to be hereafter granted, by the United States concerning said lands; provided, however, that upon appropriate notification by the licensee to said District Engineer, the United States, insofar as may be consistent with other uses and purposes of the project, will not enter into any new easements, leases licenses or permits, or renewals thereof, which will, in the opinion of the District Engineer, adversely affect the current operations of the licensee under the provisions of the license, or which will conflict with the definitely scheduled program of the licensee for the expansion of its activities under the provisions of this license.

9. The licensee shall not discriminate against any person or persons because of race, creed, sex, color or national origin in the conduct of its operations thereunder. The licensee furnishes as part of this contract an assurance (Exhibit"B") that it will comply with Title VI of the Civil Rights Act of 1964 (78 Stat. 241) and Department of Defense Directive 5500.11 issued pursuant thereto and published in Part 300 of Title 32, Code of Federal Regulations.

10. That no cuts or fills along the shoreline shall be made by the licensee without the prior approval of the said District Engineer.

11. That, within the limits of their respective legal powers, the parties to the lease shall protect the project agaist any pollution of its water. The lessee shall comply promptly with any regulations, conditions or instructions affecting the activity hereby authorized if and when issued by the Environmental Protection Agency and/or a state water pollution control agency having jurisdiction to abate or prevent water pollution. Such regulations, conditions or instructions in effect or prescribed by the Environmental Protection Agency or state agency are hereby made a condition of this lease.

12. That ingress to and egress from the project area shall be afforded the licensee over existing access roads such interior roads as may be constructed, and at such additional places over Government-owned land as may be approved by said District Engineer. The licensee shall provide appropriate markings at its own expense.

13. That the right is hereby expressly reserved to the United States, its officers, agents and employees, to enter upon the said land and water areas, at any time and for any purpose necessary or convenient in connection with river and harbor and flood control work, and to remove therefrom timber, or other material, required or necessary for such work; to flood said premises when necessary, and/or to make any other use of said land as may be necessary in connection with public navigation and flood control, and the licensee shall have no claim for damages of any character on account thereof against the United States or any agent, officer or employee thereof.

14. That any property of the United States damaged or destroyed by the license incident to the exercise of the privileges herein granted shall be promptly repaired or replaced by the licensee to the satisfaction of the said District Engineer.

15. That the United States shall not be responsible for damages to property or injuries to persons which may arise, from or be incident to, the exercise of the privileges herein granted, or for damages to the property of the licensee, or for damages to the property or injuries to the person of the licensee's officers, agents, servants or employees, or others who may be on the said premises at their invitation or the invitation of any one of them, arising from or incident to the flooding of said premises by the Government or flooding from any other cause, or arising from or incident to any other governmental activities on the said premises, and the licensee shall hold the United States harmless from any and all such claims to the extent permitted under Minnesota law M.S. 3.736.

16. That this license may be relinquished by the licensee at any time by giving to the Secretary of the Army, through the said District Engineer at least thirty (30) days notice in writing.

17. That this license may be revoked by the Secretary of the Army in the event the licensee violates any of the terms and conditions of this license and continues and persists therein for a period of thirty(30) days after notice thereof, in writing, by the said District Engineer.

18. That on or before the date of expiration of this license or its relinquishment by the licensee, the licensee shall vacate the said Government premises, remove all property of the licensee therefrom, and restore the premises to a condition satisfactory to the said District Engineer. If, however, this license is revoked, the licensee shall vacate the premises, remove said property therefrom, and restore the premises as aforesaid within such time as the Secretary of the Army may designate. In either event, if the licensee shall fail or neglect to remove said property and so restore the premises, then said property shall become the property of the United States, or its officers or agents shall be created by or made on account thereof.

ASSURANCE OF COMPLIANCE WITH THE DEPARTMENT OF DEFENSE DIRECTIVE UNDER TITLE VI OF THE CIVIL RIGHTS ACT OF 1964

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES (hereinafter called "Applicant-Recipient")

HEREBY AGREES THAT it will comply with title VI of the Civil Rights Act of 1964 (P.L. 88-352) and all requirements imposed by or pursuant to the Directive of the Department of Defense (32 CFR Part 300, issued as Department of Defense Directive 5500.11, December 28, 1964) issued pursuant to that title, to the end that, in accordance with title VI of that Act and the Directive, no person in the United States shall, on the ground of race, color, or national origin be excluded from participation in, be denied the benefits of, or be otherwise subjected to discrimination under any program or activity for which the Applicant-Recipient receives Federal financial assistance from The Department of the Army and HEREBY GIVES ASSURANCE THAT it will immediately take any measures necessary to effectuate this agreement.

If any real property or structure thereon is provided or improved with the aid of Federal financial assistance extended to the Applicant-Recipient by the Department of the Army, this assurance shall obligate the Applicant-Recipient, or in the case of any transfer of such property, any transferee, for the period during which the real property or structure is used for a purpose for which the Federal financial assistance is extended or for another purpose involving the provision of similar services or benefits. If any personal property is so provided this assurance shall obligate the Applicant-Recipient for the period during which it retains ownership or possession of the property. In all other cases, this assurance shall obligate the Applicant-Recipient for the period during which the Federal financial assistance is extended to it by the Department of the Army.

THIS ASSURANCE is given in consideration of and for the purpose of obtaining any and all Federal grants, loans, contracts, property, discounts or other Federal financial assistance extended after the date hereof to the Applicant-Recipient by the Department, including installment payments after such date on account of arrangements for Federal financial assistance which were approved before such date. The Applicant-Recipient recognizes and agrees that such Federal financial assistance will be extended in reliance on the representations and agreements made in this assurance, and that the United States shall have the right to seek judicial enforcement of this assurance. This assurance is binding on the Applicant-Recipient, its successors, transferees, and assignees, and the person or persons whose signatures appear below are authorized to sign this assurance on behalf of the Applicant-Recipient.

Dated 5/30/80

BY: C R Burrows
Director, Div. Fish & Wildlife

(Applicant-Recipient's Mailing Address

EXHIBIT B

IN WITNESS WHEREOF I have hereunto set my hand this 14th day of JULY, 1980

Gordon M. Hobbs
Assistant for Real Property
OASA(IL&FM)

The above instrument, together with the provision and conditions thereof, is hereby accepted this 20th day of May. 1980.

Approved:

Roger Holmes, Chief
Section of Wildlife

C.R. Burrows, Director
Division of Fish and Wildlife

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

BY

TITLE: Steven G. Thorne
Deputy Commissioner

WARREN SPANNAUS, Attorney General
APPROVED AS TO FORM AND EXECUTION
By
Spec. Asst. Atty. Gen., Dept. of Natural Resources
Date 5/20/80

AMENDMENT NO. 1
LICENSE FOR WILDLIFE CONSERVATION AND MANAGEMENT PURPOSES
DACW22-3-80-5012
ORWELL RESERVOIR, MINNESOTA

THIS AMENDMENT NO. 1 pertains to License Contract No. DACW22-3-80-5012, dated July 14, 1980, granted to the State of Minnesota, Department of Natural Resources, licensee, for wildlife conservation and management purposes.

WITNESSETH:

WHEREAS, the United States has acquired additional lands at the Orwell Reservoir Project and it is the desire of the parties hereto to include this additional land in said license.

NOW THEREFORE, in consideration of the premises, said License No. DACW22-3-80-5012, is hereby amended in the following particular but in no others:

The 35.0 acre tract of land as shown outlined in red on the attached Exhibit "C" is added to said license increasing the total area of the licensed premises from 1957.6 acres to 1992.6 acres, more or less.

IN WITNESS WHEREOF, I have hereunto set my hand by authority of the Secretary of the Army this 20th day of July, 19 89.

Billy G. Cabe

Billy G. Cabe, Chief
Real Estate Division

The above Amendment No. 1 to said license is hereby agreed to and accepted this 10 day of July, 1989.

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

BY

TITLE: COMMISSIONER

EXHIBIT D-6

Letter containing review comments, regarding Orwell Reservoir Operation Plan Evaluation, from the State of Minnesota Department of Natural Resources, 31 December 1985.

This resulted in increasing the minimum outflow of 40 cfs to a year-round minimum outflow of 80 cfs.

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES

BOX 500 LAFAYETTE ROAD • ST. PAUL, MINNESOTA • 55146

NR INFORMATION
(612) 296-6157

December 31, 1985

Colonel Joseph Briggs
St. Paul District Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, MN 55101

Dear Colonel Briggs:

Thank you for the opportunity to review and comment on the Orwell Reservoir Operation Plan Evaluation. The document provides a thorough review of a range of operating plans for the reservoir and identifies alternatives that could greatly improve fish and wildlife habitat and recreation opportunities within the reservoir and on the Otter Tail River downstream from the project site.

Main Reservoir

Alternative #2, the Corps of Engineer's recommended National Economic Development (NED) plan, is perhaps more realistic from a flood control standpoint than Alternative #1, the best of the 9 alternatives from a fish and wildlife standpoint. With some modification, Alternative #2 should be acceptable from a fish, wildlife, and erosion control perspective. The major problem with Alternative #2 is the extended period the reservoir would be lowered from 1068 to 1064 based on the proposed rule curve. The 1068 level should be resumed as soon as possible after the initial spring runoff, and maintained at that level. It is implicit in the document and was reaffirmed at a December 3, 1985 meeting with the Corps that efforts will be made to accomplish this rapid return to the 1068 elevation. It is also our understanding that the extent of the spring drawdown will be based on annual runoff predictions and will not necessarily require the full drawdown to 1064 each year.

Bank erosion, as it affects the shoreline of the reservoir (as discussed on page 100 and several other places in the document) and islands within the reservoir, is a serious problem. Stabilizing reservoir levels at 1068 would alleviate this problem. The Corps states on page 63 that the eroded bank faces of the reservoir would gradually (up to 15 years) attain a stable angle of repose and naturally revegetate. The Corps assumes costs of accelerating the bank stabilization to be high because shaping and seeding would be necessary. The use of rock riprap was eliminated from the project plan because of cost estimates exceeding $250,000. Future discussions between the Corps of Engineers and the DNR are strongly encouraged to pursue an active program to accelerate bank stabilization and revegetation with the appropriate native species. We feel accelerated bank stabilization would: enhance conditions for the establishment of a productive littoral zone within a more reasonable time frame, improve water quality within and downstream of the reservoir, and enhance the value of the islands for various wildlife species.

We encourage the initiation of a bank erosion study, using erosion stakes and photo stations, to monitor the current rate of bank erosion. Areas of severe bank erosion would receive first priority. As discussed at the December 10, 1985 meeting with Corps and DNR staff, further interagency discussion and coordination is recommended to define in more detail the nature of such a study and the level of DNR involvement regarding study implementation and/or data collection.

Instream Flow

Compared to existing operation, all nine alternative operation plans listed in the ROPE report will increase instream flow in the Otter Tail River below Orwell Reservoir by about 80 cfs, on the average, for the period July 15 through September 20. Under the existing operation plan, part of the inflow to Orwell Reservoir is stored during this period to raise the pool elevation to 1070. Increasing flow in the Otter Tail River downstream of Orwell Reservoir during the summer will increase available habitat for fish and wildlife resources during a critical period and should benefit recreational use of the river.

The "Regulation Schedule" on the page opposite the rule curve for each of the 9 alternatives contains a statement under "Operations" for Flood Control, Condition-Flood Protection that "Minimum discharge shall not be less than 40 cfs". Based on the text of the document this statement does not appear appropriate. To reduce downstream flooding during periods of high flow a portion of the inflow will be stored in the reservoir, but not to the extent that the outflow would be reduced to 40 cfs. Also, the text incorporates DNR's recommendations of a minimum release of 80 cfs for the whole year and considerably higher flows for spawning from late March through May. We recommend that the statement regarding the 40 cfs minimum discharge be deleted from the portion regarding Flood Control. The statement "Minimum discharge shall not be less than 80 cfs" should be added. This could be done with either a separate heading or by revising one of the existing headings to include a minimum for the whole year.

A portion of the description of "Operations" for summer and fall floods in each of the 9 alternatives needs to be clarified or restated. The statement is "...surcharge the pool by 90 percent of inflow..." This could be interpreted to mean store 90 percent of inflow and discharge the remaining 10 percent of inflow. It is our understanding that the intent of this statement is to surcharge the pool by discharging 90 percent of inflow and storing 10 percent.

On pages 106 and 107 of the plan there is a discussion of cost estimates for replacement of the low flow control valves. The existing low flow conduits discharge into the stilling basin and cannot be used during periodic routine inspections of the stilling basin which require dewatering. This section of the plan should also address extending the existing low flow conduits beyond the stilling basin or some other means of providing a continuous discharge to the river downstream of the dam during the routine inspections. This concern was listed in earlier DNR correspondence regarding the plan.

Use of reservoir storage to augment releases for instream flows during periods when inflow to the reservoir is less than 80 cfs was discussed at the December 3 and 10, 1985 meetings with Corps staff. DNR recommendations for instream flows included a year-round minimum release of 80 cfs. This recommendation was made with the understanding that there would be certain periods, such as during the 1976-77 drought, when it would not be possible to maintain the 80 cfs minimum release. The amount of storage in the reservoir is not adequate to maintain an 80 cfs minimum release during a prolonged period of low inflow to the reservoir. Operation during such periods should be clarified in the ROPE report.

We recommend the following procedure which is a combination of two alternatives discussed at the December 10, 1985 meeting.

When reservoir inflow is less than 80 cfs:

1. Maintain release of 80 cfs for the first 30 days of reservoir inflows less than 80 cfs.

2. Next 30 days of reservoir inflows less than 80 cfs: if reservoir inflow is between 70 and 80 cfs, continue release of 80 cfs. If reservoir inflow is less than 70 cfs, release the greater of (a) inflow plus 10 cfs from storage or (b) 50 cfs.

3. If reservoir inflow remains less than 80 cfs for 60 days, contact DNR for a coordination meeting and continue releases as per 2.

We will be conducting further time series analyses of flows and available habitat utilizing the IFIM-PHABSIM models. These modeling efforts may be useful in identifying additional operation alternatives during low flow periods.

South Arm Subimpoundment

Concerns about the adequacy of the watershed above the south arm subimpoundment site were discussed at the December 10, 1985 meeting with the Corps. The 25 square mile size of the watershed should be adequate (in most years) to achieve the desired water elevation for the subimpoundment. Also, under certain conditions it may be possible to fill the subimpoundment with water from the main reservoir through the south arm control structure.

Additional subimpoundment sites were identified through previous discussions and coordination with the Corps. We realize the Corps will not be constructing any of these additional subimpoundment structures as part of this project. We do, however, feel the final Orwell ROPE Report should reflect a willingness on the part of the Corps to permit the construction of the previously identified subimpoundment sites by nonfederal agencies. In this way these subimpoundments can be considered for future development.

Interagency Coordination

We encourage the continued coordination between the DNR and the Corps of Engineers. To facilitate this coordination we suggest that a tentative schedule outlining the chronology of the implementation of the Operations Plan be included in the final Orwell ROPE Report.

Finally, we feel the potential exists to increase or enhance fish, wildlife, and recreational resources at other Corps of Engineer reservoir sites in the state. Staff discussions between the DNR and the Corps of Engineers (December 10, 1985 meeting) indicated a willingness on the part of the Corps to examine other Reservoir Project Operation Plans. We would strongly encourage this and would appreciate the opportunity to participate in a similar way to that of our involvement with Orwell Dam.

Thank you for the opportunity to provide comments on this report. If you have any questions, please contact Joseph Gibson, Federal Projects Coordination at 296-2773.

Sincerely,

DIVISION OF WATERS

Larry Seymour
Director

LS/JCG:sr
cc: Larry Shannon
Commissioner Alexander
Gerald Paul
Tom Kalitowski
Terry Lejcher
West Ottertail SWCD

EXHIBIT D-7

Lake Traverse-Orwell Reservoir Operation Plan Evaluation (ROPE), Recommended Plan, April 1994.

This portion of the document recommends the temporary fall rise in pool elevation and the occassional drawdown to drain the sub-impoundment areas.

runoff might be received at each reservoir each spring. Generally, the secondary drawdown will be considered for each dam any time there is a snow water content in excess of 2 inches, basin-wide, upstream from the dam. Final determination will be made by the St. Paul District Water Control Center after examining all factors and consulting with the National Weather Service and the River Forecast Center.

3. Summer and Fall Operation for Orwell Reservoir

Following spring flood control operation, Orwell Reservoir will be brought to elevation 1064.0 and held at about that elevation. During fall waterfowl migration, the pool will be raised to elevation 1066.0. After fall waterfowl migration has ended, the pool will be lowered to elevation 1064.0 prior to freeze-up. Every few years, the MDNR may request that the pool be lowered to elevation 1061.0, to allow draining of subimpoundments for vegetation management. The reservoir pool elevation of 1064.0 would be restored following these temporary drawdowns.

4. Drought Contingency Plan

The Drought Contingency Plans for Lake Traverse and Orwell Reservoir contain criteria that determine when unusually dry conditions exist at the projects that are of sufficient magnitude to require coordination with other State and Federal agencies. It is the responsibility of the St. Paul District Water Control Center to recognize when the drought criteria have been met and to trigger in-house action, as specified in the plan, to establish agency contacts. During a drought, the agency coordination would help determine the best possible water control actions to satisfy as many of the agency concerns as possible for the prevailing conditions. The Drought Contingency Plans are presently under review and will be approved in conjunction with the updates of the project Reservoir Regulation Manuals. The Lake Traverse Drought Contingency Plan is included in Appendix B.

EXHIBIT D-8

Letter from the City of Moorhead Public Service Department, 7 June 1994

This letter states the concerns of the City of Moorhead regarding water quality problems arising from the operation of White Rock Dam and about operation of the reservoirs during drought. These concerns resulted in the drawdown of Orwell Reservoir and Lake Traverse to be concurrent, being on or after 1 March.

MOORHEAD
PUBLIC SERVICE DEPARTMENT
500 CENTER AVENUE, BOX 779, MOORHEAD, MINNESOTA 56561-0779
(218) 299-5400 FAX (218) 299-5193 TDD (218) 299-5082

June 7, 1994

Mr. Robert F. Post, P.E.
Chief, Engineering and Planning Division
Department of Army
St Paul District, Corps of Engineers
190 Fifth Street East
St. Paul, MN 55101-1638

Dear Mr. Post:

The purpose of my letter is to comment on the Operation Plan Evaluation and Draft Environmental Assessment for the Lake Traverse-Bois de Sioux River and Orwell Reservoir flood control projects. I have reviewed the Operation Plan Evaluation and Draft Environmental Assessment for the Lake Traverse-Bois de Sioux River and Orwell Reservoir flood control projects. The City of Moorhead appreciates the changes in the plan which may reduce the problems with water quality in the Red River during periods of discharge from White Rock Dam.

I have two concerns I would like to outline for you. First, there is still a concern about the impact discharges from White Rock Dam have on water quality and increased chemical costs for treating the high non-carbonate hardness in the water. The high levels of non-carbonate hardness increases our chemical cost approximately $2,000 per week of discharge from the reservoir. My second concern is for the need to have enough flexibility in the operations plan for Orwell Dam to provide water to the Moorhead area during periods of drought.

The authorization of White Rock Dam and Orwell Reservoir was primarily for flood control for the Wahpeton-Breckenridge area. The impact on flood control for the Fargo- Moorhead area is minimal. The largest potential benefit to the F-M area is for water supply. Unfortunately, discharges from White Rock Dam have a large negative impact on water quality. The Red River is designated as a river, which from a water quality standpoint, should be maintained and be capable of being used as a water supply. Discharges from White Rock Dam degrade the river water quality such that it is not always acceptable as a water supply. Both Moorhead and Fargo have been forced to use our limited alternative supplies to provide good potable water to our citizens during periods of discharge from White Rock Dam. The authorization of the projects did not include authorization of negative impacts on water quality in the Red River. It is

important that the Corp of Engineers continue to pursue ways of improving water quality behind White Rock Dam. The discharges from the reservoir should not be allowed to degrade water quality in the Red River so it cannot be used as a water supply.

The second concern about the plan is the operations of the reservoirs during periods of drought in the Red River Valley. In the summer of 1988, Orwell Reservoir supplied the Fargo-Moorhead area with its water supply. Without discharges from Orwell, the Red River would have stopped flowing. It is important that the operating plan for Orwell Reservoir continues to allow for discharges from the Reservoir under drought conditions. The plan must include the option of lowering the Reservoir level below 1064 to as low as 1048. This is in conflict with the Minnesota Department of Natural Resources' Fish and Wildlife management recommendations. The flexibility in the operating plan of Orwell Reservoir to help bridge drought conditions on the Red River is important to maintaining a good standard of living in the Red River Valley.

If you have any questions about these comments , please call me at 218-299-5470.

Sincerely,

Clifford McLain, PE
Water Division Manager

CM/bal
(cliff\post1.ltr)

EXHIBIT E

STAGE-DISCHARGE TABLES

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

EXPANDED RATING TABLE

TYPE: LOG

05046000

DATE PROCESSED: 02-09-1999 @ 11:42 BY mcnellis

OTTER TAIL RIVER BL ORWELL D NR FERGUS FALLS, MN

DD: 3 TYPE: 001 RATING NO: 18.1

OFFSET: 1.40 BREAK,OFFSET: (3.00,1.70)

START DATE/TIME: 10-01-1997 (0100)

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION) .00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH FT
1.80						4.000*	4.290	4.594	4.913	5.246	3.190
1.90	5.595	5.959	6.339	6.736	7.149	7.579	8.027	8.493	8.976	9.479	4.405
2.00	10.00*	10.56	11.15	11.76	12.39	13.05	13.72	14.43	15.15	15.91	6.690
2.10	16.69	17.49	18.32	19.18	20.07	20.98	21.93	22.90	23.90	24.94	9.310
2.20	26.00*	27.38	28.82	30.32	31.87	33.49	35.16	36.90	38.71	40.58	16.51
2.30	42.51	44.52	46.60	48.75	50.98	53.28	55.66	58.12	60.66	63.29	23.49
2.40	66.00*	68.85	71.80	74.84	77.98	81.21	84.55	88.00	91.55	95.21	32.98
2.50	98.98	102.9	106.9	111.0	115.2	119.6	124.0	128.7	133.4	138.3	44.32
2.60	143.3	148.4	153.7	159.1	164.7	170.4	176.3	182.3	188.5	194.9	58.10
2.70	201.4	208.0	214.9	221.9	229.1	236.4	243.9	251.7	259.6	267.7	74.50
2.80	275.9	284.4	293.1	302.0	311.0	320.3	329.8	339.5	349.5	359.6	94.10
2.90	370.0*	376.7	383.4	390.2	397.1	404.0	411.1	418.2	425.4	432.7	70.00
3.00	440.0*	446.0	452.1	458.2	464.4	470.6	476.8	483.0	489.3	495.6	62.00
3.10	502.0*	507.3	512.7	518.0	523.4	528.8	534.2	539.7	545.1	550.6	54.10
3.20	556.1	561.6	567.1	572.7	578.2	583.8	589.4	595.0	600.7	606.3	55.90
3.30	612.0	617.7	623.4	629.1	634.8	640.6	646.3	652.1	657.9	663.7	57.60
3.40	669.6	675.4	681.3	687.2	693.1	699.0	704.9	710.9	716.8	722.8	59.20
3.50	728.8	734.8	740.9	746.9	753.0	759.1	765.2	771.3	777.4	783.5	60.90
3.60	789.7	795.9	802.1	808.3	814.5	820.7	827.0	833.2	839.5	845.8	62.40
3.70	852.1	858.5	864.8	871.2	877.5	883.9	890.3	896.7	903.2	909.6	64.00
3.80	916.1	922.6	929.1	935.6	942.1	948.6	955.2	961.8	968.3	974.9	65.50
3.90	981.6	988.2	994.8	1001	1008	1015	1022	1028	1035	1042	66.40
4.00	1048	1055	1062	1069	1076	1082	1089	1096	1103	1110	69.00
4.10	1117	1124	1131	1138	1145	1151	1158	1165	1172	1179	70.00
4.20	1187	1194	1201	1208	1215	1222	1229	1236	1243	1250	71.00
4.30	1258	1265	1272	1279	1286	1294	1301	1308	1315	1323	72.00
4.40	1330	1337	1345	1352	1359	1367	1374	1382	1389	1396	74.00

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

EXPANDED RATING TABLE TYPE: LOG

05046000

DATE PROCESSED: 02-09-1999 @ 11:42 BY mcnellis

OTTER TAIL RIVER BL ORWELL D NR FERGUS FALLS, MN DD: 3 TYPE: 001 RATING NO: 18.1

OFFSET: 1.40 BREAK,OFFSET: (3.00,1.70) START DATE/TIME: 10-01-1997 (0100)

reworked low end of rating

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)										DIFF IN Q PER TENTH FT
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	
4.50	1404	1411	1419	1426	1434	1441	1449	1456	1464	1471	75.00
4.60	1479	1486	1494	1502	1509	1517	1524	1532	1540	1547	76.00
4.70	1555	1563	1570	1578	1586	1594	1601	1609	1617	1625	78.00
4.80	1633	1640	1648	1656	1664	1672	1680	1688	1695	1703	78.00
4.80	1633	1640	1648	1656	1664	1672	1680	1688	1695	1703	78.00
4.90	1711	1719	1727	1735	1743	1751	1759	1767	1775	1783	80.00
5.40	2123	2131	2140	2148	2157	2165	2174	2182	2191	2200	85.00
5.50	2208	2217	2226	2234	2243	2251	2260	2269	2278	2286	87.00*
5.60	2295*										

Table E-1 continued

RATING TABLE
GAGE NO. 05046250 (PARTIAL RECORD STATION)
OTTER TAIL RIVER NEAR FOXHOME, MINNESOTA
VALUES ESTIMATED FROM CURVE DERIVED FROM U.S.G.S MEASUREMENTS

GAGE HEIGHT (FEET)	DISCHARGE (CFS)	GAGE HEIGHT (FEET)	DISCHARGE (CFS)	GAGE HEIGHT (FEET)	DISCHARGE (CFS)	GAGE HEIGHT (FEET)	DISCHARGE (CFS)
		14.1	545	15.1	942	16.1	1305
13.2	130	14.2	586	15.2	980	16.2	1340
13.3	174	14.3	626	15.3	1018	16.3	1375
13.4	234	14.4	666	15.4	1055	16.4	1410
13.5	283	14.5	706	15.5	1092	16.5	1444
13.6	329	14.6	746	15.6	1129	16.6	1478
13.7	372	14.7	786	15.7	1165	16.7	1512
13.8	419	14.8	825	15.8	1200	16.8	1546
13.9	462	14.9	864	15.9	1235	16.9	1580
14.0	504	15.0	903	16.0	1270	17.0	1614

Table E-2

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

EXPANDED RATING TABLE

TYPE: LOG

05051500

DATE PROCESSED: 03-28-1999 @ 09:17 BY snorbeck

RED RIVER OF THE NORTH AT WAHPETON, ND

DD: 3 TYPE: 001 RATING NO: 18.0

OFFSET: 1.0 BREAK,OFFSET: (2.0,2.0)

START DATE/TIME: 10-01-1996 (0015)

GAGE HEIGHT (FEET)	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)										DIFF IN Q PER FOOT
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	
1.0				15.00*	20.00*	26.73	33.06	39.58	46.25	53.06	64.29
2.0	60.00*	68.00*	77.00*	87.00*	98.00*	110.0*	123.0*	137.0*	152.0*	168.0*	125.0
3.0	185.0*	203.0*	223.0*	245.0*	269.0*	292.0	315.4	339.0*	368.0	397.6	243.0
4.0	428.0	459.0*	492.7	527.2	562.5	598.5	635.4	672.9	711.2	750.3	362.0
5.0	790.0*	825.4	861.1	897.2	933.7	970.6	1008	1045	1083	1121	370.0
6.0	1160*	1202	1244	1287	1331	1375	1419	1464	1509	1554	440.0
7.0	1600*	1650	1700	1751	1802	1854	1906	1959	2012	2066	520.0
8.0	2120*	2176	2232	2289	2346	2404	2462	2521	2580	2640	580.0
9.0	2700*	2767	2835	2903	2972	3042	3112	3183	3255	3327	700.0
10.0	3400*	3477	3554	3632	3711	3791	3871	3952	4034	4117	800.0
11.0	4200*	4278	4356	4434	4513	4593	4673	4754	4836	4918	800.0
12.0	5000*	5078	5157	5236	5315	5395	5475	5556	5637	5718	800.0
13.0	5800*	5878	5957	6036	6116	6196	6276	6356	6437	6518	800.0
14.0	6600*	6697	6795	6894	6993	7092	7193	7294	7395	7497	1000
15.0	7600*	7707	7815	7923	8032	8142	8252	8363	8475	8587	1100
16.0	8700*	8808	8916	9024	9133	9243	9353	9464	9576	9688	1100
17.0	9800*	9917	10040	10150	10270	10390	10510	10630	10760	10880	1200
18.0	11000*	11120	11240	11350	11470	11590	11710	11830	11960	12080	1200
19.0	12200*	12340	12470	12610	12750	12890	13030	13170	13310	13460	1400*
20.0	13600*										

Table E-3

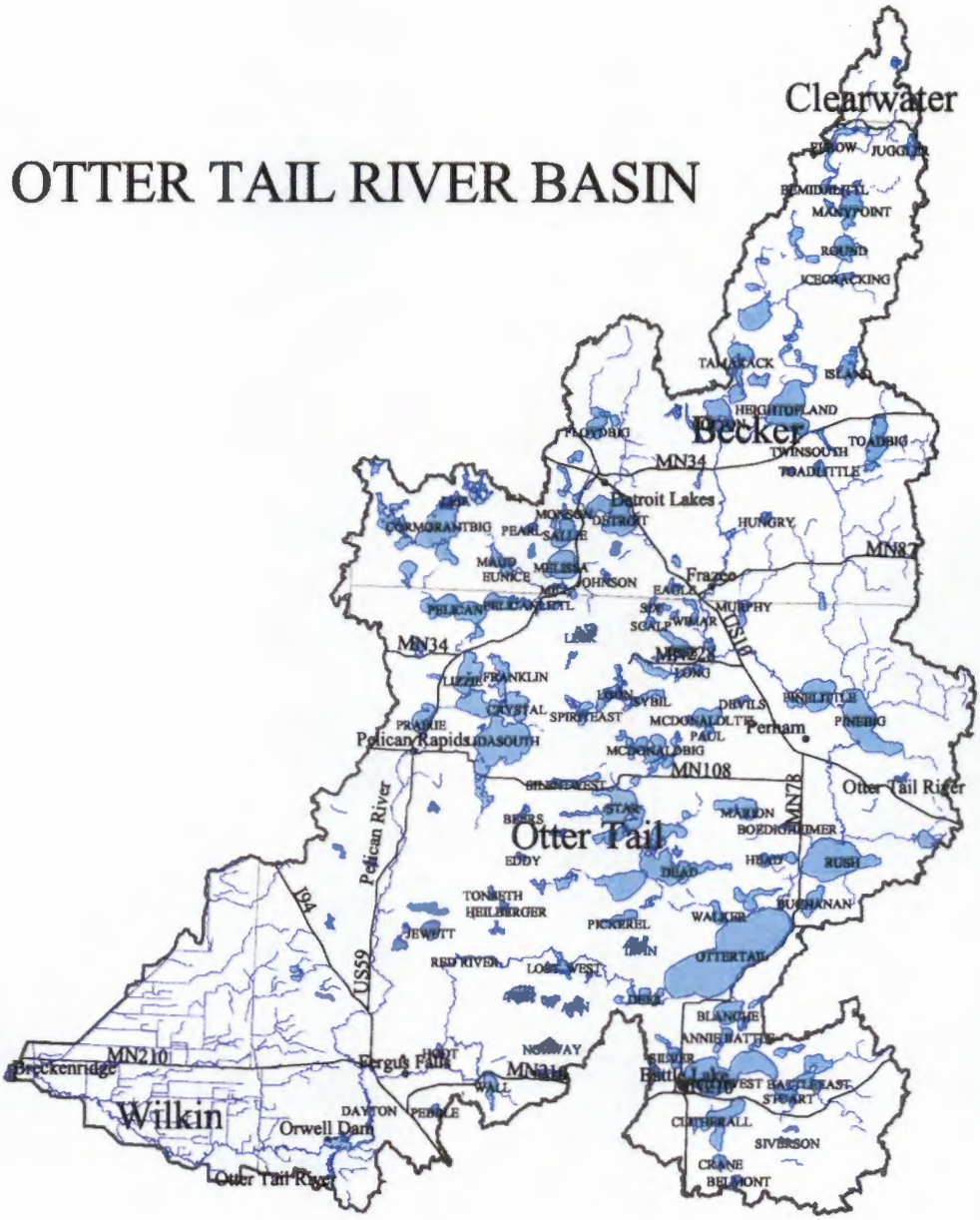
F

Elevation in Feet (1912 MSL) with Storage Capacity in Acre-Feet

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1040.0	4	6	8	9	11	13	15	17	18	20
1041.0	22	24	26	27	29	31	33	35	36	38
1042.0	40	45	51	56	62	67	73	78	84	89
1043.0	95	100	106	111	117	122	128	133	139	144
1044.0	150	161	172	183	194	205	216	227	238	249
1045.0	260	271	282	293	304	315	326	337	348	359
1046.0	370	386	403	419	436	452	469	485	502	518
1047.0	535	551	568	584	601	617	634	650	667	683
1048.0	700	725	750	775	800	825	850	875	900	925
1049.0	950	975	1000	1025	1050	1075	1100	1125	1150	1175
1050.0	1200	1230	1260	1290	1320	1350	1380	1410	1440	1470
1051.0	1500	1530	1560	1590	1620	1650	1680	1710	1740	1770
1052.0	1800	1835	1870	1905	1940	1975	2010	2045	2080	2115
1053.0	2150	2185	2220	2255	2290	2325	2360	2395	2430	2465
1054.0	2500	2543	2585	2628	2670	2713	2755	2798	2840	2883
1055.0	2925	2968	3010	3053	3095	3138	3180	3223	3265	3308
1056.0	3350	3400	3450	3500	3550	3600	3650	3700	3750	3800
1057.0	3850	3900	3950	4000	4050	4100	4150	4200	4250	4300
1058.0	4350	4408	4465	4523	4580	4638	4695	4753	4810	4868
1059.0	4925	4983	5040	5098	5155	5213	5270	5328	5385	5443
1060.0	5500	5565	5630	5695	5760	5825	5890	5955	6020	6085
1061.0	6150	6215	6280	6345	6410	6475	6540	6605	6670	6735
1062.0	6800	6875	6950	7025	7100	7175	7250	7325	7400	7475
1063.0	7550	7625	7700	7775	7850	7925	8000	8075	8150	8225
1064.0	8300	8385	8470	8555	8640	8725	8810	8895	8980	9065
1065.0	9150	9235	9320	9405	9490	9575	9660	9745	9830	9915
1066.0	10000	10100	10200	10300	10400	10500	10600	10700	10800	10900
1067.0	11000	11100	11200	11300	11400	11500	11600	11700	11800	11900
1068.0	12000	12100	12200	12300	12400	12500	12600	12700	12800	12900
1069.0	13000	13100	13200	13300	13400	13500	13600	13700	13800	13900
1070.0	14000	14125	14250	14375	14500	14625	14750	14875	15000	15125
1071.0	15250	15375	15500	15625	15750	15875	16000	16125	16250	16375
1072.0	16500	16625	16750	16875	17000	17125	17250	17375	17500	17625
1073.0	17750	17875	18000	18125	18250	18375	18500	18625	18750	18875
1074.0	19000	19150	19300	19450	19600	19750	19900	20050	20200	20350
1075.0	20500	20650	20800	20950	21100	21250	21400	21550	21700	21850
1076.0	22000	22150	22300	22450	22600	22750	22900	23050	23200	23350
1077.0	23500	23650	23800	23950	24100	24250	24400	24550	24700	24850
1078.0	25000	25165	25330	25495	25660	25825	25990	26155	26320	26485
1079.0	26650	26815	26980	27145	27310	27475	27640	27805	27970	28135
1080.0	28300									

Plates

OTTER TAIL RIVER BASIN



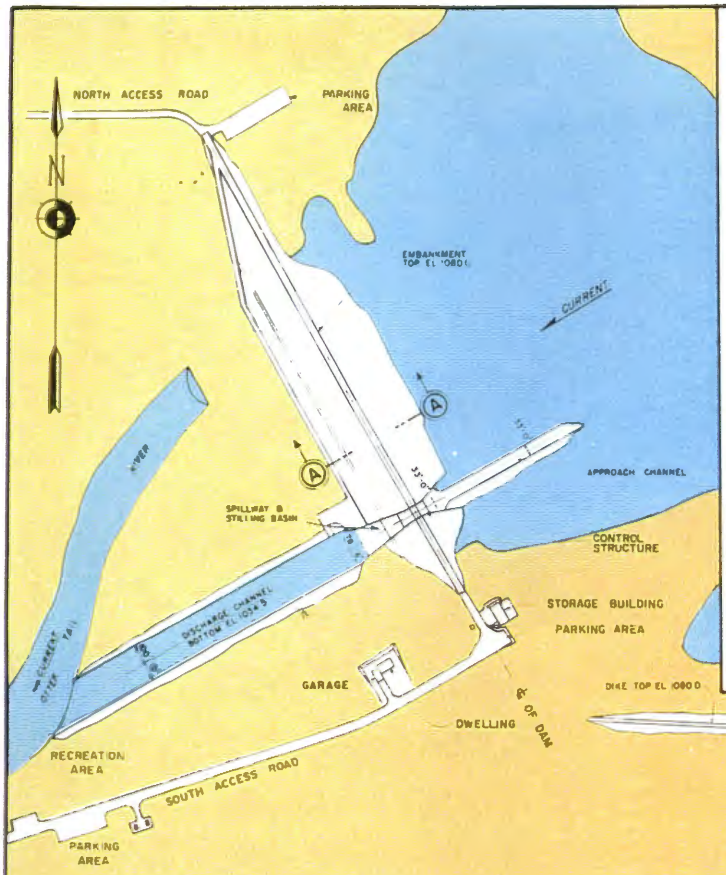
N

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

GENERAL MAP OF BASIN

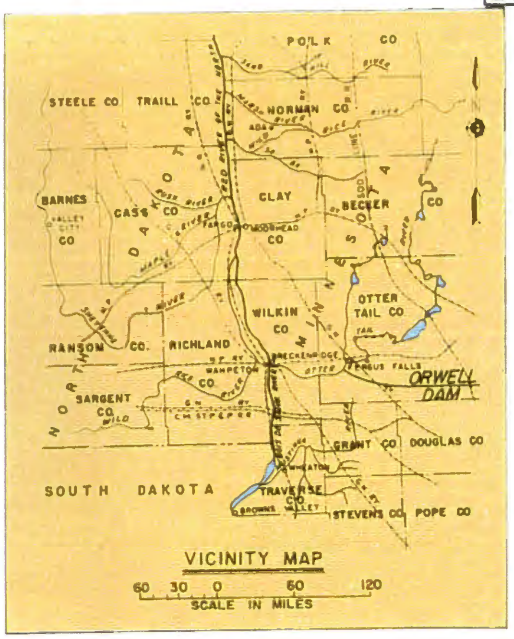
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

PLATE 2-1



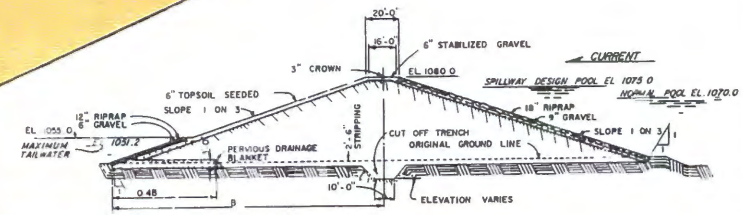
PLAN OF DAM

100 0 100 200 300
SCALE IN FEET



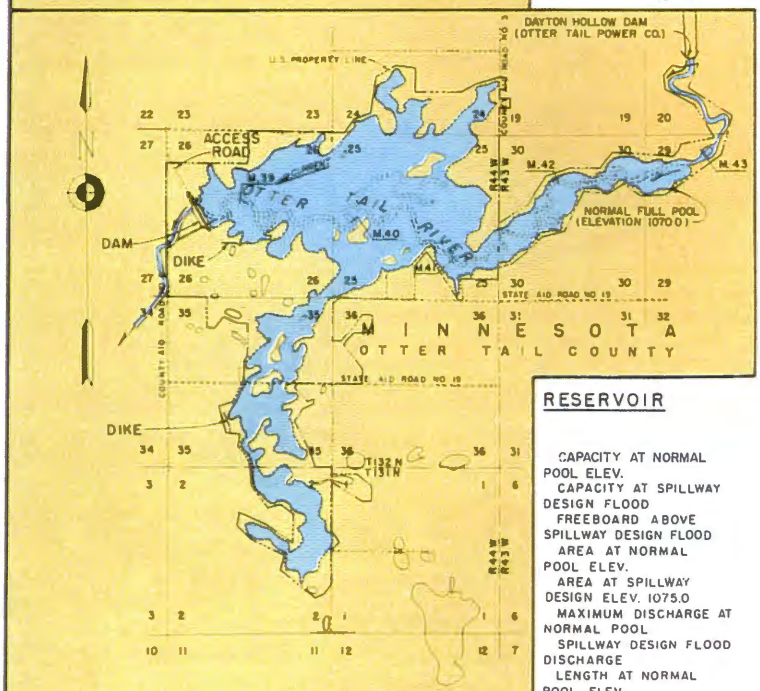
VICINITY MAP

60 30 0 60 120
SCALE IN MILES



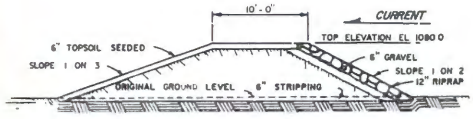
SECTION A-A
TYPICAL DAM SECTION

20 0 20 40 60
SCALE IN FEET



PLAN OF RESERVOIR

2000 0 2000 4000
SCALE IN FEET



TYPICAL DIKE SECTION

5 0 5 10 15
SCALE IN FEET

RESERVOIR

CAPACITY AT NORMAL POOL ELEV.	14,100 ACRE-FT
CAPACITY AT SPILLWAY DESIGN FLOOD	20,400 " "
FREEBOARD ABOVE SPILLWAY DESIGN FLOOD	5.0 FEET
AREA AT NORMAL POOL ELEV.	1,110 ACRES
AREA AT SPILLWAY DESIGN ELEV. 1075.0	1,420 "
MAXIMUM DISCHARGE AT NORMAL POOL	15,300 SEC.-F
SPILLWAY DESIGN FLOOD DISCHARGE	20,400 "
LENGTH AT NORMAL POOL ELEV.	4.0 MILES
WIDTH (MAX.) AT NORMAL POOL	1.0 "

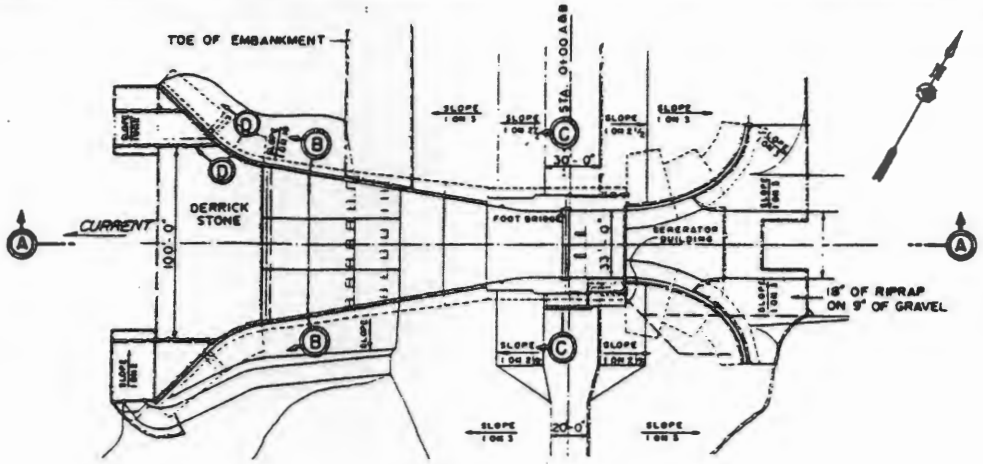
ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

PLANS AND SECTIONS
ORWELL DAM AND RESERVOIR

AS BUILT

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

PLATE 2-2

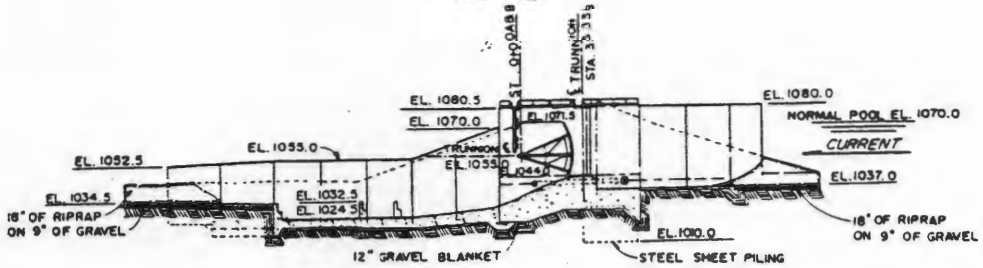


PLAN

SPILLWAY AND OUTLET WORKS

20 0 20 40 60

SCALE IN FEET

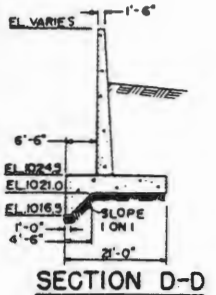


SECTION A-A

ALONG ℄ OUTLET WORKS

20 0 20 40 60

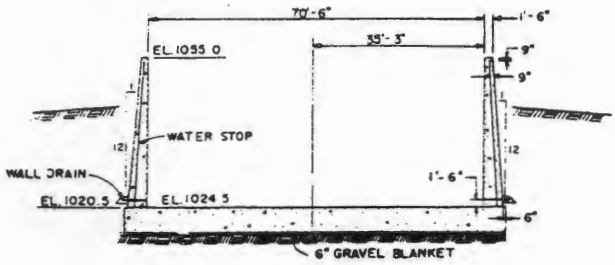
SCALE IN FEET



SECTION D-D

10 0 10 20

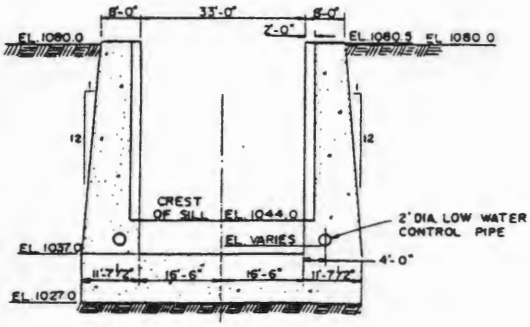
SCALE IN FEET



SECTION B-B

10 0 10 20

SCALE IN FEET



SECTION C-C

10 0 10 20

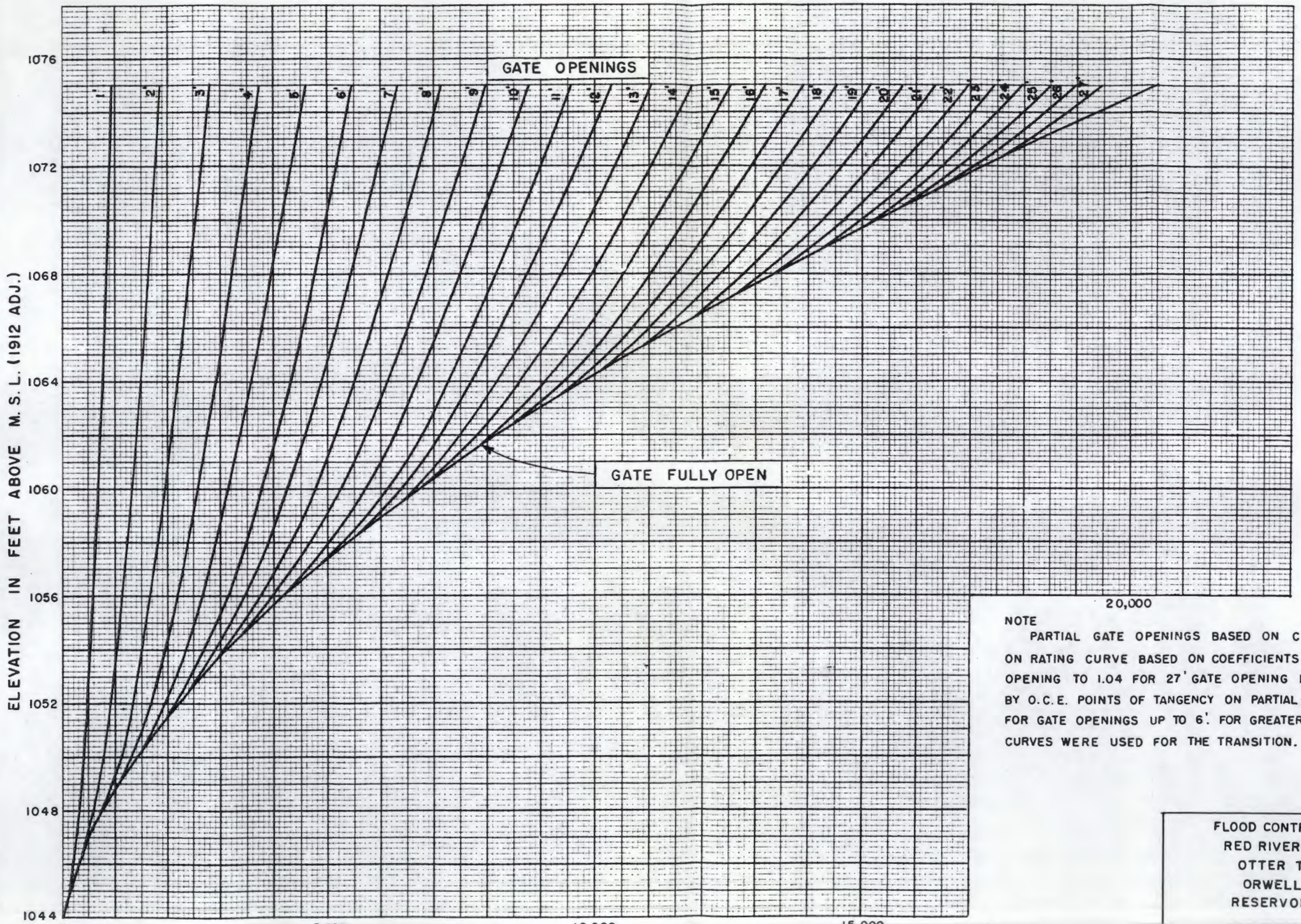
SCALE IN FEET

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

PLANS AND SECTIONS
ORWELL DAM

AS BUILT

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



NOTE

PARTIAL GATE OPENINGS BASED ON C OF 0.65. POINTS OF TANGENCY ON RATING CURVE BASED ON COEFFICIENTS VARYING FROM 1.30 FOR 1' GATE OPENING TO 1.04 FOR 27' GATE OPENING RATHER THAN $H_m = 1.25b$ PROPOSED BY O.C.E. POINTS OF TANGENCY ON PARTIAL-GATE CURVES $H_n = 2b$, WERE USED FOR GATE OPENINGS UP TO 6'. FOR GREATER OPENINGS SLIGHTLY SHARPER CURVES WERE USED FOR THE TRANSITION.

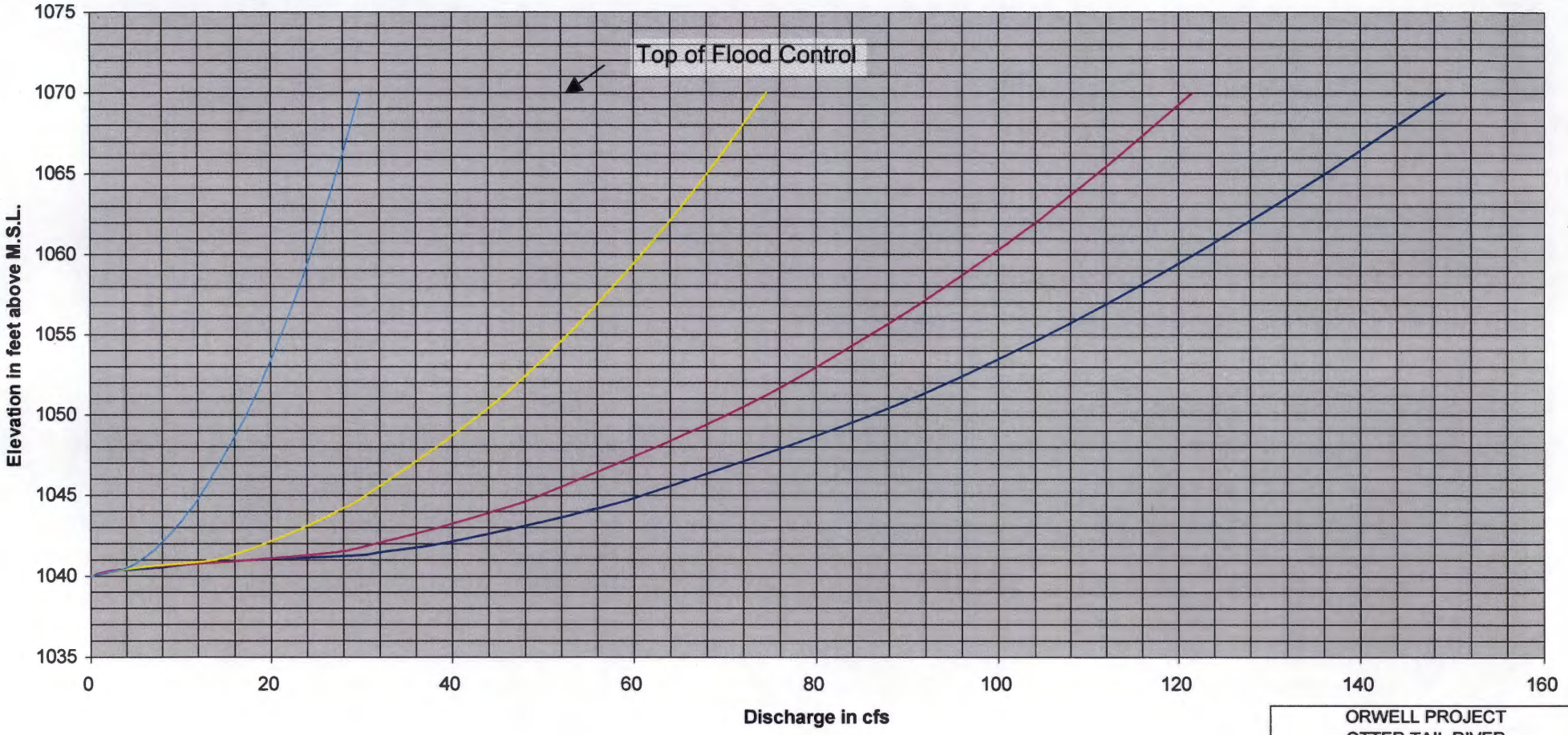
FLOOD CONTROL AND WATER CONSERVATION
RED RIVER OF THE NORTH WATERSHED
OTTER TAIL RIVER, MINNESOTA
ORWELL DAM AND RESERVOIR
RESERVOIR REGULATION MANUAL

TAINTER GATE RATING CURVE

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

PLATE 2-4

Low - Flow Conduit Rating Curves



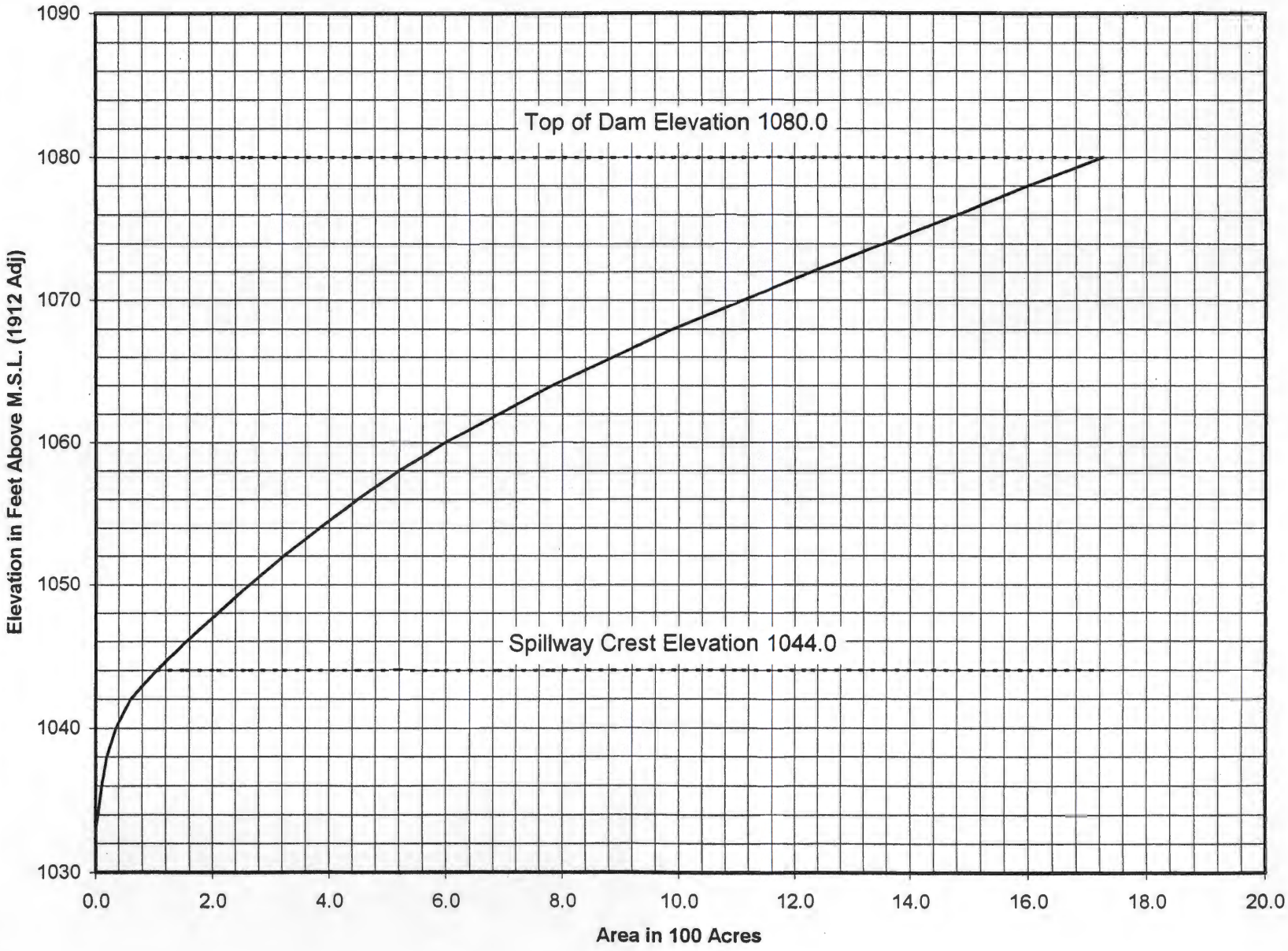
ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

LOW-FLOW CONDUIT RATING CURVES

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

PLATE 2-5

AREA / ELEVATION CURVE



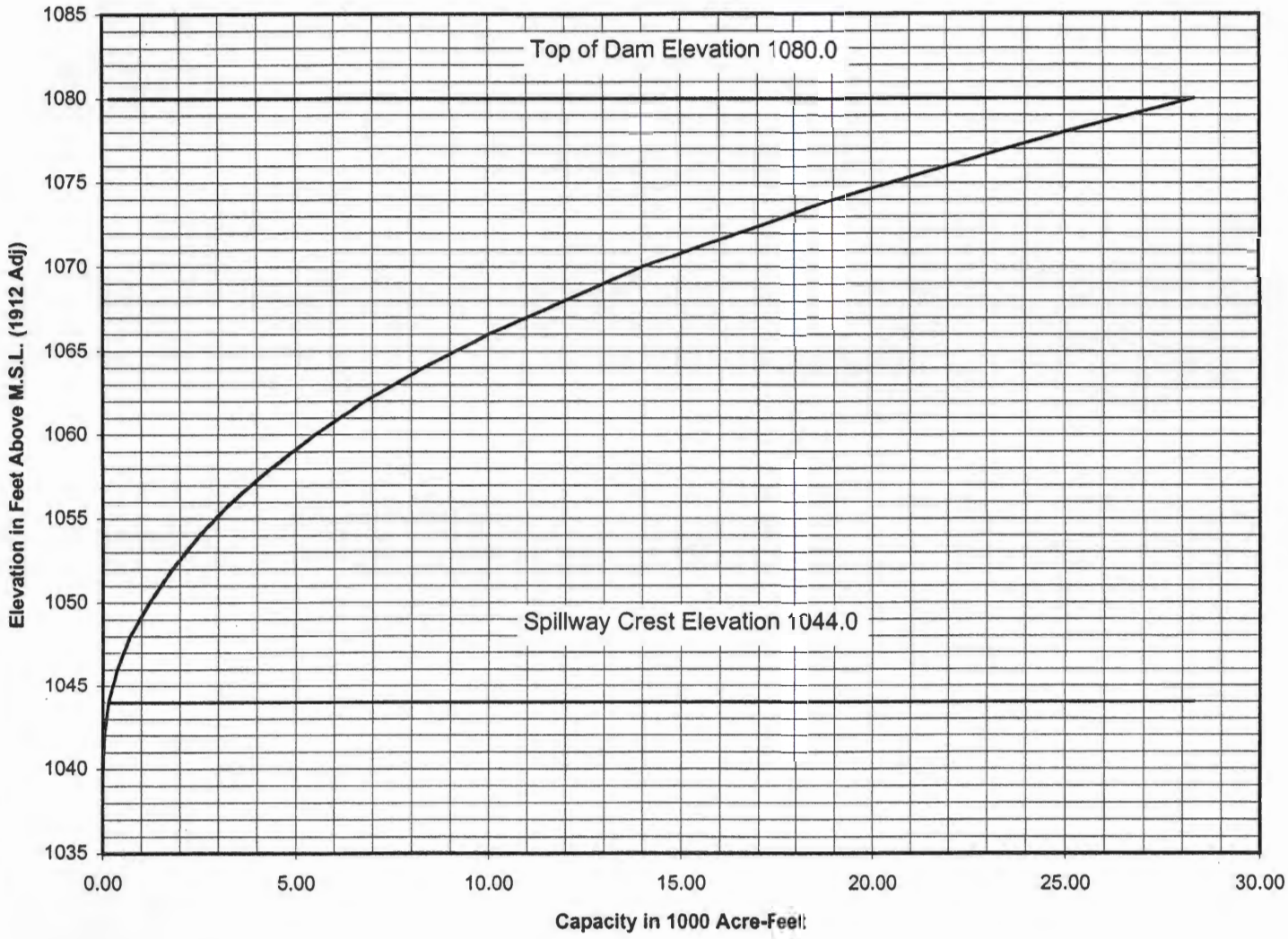
ORWELL RESERVOIR PROJECT
OTTERTAIL RIVER
WATER CONTROL MANUAL

AREA / ELEVATION CURVE

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

PLATE 2-6

CAPACITY / ELEVATION CURVE

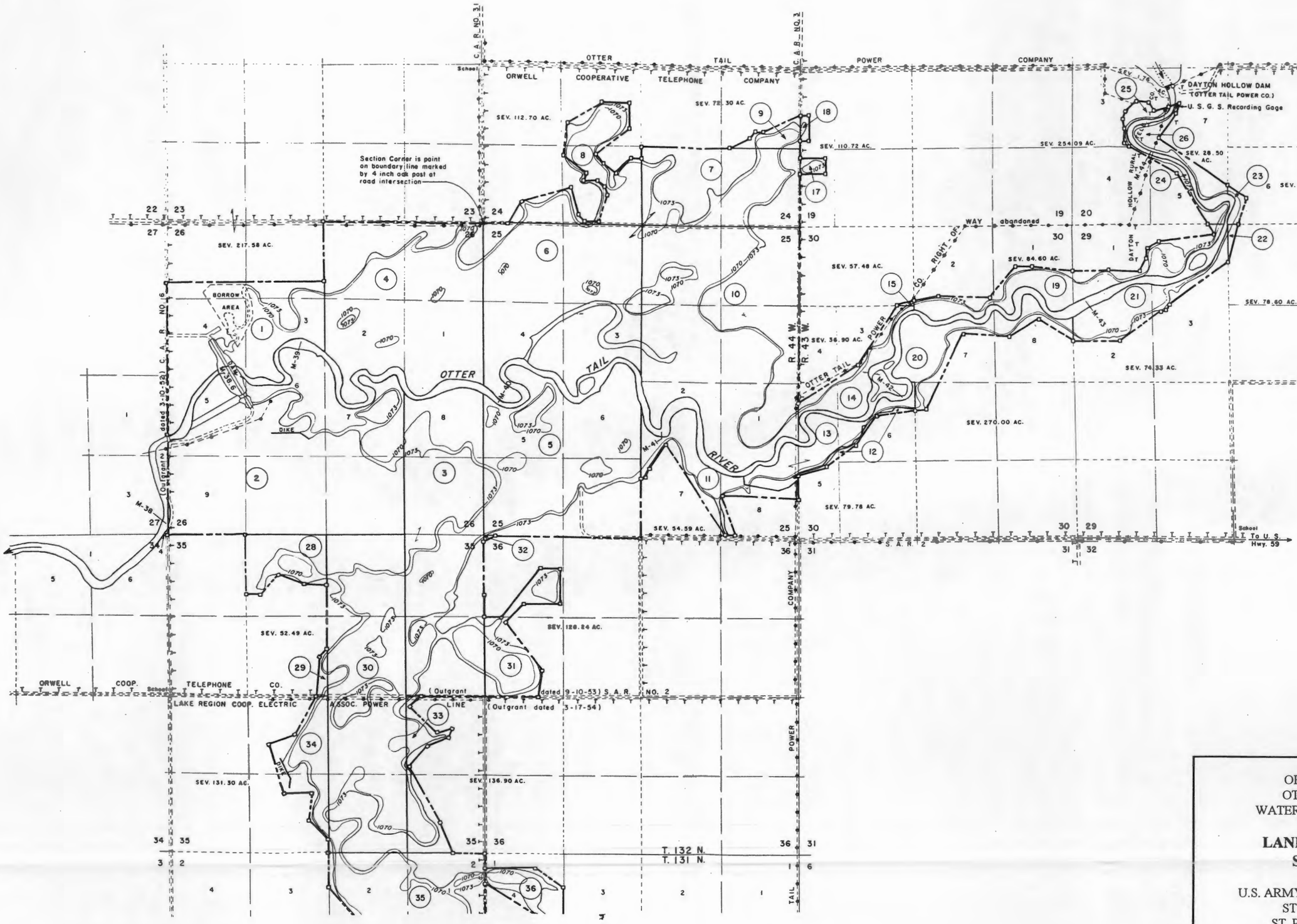


ORWELL RESERVOIR PROJECT
OTTERTAIL RIVER
WATER CONTROL MANUAL

CAPACITY / ELEVATION CURVE

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

PLATE 2-7

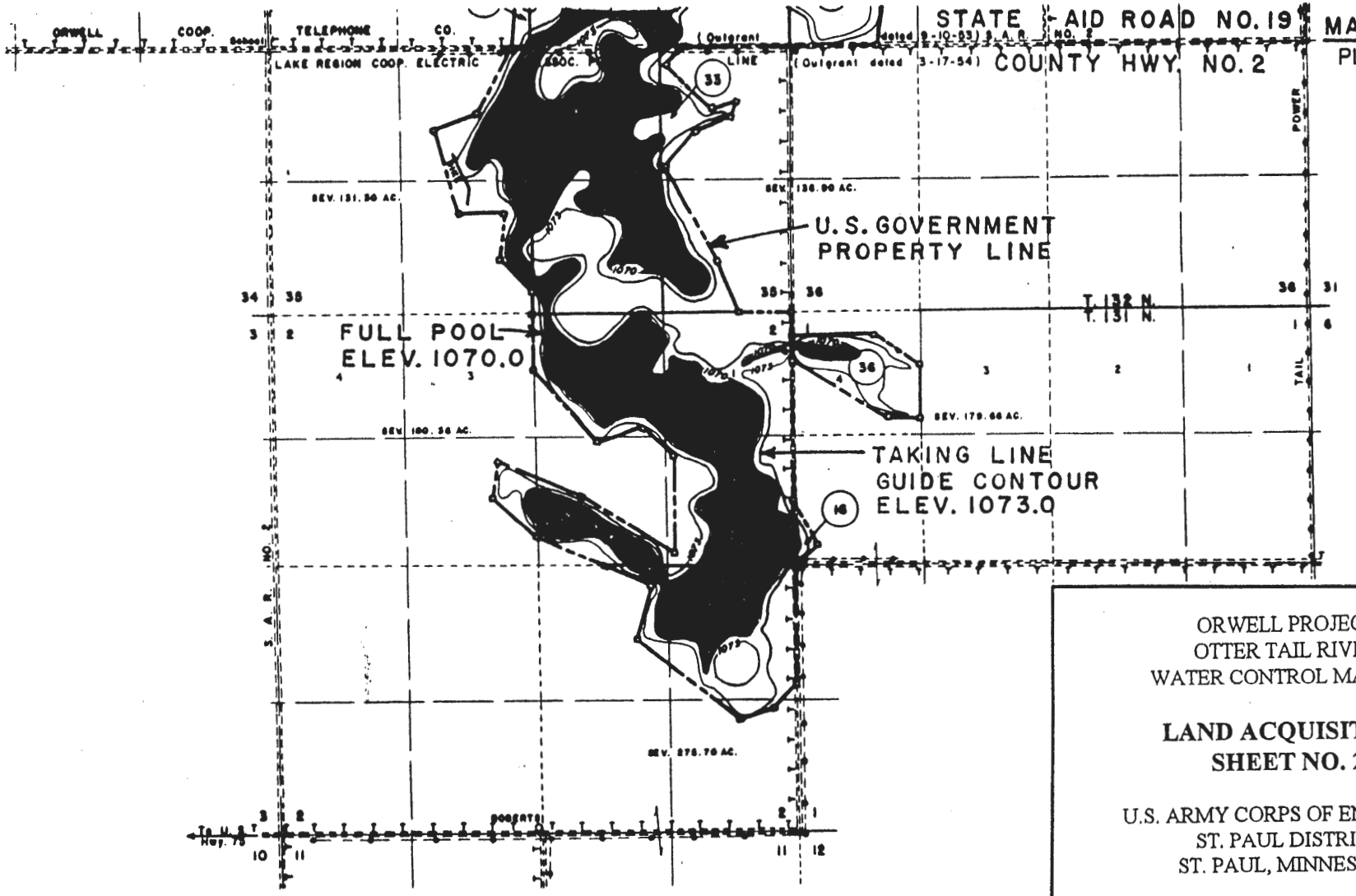


ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

LAND ACQUISITION
SHEET NO. 1

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

PLATE 2-8



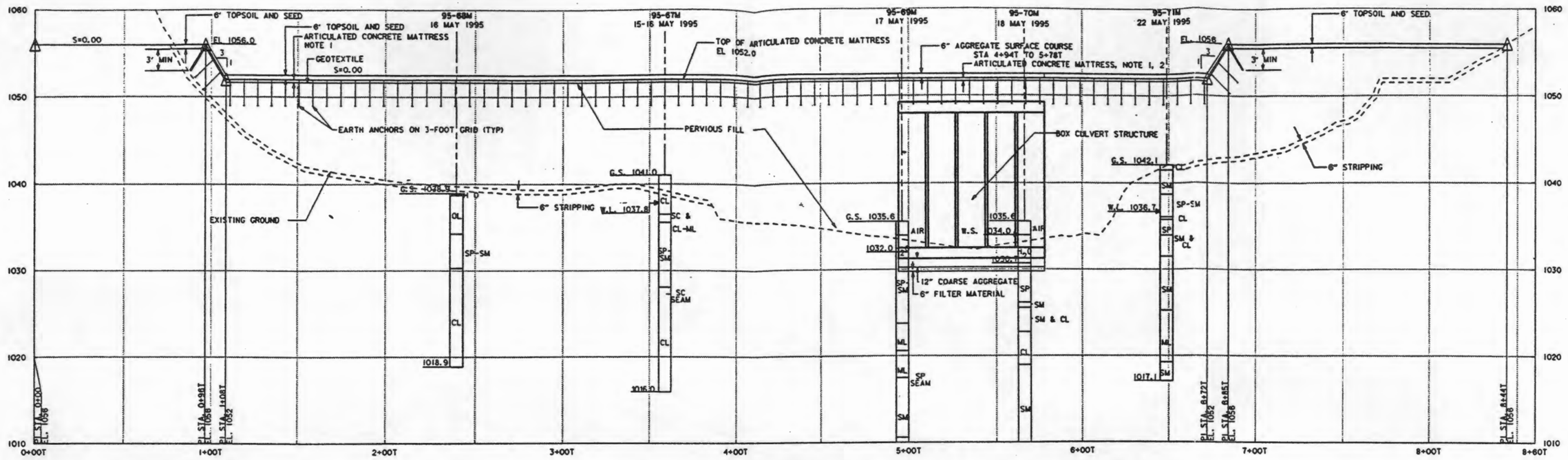
ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

LAND ACQUISITION
SHEET NO. 2

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

CORPS OF ENGINEERS
U.S. ARMY

PLATE 2-9



CONTROL LINE 'T' PROFILE

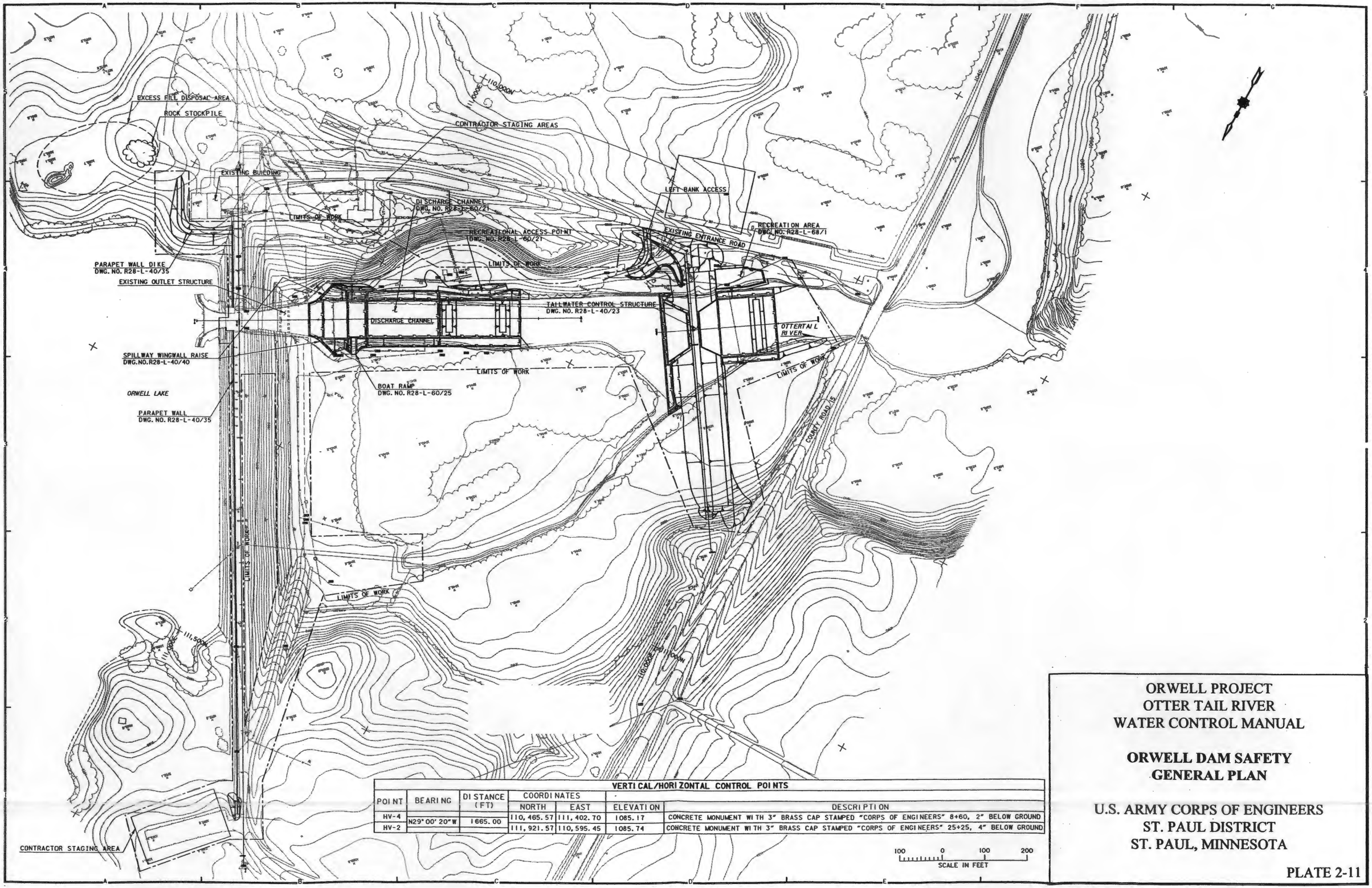
TAILWATER CONTROL STRUCTURE

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

ORWELL DAM SAFETY
TAILWATER CONTROL STRUCTURE

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

PLATE 2-10



VERTICAL/HORIZONTAL CONTROL POINTS

POINT	BEARING	DISTANCE (FT)	COORDINATES NORTH	COORDINATES EAST	ELEVATION	DESCRIPTION
HV-4	N29° 00' 20"W	1665.00	110,465.57	111,402.70	1085.17	CONCRETE MONUMENT WITH 3" BRASS CAP STAMPED "CORPS OF ENGINEERS" 8+60, 2" BELOW GROUND
HV-2			111,921.57	110,595.45	1085.74	CONCRETE MONUMENT WITH 3" BRASS CAP STAMPED "CORPS OF ENGINEERS" 25+25, 4" BELOW GROUND

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

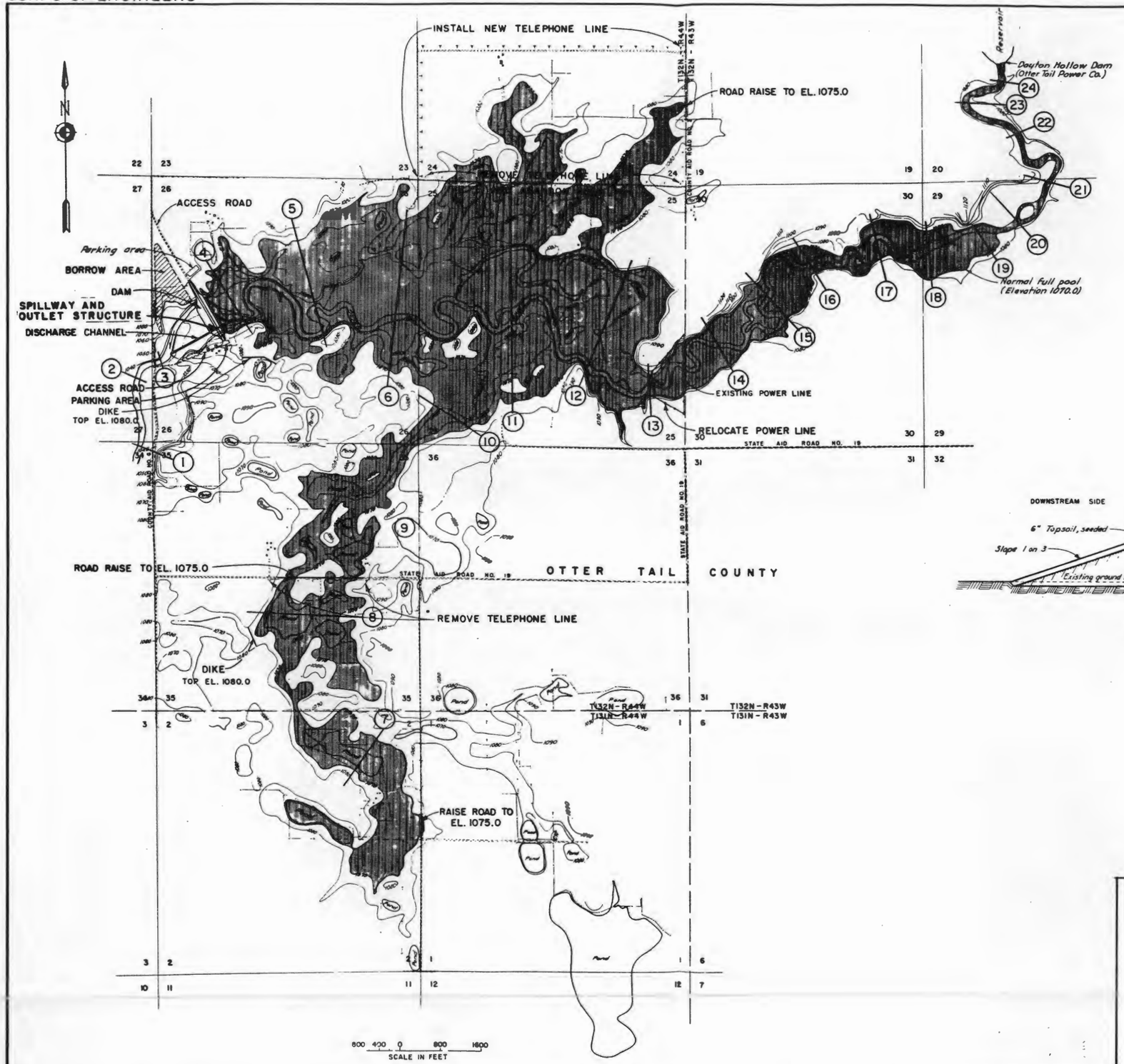
ORWELL DAM SAFETY
GENERAL PLAN

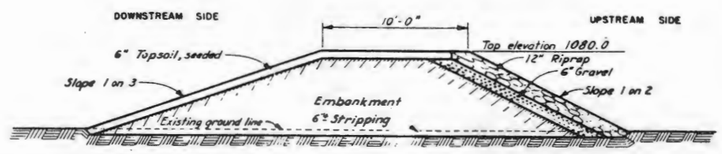
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

PLATE 2-11

CORPS OF ENGINEERS

U. S. ARMY





TYPICAL DIKE SECTION

4 2 0 4 8
SCALE IN FEET

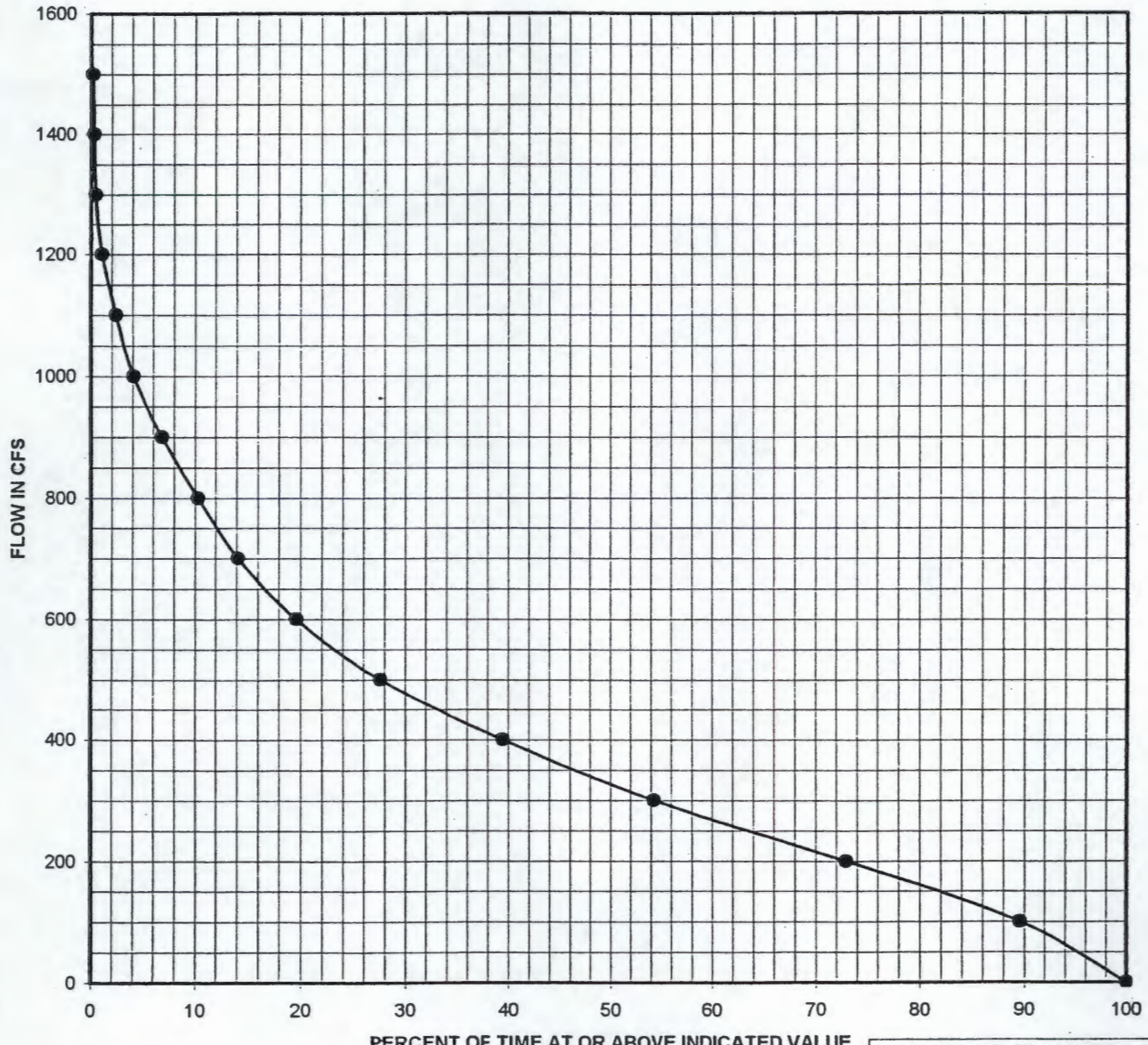
ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

RESERVOIR SEDIMENTATION RANGES

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

PLATE 4-1

ORWELL RESERVOIR PROJECT
RESERVOIR INFLOW-DURATION
PERIOD OF RECORD (1953-1995)

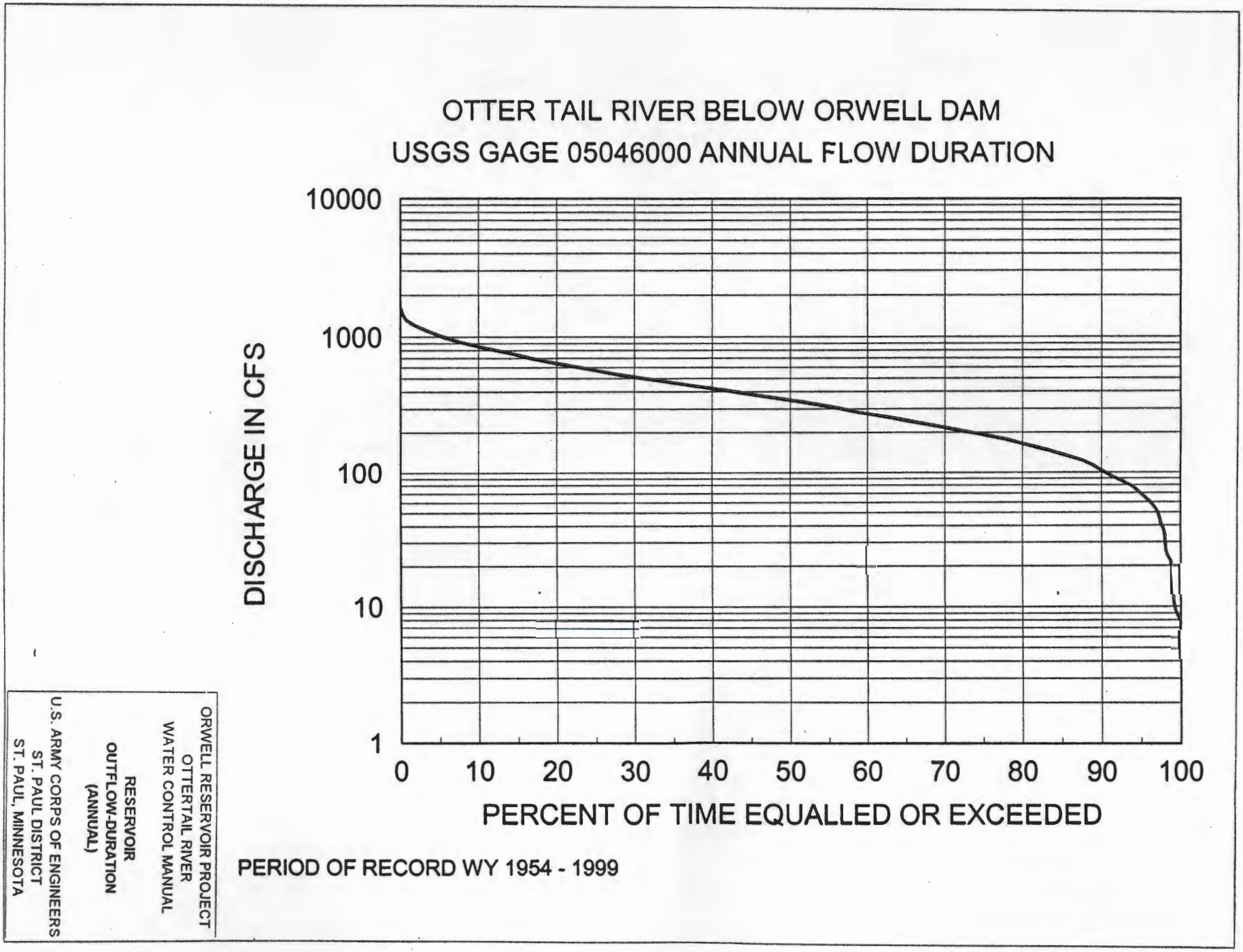


ORWELL RESERVOIR PROJECT
OTTERTAIL RIVER
WATER CONTROL MANUAL

RESERVOIR INFLOW-DURATION (ANNUAL)

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

PLATE 4-2



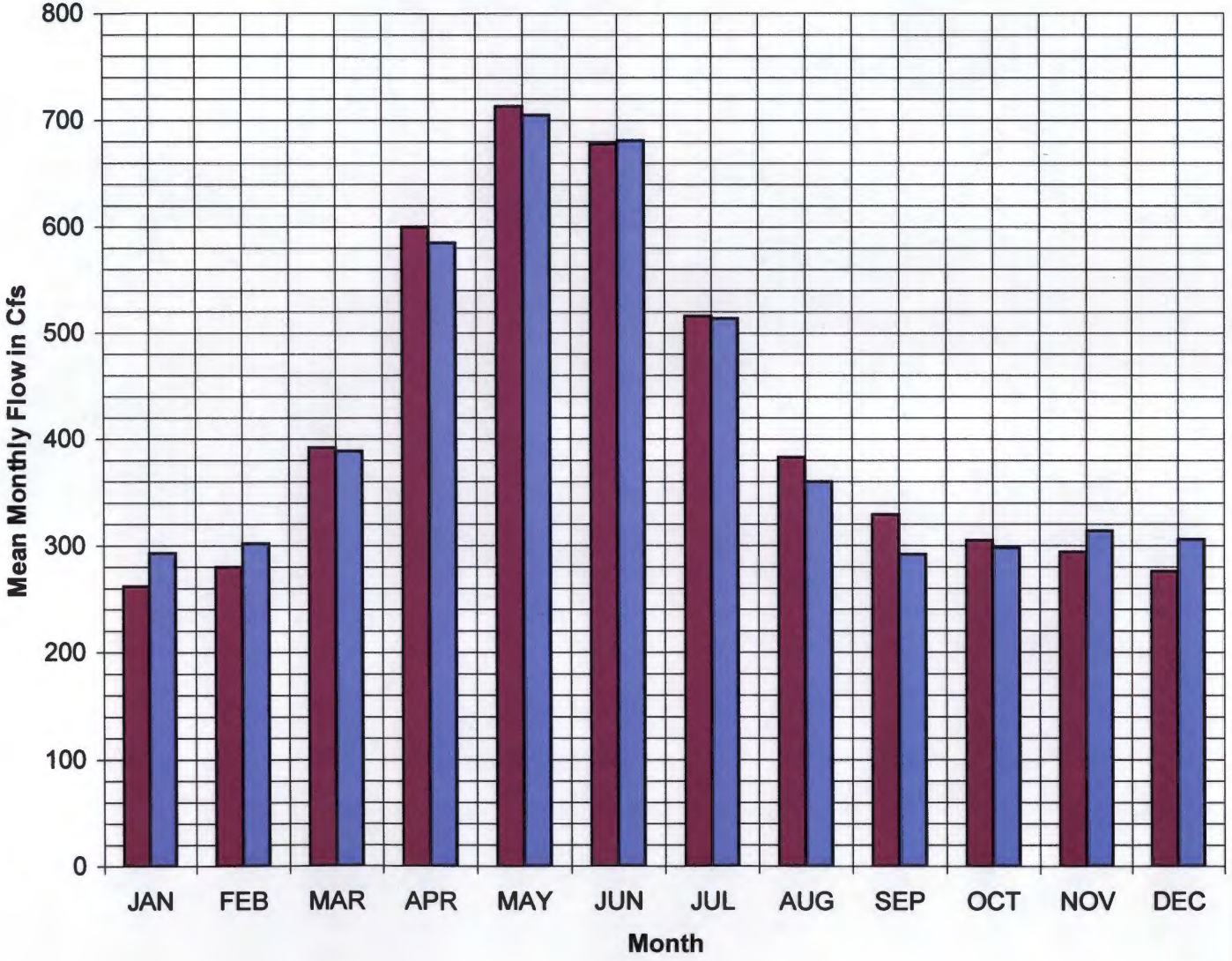
ORWELL RESERVOIR PROJECT
OTTERTAIL RIVER
WATER CONTROL MANUAL

RESERVOIR
OUTFLOW-DURATION
(ANNUAL)

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

PLATE 4-3

ORWELL RESERVOIR
Reservoir Monthly Inflow-Outflow



INFLOW OUTFLOW

Period of Record (1953 - 1999)
Note: Partial Record for 1953
No Data Prior to August 1953

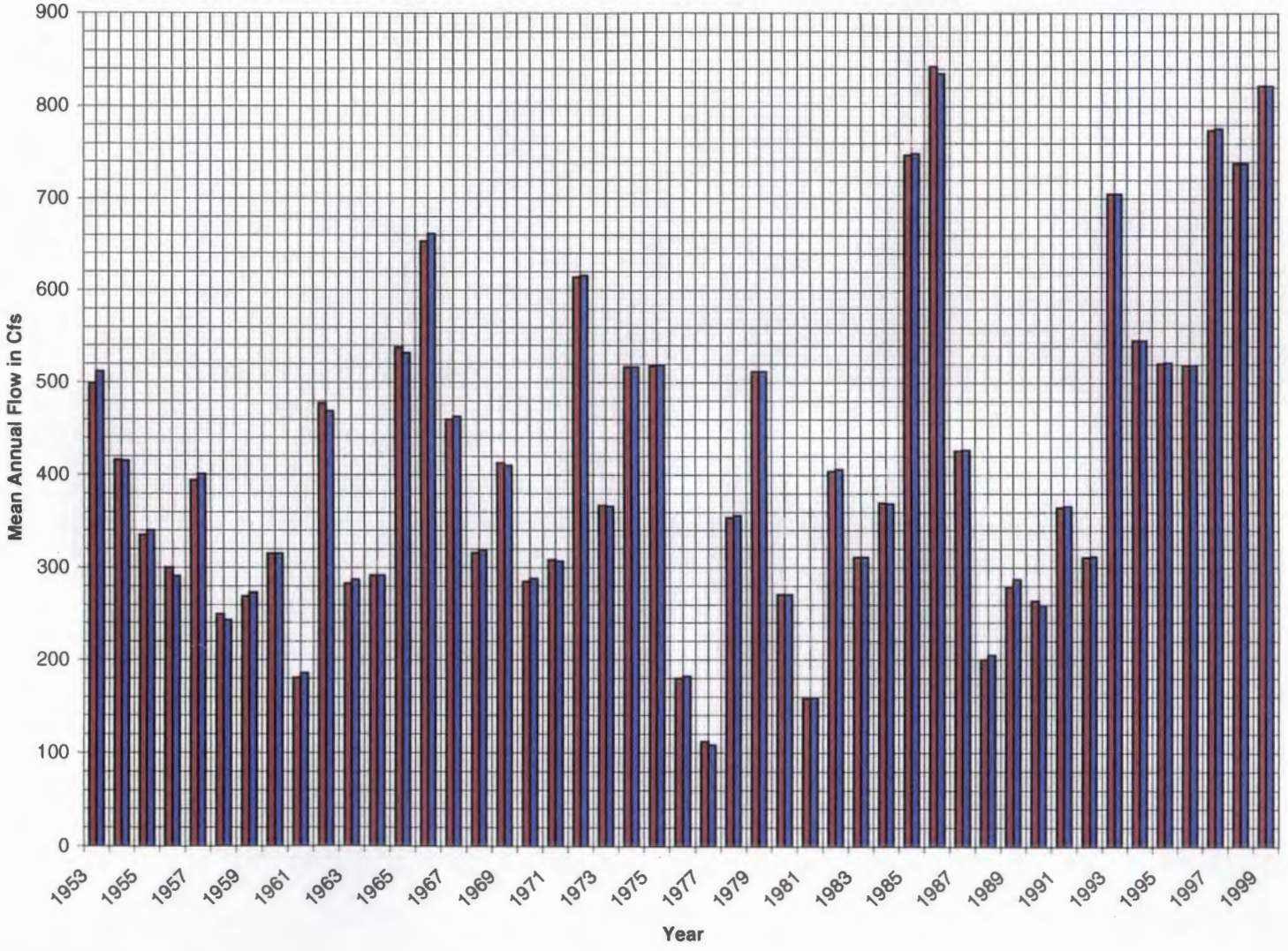
ORWELL RESERVOIR
OTTERTAIL RIVER
WATER CONTROL MANUAL

MEAN MONTHLY INFLOW AND OUTFLOW DISTRIBUTION

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

PLATE 4-4

ORWELL RESERVOIR
Reservoir Annual Inflow - Outflow



Period of Record (1953 - 1999)
Note: Partial Record for 1953
No Data Prior to August 1953

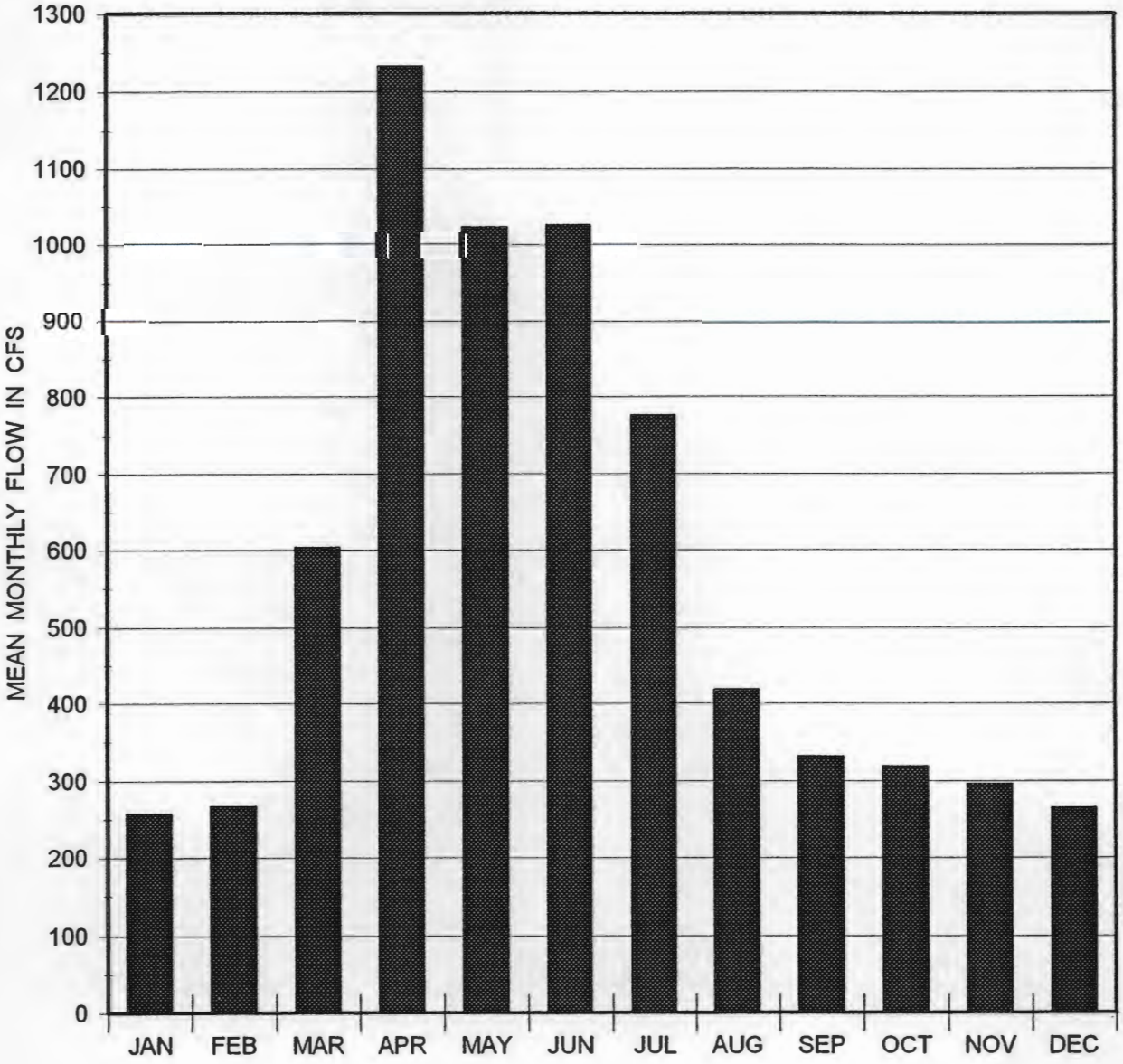
ORWELL RESERVOIR
OTTERTAIL RIVER
WATER CONTROL MANUAL

MEAN ANNUAL INFLOW AND OUTFLOW DISTRIBUTION

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

PLATE 4-5

RED RIVER OF THE NORTH
AT WAHPETON, N.D.
MONTHLY STREAMFLOW



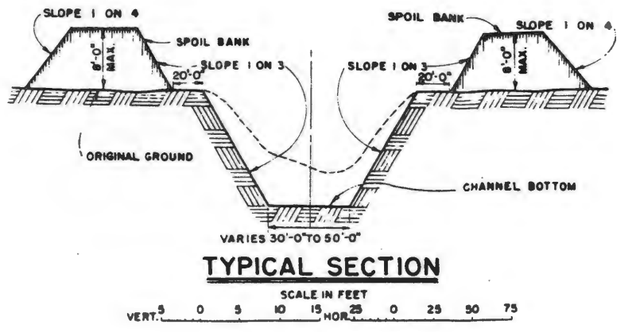
U.S.G.S. GAGE NO. 05051500
PERIOD OF RECORD (1942 - 1994)

ORWELL RESERVOIR PROJECT
OTTERTAIL RIVER
WATER CONTROL MANUAL

RED RIVER OF THE NORTH AT WAHPETON, N.D. MONTHLY STREAMFLOW DISTRIBUTION

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

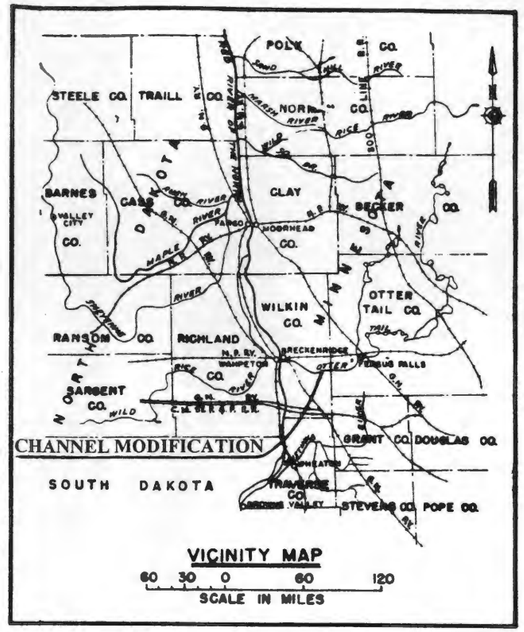
PLATE 4-6



TYPICAL SECTION

SCALE IN FEET

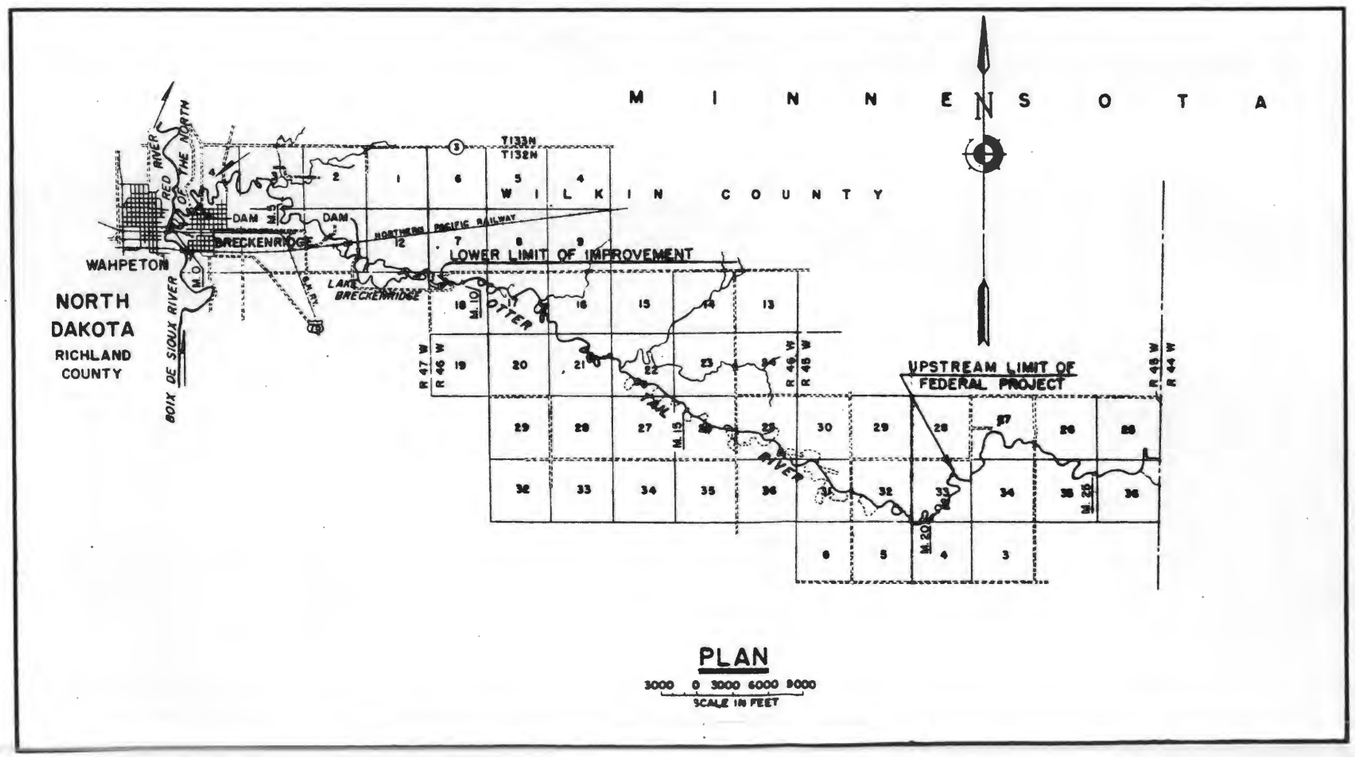
VERT. 5 0 5 10 15 HOR. 25 0 25 50 75



VICINITY MAP

60 30 0 60 120

SCALE IN MILES



PLAN

3000 0 3000 6000 9000

SCALE IN FEET

LENGTH
11.4 MILES.

CHANNEL WIDTH
30 TO 50 FEET.

DESIGN CAPACITY
1205 TO 1270 CFS PROVIDING FOR FLOODS OF 10 YEAR FREQUENCY WITH MINIMUM OF 1 FOOT FREEBOARD AT CRITICAL SECTIONS. FOR PROFILE, SEE PLATE II.

M.20 - MILES ABOVE MOUTH OF RIVER

LEGEND

PROJECT CHANNEL CUT-OFF.

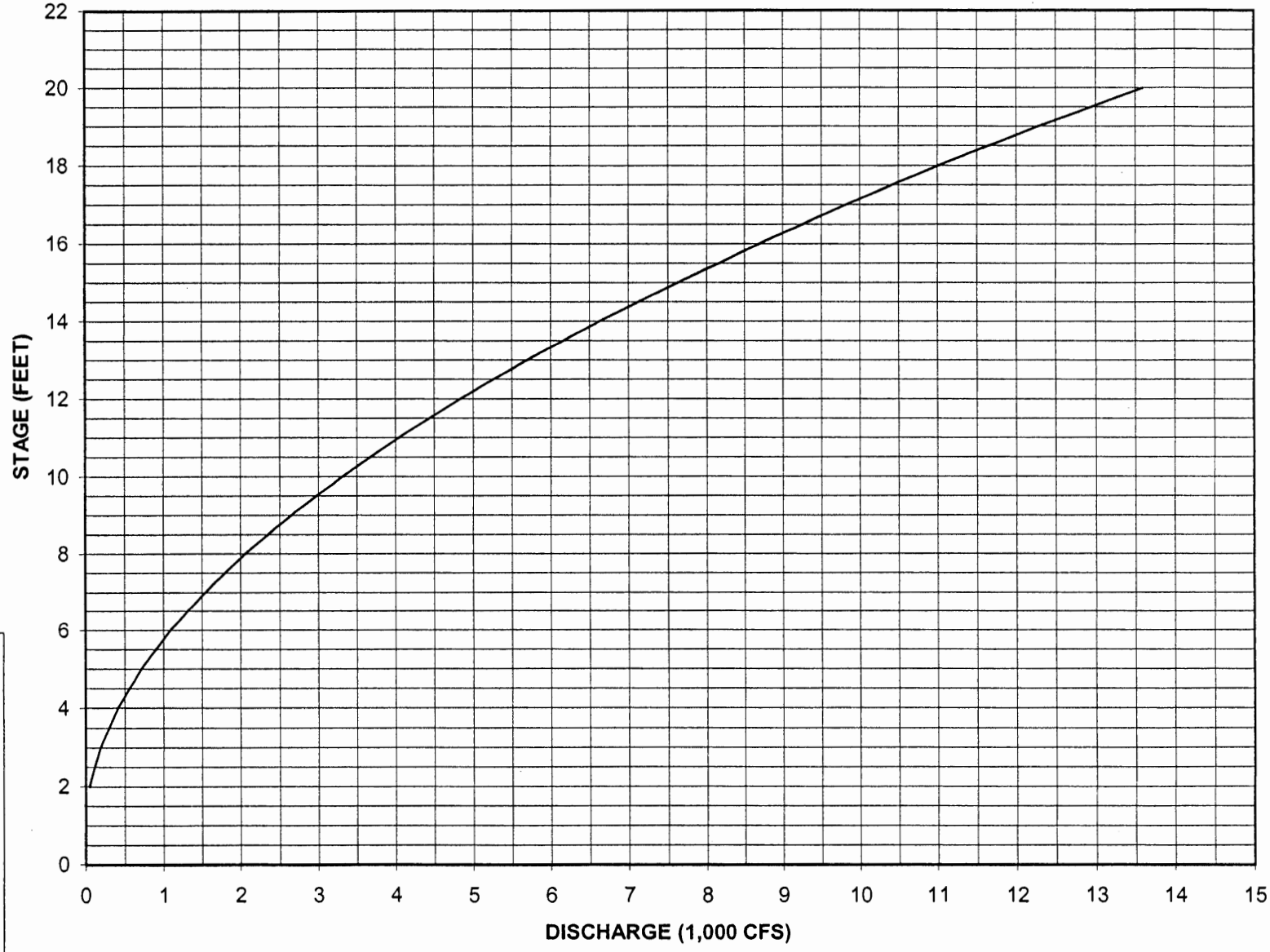
ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

CHANNEL MODIFICATION PLAN AND SECTION

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

PLATE 4-7
USACE-MVP-0000118572

STAGE-DISCHARGE RATING CURVE
RED RIVER OF THE NORTH AT WAHPETON, ND

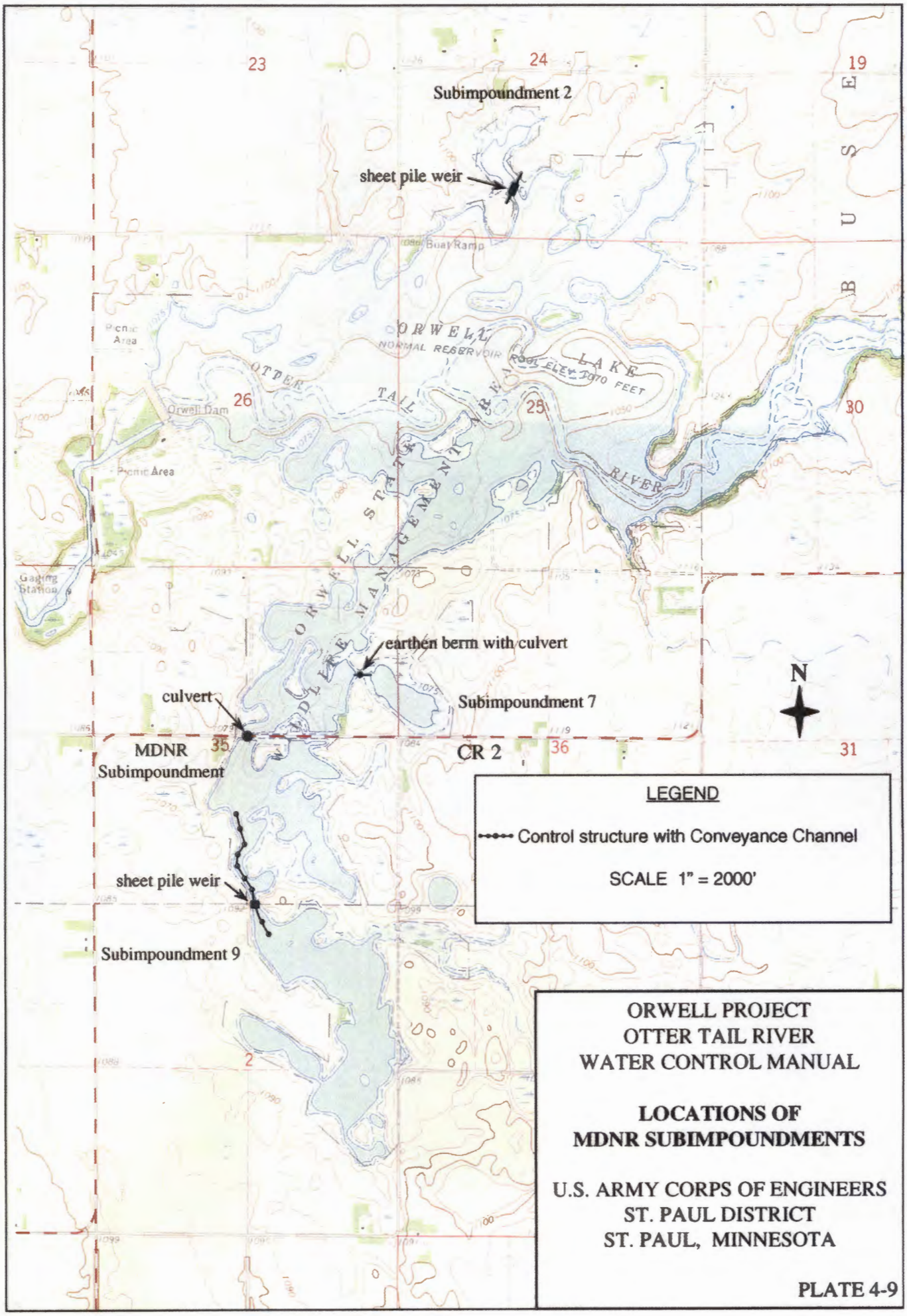


ORWELL RESERVOIR PROJECT
OTTERTAIL RIVER
WATER CONTROL MANUAL

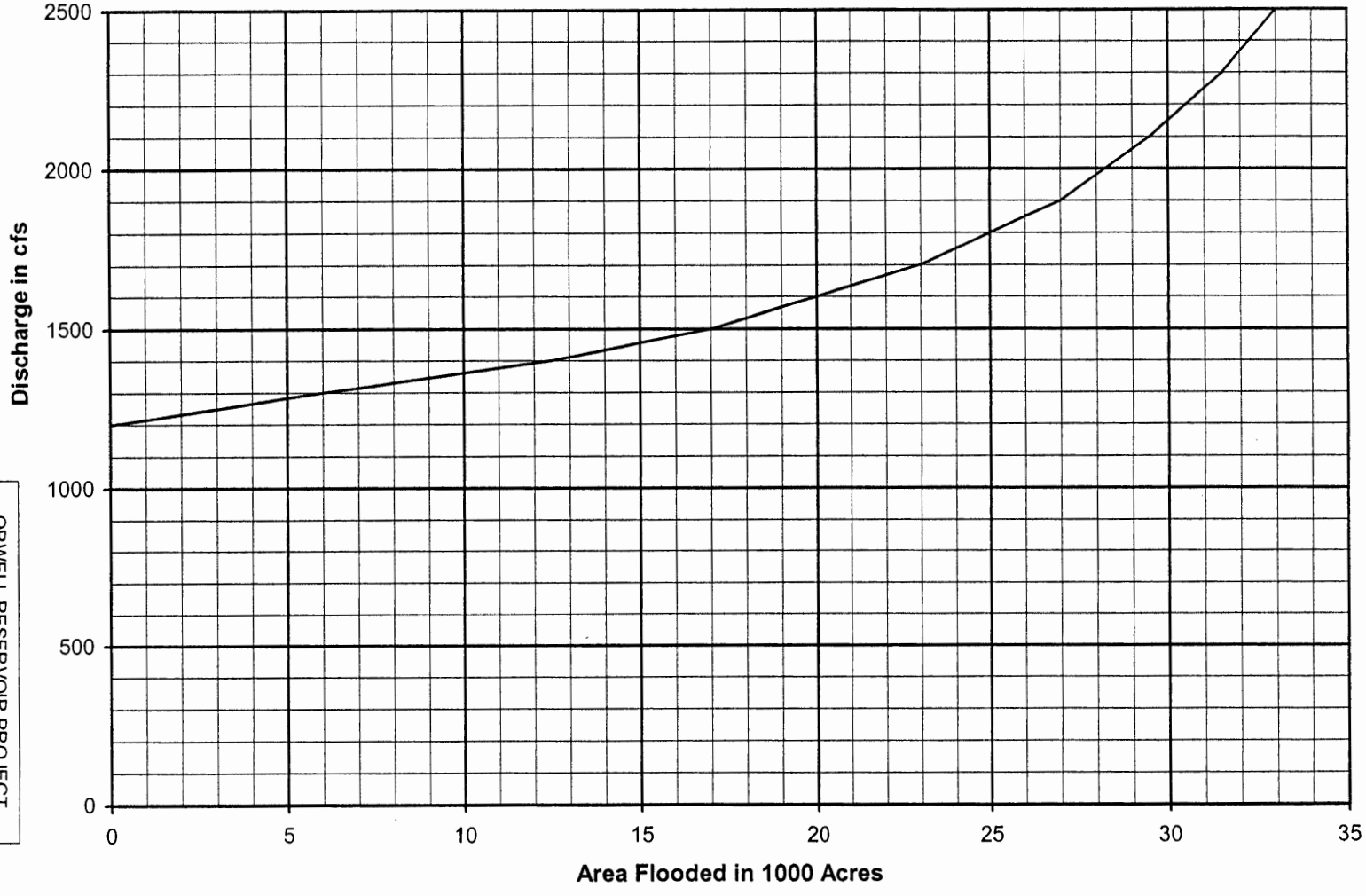
STAGE-DISCHARGE
U.S.G.S. GAGE NO. 05051500
RED RIVER OF THE NORTH
AT WAHPETON, NORTH DAKOTA

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

PLATE 4-8



DISCHARGE - AREA FLOODED
AGRICULTURAL AREA DOWNSTREAM OF ORWELL DAM



ORWELL RESERVOIR PROJECT
OTTERTAIL RIVER
WATER CONTROL MANUAL

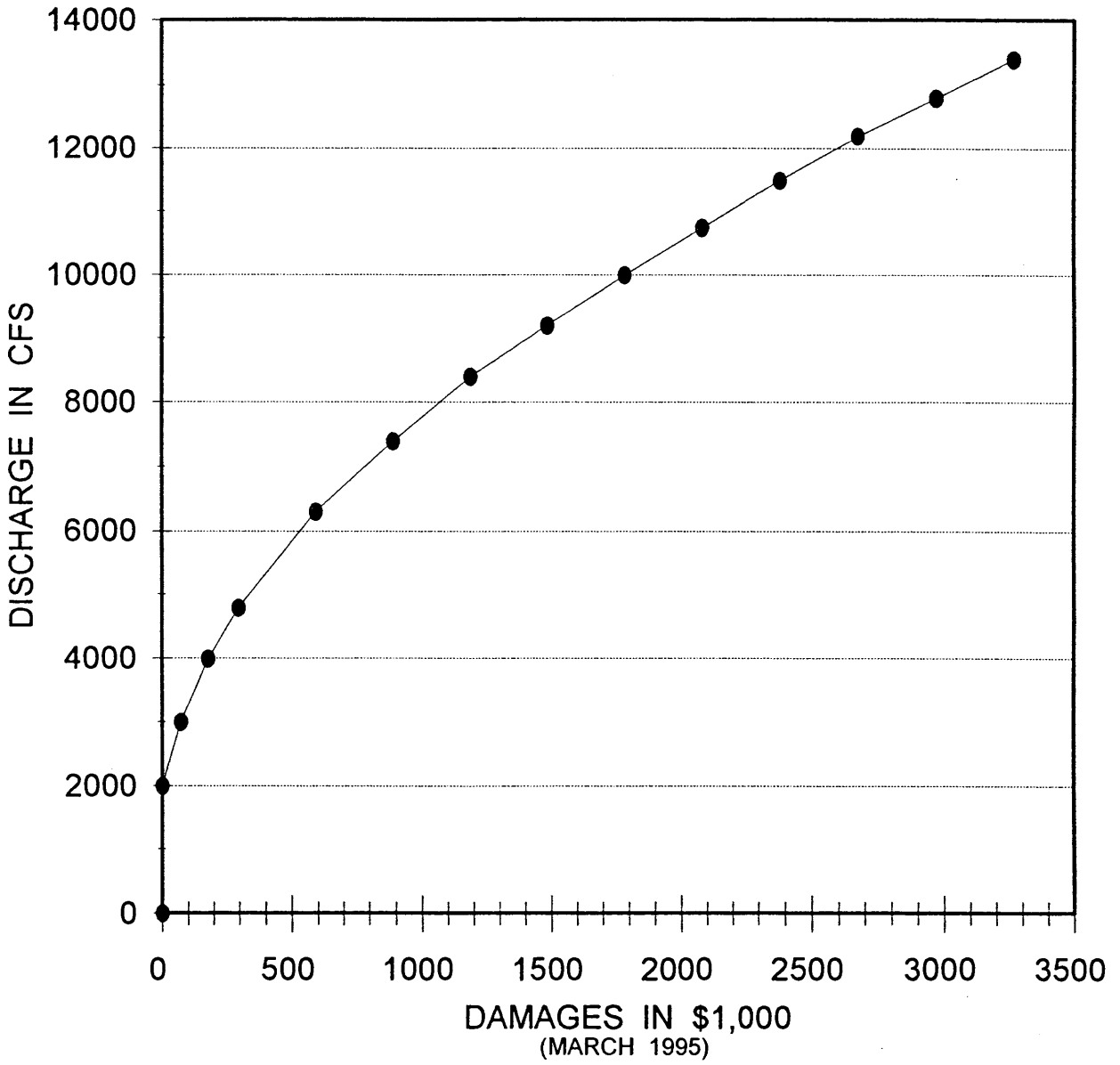
DISCHARGE-AREA FLOODED AGRICULTURAL AREA DOWNSTREAM OF ORWELL DAM

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

PLATE 4-10

ORWELL PROJECT

WAHPETON URBAN
DISCHARGE - DAMAGE



WAHPETON URBAN DAMAGES ARE REFERENCED TO THE RED RIVER OF THE NORTH AT WAHPETON, N.D. U.S.G.S. GAGE NO. 05051500

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

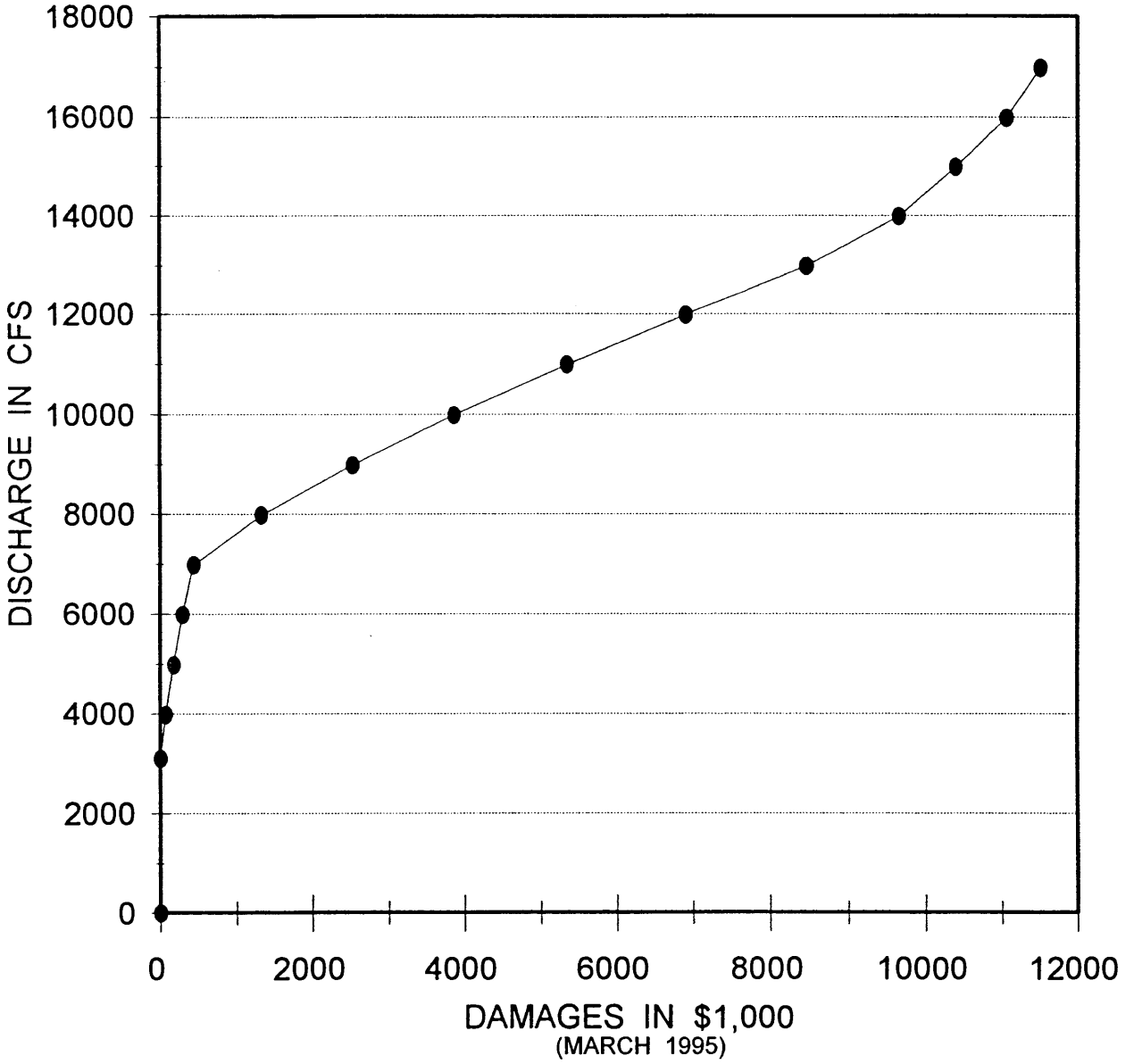
WAHPETON URBAN DISCHARGE-DAMAGE

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

PLATE 4-11

ORWELL PROJECT

BRECKENRIDGE URBAN
DISCHARGE - DAMAGE



BRECKENRIDGE URBAN DAMAGES ARE REFERENCED TO THE RED RIVER OF THE NORTH AT WAHPETON, N.D. U.S.G.S. GAGE NO. 05051500

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

BRECKENRIDGE URBAN DISCHARGE-DAMAGE

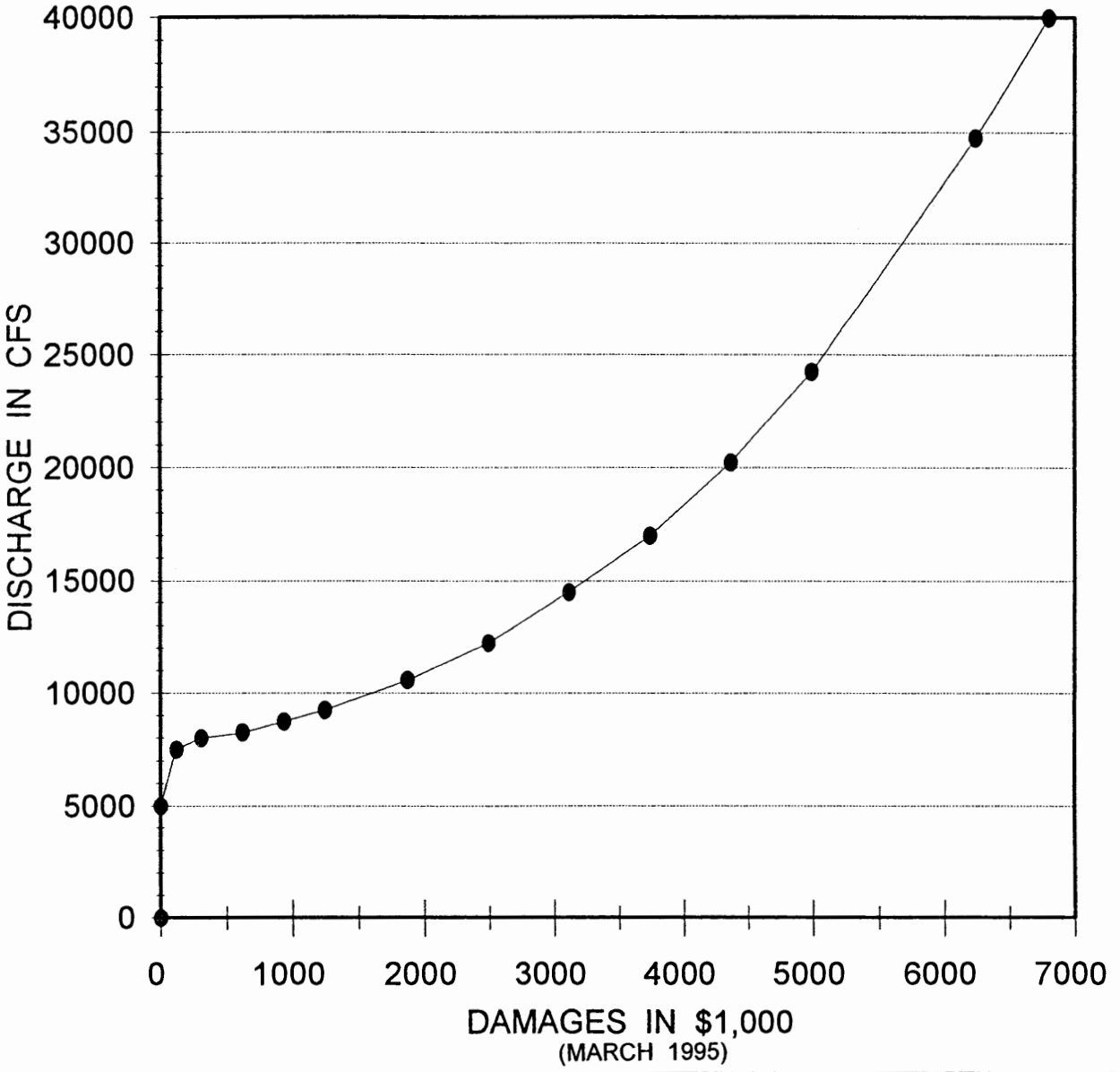
U.S. ARMY CORPS OF ENGINEERS
ST. PAUL DISTRICT
ST. PAUL, MINNESOTA

PLATE 4-12

ORWELL PROJECT

FARGO URBAN

DISCHARGE - DAMAGE



FARGO URBAN DAMAGES ARE REFERENCED TO THE RED RIVER OF THE NORTH AT FARGO, N.D. U.S.G.S. GAGE NO. 05054000

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

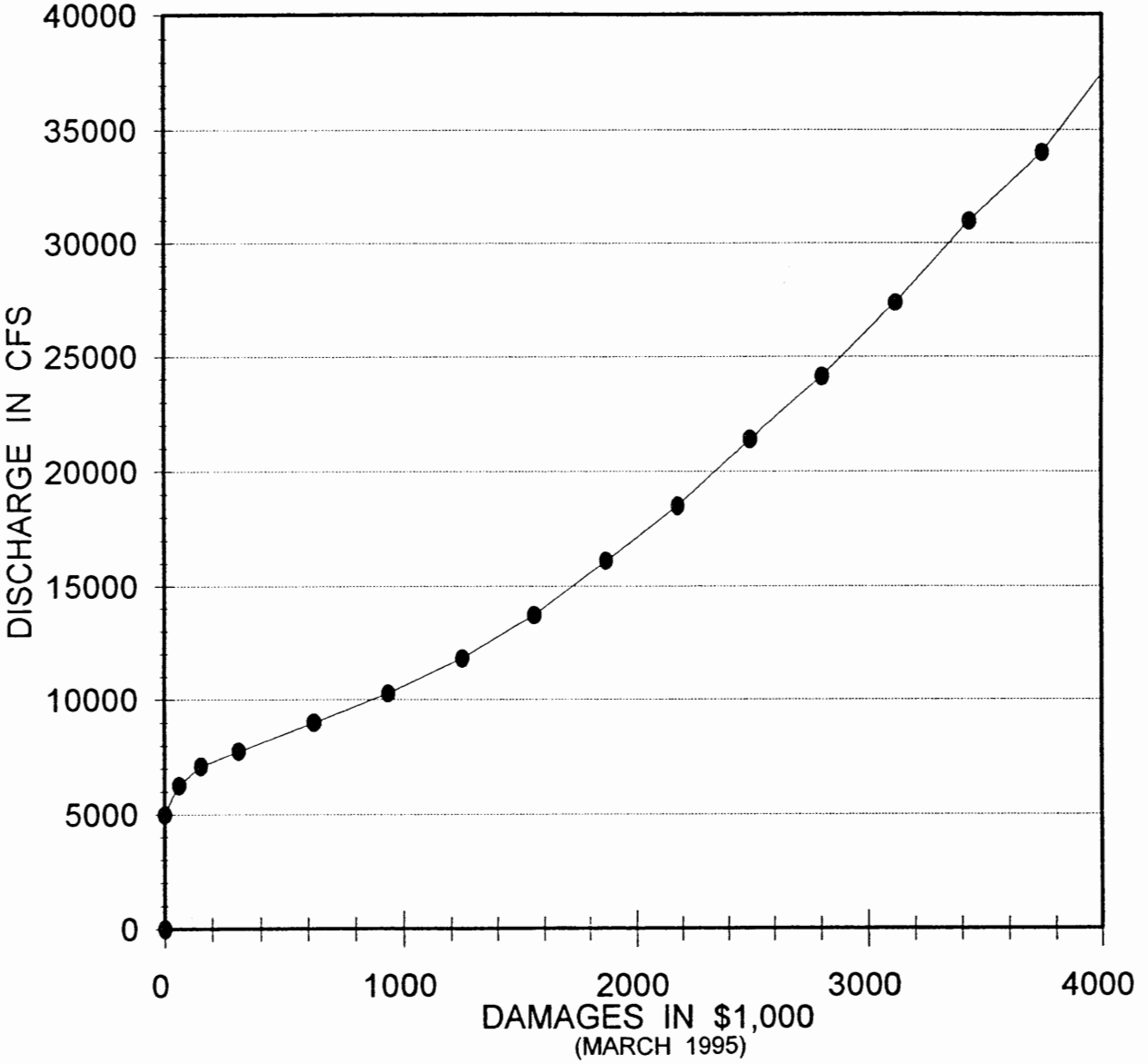
FARGO URBAN DISCHARGE-DAMAGE

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

PLATE 4-13

ORWELL PROJECT

MOORHEAD URBAN
DISCHARGE - DAMAGE



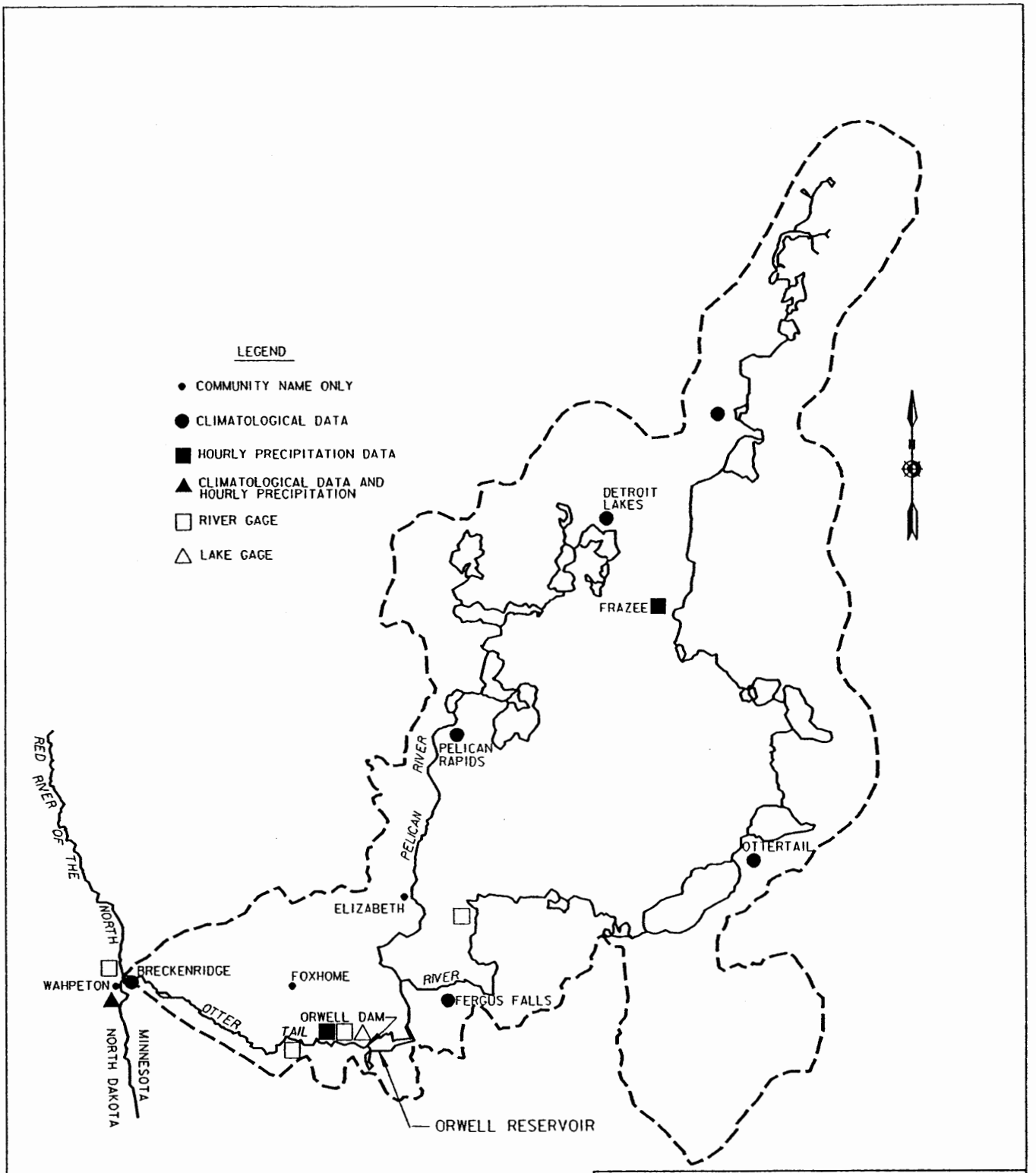
MOORHEAD URBAN DAMAGES ARE REFERENCED TO THE RED RIVER OF THE NORTH AT FARGO, N.D. U.S.G.S GAGE NO. 05054000

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

MOORHEAD URBAN DISCHARGE-DAMAGE

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

PLATE 4-14

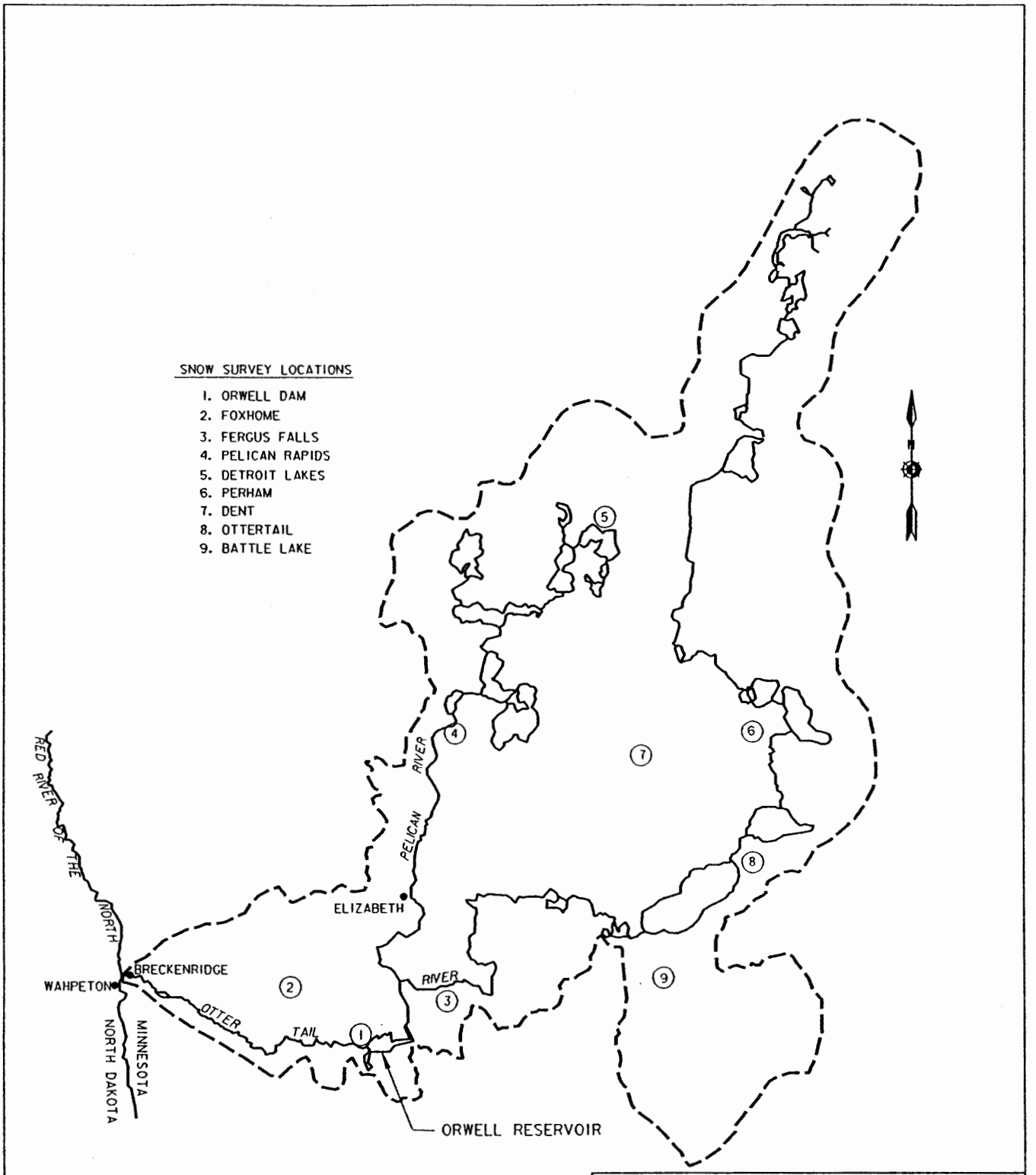


ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

HYDROMETEOROLOGICAL STATIONS

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

PLATE 5-1

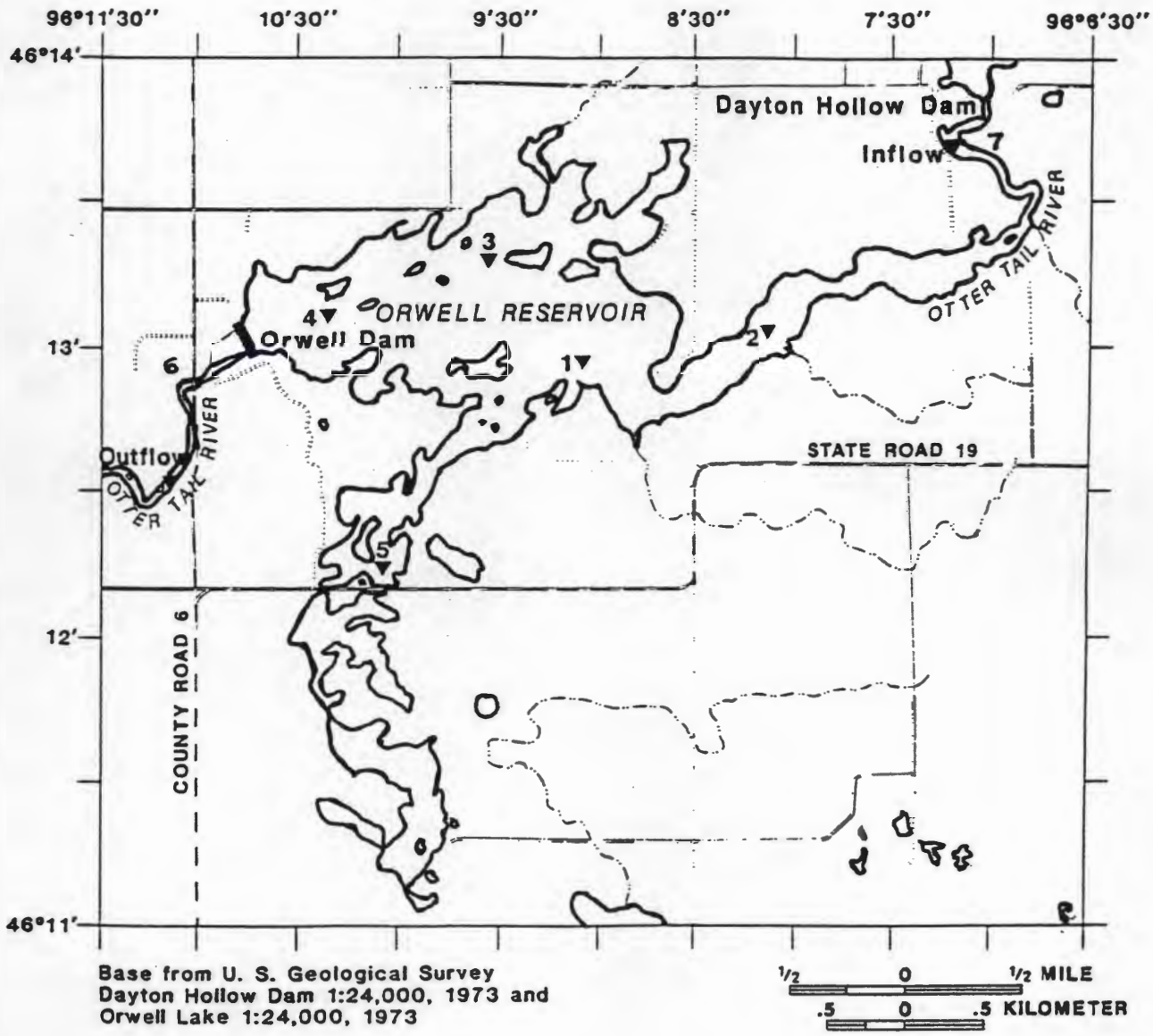


ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

SNOW SURVEY LOCATIONS

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

PLATE 5-2



EXPLANATION

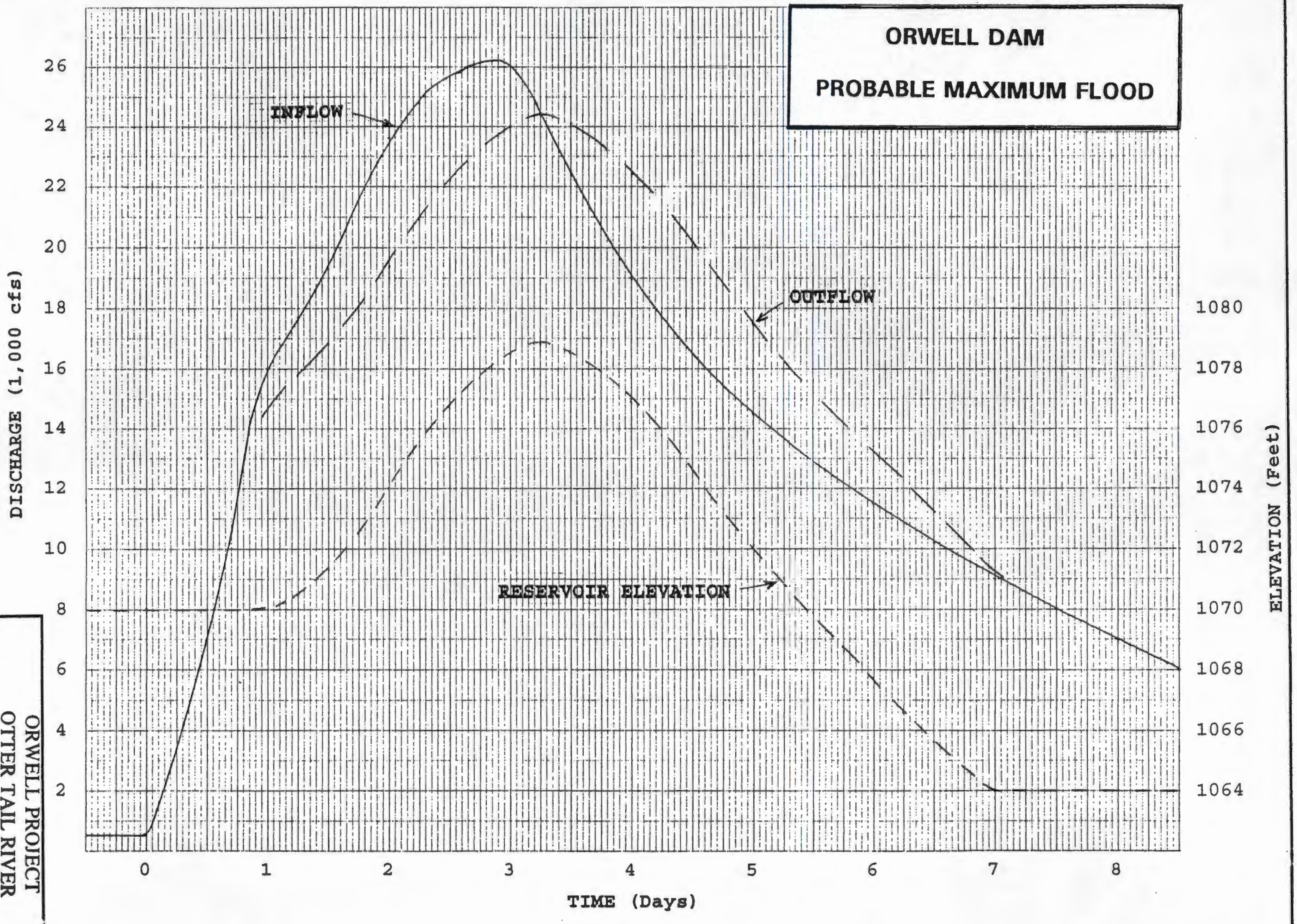
1▼ SAMPLING SITE

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

WATER QUALITY STATIONS

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

PLATE 5-3

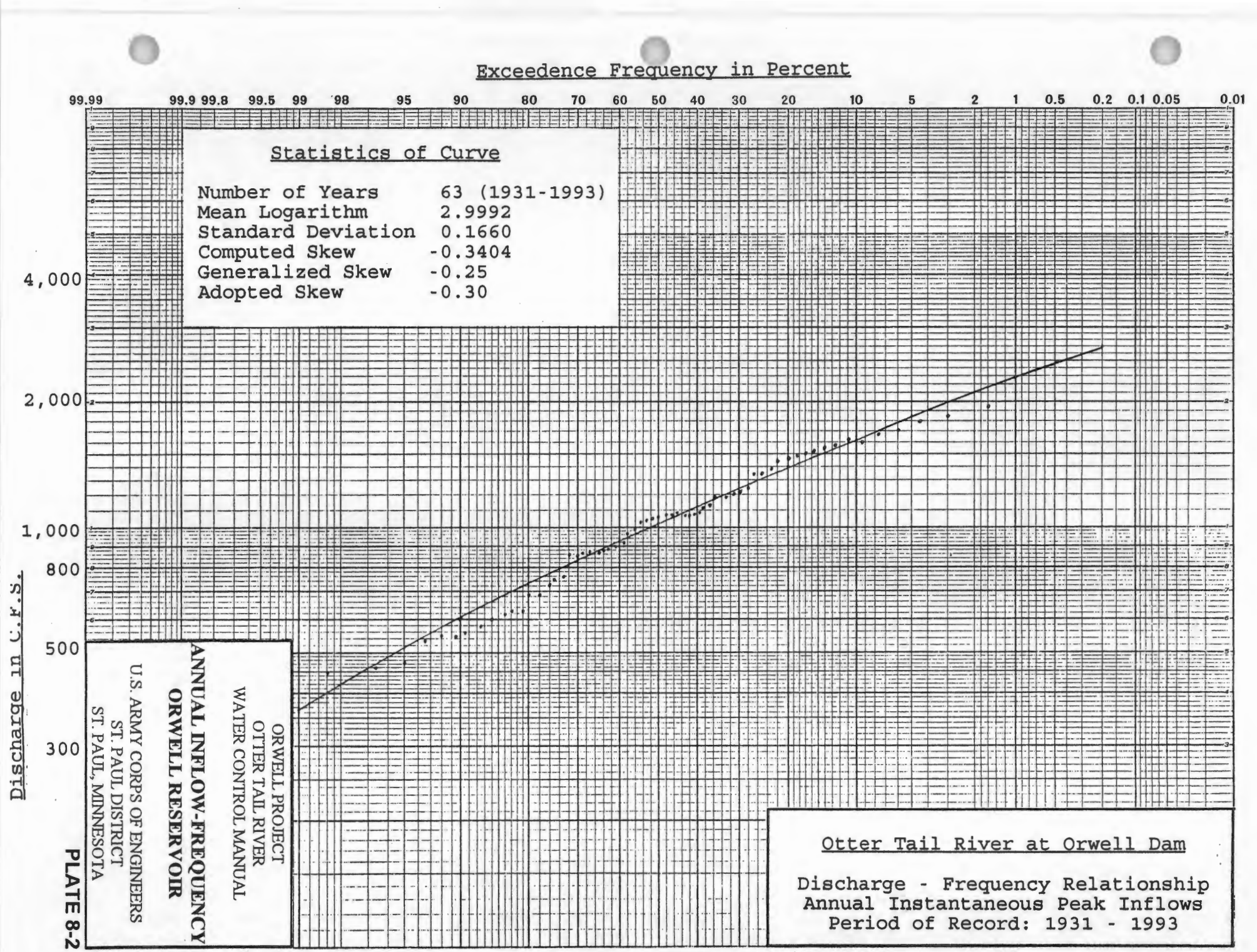


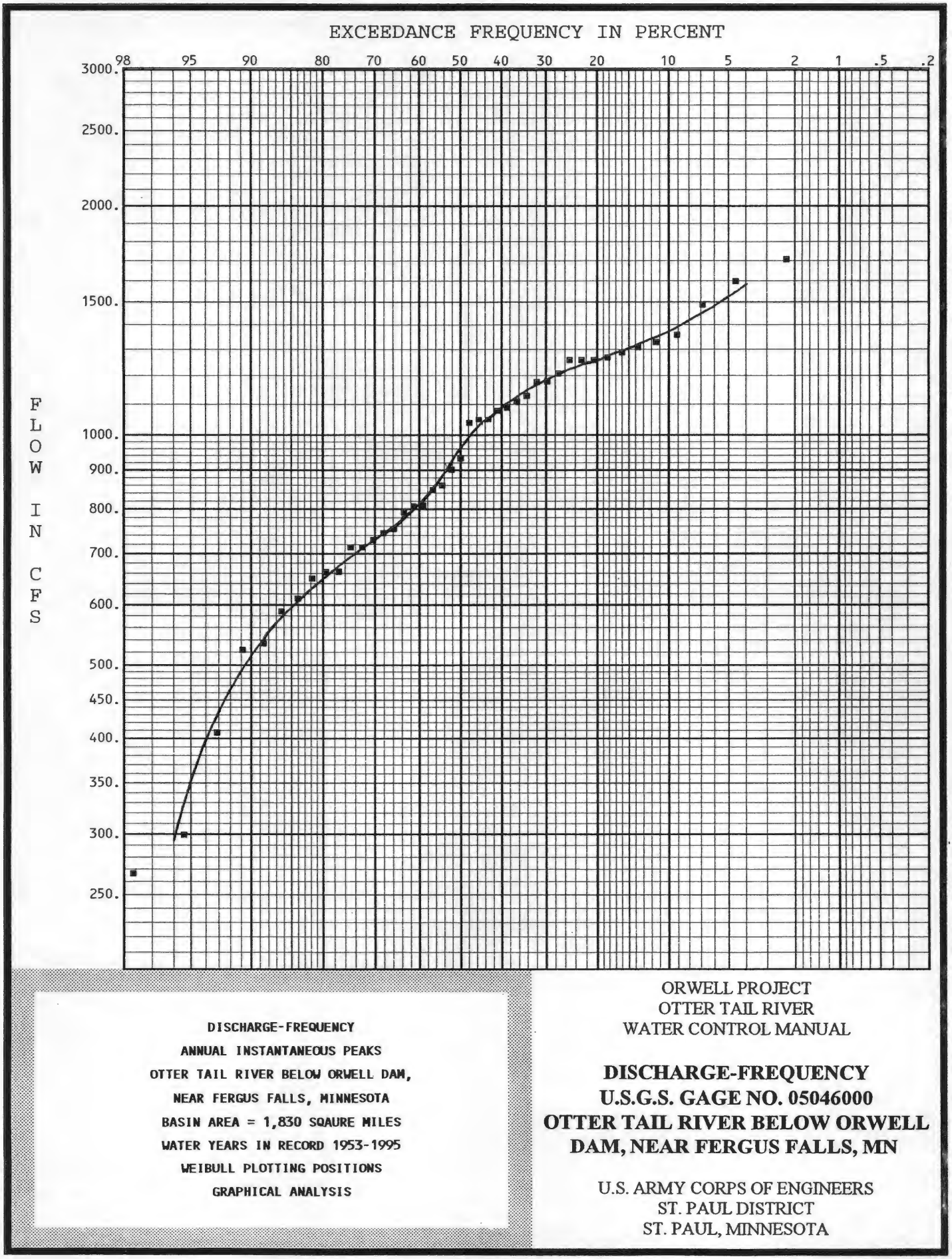
ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

PROBABLE MAXIMUM FLOOD HYDROGRAPHS

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

PLATE 8-1





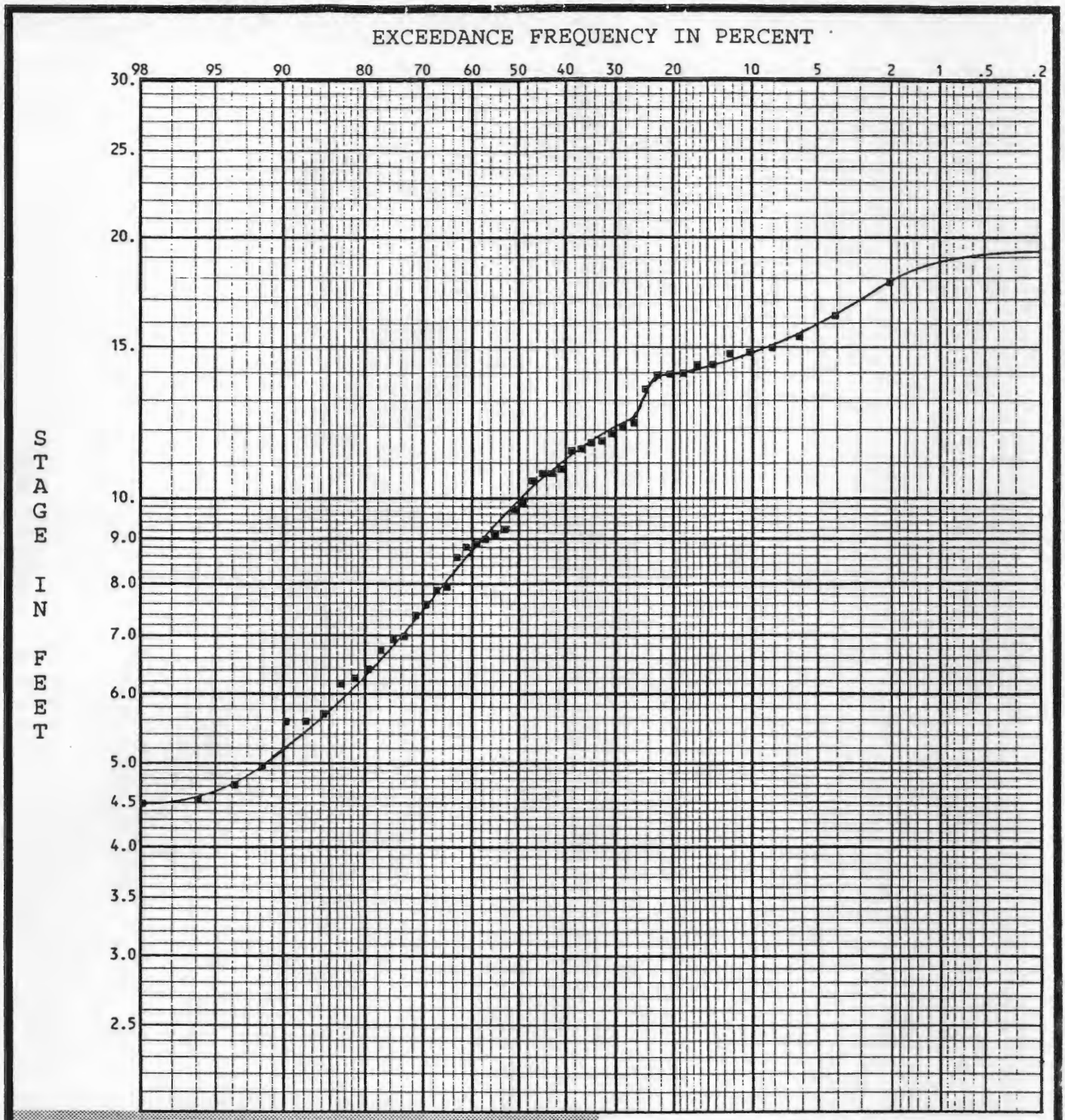
DISCHARGE-FREQUENCY
ANNUAL INSTANTANEOUS PEAKS
OTTER TAIL RIVER BELOW ORWELL DAM,
NEAR FERGUS FALLS, MINNESOTA
BASIN AREA = 1,830 SQAURE MILES
WATER YEARS IN RECORD 1953-1995
WEIBULL PLOTTING POSITIONS
GRAPHICAL ANALYSIS

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

DISCHARGE-FREQUENCY
U.S.G.S. GAGE NO. 05046000
OTTER TAIL RIVER BELOW ORWELL DAM, NEAR FERGUS FALLS, MN

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

PLATE 8-3



STAGE-FREQUENCY CURVE

ANNUAL INSTANTANEOUS PEAKS

MIXED POPULATION CURVE (ICE AND OPEN WATER EVENTS)

WATER YEARS IN RECORD 1942 - 1989

GAGE ZERO = 942.97 FEET (NGVD 1929)

BASIN AREA = 4,010 SQ MI (1,020 SQ MI EFFECTIVE)

WEIBULL PLOTTING POSITIONS

PLOTTED GRAPHICALLY

ORWELL PROJECT
OTTER TAIL RIVER
WATER CONTROL MANUAL

STAGE-FREQUENCY
U.S.G.S. GAGE NO. 05051500
RED RIVER OF THE NORTH
AT WAHPETON, ND

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

PLATE 8-4

The Persistent Identifier
under Project: Orwell Reservoir Dam, Minnesota
for Title: **Water Control Manual Flood Control Otter Tail River, Minnesota**
with POC: Christine Afdahl

is: USACE-MVP-0000118572

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