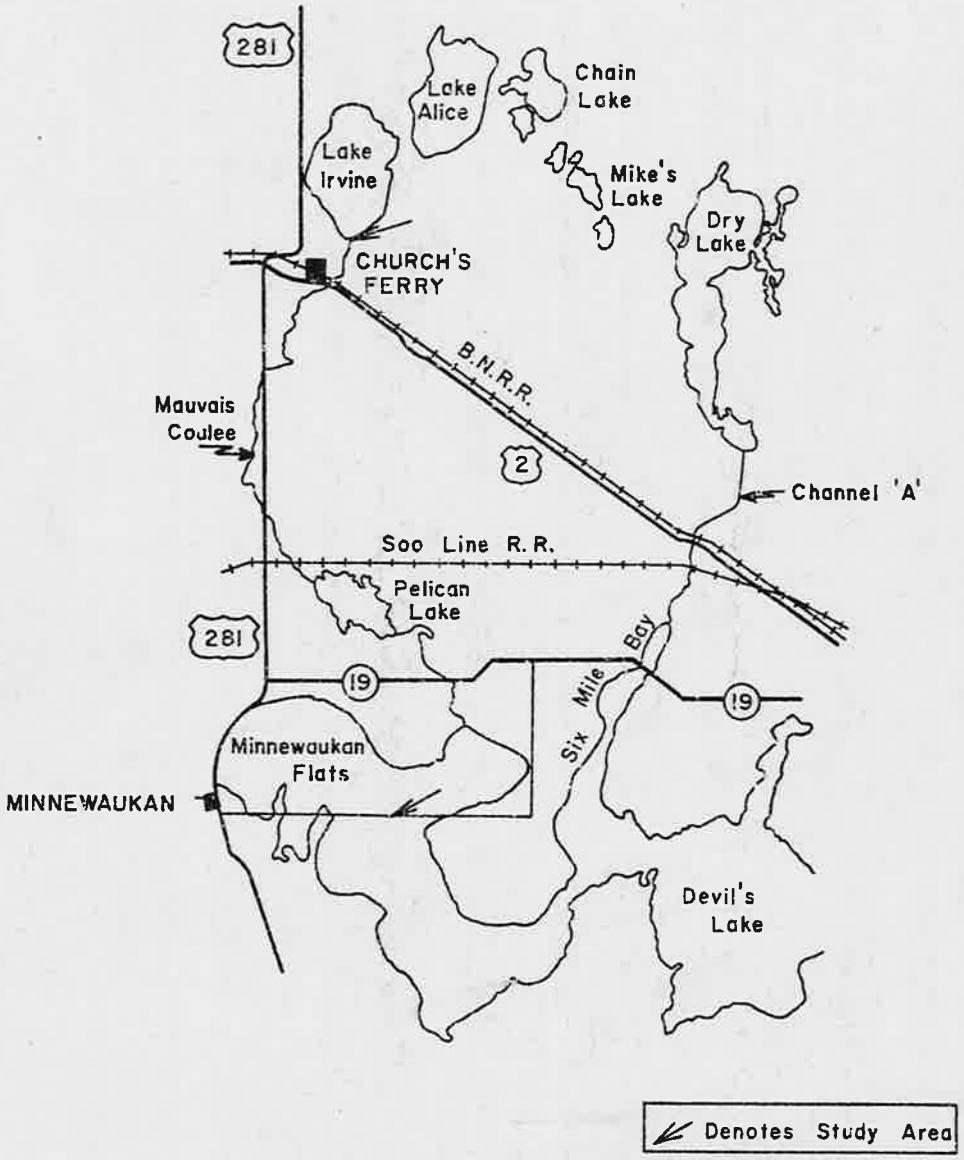
PRELIMINARY ENGINEERING REPORT

LOWER MAUVAIS COULEE
WATER SURFACE PROFILE STUDY

S.W.C. PROJECT NO. 1614



NORTH DAKOTA
STATE WATER COMMISSION
DECEMBER 1980

PRELIMINARY ENGINEERING REPORT

Lower Mauvais Coulee
Water Surface Profile Study

SWC Project #1614
December, 1980

North Dakota State Water Commission
State Office Building
900 East Boulevard
Bismarck, North Dakota 58505

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1. INTRODUCTION

The area around Chain Lake, Lake Alice and Lake Irvine has a history of flooding problems. These are due mostly to sheet flooding caused by spring runoff which raises the lake levels. To help remedy this problem, it was suggested that the control structure at the outlet to Lake Irvine be modified to allow more flow out of the lake. It was recognized that these increased flows could cause flooding problems along Lower Mauvais Coulee between Lake Irvine and Devils Lake.

On October 12, 1979, the North Dakota State Water Commission entered into an agreement with the Devils Lake Joint Water Management Board. The purpose of the agreement was the development of water surface profiles along Mauvais Coulee and portions of its tributaries. These profiles will aid in determining the effect of existing channel conditions and structures on selected flows. A copy of the agreement is included in Appendix A. The original agreement called for the investigation of Mauvais Coulee from Lake Irvine to Pelican Lake. On April 30, 1980, the original agreement was amended to expand the study area so it extended from Lake Irvine to the road across Devils Lake four miles east of the city of Minnewaukan.

The total length of Mauvais Coulee included in this study is 23 miles. Figure 1 is a general map of the area showing the location of Chain Lake, Devils Lake, Channel A and the Lower Mauvais Coulee.

II. DESCRIPTION OF PROBLEM

The Devils Lake Basin is a closed drainage basin with a total area of approximately 3,800 square miles. Lower Mauvais Coulee, at the outlet of Lake Irvine, has a drainage area of nearly 2,000 square miles.

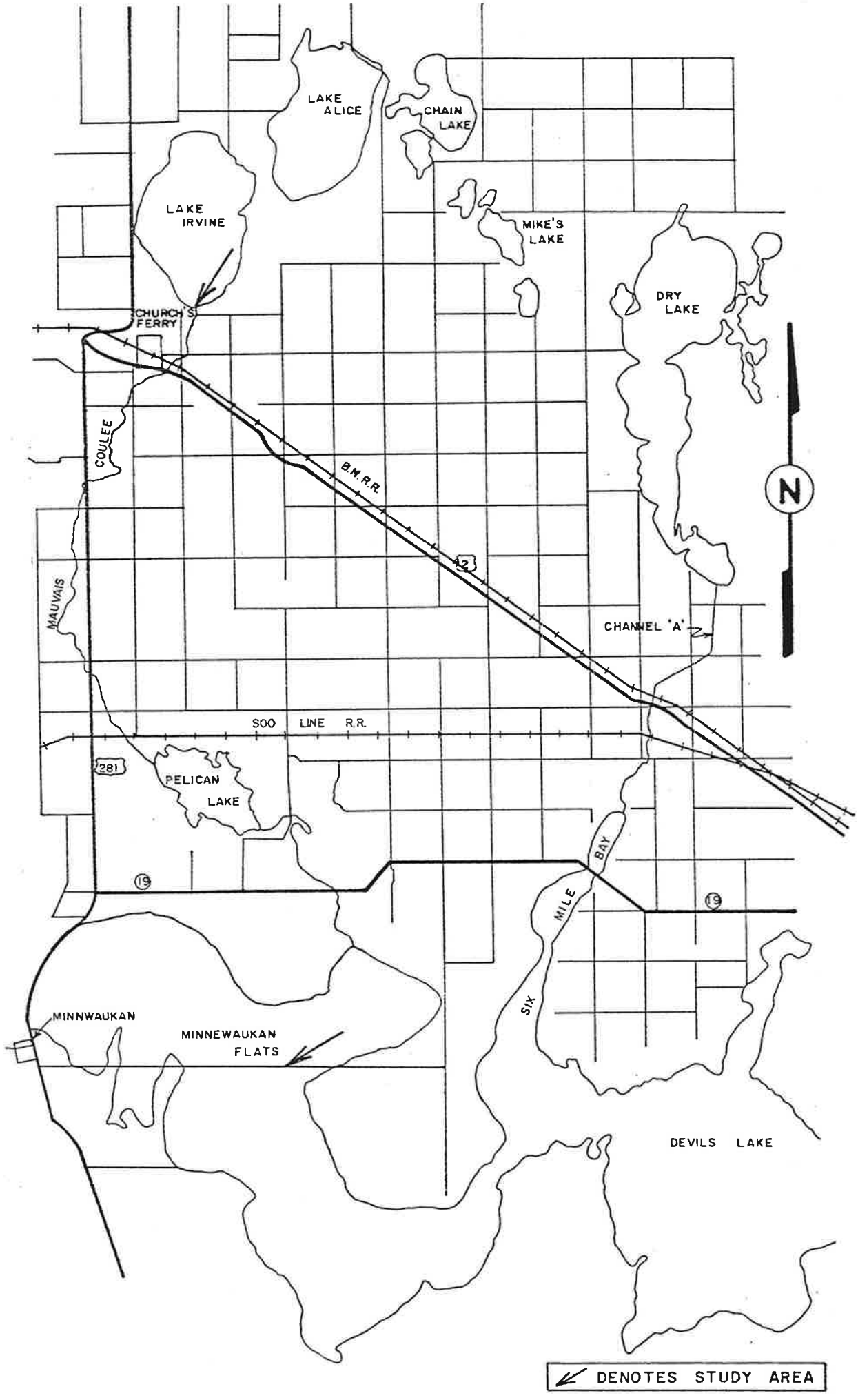

LAKE ALICE
CHAIN LAKE
LAKE IRVINE
MIKE'S LAKE
DRY LAKE
CHURCH'S FERRY
COULEE
B.M.R.R.
MAUVAIS
N
CHANNEL 'A'
SOO LINE R.R.
281
PELICAN LAKE
BAY
MILE
SIX
MINNWAUKAN
MINNEWAUKAN FLATS
DEVILS LAKE
DENOTES STUDY AREA

Figure 1

Little Coulee is the only major tributary to Mauvais Coulee below Lake Irvine and has a drainage area of approximately 400 square miles.

A main problem in the basin is damage to agricultural crops by sheet flooding. In the spring, flood waters raise the levels of the many lakes and sloughs and inundate thousands of acres of adjacent cropland. Table 1 shows the area of various lakes at the outlet elevation, the meandered elevation, and the 1979 flood level. Approximately 16,000 acres of deeded land were flooded between Dry Lake and Lake Irvine in 1979. In addition, another 1,500 acres of deeded land were flooded between Pelican Lake and Devils Lake in 1979. Due to Channel "A", flooding in 1979 was less severe than in 1974. It was estimated that 19,000 acres of deeded land were flooded between Dry Lake and Lake Irvine in 1974 and that 13,000 acres were flooded in 1969.

TABLE 1

Lake Surface Areas

Lake	Outlet[1] Level	Outlet[1] Acres	Meandered[2] Level	Meandered[2] Acres	1979 Peak Level	1979 Peak Acres
Dry	1445.0	4,450	1446.5	5,500	1451.0	7,500
Mikes	1443.0	600	1445.6	950	---	[3]
Chain	1441.6	1,000	1443.2	1,050	---	[3]
Alice	1441.6	2,800	1443.2	3,500	1447.1	[3]
Irvine	1441.0	3,400	1441.0	3,700	---	22,000[3]
Pelican	---	---	1435.0	1,100	1436.6	2,150
Oswalds Bay	---	---	1435.0	650	1435.0	1,100
TOTALS	---	---	---	16,450	---	32,750

[1] The level at which the lake will discharge to another area. The level shown is only approximate and may change from year to year.

[2] The level at which the lake was meandered. The levels shown are estimates.

[3] During flood periods, these lakes are normally joined. The acreage shown only includes the flooded land that became part of one of the lakes. It does not include all flooded farmland.

CHANNEL "A"

Channel "A" was constructed in 1978 by the Ramsey County and Cavalier County Water Management Boards. The channel connects Dry Lake to Six Mile Bay on Devils Lake. Its intended purpose was to decrease flooding in the upper lakes area by moving the water into Devils Lake more quickly. Under natural conditions, the water moved from Sweetwater-Morrison Lakes to Dry Lake to Mikes Lake to Chain Lake and on to Lake Alice and Lake Irvine. Lower Mauvais Coulee connects Lake Irvine to Devils Lake. Channel "A" divides the watershed into two sections. Lake Sweetwater, Lake Morrison and Dry Lake now outlet into Channel "A". The remaining lakes still follow the natural watercourse.

A control structure has been proposed for the natural outlet of Dry Lake into Mikes Lake. The proposal includes an earth embankment with an overflow spillway at elevation 1449.5 msl. No water would be able to flow to Mikes Lake until Dry Lake reached 1449.5 msl.

The operating plan for Dry Lake and Channel "A" requires that Dry Lake be drawn down to elevation 1445.0 each fall. The Channel "A" control gates would remain open during the winter months and also during the snowmelt period. These gates could be temporarily closed after the peak flood period. Details of the Channel "A" operating plan are included in Appendix B.

III. ENGINEERING ANALYSIS

STUDY PROCEDURES

To begin with, the historical flood conditions were determined by defining historical lake levels, discharge rates and acres flooded. Next, a base condition was found by estimating the 1979 flood levels

that would have resulted if Channel "A" would have been fully operational. In order to estimate the flooding impact, some field data was necessary. Therefore, a topographic survey was conducted. This survey included the measuring of stream profiles, cross sections, and structural details along Lower Mauvais Coulee.

After the stream characteristics were measured and the historic flood levels were studied, water surface profiles were developed. The profiles were developed with the use of the Corps of Engineers Water Surface Profile Program, HEC 2. This program was used to develop flood profiles along Lower Mauvais Coulee of the 1979 historical flood. Flood level information for a flow equal to half the 1979 flood, approximately the 25 year flood, was developed. In 1979 Channel "A" was not fully operational. Therefore, flood levels were calculated along Lower Mauvais Coulee assuming Channel "A" to be fully operational. Flood levels were also estimated for the case in which various structural and channel modifications were implemented along the coulee.

Using the water surface profiles, the impacts of the flood levels resulting from the alternatives were evaluated. These impacts were studied for the entire area from Dry Lake to the Minnewaukan Flats portion of Devils Lake. Next, the cost of these alternates was estimated. Then, after considering the impacts on flood levels and the costs, recommendations for channel improvement along Lower Mauvais Coulee were made.

HISTORICAL FLOOD EVENTS

The 1979 flood in the Devils Lake Basin generated the greatest volume of runoff since record keeping began. It increased the storage in Devils Lake from 461,000 acre-feet in April of 1979 to 746,000 acre-

feet by September of 1979. Based on the annual lake fluctuations recorded since 1867, it appears unlikely that the 1979 volume was exceeded in the years between 1867 and 1980. The total storage in Devils Lake has been increased by 100,000 acre-feet in only four years since 1930. In 1979 the storage was increased by 285,000 acre-feet. The increase in storage was 200,000 acre-feet in 1974, 120,000 acre-feet in 1950 and 100,000 acre-feet in 1969.

The 1950 runoff may have been the second largest volume produced over the entire basin. However, in 1950 many of the wetlands and lakes in the upper basin were low or dry and the area around them was undrained. As a result, a lower percentage of the total runoff reached Devils Lake.

BASE FLOOD

The Devils Lake Basin has undergone too many changes to accurately define the 25 year and 100 year floods from historical data. For this reason the 1979 flood was considered the base flood rather than the typical 100 year event. Since it provided the highest volume of inflow to Devils Lake since 1867, the 1979 flood may be approximately equal to a 100 year flood. The total flow in Lower Mauvais Coulee in 1979 was 170,000 acre-feet. Channel "A" carried an additional 56,000 acre-feet. Therefore, the area above Lake Irvine contributed a total inflow of 226,000 acre-feet.

The State Water Commission normally requires all bridges to be designed for the 25 year flood. For purposes of this study, a flood equal to 50 percent of the 1979 base flood was used to approximate the 25 year event. This 25 year base flood was used to determine the needed structure sizes of the stream crossings. Its magnitude is larger than the 1969 flood but smaller than the flood of 1974. With Channel "A"

fully operational, a 25 year flood would result in a peak level at Lake Alice-Irvine of near 1445.2 msl. A 25 year flood would yield a peak discharge from Lake Irvine of 700 cfs, and the flow below the confluence of Little Coulee would increase to 900 cfs.

Channel "A" was only operated for part of the year in 1979 (Appendix D shows the discharge of Channel "A" in 1979). In addition, the proposed control structure across the natural outlet of Dry Lake has not been constructed. Therefore, to accurately assess the impacts of any proposed changes to Lower Mauvais Coulee, it was necessary to adjust the 1979 flows to reflect full operation of Channel "A" according to the proposed operating plan.

Table 2 summarizes the historical and projected flows at Dry Lake and Lake Irvine for a 1979 equivalent runoff.

TABLE 2

1979 Streamflow at Dry Lake with Channel "A"

	1979 Historical	Channel A Fully Operational
Inflow	80,000 a.f.	80,000 a.f.
Channel "A" Outflow	56,000 a.f.	75,000 a.f.
Natural Outlet Flow	24,000 a.f.	5,000 a.f.

1979 Streamflow at Lake Irvine with Channel "A"

	1979 Historical	Channel A Fully Operational
Inflow	170,000 a.f.	151,000 a.f.
Natural Outflow	1,030 cfs	1,000 cfs

HYDROLOGIC INVESTIGATION

Seventeen crossings exist on Lower Mauvais Coulee between Lake Irvine and Devils Lake. These structures are generally inadequate to pass a flood equal to that of 1979. Table 3 lists specific details of

the structure. Figure 2 is a map of the study area showing the structure locations.

In 1979, the peak discharge from Lake Irvine was 1030 cfs. Below the confluence with Little Coulee, the peak discharge on Lower Mauvais Coulee was 1400 cfs. Figure 3 shows the water surface profile of the 1979 historical flood from Lake Irvine to the upper end of Pelican Lake. Figure 4 shows the 1979 water surface profile from Pelican Lake to the end of the study area. The figures also show the water surface profiles of the 25 year base flood.

A combination of high stream flows and high backwater caused by downstream conditions resulted in the overtopping of several roads in 1979. The following roads crossing Lower Mauvais Coulee were overtopped in 1979:

1. Structure No. 1 - Lake Irvine Outlet Road
2. Structure No. 2 - Old Highway #2
3. Structure No. 6 - Benson County Road
4. Structure No. 14 - Bridge Below Pelican Lake

Minnewaukan Road would have overtopped in 1979, had the roadway not been cut to decrease upstream flooding problems.

Six crossings caused at least six inches of backup water during the 1979 flood. Structure number six is a 26-foot long bridge that was overtopped and increased the water level by about six to eight inches. Structure number eight consists of seven 5'x 7' culverts. The inverts are at varying elevations. These culverts increased the water surface elevation 1.8 feet and are the greatest restriction between Lake Irvine and Pelican Lake. Structure number nine is a 27 foot long bridge that caused a seven inch increase in water levels. This bridge is high enough but too narrow for high flows. The water levels increased approximately six inches behind structure number ten, a 47-foot long bridge.

ATKINS

MAZA

MAZA

TOWNER CO
BENSON CO

TOWNER CO
RAMSEY CO

BENSON CO
RAMSEY CO

IRVINE

CHAIN LAKES

LAC AUX MORTES NATIONAL WILDLIFE REFUGE

LAC AUX MORTES

LAKE IRVINE

NORMANIA

COULEE

COULEE

COULEE

Stink Lake

Silver Lake

Lake Mortes

Mauvais Coulee

Antiochia Ch

School No 7

Church's Ferry

STRUCTURE NO.1

STRUCTURE NO.2

STRUCTURE NO. 3

STRUCTURE NO.4

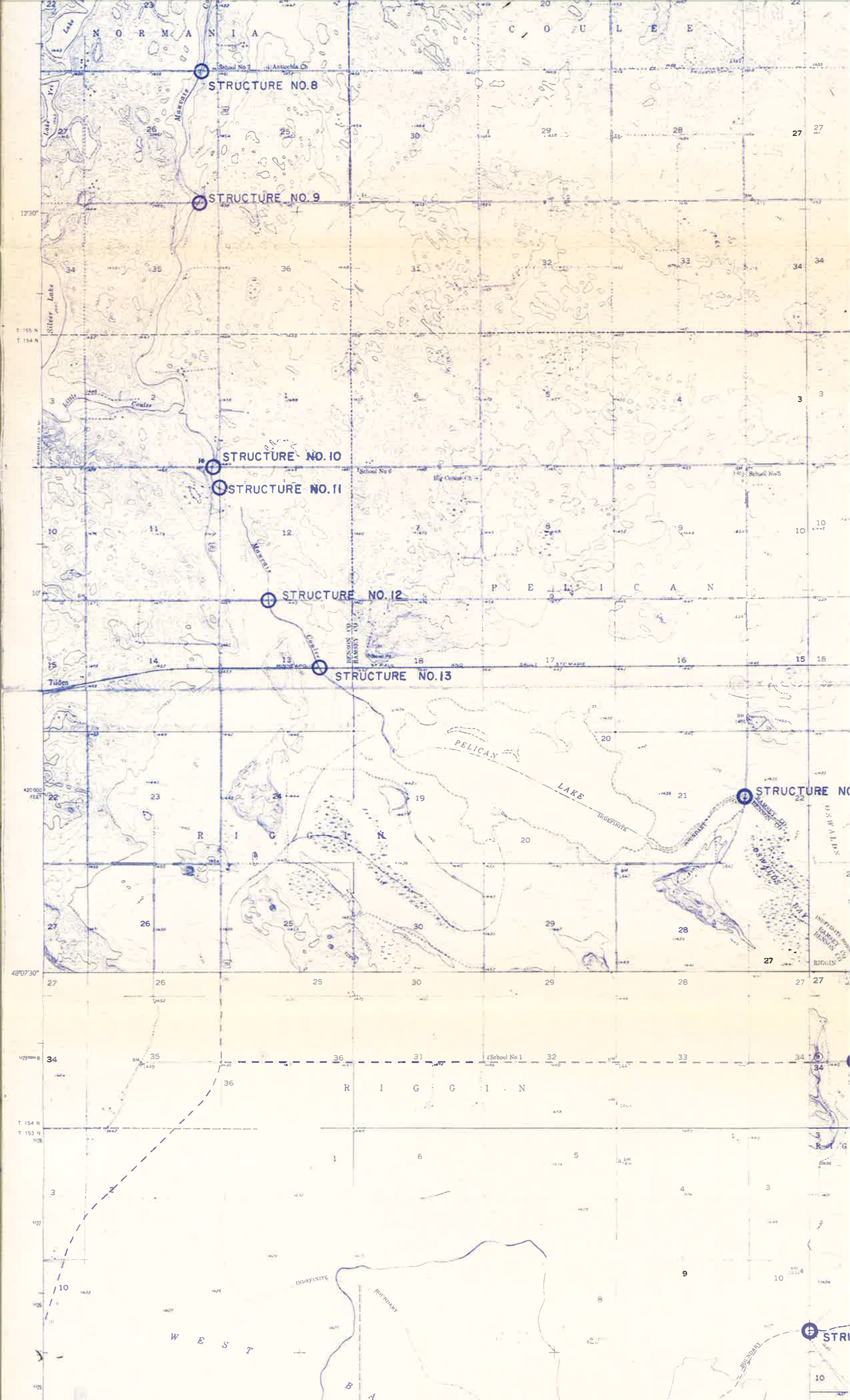
STRUCTURE NO.5

STRUCTURE NO.6

STRUCTURE NO.7

STRUCTURE NO.8

STRUCTURE NO. 9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COULEE
PELICAN
RIGGIN
WEST
Tilden
Antiochia Ch
School No 7
School No 6
School No 5
School No 1
Little Coulee
Big Coulee Ch
Silver Lake
PELICAN LAKE
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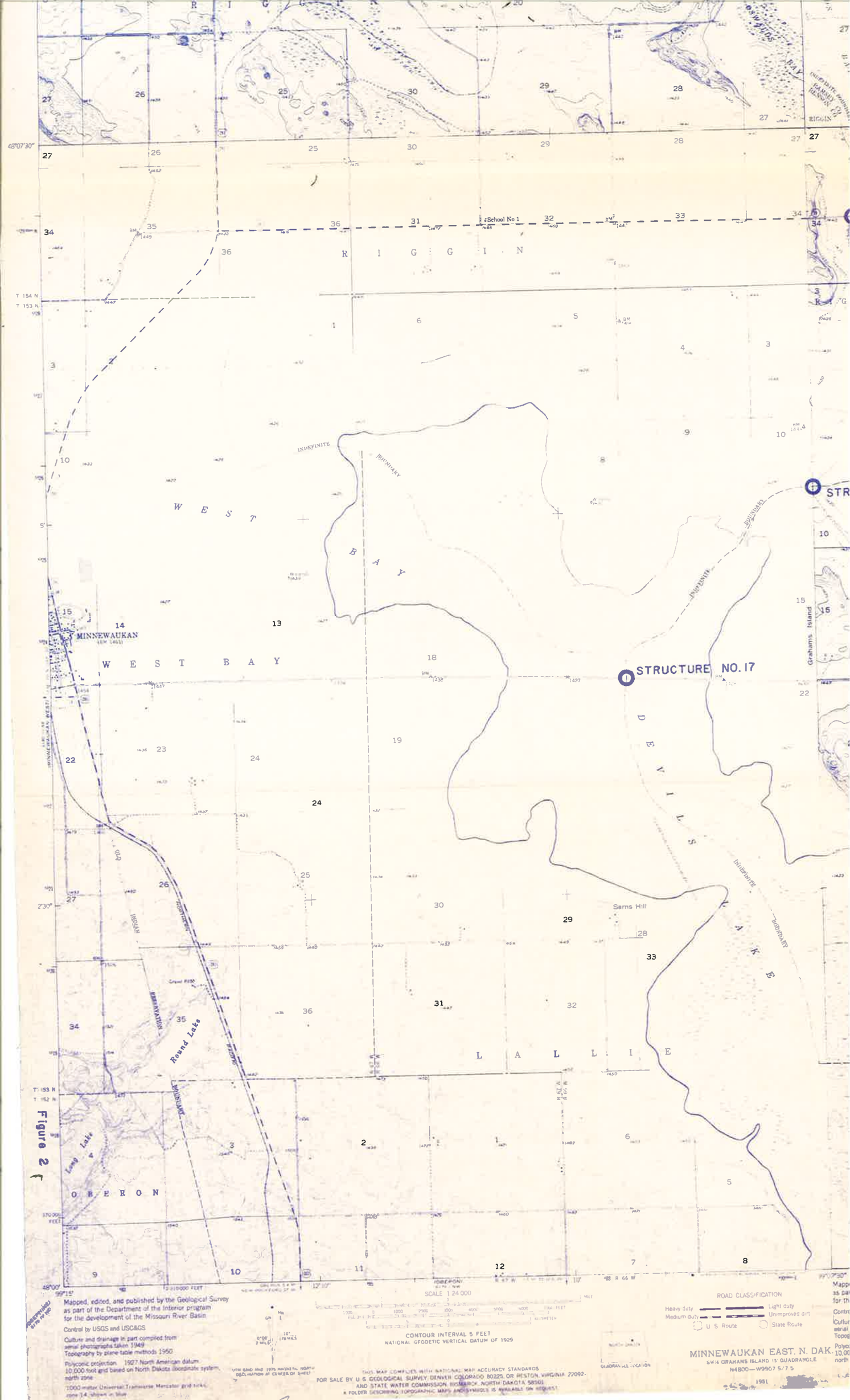


Mapped, edited, and published by the Geological Survey as part of the Department of the Interior program for the development of the Missouri River Basin

Control by USGS and USC&GS

Culture and drainage in part compiled from aerial photographs taken 1949

Topography by plane-table methods 1950

Polyconic projection. 1927 North American datum

10,000-foot grid based on North Dakota coordinate system, north zone

1000-meter Universal Transverse Mercator grid ticks, zone 14, shown in blue

SCALE 1:24 000

CONTOUR INTERVAL 5 FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

ROAD CLASSIFICATION

Heavy duty — Light duty

Medium duty — Unimproved dirt

U.S. Route — State Route

MINNEWAUKAN EAST, N. DAK.

SW/4 GRAHAMS ISLAND 15' QUADRANGLE

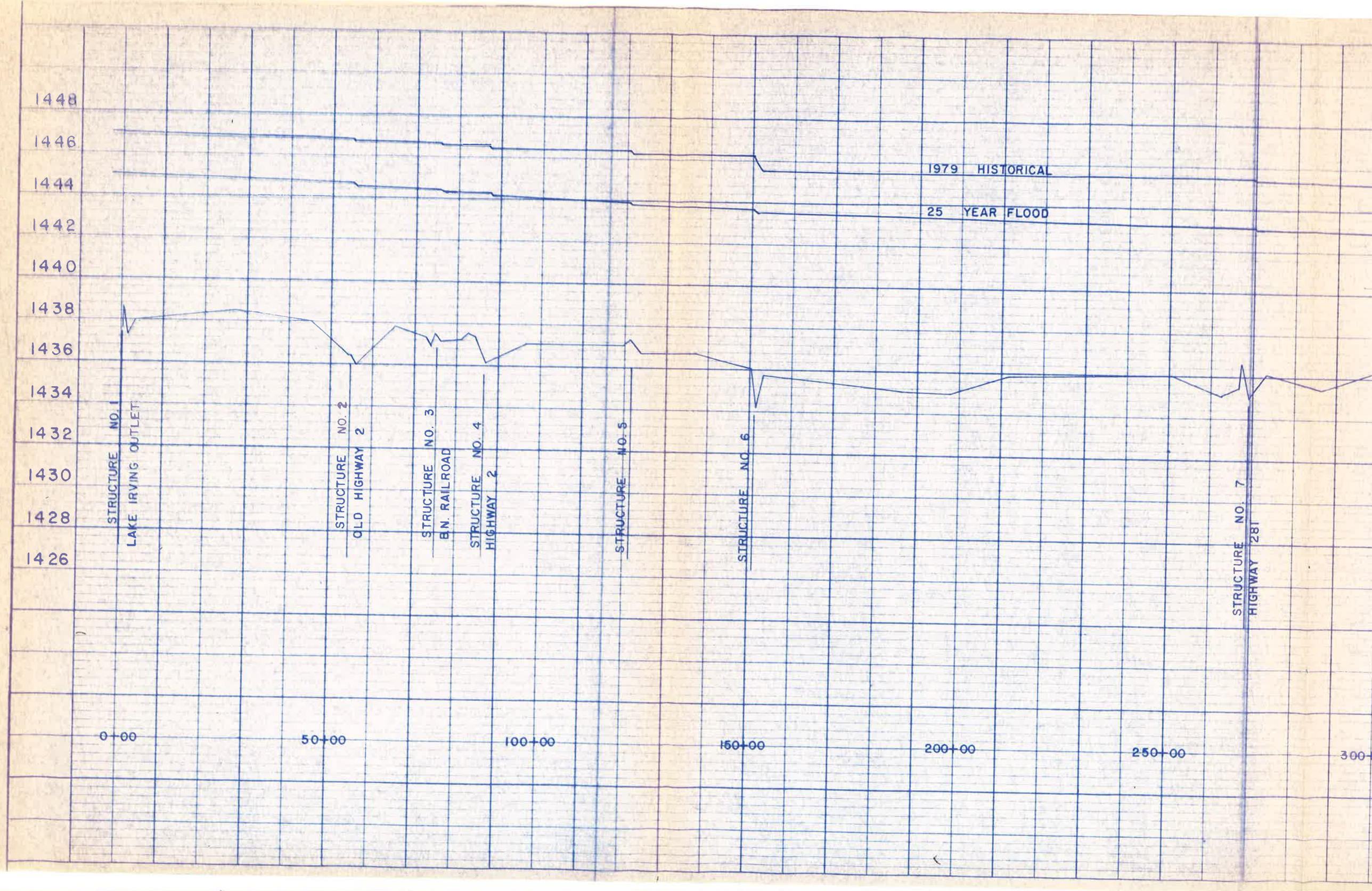
N4800—W9907.5/7.5

1951

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS

FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092, AND STATE WATER COMMISSION, BISMARCK, NORTH DAKOTA 58501

A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST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1979 HISTORICAL
25 YEAR FLOOD
STRUCTURE NO. 1
LAKE IRVING OUTLET
STRUCTURE NO. 2
OLD HIGHWAY 2
STRUCTURE NO. 3
B.N. RAILROAD
STRUCTURE NO. 4
HIGHWAY 2
STRUCTURE NO. 5
STRUCTURE NO. 6
STRUCTURE NO. 7
HIGHWAY 281
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250+00
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LOWER MAUVAIS COULEE
WATER SURFACE PROFILES
EXISTING CONDITIONS

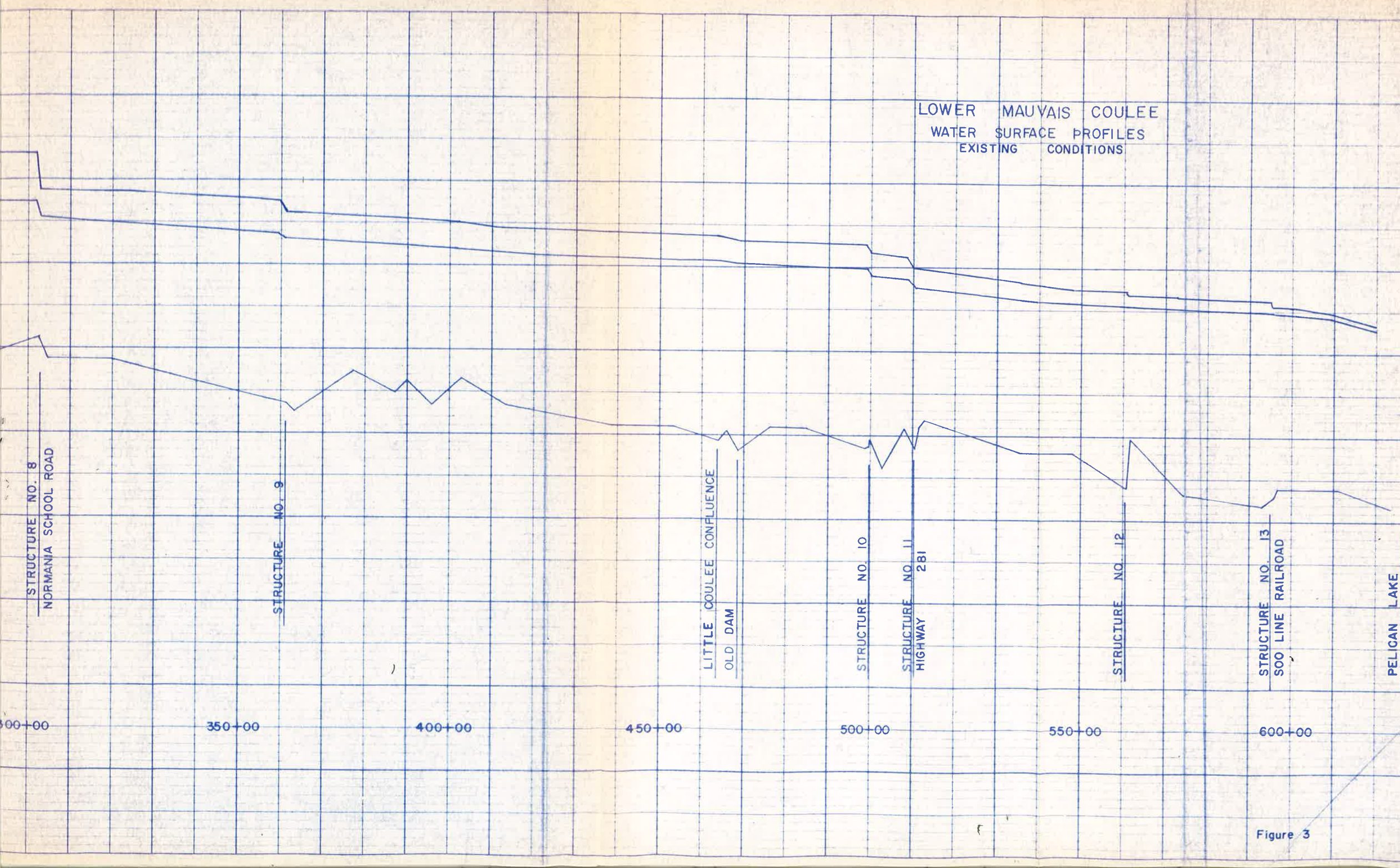

Figure 3

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1979 HISTORICAL
25 YEAR FLOOD

PELICAN LAKE

OSWALDS

STRUCTURE NO. 13
SOO LINE RAILROAD

STRUCTURE NO. 14
BRIDGE BELOW PELICAN LAKE

600+00
650+00
700+00
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LOWER MAUVAIS COULEE

WATER SURFACE PROFILES

EXISTING CONDITIONS

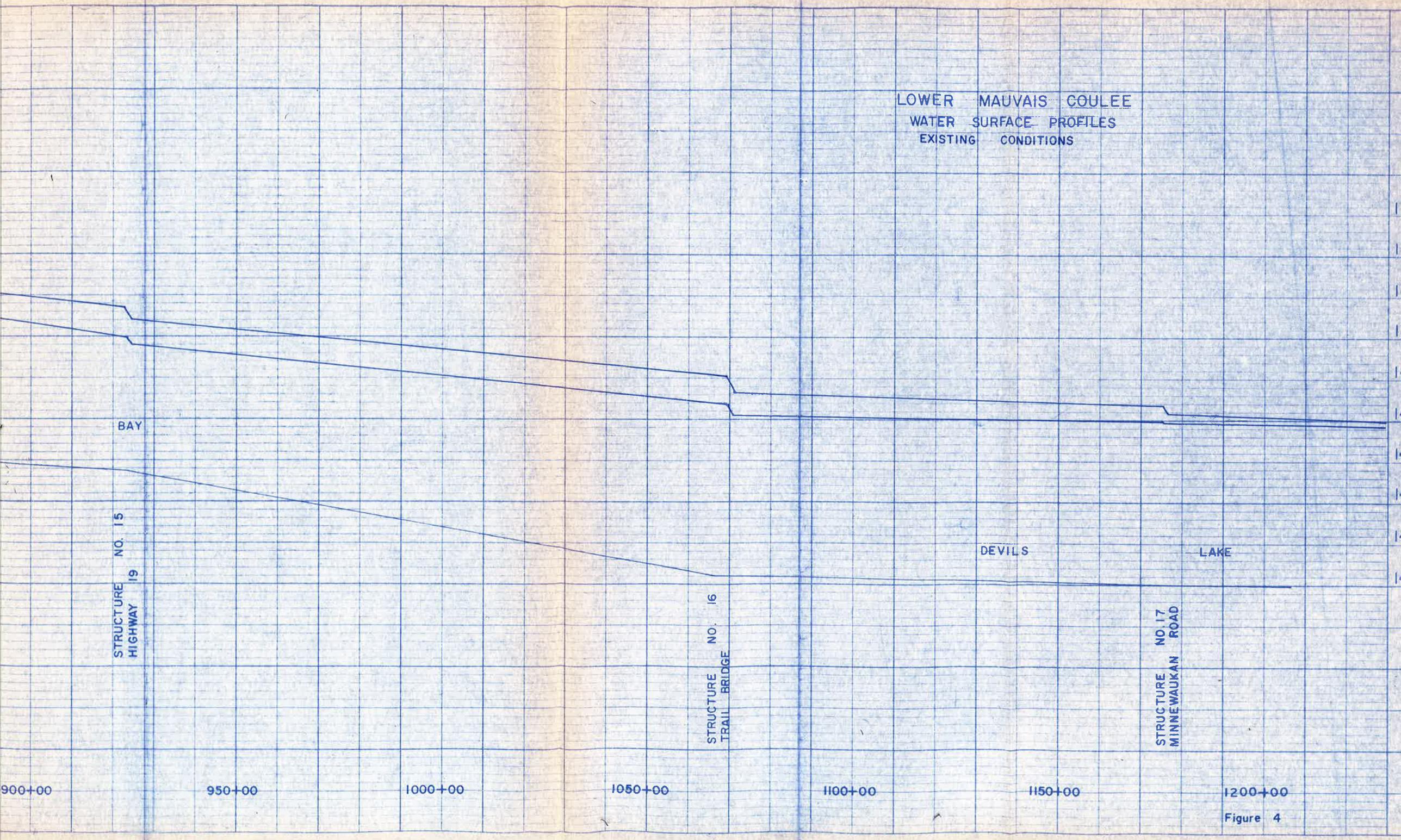

Figure 4

TABLE 3 - STRUCTURE DESCRIPTIONS
LOWER MAUVAIS COULEE

Structure Number	General Description	County	Legal Description S-T-R	Type	Width Feet	Roadway Elv. msl	Deck Elv. msl	Low Chord Elv. msl	1979 Water Level msl
1	Lake Irvine Outlet Road	Ramsey	32-156-66 5-155-66	Bridge CMP Culvert	17' 10'x18'	1446.3	1446.9	1445.8	1447.0
2	Old Highway 2	Ramsey	5/8-155-66	Concrete Bdg.	76'	1445.3	1447.4	1440.0	1446.7
3	Burlington Northern	Ramsey	7-155-66	R.R. Bridge Concrete Cul.	80' 8'x10'	1451.3 1451.3	1451.3 --	1449.3 --	1446.6 --
4	Highway 2	Ramsey	7-155-66	Concrete Bdg. Concrete Cul.	58' 7.5'x12'	1449.0 1449.0	1449.0 --	1446.8 --	1446.4 --
5	--	Co.Line	7-155-66 12-155-67	Wooden Bdg.	58'	1449.0	1448.5	1447.5	1446.3
6	--	Benson	12/13-155-67	Concrete Bdg.	26'	1445.7	1445.5	1444.3	1445.7
7	North Hwy. 281	Benson	23/24-155-67	Concrete Bdg.	41'	1449.5	1449.6	1448.6	1445.4
8	Normania School Road	Benson	23/26-155-67	CMP Culverts	7-5'x7'	1448.0	--	--	1445.3
9	--	Benson	26/35-155-67	Wood Bridge	27'	1444.6	1444.6	1443.6	1442.8
10	--	Benson	2/11-154-67	Bridge	47'	1444.1	1444.0	1441.4	1441.2
11	South Hwy. 281	Benson	11/12-154-67	Concrete Bdg.	58'	1446.5	1446.6	1445.3	1440.3
12	--	Benson	12/13-154-67	Bridge	58'	1440.7	1441.6	1440.6	1438.9
13	Soo Line R.R.	Benson	13-154-67	R.R.Bridge	106'	1445.6	1445.6	1445.1	1438.4
14	Below Pelican L.	Co.Line	21/22-154-66	Bridge	38'	1436.6	1438.0	1436.0	1436.5
15	Highway 19	Co.Line	34-154-66	Concrete Bdg.	52'	1436.0	1436.0	1433.5	1433.5
16	Trail Bridge	Co.Line	10-153-66	Bridge	38'	1430.0	1430.8	1430.0	1430.0
17	Minnewaukan Rd.	Co.Line	16/17/20/21 153-66	CMP Culverts	13-3'x5'	1428.3	--	--	1428.2

A six inch water surface level increase also occurred across structure number eleven, the 58-foot long south Highway 281 bridge. Structure number sixteen is a 38-foot long bridge that increased water levels about eight inches. This eight inch increase does not cause any substantial flooding on private land. The area above the bridge is meandered at approximately elevation 1435.0 msl or five feet above the 1979 water level.

In addition to roadway structures, there are several channel restrictions along Lower Mauvais Coulee. Major channel restrictions exist between the north Highway 281 bridge (structure seven), and the confluence with Little Coulee. Several small trees are in the channel along this stretch of the coulee. In addition there are some low flow channel crossings. This area's most significant restrictions are located in the south half of Section 35, Township 155 North, Range 67 West. The two mile long reach of channel above Pelican Lake is partially choked with tall cattails and grasses. This channel is not able to pass a 1979-type flow. The greatest channel blockage occurs between Pelican Lake and Oswalds Bay, south of Highway 19. In this area the vegetation is six to eight feet tall and almost completely blocks the flow. During high flows, the water level rises in this marsh until the water flows around the outer portions of the tall vegetation. This reach likely increases water levels from three to five feet during all flows.

IV. ALTERNATIVES

Since there are several problem areas along Lower Mauvais Coulee, a phased project is suggested. The phase one plan would include projects that would provide the greatest benefits. Phase two would provide additional flood relief but would involve several projects and considerable

cost. Water surface profiles for phase one are shown on figures 5 and 6. Those for phase two are shown on figures 7 and 8.

PHASE ONE

The first project considered under phase one is the replacement of the culverts along the Normania School Road, structure number eight. These culverts should be replaced by a bridge. The bridge would have a 30 foot channel bottom with 2:1 side slopes. Its length would be about 66 feet and its net flow area would be 427 square feet. The low chord of the bridge should be at elevation 1446.0 msl. This would mean the road would have to be raised about a foot to match the new bridge deck. The length of roadway affected would be about four hundred feet. This project would cost $149,000. Appendix C shows the cost breakdown for this and the other projects.

A local proposal for Mauvais Coulee improvement is to install one of the ten foot diameter culverts from Channel "A" Railroad Crossing in the Normania School Road. The total area of the seven culverts is about 185 square feet. The ten foot culvert would add another 75 square feet for a total of 260 square feet.

The ten foot culvert addition would be less than recommended above. However,it would make the Normania Crossing approximately equivalent to the 26 and 27 foot structures number six and nine. These bridges are recommended for replacement or removal under the Phase 2 plan. Therefore, the decision to install the ten foot culvert depends upon how much improvement is desirable or economically possible. The ten foot culvert addition is adequate for a Phase one improvement level. The culvert is

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100 YEAR (1979 EQUILAVENT)
25 YEAR FLOOD

PELICAN LAKE

OSWALDS

STRUCTURE NO. 13
SOO LINE RAILROAD

STRUCTURE NO. 14
BRIDGE BELOW PELICAN LAKE

600+00
650+00
700+00
750+00
800+00
850+00
900+00

LOWER MAUVAIS COULEE
WATER SURFACE PROFILES
PHASE 2 ALTERNATIVE

BAY

STRUCTURE NO. 15
HIGHWAY 19

STRUCTURE NO. 16
TRAIL BRIDGE

DEVILS LAKE

STRUCTURE NO. 17
MINNEWAUKAN ROAD

900+00 950+00 1000+00 1050+00 1100+00 1150+00 1200+00

Figure 8

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100 YEAR (1979 EQUILAVENT)

25 YEAR FLOOD

STRUCTURE NO. 1
LAKE IRVING OUTLET

STRUCTURE NO. 2
OLD HIGHWAY 2

STRUCTURE NO. 3
B.N. RAILROAD

STRUCTURE NO. 4
HIGHWAY 2

STRUCTURE NO. 5

STRUCTURE NO 6

STRUCTURE NO. 7
HIGHWAY 281

0+00
50+00
100+00
150+00
200+00
250+00

LOWER MAUVAIS COULEE
WATER SURFACE PROFILES
PHASE I ALTERNATIVE

STRUCTURE NO. 8
NORMANIA SCHOOL ROAD

STRUCTURE NO. 9

LITTLE COULEE CONFLUENCE
OLD DAM

STRUCTURE NO. 10

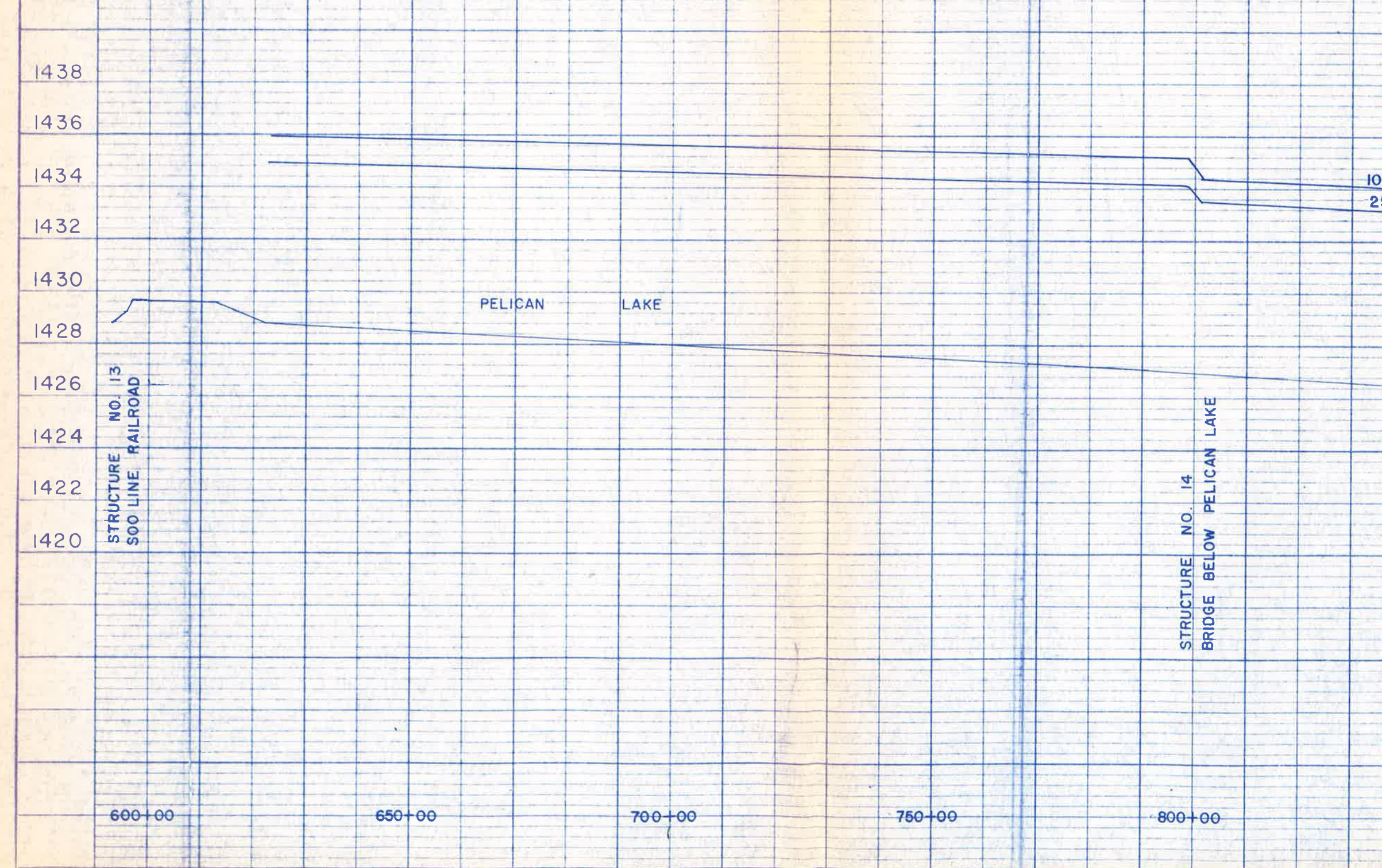
STRUCTURE NO. 11
281
HIGHWAY

STRUCTURE NO. 12

STRUCTURE NO. 13
SOO LINE RAILROAD

300+00 350+00 400+00 450+00 500+00 550+00 600+00

Figure 5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PELICAN LAKE
STRUCTURE NO. 13
SOO LINE RAILROAD
STRUCTURE NO. 14
BRIDGE BELOW PELICAN LAKE
600+00
650+00
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LOWER
WATER
PHAS

EQUILAVENT)

BAY

STRUCTURE NO. 15
HIGHWAY 19

STRUCTURE NO. 16
TRAIL BRIDGE

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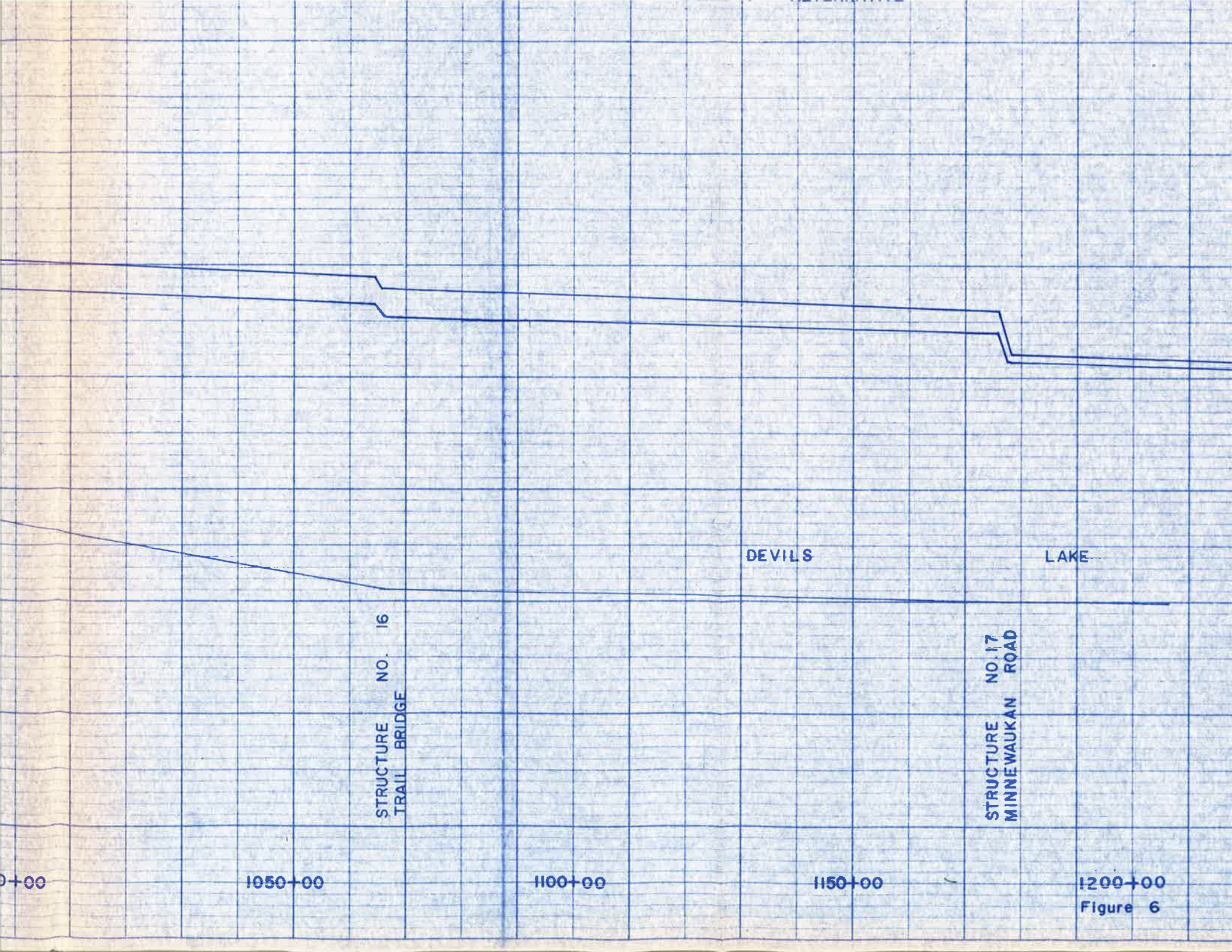
950+00

1000+00

1050+00

1100+00


DEVILS
LAKE
STRUCTURE NO. 16
TRAIL BRIDGE
STRUCTURE NO. 17
MINNEWAUKAN ROAD
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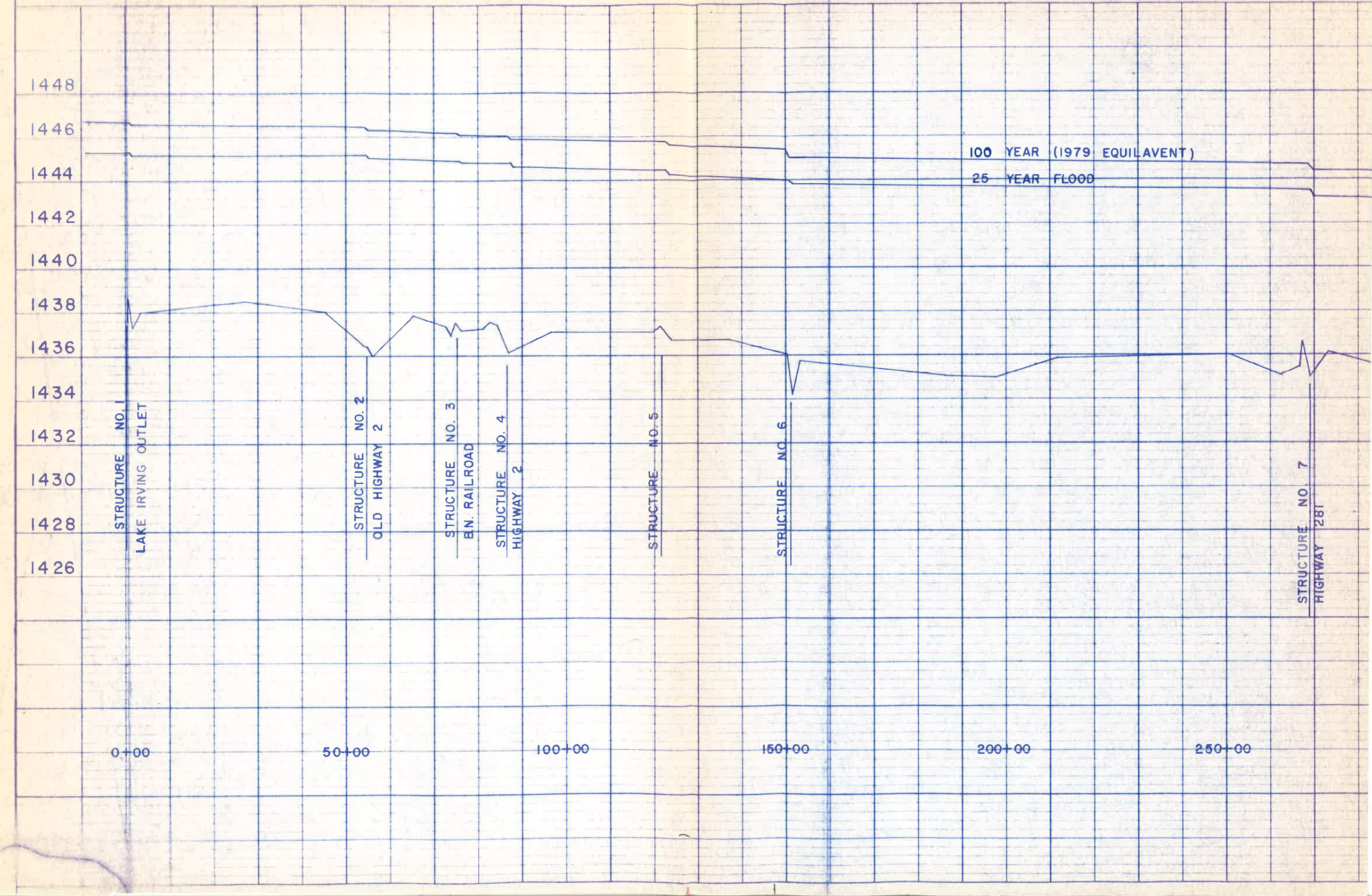
1100+00
1150+00
1200+00

Figure 6


1448
1446
1444
1442
1440
1438
1436
1434
1432
1430
1428
1426
100 YEAR (1979 EQUILAVENT)
25 YEAR FLOOD
STRUCTURE NO. 1
LAKE IRVING OUTLET
STRUCTURE NO. 2
OLD HIGHWAY 2
STRUCTURE NO. 3
B.N. RAILROAD
STRUCTURE NO. 4
HIGHWAY 2
STRUCTURE NO. 5
STRUCTURE NO. 6
STRUCTURE NO. 7
HIGHWAY 281
0+00
50+00
100+00
150+00
200+00
250+00

300+00

STRUCTURE NO. 8
NORMANIA SCHOOL ROAD

350+00

STRUCTURE NO. 9

400+00

450+00

LITTLE COULEE CONFLUENCE
OLD DAM

500+00

STRUCTURE NO. 10

STRUCTURE NO. 11
HIGHWAY 281

LOWER MAUV
WATER SURFAC
PHASE 2 AL

AIS COULEE
E PROFILES
TERNATIVE

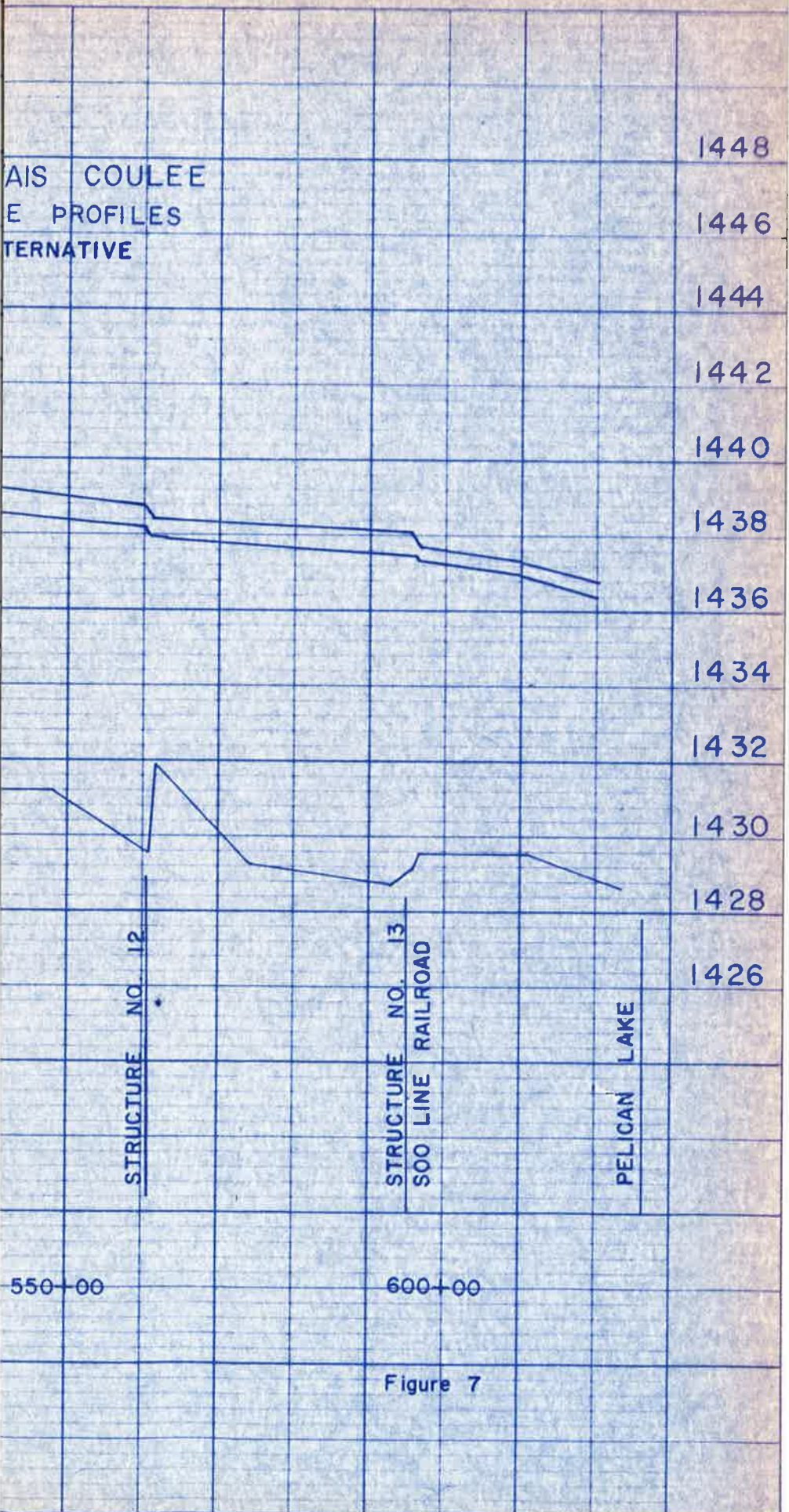


Figure 7

not adequate for the Phase two plan and replacement with a bridge would become a high priority project.

If the ten foot culvert is installed, the bottom of the culvert should be placed at 1434 msl, approximately two feet below the existing channel bottom. This will enable the culvert to flow full during a large flood event. The existing top of roadway is at 1445 msl and installing the pipe at 1434 msl would leave about one foot of cover without raising the top of the roadway. This project would cost about $12,500.

About three miles of Lower Mauvais Coulee need to be snagged and cleared. This area is located between structure number seven and the confluence with Little Coulee. The project would include the removal of all trees below the high water mark in the coulee, the cutting or burning of cattails and tall grasses in several areas, and a small amount of earthwork to remove low flow crossings and other obstructions. The remains of a small dam just below the confluence of Little Coulee should have additional material removed. It is estimated that this project will cost $12,000.

At present the 4.5 mile channel below Pelican Lake severely retards the flow of water. This area is overgrown with vegetation six to eight feet tall. A pilot path through this dense growth should be developed to increase flows. This path would be about 75 feet wide. Developing this path would require that the vegetation be dredged out or cut. Dredging would be a costly operation that would probably be uneconomical, due to the fact that it would have to be done in accordance with Section 404. The dredged material would have to be removed from the area and deposited elsewhere. Because the area is a large slough, it would be very difficult to get the necessary equipment into the area where the

pilot path would be dredged. Possibly the best solution would be to cut the vegetation after the water freezes and before the area gets snowed in. This cutting and clearing project would cost about $12,300.

PHASE TWO

The phase two plan involves some rather expensive structural modifications along Lower Mauvais Coulee. All these projects need not be implemented at one time. Instead they could be constructed over a number of years. The following paragraphs outline a plan for making various improvements after the implementation of the phase one projects. These projects will be discussed in the order of their importance. Many of them are located by referring to structure numbers. Figure 2 shows the project area and identifies the various structure locations.

Structure number six is located between Sections 12 and 13, Township 155 North, Range 67 West. This 26 foot bridge was overtopped in 1979. If a new bridge is constructed on the Normania School Road, the increased flow would cause substantial problems affecting the safety of this bridge. The bridge would have a 30 foot wide bottom with 2:1 side slopes. The width across the top of the channel would be about 66 feet resulting in a net opening of 427 square feet. The elevation of the low chord of the bridge should be 1446.5 msl. This will require that the roadway be raised about four feet at the bridge. The road raising will affect about 500 feet of roadway. Estimated cost of this project is about $155,000.

It may be possible that the crossing at structure number six could be abandoned. If abandonment is acceptable to the county, the bridge

could be completely removed. Any fill material used for the bridge approaches should be removed to eliminate restriction in the channel. This project would cost about $10,000.

Structure number nine should be replaced or, if acceptable to the county, removed completely. Located between Sections 26 and 35, Township 155 North, Range 67 West, this 27 foot long bridge has adequate height, but its narrow span will cause a water surface level increase of approximately six inches during a 1979 equivalent flood. The new bridge should have an opening of at least 400 square feet and a minimum low chord elevation of 1445 msl. The roadway will have to be raised about 3.4 feet at the bridge so it will match the new bridge deck elevation. Constructing the new bridge along with the necessary road raising and other miscellaneous items would cost about $151,000. Complete removal of the bridge without replacement would cost $10,000.

If a pilot path is developed below Pelican Lake, a larger bridge should be constructed where the existing structure number fourteen is located. This 38 foot bridge is located below Pelican Lake between Sections 21 and 22, Township 154 North, Range 66 West. A new structure is needed here to allow increased flow to go from Pelican Lake through the phase one pilot path in the dense vegetation. The bridge should have a 45 foot channel bottom with 2:1 side slopes and a top width of about 82 feet. The net opening under the structure should be 550 square feet and the low chord elevation should be 1437 msl. The bridge deck elevation would have to be around 1440.5 msl. Also, approximately 3,000 feet of would be raised to 1438 msl. At the bridge the road would rise to match the bridge deck and then go back to elevation 1438 msl. The cost of this project is estimated to be about $221,000.

It may be possible to abandon the crossing and have the bridge completely removed, at a cost of about $10,000.

To control releases from Lake Irvin , a control structure should be constructed across its outlet. This structure would be a weir 75 feet wide and will cost about $51,000.

Water levels at the Lake Irvine Outlet road, structure number one, were at elevation 1447 msl in 1979. Therefore the road should be raised to elevation 1448. This roadway raising will involve 5,300 feet of road. Raising the road will channel all discharges from Lake Irvine into the existing dikes, resulting in controlled releases from Lake Irvine. Allowing the road to be overtopped does not increase the flow from the Lake, as all of the flow must still pass through the downstream bridges. The existing structure number one would also have to be replaced if this road is raised. Its replacement should have a flow area of 400 square feet and a low chord elevation of 1447 msl. The road profile will have to be raised a couple feet above 1448 at the bridge to match with the new deck elevation. This project will cost about $230,000. If acceptable to the county, this road could be abandoned and the existing structures removed. The control weir would be constructed along the roadway centerline. To restrict discharges from the Lake to only the outlet weir, the old road would have to be raised to 1448 msl and used as a dike. This would cost about $114,000.

The dikes located between Lake Irvine and Highway 2 should be raised to elevation 1448 msl. Natural channel capacity in this area is inadequate to handle natural flows. The existing dikes are adequate in certain areas but need improvements. These dikes will not function

properly unless the road below Lake Irvine is raised and a control structure constructed to direct water into the dikes. Gated culverts need to be installed through the dikes to allow the land outside of the dike to be drained into the coulee. These dikes along with a Lake Irving control structure would keep approximately 1,000 acres of farmland below the lake relatively free from flooding. The cost of this project would be around $182,000.

Structure number two is the old Highway 2 bridge. This 76-foot long bridge is adequately wide but is too low. Both the bridge and the old highway were inundated in 1979. This structure should be replaced or, if acceptable to the county, removed completely. The new bridge would be about the same length, but its low chord elevation would be raised to elevation 1447. Therefore, the road would have to be raised about 2.6 feet at the bridge. The length of roadway affected would be about 800 feet. Replacement of this bridge would cost an estimated $182,000. Completely removing the bridge would cost about $12,000.

The 47-foot long bridge located between Sections 2 and 11, Township 154 North, Range 67 West is structure number ten. This bridge is a little narrow and low to pass a flood equal to the one in 1979, when effects of upstream improvements suggested in this report are considered. Therefore, this bridge should be replaced with a wider and higher one. This new bridge should have an opening of 550 square feet with a width of 82 feet. To match the new bridge deck the road will have to be raised about 2.5 feet. This will involve about 500 feet of roadway and cost an estimated $182,000. However, replacement of this bridge is not considered a high priority project.

Between structure number eleven (south Highway 281 bridge) and Pelican Lake, the channel should be enlarged to decrease the amount of backwater. This enlargement would not increase the flow from Lake Irvine, but would lower the water levels along this reach of Lower Mauvais Coulee. The channelization would include a channel with a bottom width of 40 feet and having 3:1 side slopes. Estimated costs of this project are about $50,000.

Structure number seventeen is located on a county road, referred to as the Minnewaukan Road, heading east out of the City of Minnewaukan. The crossing presently has thirteen small diameter culverts through the road. Their capacity is extremely inadequate to pass a large flow without a buildup of water behind them. The road would be overtopped by a 25 year flood. This road was cut in 1979 to increase flow into Devils Lake. It is suggested that a bridge with a 550 square foot opening be constructed to replace the culverts. The roadway would probably have to be raised two or three feet so the bridge is able to pass high flows. This project is estimated to cost about $180,000. It is recommended that this project be given a low priority because the roadway top is at elevation 1428 msl, seven feet below the meander level of 1435 msl. Although the crossing as it exists increases the water level, it does not result in the flooding of any deeded land. The sewage lagoons for the City of Minnewaukan will not be impacted since the top of the dikes are at elevation 1436.3 msl and the bottoms of the lagoons are at about elevation 1431 msl.

The Highway 19 bridge, structure number 15, should be raised or replaced. In 1979 the structural steel for this bridge was under water.

The low chord should be at elevation 1435 msl. To raise the bridge would require that the area around the old footings be excavated so they could be enlarged. Numerous piling would have to be driven to provide a base for the jacks that would raise the bridge. Also, the steel beams would have to be jackhammered out of their bearing spot in the existing abutment and the rebar cleaned. After raising the deck, the abutment wall would have to be enlarged and the deck would have to be reset into the abutment. This work may be difficult to do due to the conditions in the field and the small amount of room under the bridge in which to drive the temporary piles. In cases like this, the Highway Department usually prefers to replace the whole bridge. This would allow a safer bridge to be installed. Whether the bridge is raised or replaced, the roadway will have to be raised about 2.5 feet at the bridge. This would affect 1,800 feet of highway. To raise the bridge and do the necessary roadwork would cost $208,000; to replace the bridge and do the necessary roadwork would cost about $325,000.

V. DISCUSSION OF IMPACTS

The impacts of the phase one and phase two alternatives are shown in tables 4 and 5. These alternatives do not significantly reduce the flood peaks of the Chain Lakes area. The combined inflows into all of the lakes are far above the capacity of Lower Mauvais Coulee. As a result, the initial flood waters will increase the lake levels and cause a certain amount of flooding.

With Channel "A" fully operational and with the implementation of certain channel improvements, lake levels can experience significant decreases a few weeks after the main peak occurs. For example, on May 8, 1979, Lake Alice peaked at 1447.1 msl. On June 2, 1979, the lake level was still at 1446.3 msl. If Channel "A" would have been fully

TABLE 4

IMPACTS OF A 100 YEAR FLOOD

	1979 Historical	1979 Flood Flow With Phase 1 Projects	1979 Flood Flow With Phase 2 Projects
1. Peak Discharge from Lake Irvine	1,030 cfs	1,200 cfs	1,350 cfs
2. Peak Elevation of Lake Alice	1447.1 msl	1446.8 msl	1446.6 msl
3. Level of Lake Alice 30 days after Peak	1446.3 msl	1445.5 msl	1445.0 msl
4. Peak Elevation of Pelican Lake	1436.6 msl	1435.5 msl	1435.5 msl
5. Deeded Acres in the Chain Lakes Area Flooded at the Peak	13,400 acres	12,100 acres	10,800 acres
6. Deeded Acres in the Chain Lakes Area Flooded 30 days after the Peak	10,400 acres	8,000 acres	5,800 acres
7. Deeded Acres Flooded Around and Below Pelican Lake	1,500 acres	850 acres	850 acres

TABLE 5

IMPACTS OF A 25 YEAR FLOOD

	Existing Conditions	25 Year Flood With Phase 1 Projects	25 Year Flood With Phase 2 Projects
1. Peak Discharge from Lake Irvine	650 cfs	750 cfs	850 cfs
2. Peak Elevation of Lake Alice	1445.4 msl	1445.1 msl	1444.9 msl
3. Level of Lake Alice 30 days after Peak	1446.6 msl	1444.1 msl	1443.7 msl
4. Peak Elevation of Pelican Lake	1436.0 msl	1434.5 msl	1434.5 msl
5. Deeded Acres in the Chain Lakes Area Flooded at the Peak	7,700 acres	6,800 acres	5,600 acres
6. Deeded Acres in the Chain Lakes Area Flooded 30 Days After the Peak	5,300 acres	3,800 acres	2,200 acres
7. Deeded Acres Flooded Around and Below Pelican Lake	1,000 acres	500 acres	500 acres

operational, and if the phase one projects had been constructed, Lake Alice could have been lowered to 1445.5 msl by June 2, 1979. With the implementation of the phase two projects, the lake could have been lowered another six inches by June 2, 1979.

Channel "A", along with the phase one and phase two projects, will show greater reductions for flood flows less than those that occurred in 1979. For example, the phase one and phase two projects together would result in a 60% reduction in the acres of private land flooded by a 25 year event. During a 100 year flood the phase one and phase two improvements would result in a 45% reduction in the acres flooded. These acres are those that are still flooded thirty days after the main peak. This increased reduction in acres flooded during the 25 year flood compared to the 1979 historical flood is due to the ability of Channel "A" and Lower Mauvais Coulee to pass a larger percentage of the total volume of water running off during the 25 year flood.

VI. SUMMARY

Flooding is a major problem in the Devils Lake Basin. In 1979 nearly 15,000 acres of private land were inundated between Dry Lake and Devils Lake. Virtually all the structures located on Lower Mauvais Coulee are unable to pass a flood equivalent to the one in 1979 without causing some backwater. The Normania School Road, structure number eight, is the greatest restriction between Lake Irvine and Pelican Lake. In 1979 it backed up 1.8 feet of water. Highwater stages around and below Pelican Lake are caused mostly by the dense vegetation in Oswald's Bay.

To help reduce the amount of flooding, a two-phased project is proposed. Phase one includes projects that would provide the greatest benefit. Phase two would provide additional flood relief, however, it involves numerous projects having considerable costs. Table 6 is a list of the phase one and phase two projects and their costs. The projects are listed in their order of importance and should be constructed in this order. Channel "A" significantly reduced the number of acres flooded in 1979. With full operation of the channel, additional flood reduction will occur regardless of the changes made to Lower Mauvais Coulee. It is not possible to eliminate flooding on all deeded land. Even with replacement of all structures along the Coulee and significant channel modifications, certain private lands would be flooded, due to the low meandered elevations that exist.

It is recommended that several channel and structural improvements be made along Lower Mauvais Coulee. These projects should be developed in the two phases as described in this report. They should be constructed in accordance with the priority guidelines discussed in this report and summarized in table 6. It is also recommended that the local officials consult with the State Water Commission staff before undertaking any of the recommended projects. Additional information can be obtained at this time on a site specific basis.

TABLE 6

PRELIMINARY COST SUMMARY

ITEM	COST
PHASE ONE IMPROVEMENTS:	
1. Replace Culverts with Bridge on Normania School Road	$149,000
1A. Install 10' diameter Culvert from Channel "A" at Normania School Road Crossing	12,500
2. Snag and Clear 3 miles of Coulee	12,000
3. Develop Pilot Path below Pelican Lake	12,300
PHASE TWO IMPROVEMENTS:	
1. Phase One Improvements	$173,300
2. Replace Structure #6	155,000
Removal Only of Structure	10,000
3. Replace Structure #9	151,000
Removal Only of Structure	10,000
4. Replace Structure #14	221,000
Removal Only of Structure	10,000
5. 75' Lake Irvine Control Structure	51,000
5A. Replace Structure #1 and Raise Road	230,000
5B. Remove Structure #1, Install Control Structure and Raise Road as a Dike	114,000
6. Raising Dikes Between Lake Irvine & Hwy. 2	182,000
7. Replace Old Hwy. 2 Bridge	182,000
Removal Only of Structure	12,000
8. Replace Structure #10 (Low Priority)	182,000
9. Widen Channel Between Crossing #11 & Pelican Lake	50,000
10. Remove Culverts, Install Bridge on Minnewaukan Road (Low Priority)	182,000

PRELIMINARY COST SUMMARY (Cont'd)

ITEM	COST
11. Raise Highway 19 and the Bridge (Low Priority)	208,000
Raise Highway 19 and Replace the Bridge (Low Priority)	325,000
12. Remove the Trail Bridge in Sec. 10-153-66	6,500

SOME PROBABLE PROJECT COMBINATIONS:

1. Phase One Costs	$173,300
2. Phase Two Costs Without Phase One And Assume Replacing Bridges and Doing All the Projects	$1,917,500
3. Phase Two Costs With Phase One And Assume Replacing Bridges and Doing All the Projects	$2,090,800
4. Phase Two Costs With Phase One And Assume Removing the Unimportant Bridges	$1,423,800
5. Phase Two Costs With Phase One And Assume Replacing the Bridges And Not Doing the Low Priority Projects	$1,401,800
6. Phase Two Costs With Phase One And Assume Removing the Unimportant Bridges and Not Doing the Low Priority Projects	$734,800

APPENDIX A

PRELIMINARY INVESTIGATION AGREEMENT

APPENDIX B

CHANNEL "A" OPERATING PLAN

A G R E E M E N T

Channel A Operating Plan

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, acting through the North Dakota State Engineer, Vern Fahy; the Ramsey County Water Management District, acting through its chairman, Robert Garske; and the Cavalier County Water Management District, acting through its chairman, Russ Schroeder.

II. INTENT AND PURPOSE

In 1977, the State Engineer, the Ramsey County Water Management District, and the Cavalier County Water Management District entered into an agreement entitled "Cost Participation By the North Dakota State Water Commission for the Construction of Channel "A" in Ramsey County". Pursuant to the 1977 agreement, the State Water Commission granted $600,000 to the Ramsey and Cavalier Water Management Districts as partial funding for the Channel "A" project, which was subsequently constructed by the Ramsey and Cavalier Water Management Districts. Section VII of the 1977 agreement, as amended, provides as follows:

> The Boards shall operate and maintain Channel "A" under a management plan approved by the State Engineer. Specifically:
> 1. The Board shall annually submit a maintenance program to the State Engineer for his approval. The program shall be submitted on or before January 15 of each year and shall include the details of the previous years; maintenance and the proposal for maintenance during the forthcoming year.
> 2. The operation of any gate or control structure must be approved by the State Engineer.

The purpose of this agreement is to establish the management plan required by the 1977 agreement. Execution of this agreement by the State Engineer will constitute approval of the management plan for operation and maintenance as established herein. The Ramsey County Water Management District shall operate and maintain the Channel "A" project in accordance with this agreement.

III. PLAN OF OPERATION

The Channel "A" project shall be operated in the following manner:

1. A permanent control structure will be built in the natural outlet to Dry Lake. This location is at or near the northwest corner of Dry Lake. The elevation of the structure shall be 1449.5 msl. The structure shall be designed so that there will be uncontrolled overflow over the spillway at this elevation.

2. Consideration shall be given toward including a low level drawdown in this control structure. In no event shall the drawdown elevation be lower than 1445 msl. The discharge capacity of this drawdown shall be designed in accordance with channel hydraulics downstream.

3. Operation of the control structure in the Channel "A" project (south end of Dry Lake) will include drawdown to elevation 1445 msl, starting October 1 of each year.

4. The gates on the Channel "A" control structure shall remain open over the winter months.

5. By April 1, or earlier if necessary, an outlook will be prepared by the State Engineer for runoff for the coming spring. If the runoff will be below normal and will not cause flooding, the Channel "A" gates shall be closed to store water in Dry Lake. If the runoff will be large enough to cause flooding, the gates shall remain open through the spring runoff.

6. After the runoff starts to recede and the level of Dry Lake drops to elevation 1447.5 msl, the Channel "A" gates will be closed and shall remain closed until October 1 of that year. If heavy rainfall during the summer months poses a threat of substantial flooding in the area the gates may be opened, at the direction of the State Engineer.

7. If the Channel "A" gates are closed because of a spring outlook for low runoff, and if the level of the Lake rises above

1447.5 msl, the gates may then be opened to draw the level of Dry Lake to 1447.5 msl. The gates shall then remain closed until October 1.

The Ramsey County Water Management District shall be responsible for physical operation of the Channel "A" project, and the permanent control structure in the natural outlet of Dry Lake. The operation of the Channel "A" gates and any other outlet gates to Dry Lake shall be approved by the State Engineer in all instances.

IV. MODIFICATION OF MANAGEMENT PLAN FOR OPERATION & MAINTENANCE

Changes to any provisions of this agreement shall not be effective unless such changes are made in writing, signed by the parties, and attached hereto. Any variation from the operation and maintenance of the Channel "A" project as set forth in this agreement shall require separate written approval of the State Engineer.

V. PREVIOUS AGREEMENT

The 1977 agreement entitled "Cost Participation By the North Dakota State Water Commission for the Construction of Channel "A" in Ramsey County", and amendments thereto, shall remain in full force and effect, and shall in no way be altered by this agreement.

DATE:

Oct. 21, 1980

NORTH DAKOTA STATE WATER COMMISSION
By:

David A. Sprynczynatyk
for Vern Fahy
State Engineer and Secretary

DATE:

BOARD OF COMMISSIONERS
RAMSEY COUNTY WATER MANAGEMENT DISTRICT
By:

Robert Garske
Chairman

DATE:

BOARD OF COMMISSIONERS
CAVALIER COUNTY WATER MANAGEMENT DISTRICT
By:

APPENDIX C

PRELIMINARY COST BREAKDOWNS

PHASE ONE:

1. Replace Structure #8, Normania School Road.

a.	Mobilization @ $5,000/L.Sum	$ 5,000
b.	Removal of Culverts @ $1,500/L.Sum	1,500
c.	Concrete Bridge 1980 ft. of deck @ $50/ft.^{2}	99,000
d.	2000 C.Y. of Borrow @ $2/C.Y.	4,000
e.	250 tons of gravel @ $5/ton	1,250
f.	Traffic Control @ $4,000/L.Sum	4,000
g.	1 Acre of Seeding @ $150/acre	150
	SUBTOTAL	114,900
	±30% Engr. & Cont.	34,100
	TOTAL COST	$149,000

1A. Install 10' Diameter Culvert from Channel "A" at Structure #8.

a.	Mobilization @ $600/L.Sum	$ 600
b.	Crane 5 crane days @ $410/day	2,050
c.	Excavation 750 C.Y. @ $6/C.Y.	4,500
d.	Foundation Fill 56 C.Y. @ $10/C.Y.	560
e.	Backfill 600 C.Y. @ $0.75/C.Y.	450
f.	Moving the Culvert @ $600/L.Sum	600
g.	Relay 5'x7' culvert 60 ft. @ $15/ft.	900
	SUBTOTAL	9,660
	±30% Engr. & Cont.	2,840
	TOTAL COST	$ 12,500

2. Snag and Clear Three Miles of Coulee.

a.	Snag and Clear 3 Miles @ $3,000/mile	$ 9,000
b.	±30% Engr. and Cont.	3,000
	TOTAL COST	$ 12,000

3. Develop Pilot Path Below Pelican Lake

a.	41 acres of Clearing @ $230/acre	$ 9,430
b.	±30% Engr. and Cont.	2,870
	TOTAL COST	$ 12,300

PHASE TWO:

1. Phase One Improvements

	TOTAL COST	$173,300

2. Replace Structure #6

a.	Mobilization @ $5,000/L.Sum	$ 5,000
b.	Remove Old Bridge @ $3,000/L.Sum	3,000
c.	Concrete Bridge 1980 ft.^{2} of deck @ $50/ft.^{2}	99,000
d.	3,100 C.Y. of Borrow @ $2/C.Y.	6,200
e.	370 tons of gravel @ $5/ton	1,850
f.	Traffic Control @ $4,000/L.Sum	4,000
g.	1 Acre of Seeding @ $150/acre	150
	SUBTOTAL	$119,200
	±30% Engr. & Cont.	35,800
	TOTAL COST	$155,000

3. Replace Structure #9

a.	Mobilization @ $5,000/L.Sum	$ 5,000
b.	Remove Old Bridge @ $3,000/L.Sum	3,000
c.	Concrete Bridge 1980 ft^2 of deck @ $50/ft^2	99,000
d.	2000 C.Y. of Borrow @ $2/C.Y.	4,000
e.	274 tons of gravel @ $5/ton	1,370
f.	Traffic Control @ $4,000/L.Sum	4,000
g.	1 Acre of Seeding @ $150/acre	150
	SUBTOTAL	116,520
	±30% Engr. & Cont.	34,480
	TOTAL COST	$151,000

4. Replace Structure #14

a.	Mobilization @ $5,000/L.Sum	$ 5,000
b.	Remove Old Bridge @ $3,000/L.Sum	3,000
c.	Concrete Bridge 2,460 ft^2 of deck @ $50/ft^2	123,000
d.	15,000 C.Y. of Borrow @ $1.50/ C.Y.	22,500
e.	2,300 tons of gravel @ $5/ton	11,500
f.	Traffic Control @ $4,000/L.Sum	4,000
g.	7 Acres of Seeding @ $150/acre	1,050
	SUBTOTAL	$170,050
	±30% Engr. & Cont.	50,950
	TOTAL COST	$221,000

5. 75 Foot Lake Irving Outlet Control Structure

a.	Mobilization @ $3,000/L.Sum	$ 3,000
b.	61 C.Y. of Concrete @ $360/C.Y.	21,960
c.	7,930 lbs. of steel @ $0.60/lb.	4,758
d.	385 L.F. Sheet Pile @ $25/L.F.	9,625
	SUBTOTAL	39,343
	±30% Engr. & Cont.	11,657
	TOTAL COST	$ 51,000

5A. Replace Structure #1 and Raise Road

a.	Mobilization @ $5,000/L.Sum	$ 5,000
b.	Remove Old Bridge & Box Culvert @ $4,500/L.Sum	4,500
c.	Concrete Bridge 1980 ft^2 of deck @ $50/$ft^2$	99,000
d.	28,000 C.Y. of Borrow @ $1.50/C.Y.	42,000
e.	3,950 tons of gravel @ $5/ton	19,750
f.	Traffic Control @ $5,000/L.Sum	5,000
g.	12 Acres of Seeding @ $150/acre	1,800
	SUBTOTAL	$177,050
	±30% Engr. & Cont.	52,950
	TOTAL COST	$230,000

5B. Remove Structure #1, Install Control Weir and Raise Road as a Dike

a.	Mobilization @ $3,000	$ 3,000
b.	Remove Old Bridge & Box Culvert @ $4,500/L.Sum	4,500
c.	28,000 C.Y. of Borrow @ $1.50/C.Y.	42,000
d.	12 Acres of Seeding @ $150/Acre	1,800
e.	61 C.Y. of Concrete @ $360/C.Y.	21,960
f.	7,930 lbs. of steel @ $0.60/lb.	4,758
g.	385 L.F. Sheet Pile @ $25/L.F.	9,625
	SUBTOTAL	$ 87,643
	±30% Engr. & Cont.	26,357
	TOTAL COST	$114,000

6. Raise the Dikes Between Lake Irving and Highway 2

a.	Mobilization @ $3,000/L.Sum	$ 3,000
b.	77,000 C.Y. of Borrow @ $1.50/C.Y.	115,500
c.	25 Acres of Seeding @ $1.50/C.Y.	3,750
d.	Gated Pipes - 8 @ $2,600/Ea.	20,800
	SUBTOTAL	140,053
	±30% Engr. & Cont.	41,947
	TOTAL COST	$182,000

7. Replace the Old Highway 2 Bridge, Structure #2

a.	Mobilization @ $5,000/L.Sum	$ 5,000
b.	Removal of Old Bridge @ $4,000/L.Sum	4,000
c.	Concrete Bridge 2280 ft. of deck @ $50/ft^2	114,000
d.	3300 C.Y. of Borrow @ $1.50/C.Y.	4,950
e.	378 tons of H.B.P. @ $12/ton	4,536
f.	624 tons of gravel @ $5/ton	3,120
g.	133 Gal. of R.C. for Seal Coat	133
h.	27 tons of Blotter Material @ $5/ton	135
i.	Traffic Control @ $4,000/L.Sum	4,000
j.	1 Acre of Seeding @ $150/acre	150
	SUBTOTAL	140,024
	±30% Engr. & Cont.	41,976
	TOTAL COST	$182,000

8. Replace Structure #10 (Low Priority)

a.	Mobilization @ $5,000/L.Sum	$ 5,000
b.	Remove Old Brige @ $3,000/L.Sum	3,000
c.	Concrete Bridge 2460 ft^2 of deck @ $50/ft^2	123,000
d.	2150 C.Y. of Borrow @ $1.50/C.Y.	3,225
e.	380 tons of gravel @ $5/ton	1,900
f.	Traffic Control @ $4,000/L.Sum	4,000
g.	1 Acre of Seeding @ $150/acre	150
	SUBTOTAL	140,275
	±30% Engr. & Cont.	41,725
	TOTAL COST	$182,000

9. Widen the Channel Between Crossing #11 and Pelican Lake

a.	Mobilization @ $2,500/L.Sum	$ 2,500
b.	27,220 C.Y. of Excavation @ $1.20/C.Y.	32,664
c.	Seeding 21 acres @ $150/acre	3,150
	SUBTOTAL	38,314
	±30% Engr. & Cont.	11,686
	TOTAL COST	$ 50,000

10. Replace Structure #17 on Minnewaukan Road

a.	Mobilization @ $5,000/L.Sum	$ 5,000
b.	Removal of Culverts @ $3,000/L.Sum	3,000
c.	Concrete Bridge - 2,460 ft^2 of deck @ $50/$ft^2$	123,000
d.	2,500 C.Y. of Borrow @ $1.50/C.Y.	3,750
e.	300 ton of gravel @ $5/ton	1,500
f.	Traffic Control @ $4,000/L.Sum	4,000
g.	1 Acre of Seeding @ $150/acre	150
	SUBTOTAL	140,400
	±30% Engr. & Cont.	41,600
	TOTAL COST	$182,000

11. Raise Highway 19 and Raise Structure #15

a.	Mobilization @ $5,000/L.Sum	$ 8,000
b.	Freeing Beams and Cleaning Off Rebar Tieing Beam Anchor to the Abutment @ $2,000/L.Sum	2,000
c.	Piling 375 L.F. @ $18/L.F.	6,750
d.	Jacking costs @ $3,600/L.Sum	3,600
e.	Structural Excavation 273 C.Y. @ $6/C.Y.	1,638
f.	Concrete 44 C.Y. @ $400/C.Y.	17,600
g.	Steel 5720 lb. @ $0.65/lb.	3,718
h.	11,000 C.Y. of Borrow @ $1.50/C.Y.	16,500
i.	H.B.P. 3660 tons @ $12/ton	43,920
j.	240 tons Asphalt @ $120/ton	28,800
k.	550 Gal. Tack Coat @ $1/Gal.	550
l.	550 Gal. Seal Coat @ $1/Gal.	550
m.	104 tons of Blotter Sand @ $5/ton	520
n.	3,800 tons of gravel @ $5/ton	19,000
o.	Traffic Control @ $6,000/L.Sum	6,000
p.	4 Acres of Seeding @ $150/Acre	600
	SUBTOTAL	$159,745
	±30% Engr. & Cont.	48,255
	TOTAL COST	$208,000

11A Raise Highway 19 and Replace Structure #15

a.	Mobilization @ $8,000/L.Sum	$ 8,000
b.	Removal of Old Bridge @ $3,000/L.Sum	3,000
c.	Concrete Bridge - 2460 ft^2 @ $50/$ft^2$	123,000
d.	11,000 C.Y. of Borrow @ $1.50/C.Y.	16,500
e.	3,660 tons H.B.P. @ $12/ton	43,920
f.	240 tons of Asphalt Cement @ $120/ton	28,800
g.	550 Gal. Tack Coat @ $1/Gal.	550
h.	550 Gal. Seal Coat @ $1/Gal	550
i.	104 tons of Blotter Sand @ $5/ton	520
j.	3800 tons of gravel @ $5/ton	19,000
k.	Traffic Control @ $6,000/L.Sum	6,000
l.	4 Acres of Seeding @ $150/acre	600
	SUBTOTAL	250,440
	±30% Engr. & Cont.	74,560
	TOTAL COST	$325,000

12. Remove Trail Bridge in Section 10-153-66

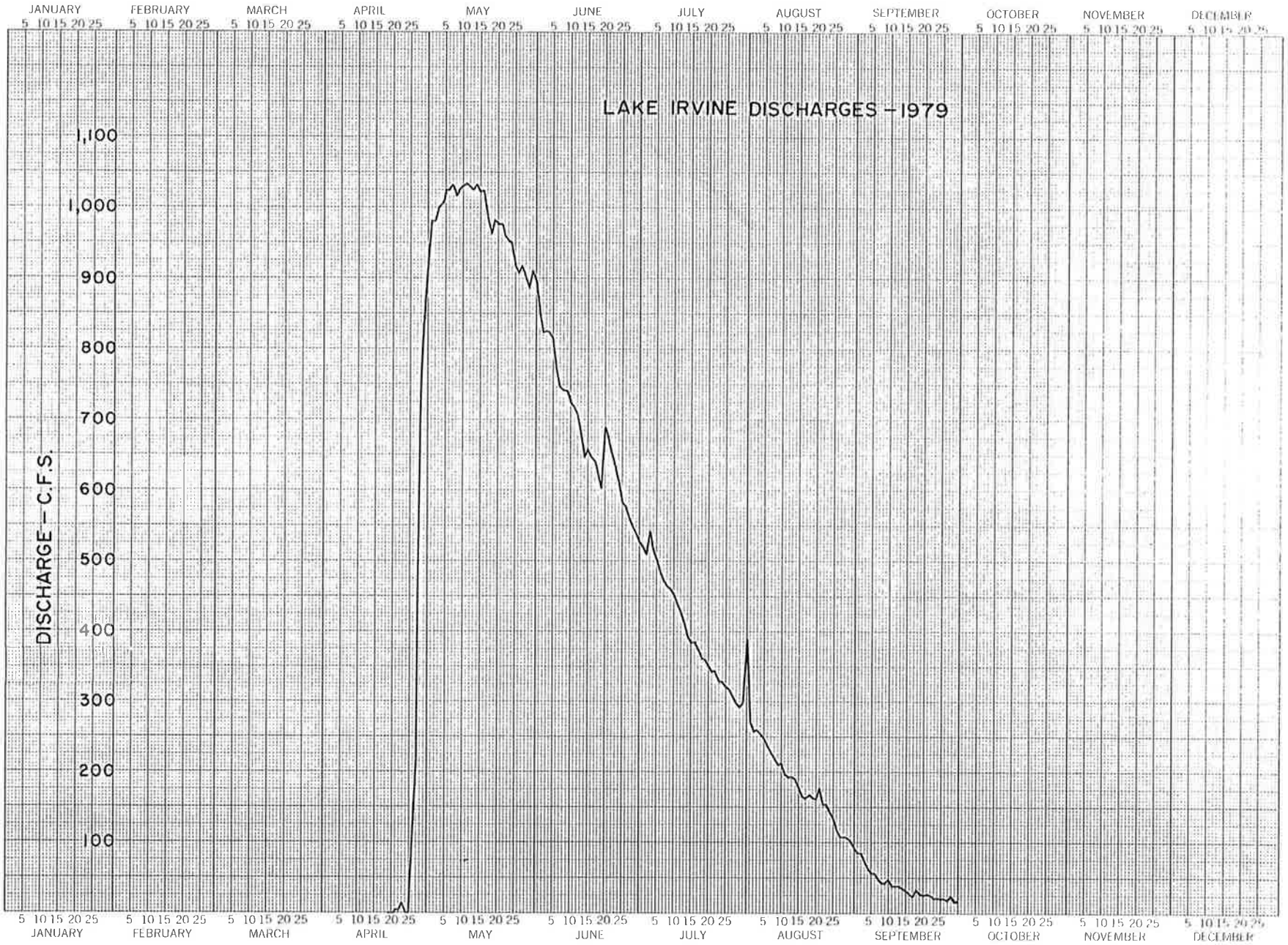
a.	Mobilization @ $3,000/L.Sum	$ 3,000
b.	Remove Old Bridge @ $2,000/L.Sum	2,000
	SUBTOTAL	$ 5,000
	±30% Engr. & Cont.	1,500
	TOTAL COST	$ 6,500

APPENDIX D

1979 FLOOD DATA

1. Lake Irving Discharge Hydrograph
2. Channel "A" Discharge Hydrograph
3. Miscellaneous Lake Levels

46 2890



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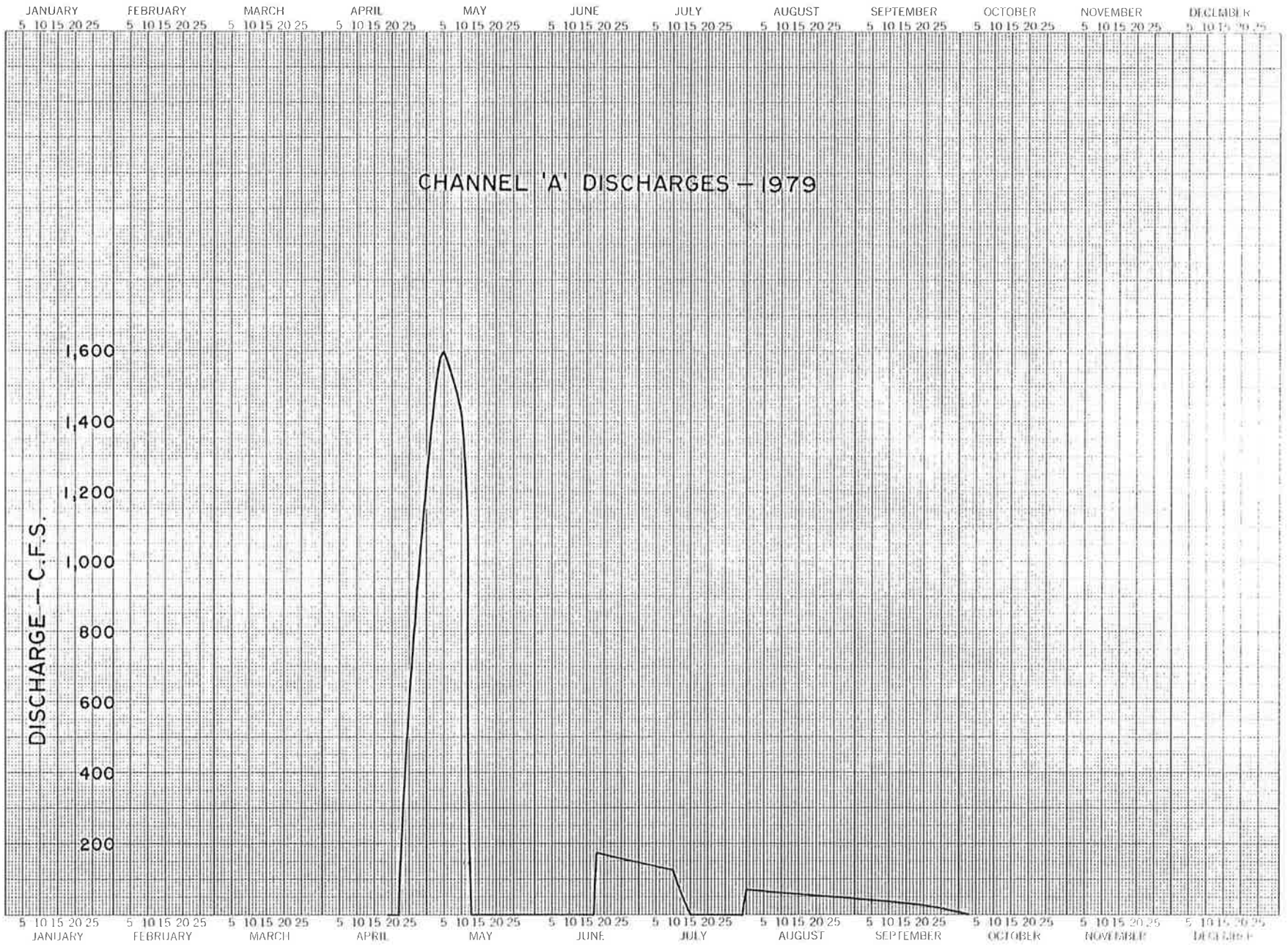


1979

DEVILS LAKE LEVELS

(By Highway Department Unless Noted)

Date	Main Lake	Mission Bay	East Bay	East Devils Lake	Dry Lake	Lake Alice
4 Apr 79	1422.46 (USGS)		1421.0	1404	1446.4 (SWC)	1441.6
25 Apr	1423.17 (USGS)			1404		
26 Apr						1446.1 (F/W)
27 Apr	1423.4 (USGS)	1422.2	1421.07		1449.2 (SWC)	
30 Apr	1424.1 (USGS)				1449.6 (WMD)	
1 May						1446.9 (F/W)
2 May	1424.33	1422.33	1422.05			
3 May	1424.5	1422.45	1422.08		1450.95 (SWC)	
4 May	1424.62	1422.62	1422.10		1451.00 (SWC)	
7 May	1425.25	1422.93	1422.21			
8 May	1425.44	1422.91	1422.25			1447.1 (near peak) (F/W)
10 May	1425.75	1423.08	1422.4		1450 (WMD)	
11 May	1426.02	1423.17	1422.5		1449.1 (WMD)	
*14 May	1426.42	1424.04	1422.68			
15 May	1426.42	Windy	1422.79			1447.02 (F/W)
16 May	1426.42	1424.92	1422.9			
17 May	1426.5	1424.92	1423.1			
18 May	---	1425.08	1423.2	1405.78 (USGS)		
21 May	1426.5	1425.3	1423.83			1446.7 (F/W)
24 May	1426.43	1425.4	1424.33			
29 May	1426.33	1425.63	1425.0			
31 May	1426.38	1425.75	1425.24			

* Hwy 57 Cut 7:30 pm, 13 May 79

Date	Main Lake	Mission Bay	East Bay	East Devils Lake	Dry Lake	Lake Alice
1 June						1446.25
8 June	1426.38	1426.03	1425.84			
10 June					1449.0 (WMD)	
12 June	1426.4	1426.13	1426.03			
13 June						1445.5 (F/W)
18 June	1426.42	1426.25	1426.1			
21 June	1426.67	1426.5	1426.3		1448.6 (WMD)	1445.2 (F/W)
22 June	1426.71	1426.5	1426.47	1410.85		
25 June						1445.0 (F/W)
27 June	1426.88 (USGS)			1411.34 (SWC)	1448.3 (SWC)	
28 June	1426.93 (USGS)					
	1426.77	1426.65	1426.33			
3 Jul	1427.0	1426.75	1426.88	1414.22		
6 Jul	1426.97	1426.75	1426.67			
12 Jul	1426.96	1426.7	1426.63	1417.15		
20 Jul	1426.71	1426.55	1426.41			1443.5 (F/W)
27 Jul	1426.5	1426.38	1426.29	1421.98		
3 Aug	1426.54	1426.41	1426.39	1424.4		
10 Aug				1425.91		
13 Aug	1426.38	1426.3	1426.2		1446.6	1442.3
23 Aug						1441.8 (F/W)
7 Sep	1426.31	1426.31		1426.40?		
10 Nov	1425.75	Frozen	Frozen	1425.75	1446.±3	1441.6 (F/W)

Readings By

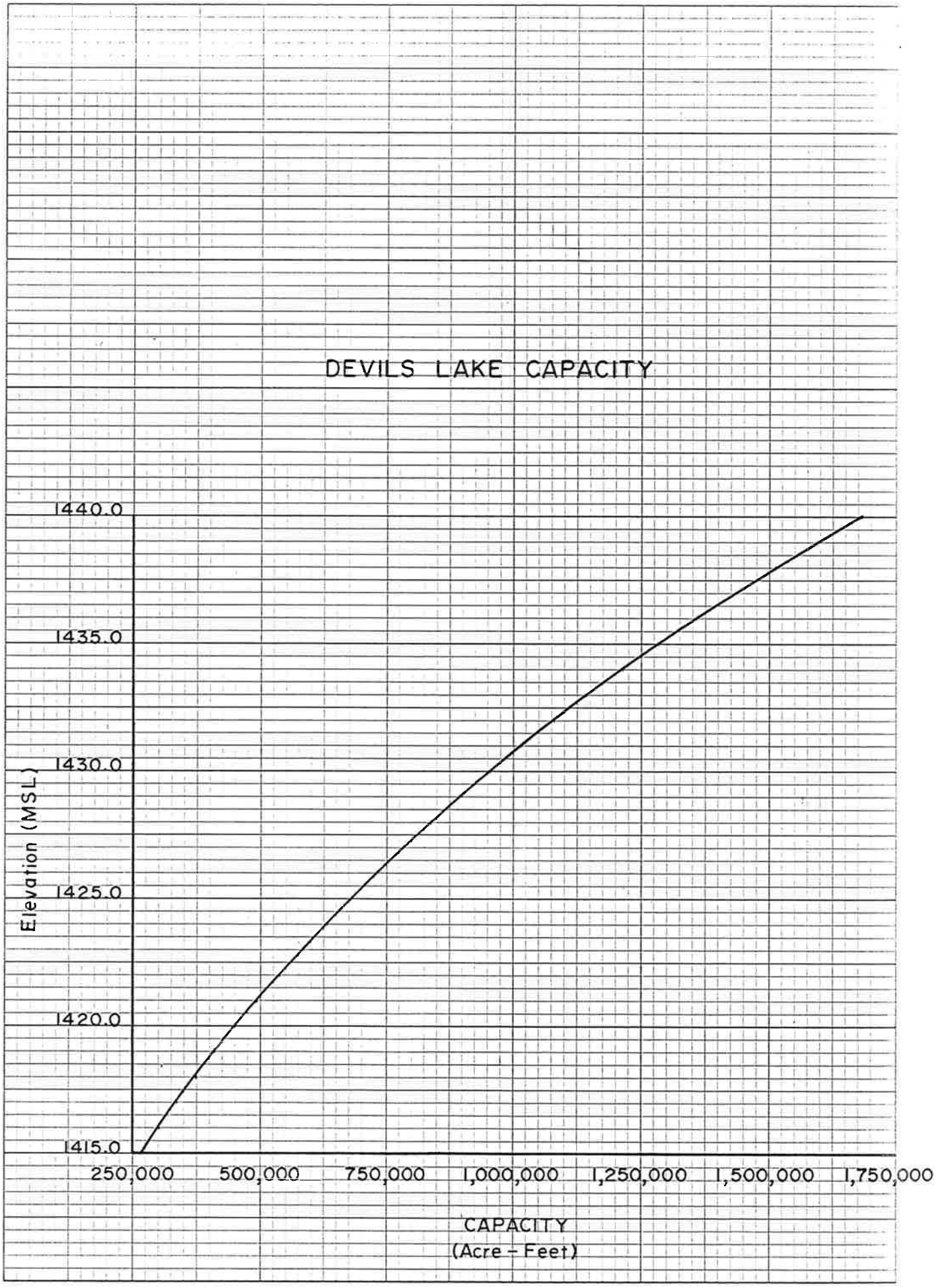
SWC - State Water Commission
WMD - Ramsey County Water Management District
USGS - U.S. Geological Survey or by SWC at designated Gage.
F/W - U.S. Fish & Wildlife Service

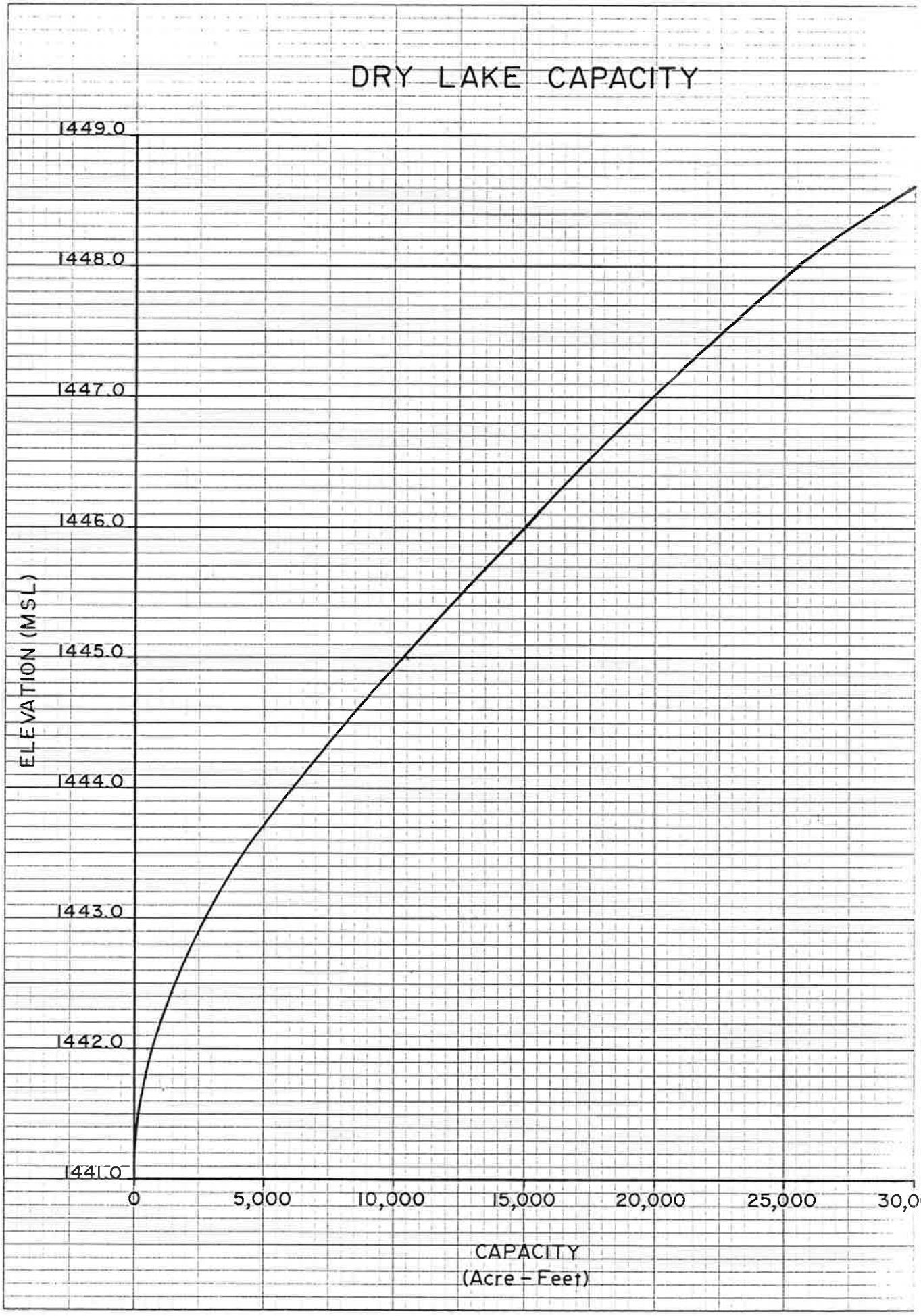
Note: Dry Lake Readings by Water Management District were lower than readings taken by Water Commission around 3 & 4 May.

APPENDIX E

LAKE CAPACITY DATA

1. Devils Lake Capacity Curve
2. Dry Lake Capacity Curve
3. Capacities of Lakes Mike, Chain, Alice, and Irving





CAPACITY (Acre-Feet)

Elevation	Mikes Lake	Chain Lake	Lake Alice	Lake Irvine	Total
1441.6	700	1,400	3,800	8,800	14,700
1442.0	900	1,700	5,050	10,500	18,150
1443.0	1,200	2,625	8,900	14,600	27,300
1444.0	2,400	4,100	13,500	19,000	39,000
1445.0	3,600	8,250	19,500	25,500	56,850
1446.0	5,800	13,000	28,000	37,000	83,800
1447.0	9,000	22,000	34,000	46,000	111,000