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THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
WINTER OF 1983-1984

BY

U.S. ARMY ENGINEER DISTRICT, DETROIT
DETROIT, MICHIGAN

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TABLE OF CONTENTS

	<u>PAGE</u>
INTRODUCTION	1
ICE BOOM OPERATION	1
ACTIVITIES RELATED TO ICE BOOM OPERATION	4
WATER LEVELS, FLOWS AND ICE THICKNESS	9
CONCLUSIONS	11
RECOMMENDATIONS	12
APPENDIX A: Inventory of Ice Passing through the Little Rapids Cut Ice Boom and Other Boom Events, 1983-1984 Season	
APPENDIX B: Summary of Aerial Photos, in the Vicinity of Soo Harbor and Little Rapids Cut, Winter 1983-1984	
APPENDIX C: Data Analysis	

LIST OF TABLES

<u>TABLE</u>		<u>PAGE</u>
1	Average Winter Air Temperatures, Sault Ste. Marie Michigan	4
2	Ice Thickness, St. Marys River, Winter 1983-84	7

LIST OF FIGURES

<u>FIGURE</u>		<u>PAGE</u>
1	Location of Little Rapids Cut Ice Boom and Ice Stabilization Islands	2
2	Location of Ice Measuring Stations	6
3	Location of Water Level Gage Stations	8
4	Average Quarter Month Levels, at U.S. Slip and Frechette Gages, for the Preboom, Postboom and 1983-1984 Winter Seasons	10



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THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM WINTER OF 1983-1984

INTRODUCTION

The St. Marys River is considered one of the key links in the Great Lakes-St. Lawrence Seaway transportation system. Both the United States and Canadian governments have made considerable monetary investments to ensure safe and economic transportation of goods and materials through the St. Marys River, especially in the Sault Ste. Marie area. Five navigation locks were built to traverse approximately 20 feet of fall at the St. Marys Rapids, and a 600 foot wide channel, Little Rapids Cut, was excavated in the lower river between Sugar Island and the mainland of Michigan, to improve the navigation channel. Between 1971 and 1979, the Great Lakes-St. Lawrence Seaway Navigation Season Extension Program investigated the feasibility of year round navigation on the St. Marys River and through the Soo Locks. It was as part of this program that the ice boom at the head of Little Rapids Cut was first installed.

Under normal winter conditions, sufficient ice cover would develop in Soo Harbor by late December to form an ice bridge at the head of Little Rapids Cut. Undisturbed, this ice bridge would mainly prevent ice from moving into the cut. The ice bridge was often disturbed by weather conditions or by local vessel traffic, which did not transit the locks. With the advent of the extended navigation demonstration program in 1971, the ice bridge was continuously breached by ship traffic. Increased ice movement into the cut halted or interfered with ongoing ferry operations between Sugar Island and the mainland, blocked the navigation channel and increased the chances of ice jams in the lower cut.

To help stabilize the ice cover in Soo Harbor and thus moderate ice problems in the cut, and to act as an aid to winter navigation, an ice boom with a 250-foot wide navigation opening was placed at the head of Little Rapids Cut for the winter of 1975-1976. Because of its effectiveness during that winter, the boom continued to be deployed each winter of the demonstration program. This program concluded after the 1978-1979 winter season. Since the boom provided utility independent of winter navigation, a decision was made to reinstall the system each winter, for an indefinite period. Authority was given to the Soo Area Office, Detroit District, Corps of Engineers to make the installation a part of its regular winter operations.

This report has been prepared to document the operation of the Little Rapids Cut boom during the 1983-84 winter season.

ICE BOOM OPERATION

The east and west arms of the floating timber ice boom at the head of the Little Rapids Cut were installed on 7-9 November and 29 November - 9 December 1983, respectively. The boom's configuration and location are shown in Figure 1. Positioned just upstream of the Sugar Island ferry crossing, the boom is composed of a west arm, which extends 400 feet out from the mainland, and a

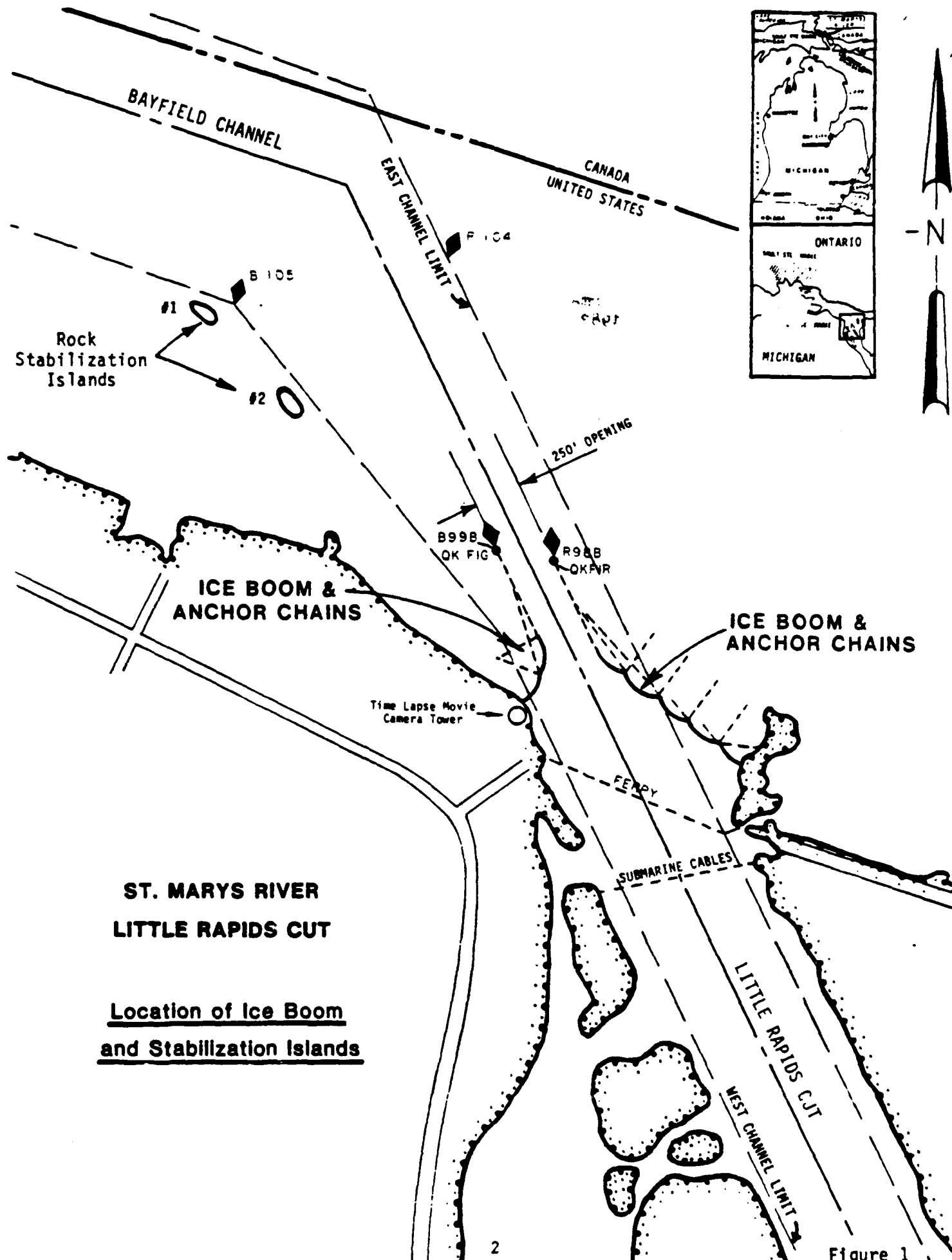


Figure 1

longer east arm which extends from Mouse Island about 1,000 feet into the river. Mouse Island is a small island just upstream of the Sugar Island ferry slip on the east shore of Little Rapids Cut. The configuration of the boom provides a 250-foot opening in the center of the navigation channel for ship passage. Initially, a sunken barge and crane weights were placed above the west boom arm each winter, to stabilize the ice sheet. These were replaced in 1981 with two permanent rock islands, as illustrated in Figure 1.

By mid-December, ice had begun to form along the shore both above the locks and in Soo Harbor, but the lock approaches and the areas behind both boom arms remained ice free. During the second half of December temperatures averaged 12.4 °F below normal and 13.8 °F below those recorded during the first half of December 1983. As a result of these colder than normal temperatures, ice began forming behind the boom, on 19 December. By 28 December there was a solid ice cover behind both boom arms, Soo Harbor was 80% ice covered and the Lake Nicolet ice field was three miles below the Little Rapids Cut ferry crossing.

The locks officially closed to traffic at midnight, 1 January 1984. At that time, the upper river was ice covered, the shipping channel was filled with refrozen, broken ice, the lock approaches were ice covered, Soo Harbor was mostly ice covered with open water only in the rapids and along the Canadian shore, and the ice field was only one mile below the ferry crossing.

Temperatures warmed up slightly in early January, resulting in a temporary build-up of brash ice in the cut at the edge of the Lake Nicolet ice field. This brought the ice field to within a half mile of the ferry crossing. Beginning around 6 January, below normal temperatures helped establish a solid, stable ice cover above the boom and maintained the Lake Nicolet ice field one mile below the ferry crossing. These conditions remained unchanged into February. During this period the coldest temperatures of the season were recorded. Between 6 and 22 January, the daily mean temperatures averaged 14.5 °F below normal. On over half of these days temperatures averaged below 0 °F.

February 1984 was the second warmest February on record at Sault Ste. Marie, Michigan. Small amounts of ice began to move out of Soo Harbor in early February, as the harbor ice field began warming up. During an eight day period (11-18 February), daily temperatures averaged above freezing and the harbor ice cover began to break up. On 14 February, heavy movements of ice into the cut reduced the ice cover behind the booms from a 95% cover of solid ice to about a 30% cover of broken ice. Ice build-up at the edge of the Lake Nicolet field at one point brought that ice field to within a half mile of the ferry crossing. By the end of February, Soo Harbor and the Old North Channel were mostly clear of ice, ice was 1-1/2 miles below the Little Rapids Cut ferry crossing, the west boom arm held various amounts of broken ice on its way out of the harbor, and the east boom arm was consistently free of ice.

Colder temperatures at the end of February and during the first half of March re-established a 50% ice cover in the harbor and solidified the ice field 1-1/2 miles below the ferry crossing. Light to moderate flows of ice continued to pass into the cut and both boom arms held varying amounts of broken ice. The harbor remained half covered with ice until mid-March. With the approach of spring, temperature began to rise. The harbor was again

essentially ice free by 19 March. The boom arms continued to hold varying amounts of broken ice until nearly the end of March, as ice cleared out of the upper river, the locks and Soo Harbor.

Due to a mild February, ice conditions on the entire St. Marys River were more favorable than usual. For this reason the Corps of Engineers granted the request of the Lake Carriers' Association and the Dominion Marine Association for early opening of the Soo Locks. The locks officially opened for navigation on 26 March, six days prior to the traditional 1 April opening date.

During early April, light to moderate flows of ice continued to pass in the cut and occasionally the west boom arm would retain some broken ice. The west boom was removed on 12 April and the east boom was removed the following day.

During the 1983-84 winter season, no ice problems were reported by the Sugar Island ferry, and there were no problems with ice jamming in the cut.

Table 1 compares the monthly mean air temperatures at Sault Ste. Marie, Michigan during the 1983-84 winter season to the average temperatures recorded during the preboom and postboom periods and also to the 30-year average.

TABLE 1
AVERAGE WINTER AIR TEMPERATURES
SAULT STE. MARIE, MICHIGAN
(degrees Fahrenheit)

	<u>DEC</u>	<u>JAN</u>	<u>FEB</u>	<u>MAR</u>
Winter 1983-1984	11.2	7.3	23.7	20.9
NWS 30-year Average (1951-1980)	20.1	13.3	14.3	23.9
Preboom Average (Dec 1968-Mar 1975)	19.9	14.0	13.5	22.9
Postboom Average (Dec 1975-Mar 1984)	17.9	9.7	15.2	24.3

ACTIVITIES RELATED TO ICE BOOM OPERATION

The effects of the Little Rapids Cut ice boom on water level and flow patterns in the Soo Harbor and Little Rapids Cut area have been investigated and monitored by the Corps of Engineers each winter since initial boom deployment in December 1975. Up to the end of the 1978-1979 winter season, these investigations were a part of the Great Lakes-St. Lawrence Seaway Navigation Season Extension Program. Monitoring continued after conclusion of

the program, as part of the operation and maintenance of the boom. The monitoring program for the winter of 1983-1984 was patterned after the procedures used in prior years.

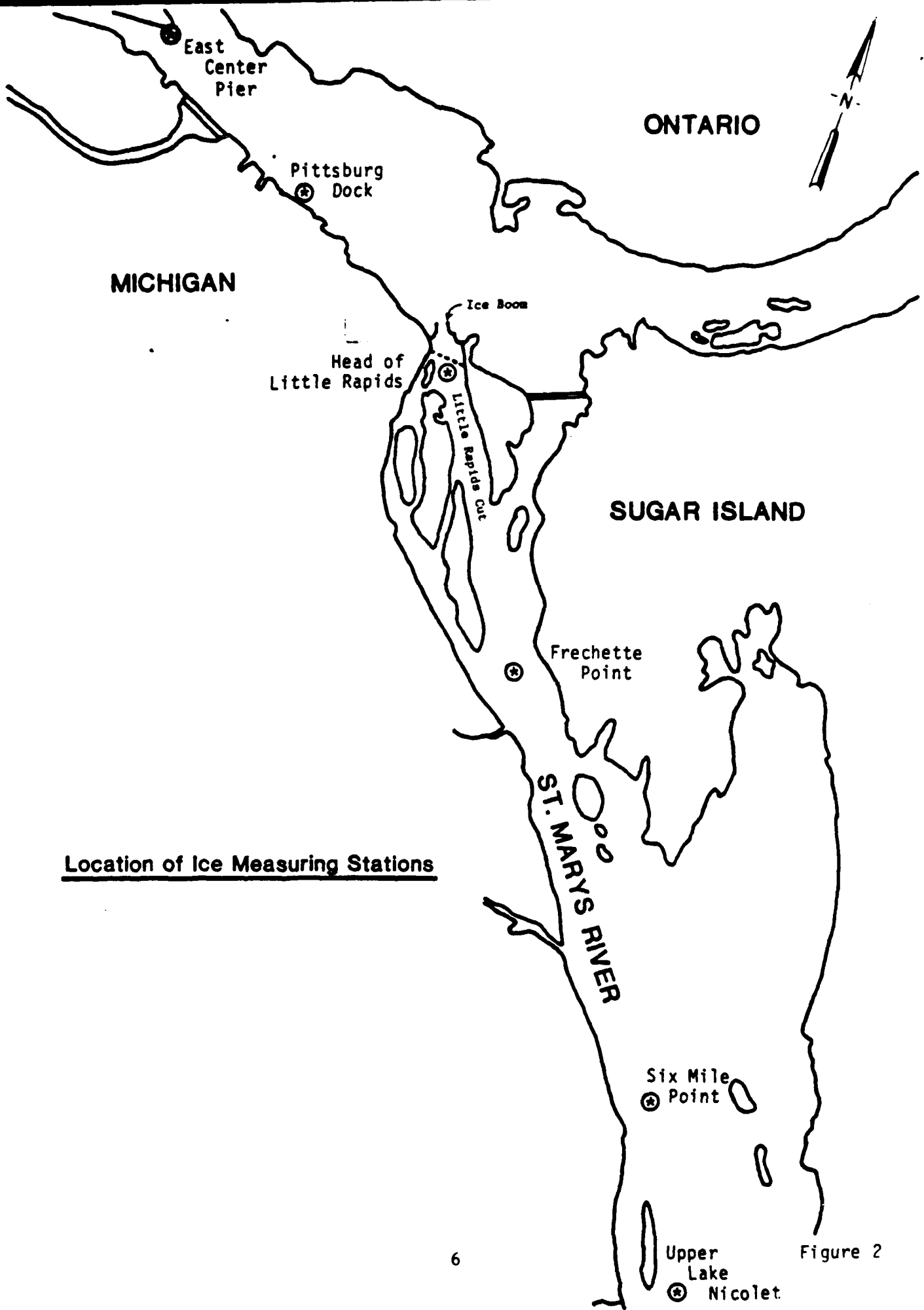
Continuous daylight observations of ice conditions in Soo Harbor and Little Rapids Cut were monitored using three time-lapse, super-8mm, movie cameras, recording approximately one frame per minute. Two cameras were installed in the U.S. Coast Guard observation tower at Mission Point, located at the head of the Little Rapids Cut on the Michigan mainland. Camera No. 1 was positioned to record ice conditions at the Sugar Island ferry crossing and downstream in the Little Rapids Cut. Camera No. 2 monitored the ice boom passageway, including the outer end of each boom arm. Both cameras were in operation during the daylight hours from mid-January through mid-April. A third camera was installed in the Administration Building of the Soo Locks to record the movement of vessels through the locks and the effect on the ice cover. Camera No. 3 was positioned in mid-December to monitor the east or downstream approach to the Poe Lock. This camera was repositioned in late March to cover the upstream approach and was removed in mid-April.

The time-lapse movies taken in the vicinity of the ice boom were reviewed and used to prepare Appendix A to this report entitled, "Inventory of Ice through the Little Rapids Cut Ice Boom and other Boom Events, 1983-1984 Season." This appendix summarizes the daily film record of ice passage through the boom opening, and the stability of the ice cover behind the boom arms. This appendix also gives prevailing meteorologic conditions. The record thus generated by the time-lapse movies is helpful in determining the chronology of ice conditions during the winter.

Six sets of low altitude, oblique aerial photographs were made of the entire St. Marys River, between 18 January and 26 March 1984. These photographs yield a more general, overall view of the ice conditions on the river than do the time-lapse movies. Appendix B, Summary of Aerial Photos taken in the Vicinity of Soo Harbor and Little Rapids Cut, Winter 1983-1984," documents the ice conditions in the area of Soo Harbor and Little Rapids Cut, as seen from the aerial photos.

Ice thickness measurements and ice characteristic observations were made at six locations along the St. Marys River, as shown in Figure 2. The results of the measurements made from 12 January to 3 March 1984 are given in Table 2. Data acquired during the previous 15 winter seasons are documented in the report, "St. Marys River - Little Rapids Cut Ice Boom, Winter of 1982-83."

Some of the data analyzed for this report were acquired in the implementation of the Soo Harbor - Little Rapids Cut Monitoring and Emergency Operations Plan, a program instituted to prevent or reduce flooding in case of an ice jam in the Little Rapids Cut. Throughout the winter season, ice conditions in and around Soo Harbor and Little Rapids Cut were visually observed and recorded daily by the Soo Area Office. These records include observations on prevailing and forecasted weather conditions, ice conditions and ship movements throughout the length of the St. Marys River system, as well as icebreaker activities and ferry operations. Also as part of this monitoring plan, the water level gage network in the lower St. Marys River (Figure 3) was closely monitored. The records of the Soo Harbor - Little Rapids Cut Monitoring and Emergency Operations Program may be found in the Great Lakes Hydraulics and Hydrology Branch Archives.



Location of Ice Measuring Stations

TABLE 2

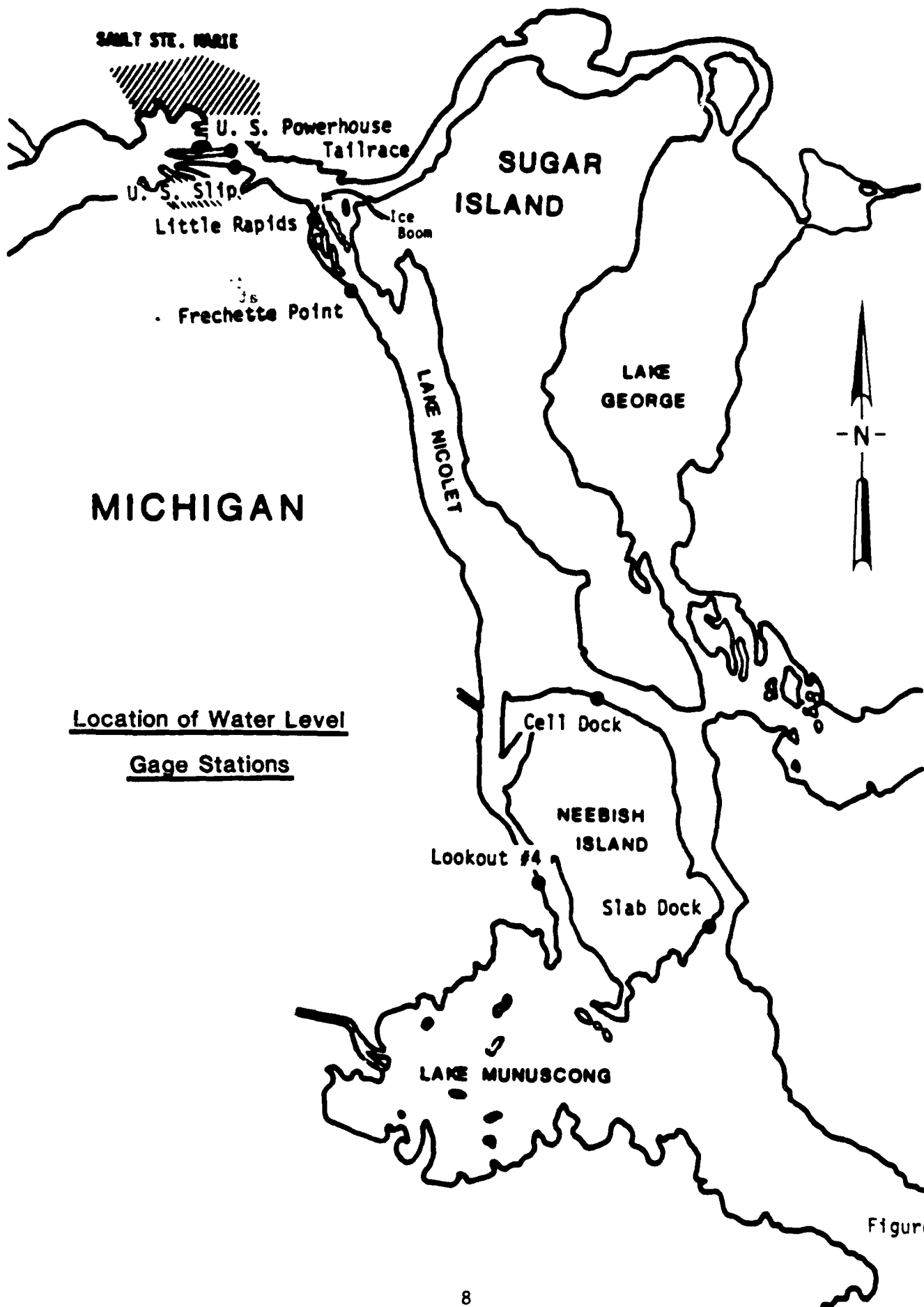
ICE THICKNESS
ST. MARYS RIVER
WINTER 1983-84

Station	12 JAN 84	19 JAN 84	2 FEB 84	9 FEB 84	16 FEB 84	23 FEB 84	29 FEB 84	9 MAR 84	15 MAR 84	23 MAR 84
East Center Pier	6½" 62% BI	10½" 81% BI	17" 82% BI	17" 77% BI	14½" 100% BI	U.A.	13" 92% BI	16" 94% BI	17" 94% BI	O.W.
Pittsburg Dock	7" 71% BI	10" 70% BI	14" 57% BI	13" 46% BI	9" 44% BI	O.W.	O.W.	O.W.	O.W.	O.W.
Head of Little Rapids	O.W.	O.W.	U.A.	U.A.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
Frechette Point	7" 71% BI	10" 75% BI	U.A.	U.A.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
Six Mile Point	10" 80% BI	11" 73% BI	12" 67% BI	19½" 59% BI	5" 60% BI	O.W.	O.W.	O.W.	O.W.	O.W.
Upper Lake Nicolet	11" 64% BI	12½" 72% BI	11" 73% BI	16" 69% BI	8" 75% BI	U.A.	5" 100% BI	8" 88% BI	9" 100% BI	O.W.

Legend:

Ice Thickness
Percent Cover
Type of Ice

O.W. = Open Water, U.C. = Unsafe Cover, U.A. = Unsafe Access
BI = Blue Ice, SN = Snow Ice



WATER LEVELS, FLOWS AND ICE THICKNESS

As has been established by the analysis in Appendix C, there has always been flow retardation during the winter in and below Little Rapids Cut. The data from the 1983-84 winter season is consistent with this pattern. In evaluating the winter of 1983-84, the water level data for Frechette and U.S. Slip gages, the temperature data recorded at Sault Ste. Marie, Michigan, the ice thickness measurements and the recorded visual observations were reviewed. As has occurred in the past, the Little Rapids gage froze-up several times during the winter, resulting in missing data. Inspection of the 1983-84 winter data has uncovered an additional problem at the Little Rapids gage, whereby the levels appear to be 0.2 to 0.3 foot above what they should be (as compared to levels recorded at Frechette and U.S. Slip gages). The gage is presently being inspected and it is anticipated that remedial actions will be taken prior to winter 1984-85.

Quarter month average water levels were computed for the U.S. Slip and Frechette gages and are plotted in Figure 4. The water levels at the two gages began to respond to the retardation of flow by ice in Lake Nicolet sooner than normal. This was the result of below normal temperatures throughout December, but particularly during the second half of the month, which allowed for the early formation of ice on the river. By the end of December, the Lake Nicolet ice field had progressed up into the cut, past the location of the Frechette gage. This is reflected in the increased differential between the levels at U.S. Slip and Frechette beginning the first quarter of January. The increased difference between U.S. Slip and Frechette levels persisted into February, but showed no abnormal fluctuations which would indicate an ice jam in or above the cut or an increase in ice retardation at the boom.

Unseasonably warm temperatures in mid-February caused the ice in the river to begin to melt and deteriorate. The levels recorded at both U.S. Slip and Frechette began to drop in the second half of February as the ice field in and below the cut began to recede down the river. During the first half of March, when temperatures averaged nearly 12 °F below normal, ice quickly reestablished itself in certain portions of the river that had lost ice cover in February. The levels at Frechette and U.S. Slip again rose, due to renewed retardation of flow below the cut resulting from the regrowth of the ice field and the consolidation and refreezing of broken ice that had accumulated at the edge of the field. This episode soon came to an end, as temperatures warmed again the second half of March. Visual observations of the river made at the end of March indicated that there was little or no ice in Soo Harbor and Little Rapids Cut, but there was still some ice in the lower reaches of Lake Nicolet. The water levels at Frechette and U.S. Slip continued to show the retarding effects of ice into April, which is not unusual.

The portion of the river being reviewed (Soo Harbor, Little Rapids Cut and Upper Lake Nicolet) developed its most extensive ice cover by the second quarter of January, which remained intact until early February. The ice thicknesses were greatest in the first quarter of February above the booms and in the second quarter below the cut. This is generally consistent with the postboom average, but was due largely to the melting of the ice cover in mid-February. By mid-February, the ice thicknesses in the harbor were declining,

AVERAGE QUARTER MONTH LEVELS
AT U.S. SLIP AND FRECHETTE GAGES
FOR PREBOOM, POSTBOOM AND 1983-84 WINTER SEASONS

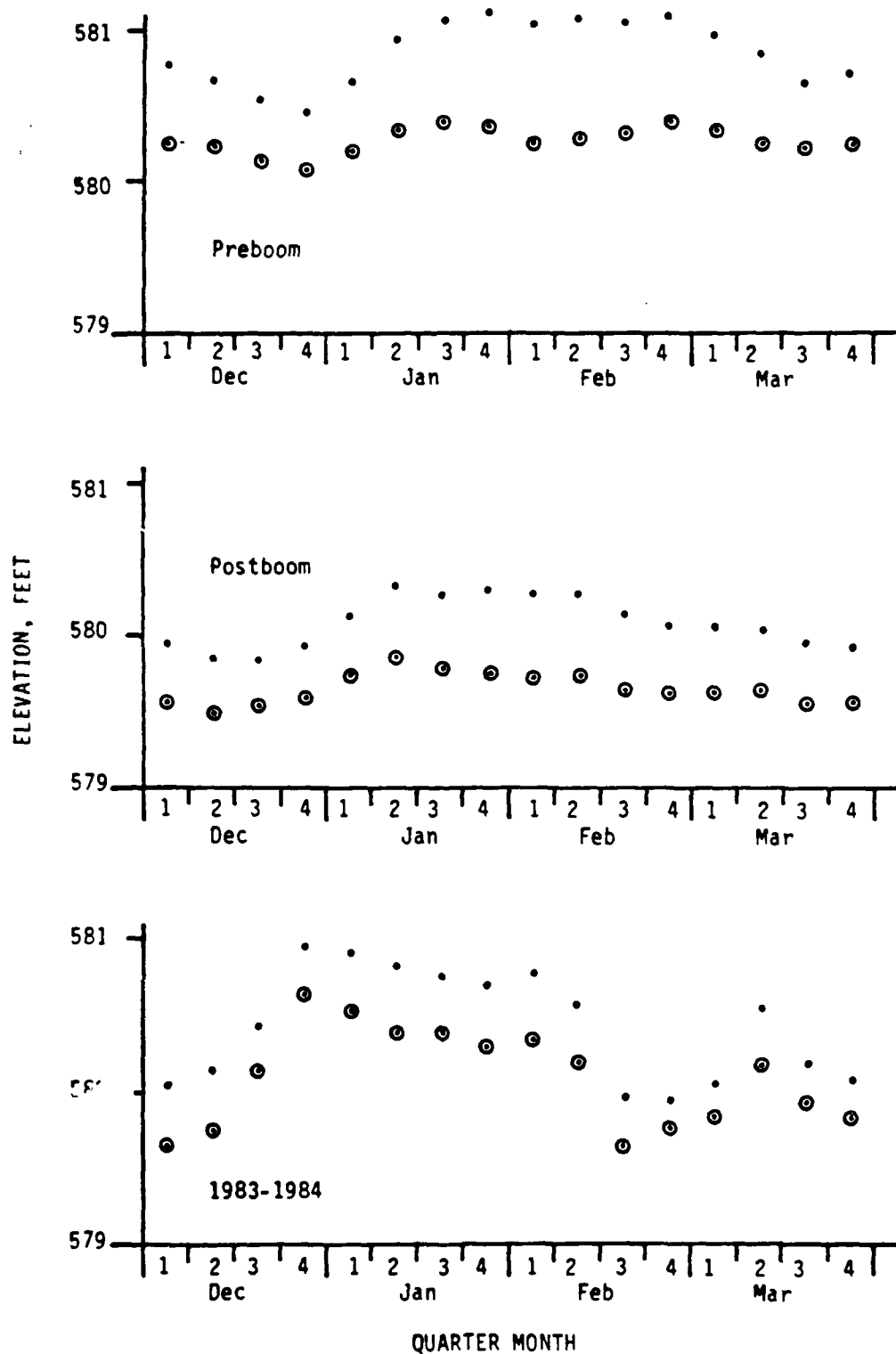


Figure 4

there was open water at Frechette Point and the ice thicknesses were decreasing in Lake Nicolet. By the end of February, there was open water at Six Mile Point. There was some re-establishment of the ice cover at the Upper Lake Nicolet and East Center Pier sites during the first half of March, but by the end of the third quarter of March there was open water at all six ice thickness measuring sites. The observations of unsafe access at the head of Little Rapids in February were due to small and moderate amounts of broken ice flowing from the harbor into the cut at the time of measurement.

CONCLUSIONS

The placement of the ice boom and the two permanent rock islands has had no discernible effect on the ice thickness in Soo Harbor and below Little Rapids Cut. There is, also, no indication that the presence of the ice boom and ice stabilization islands has adversely altered the normal retardation of flow caused naturally by ice in Soo Harbor or in and below Little Rapids Cut.

The boom system has been invaluable in stabilizing the ice cover in Soo Harbor, reducing the extent of ice accumulation in Little Rapids Cut and reducing the amount of ice in the Sugar Island ferry crossing. By reducing the possibility of ice jams in the cut, the ice boom has lessened the likelihood of emergency cutbacks in the outflow from Lake Superior, which would cause power losses at the hydropower plants. In reducing the adverse effects of natural ice conditions on the Sugar Island ferry, it has contributed to more reliable winter transportation between Sugar Island and the mainland.

RECOMMENDATION

It is recommended that a monitoring program similar to this past season's activities be continued. To better determine the effect of the ice boom on the distribution of flow around Sugar Island, if any, a program to collect information on ice characteristics and thicknesses in the north channel of the St. Marys River and the winter flow distribution around Sugar Island should be undertaken. The Little Rapids gage should be upgraded so that it is operable during the winter, and the data are reliable.

APPENDIX A

Inventory of Ice Passing Through the
St. Marys River - Little Rapids Cut Ice Boom
and other Boom Events
1983-1984 Winter Season

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON

Date	Air Temperature (F°)		Maximum Wind Speed (MPH) and Direction		Ice Behind Boom Arms	Ice Passing Into Little Rapids Cut	Other Comments
	Max.	Ave.	Min.				
10 Jan	13	-3	-19	22 NW	100%, both booms	None	Sunny, some blowing snow
11 Jan	-1	-9	-17	8 N	No change	None	Partly Cloudy
12 Jan	11	-1	-13	17 E	No change	None	Partly Sunny
13 Jan	15	10	5	15 E	No change	None	Overcast AM, partly sunny PM
14 Jan	11	-3	-16	12 NE	No change	None	Partly Sunny
15 Jan	3	-11	-24	8 SE	No change	None	Overcast, blowing snow AM; sunny PM
16 Jan	21	11	1	16 SW	No change	None	Overcast
17 Jan	13	7	0	10 W	No change	None	Overcast, snow squalls
18 Jan	9	-4	-17	11 SW	No change	Small amount passed into cut after C.G. ship passed boom area	Sunny, blowing snow
19 Jan	7	-10	-27	12 SW	No change	None	Fog, blowing snow, partly sunny

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON (CONT.)

Date	Air Temperature (F°)		Maximum Wind Speed (MPH) and Direction		Ice Behind Boom Arms	Ice Passing into Little Rapids Cut	Other Comments
	Max.	Ave.	Min.				
20 Jan	-3	-13	-23	16 NW	No change	None	Fog, sunny
21 Jan	8	-13	-33	16 W	No change	None	Fog
22 Jan	15	2	-11	11 E	No change	None	Overcast. Ice bridge developed across channel.
23 Jan	26	20	14	17 SE	No change	Ice bridge, slowly eroding downstream edge	Partly cloudy
24 Jan	33	29	24	21 SW	No change	Bridge lost approx. 40% of its area. Light flow into cut	Overcast
25 Jan	32	22	12	29 NW	No change	None	Overcast, blowing snow, snow showers
26 Jan	20	15	10	16 NW	No change	None	Partly cloudy
27 Jan	21	13	4	29 NW	No change	None	Overcast AM, sunny PM
28 Jan	22	12	2	17 SE	No change	None	Overcast
29 Jan	26	16	5	15 NW	No change	None	Overcast

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON (CONT.)

Date	Air Temperature (F°)		Maximum Wind Speed (MPH) and Direction	Ice Behind Boom Arms	Ice Passing Into Little Rapids Cut	Other Comments
	Max.	Ave.				
30 Jan	13	1	-11	14 NW	No change	Overcast
31 Jan	10	3	-5	10 E	No change	Sunny
1 Feb	25	14	3	10 E	East - 97% West - 100%	Overcast, fog
2 Feb	34	29	23	32 SE	East - 96% West - 100%	Overcast, fog
3 Feb	34	30	25	17 W	East - 94% West - 100%	Overcast, fog
4 Feb	27	20	13	12 NE	East - 94% West - 99%	Overcast, fog
5 Feb	14	6	-2	17 NE	No change	Overcast
6 Feb	6	-3	-12	15 N	East - 96% West - 100%	Mostly cloudy
7 Feb	12	-2	-15	21 NW	No change	Partly sunny
8 Feb	27	18	8	11 SW	No change	Partly cloudy

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON (CONT.)

Date	Air Temperature (°F)		Maximum Wind Speed (MPH) and Direction		Ice Behind Boom Arms		Ice Passing Into Little Rapids Cut		Other Comments
	Max.	Ave.	Max.	Min.					
9 Feb	22	14	5		21 SE	East - 94% West - 100%	Light flow	Overcast, fog	
10 Feb	36	23	10		13 E	No change	None	Cloudy, heavy fog	
11 Feb	38	35	32		10 E	East - 92% West - 100%	None	Overcast, fog. Ice field deteriorating.	
12 Feb	37	35	32		26 SE	East - 90% West - 100%	Small amounts	Overcast, fog, rain	
13 Feb	41	38	35		29 SE	East - 85% West - 100%	Small amounts	Overcast, fog, rain	
14 Feb	37	35	32		14 SW	East - 80% West - 75%	Heavy flow. Both fields breaking up and shifting downstream as day progresses	Overcast, fog, rain	
15 Feb	39	34	28		8 E	East - 30% West - 50%	Moderate flow	Mostly sunny	
16 Feb	41	35	28		17 SE	East - None West - 30-80%	Moderate to heavy flow of ice	Overcast. Area behind west boom filling with broken ice which is periodically released over and under boom.	

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON (CONT.)

Date	Air Temperature (F°)		Maximum Wind Speed (MPH) and Direction		Ice Behind Boom Arms	Ice Passing Into Little Rapids Cut	Other Comments
	Max.	Ave.	Max.	Min.			
17 Feb	40	36	32	13 SE	East - 0-10% West - 35-40%	Moderate amounts	Overcast
18 Feb	37	34	30	10 NE	No change	None	Overcast, fog
19 Feb	34	31	28	14 NW	East - None West - 100% broken ice	None	Overcast, fog, rain
20 Feb	30	27	24	14 NW	No change	Light flow of ice over west boom	Overcast, large floe lodged across channel between booms.
21 Feb	28	24	19	10 N	East - 3% West - 98%	Moderate flow	Mostly cloudy
22 Feb	44	35	25	12 S	East - None West - 40%	Light flow	Partly cloudy
23 Feb	47	37	27	17 NW	East - None West - 30-50%	Light to moderate flow	Sunny
24 Feb	34	28	22	18 NW	East - None West - 100%	Light flow	Overcast, fog
25 Feb	24	20	15	18 NW	No change	Light flow	Cloudy
26 Feb	24	14	4	18 NW	No change	Light flow	Sunny

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON (CONT.)

Date	Air Temperature (F°)		Maximum Wind Speed (MPH) and Direction	Ice Behind Boom Arms	Ice Passing Into Little Rapids Cut	Other Comments	
	Max.	Ave.					
	Max.	Min.					
27 Feb	32	20	7	15 NE	No change	Light flow	Partly cloudy
28 Feb	26	18	9	25 NW	East - None West - 50%	Heavy discharge over west boom	Mostly cloudy
29 Feb	14	7	0	21 NW	East - None West - 75%	Light steady flow throughout day	Partly cloudy
1 Mar	19	14	9	26 NW	East - None West - 100%	Light flow	Mostly sunny
2 Mar	19	14	8	25 NW	No change	Light flow	Partly sunny
3 Mar	26	16	5	15 NW	No change	Light flow	Mostly sunny
4 Mar	32	19	5	15 SE	No change	None	Partly cloudy
5 Mar	27	22	16	17 E	East - None West - 70%	Moderate flow	Overcast
6 Mar	16	5	-6	17 NW	East - 50% West - 65%	Moderate to heavy flow	Mostly sunny
7 Mar	6	-5	-15	12 NW	East - 15% West - 65%	Light flow	Sunny
8-12 Mar			2 (5 day average)				
							-- Camera malfunction --

-- Camera malfunction --

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON (CONT.)

Date	Air Temperature (F°)		Maximum Wind Speed (MPH) and Direction		Ice Behind Boom Arms	Ice Passing Into Little Rapids Cut	Other Comments
	Max.	Ave.	Min.				
13 Mar	20	15	10	17 SE	Both 100%	None	Overcast
14 Mar	31	24	17	19 E	East - 30% West - 100%	Light flow	Overcast, fog
15 Mar	35	31	26	22 E	East - 5% West - 100%	Moderate to heavy flow	Overcast, fog
16 Mar	35	22	8	20 NW	East - 7% West - 60%	Light flow	Mostly sunny
17 Mar	28	14	0	16 SE	East - 7% to none by PM West - 80% to 20% by PM	Moderate flow	Mostly cloudy
18 Mar	36	26	16	12 NW	East - None West - 20-50, variable	Light, steady flow	Overcast
19 Mar	38	31	24	13 N	No change	Light flow	Overcast
20 Mar	36	34	32	19 E	East - 10% West - 70%	None	Overcast, fog
21 Mar	41	38	35	12 E	East - None West - 100%	Light flow	Overcast, fog, rain
22 Mar	38	29	19	23 NW	East - None West - 100%	Light flow	Overcast

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON (CONT.)

Date	Air Temperature (F°)		Maximum Wind Speed (MPH) and Direction		Ice Behind Boom Arms	Ice Passing Into Little Rapids Cut	Other Comments
	Max.	Ave.	Min.				
23 Mar	28	23	17	21 NW	No change	Light flow	Partly sunny
24 Mar	41	31	20	7 S	No change	Light flow	Partly cloudy
25 Mar	39	31	23	13 NW	No change	Light flow	Sunny
26 Mar	39	30	20	8 SE	East - None West - 0-40%	Moderate flow	Sunny
27 Mar	43	32	20	10 SE	East - 1% West - 0-10%	Moderate flow	Sunny
28 Mar	49	38	27	16 NE	East - 0% West - 5%	Light flow	Sunny
29 Mar	47	38	28	15 NW	None	Light flow	Overcast
30 Mar	48	38	28	18 NW	None	Light flow	Overcast
31 Mar	43	34	25	17 NW	None	Light flow	Mostly sunny
1 Apr	46	34	22	12 NW	East - None West - 35% decreasing to 1%	Moderate flow after ship passages	Sunny
2 Apr	49	37	24	15 NW	East - None West - 2%	Light flow -- throughout day, primarily after ship passages	Partly sunny, hazy

INVENTORY OF ICE THROUGH THE ST. MARYS RIVER - LITTLE RAPIDS CUT ICE BOOM
AND OTHER BOOM EVENTS
1983-1984 WINTER SEASON (CONT.)

Date	Air Temperature (°F)		Maximum Wind Speed (MPH) and Direction		Ice Behind Boom Arms	Ice Passing Into Little Rapids Cut	Other Comments
	Max.	Ave.	Min.				
3 Apr	54	38	22	10 SE	None	Light flow	Sunny
4 Apr	59	44	29	18 SE	None	None	Sunny
5 Apr	50	43	36	31 NE	East - None West - 100%	Moderate to heavy flow	Sunny. Ice in channel between booms.
6 Apr	52	42	32	23 NW	None	Light to moderate flow, primarily after ship passages	Overcast
7 Apr	51	38	25	20 NW	None	None	Sunny
8 Apr	54	41	27	14 SE	East - None West - 5-70%	Moderate flow	Sunny
9 Apr	55	42	28	22 E	East - None West - 0-10%	Moderate flow	Sunny
10 Apr	59	45	30	14 E	East - 6% West - 3%	Light flow	Sunny
11 Apr	63	46	29	10 SE	East - None West - 0-30%	Moderate flow	Sunny
12 Apr	61	45	29	27 SE	East - None West boom removed	Light flow	Sunny
13 Apr	50	45	40	23 E	East boom removed	None	Sunny

APPENDIX B

Summary of Aerial Photos
in the Vicinity of
Soo Harbor and Little Rapids Cut
Winter 1983-1984

Summary of Aerial Photos
Taken in the Vicinity of
Soo Harbor and Little Rapids Cut
Winter 1983-1984

18 January 1984. The lock approaches were ice covered. A solid ice cover existed above the compensating works. There was open water in the St. Marys Rapids and into Soo Harbor. The U.S. Government Powerhouse tailrace and headrace were ice free to the International Railroad Bridge. Soo Harbor was approximately 80% ice covered. The areas behind both booms were 100% ice covered. There was open water in a ship track from mid-harbor to between the boom arms. Little Rapids Cut was ice free and the Lake Nicolet ice field was one mile below the Sugar Island ferry crossing.

8 February 1984. The lock approaches were ice covered. The St. Marys Rapids and the U.S. Government headrace and tailrace were ice free. There was open water immediately upstream of the compensating works and below the rapids, well into Soo Harbor along the Canadian shore. Soo Harbor was approximately 60% ice covered, but the areas behind both boom arms remained 100% ice covered. There was open water between the boom arms and back into Soo Harbor. Little Rapids Cut was ice free and the Lake Nicolet ice field was one mile below the ferry crossing.

16 February 1984. There was broken ice and some open water above the compensating works. The lock approaches were still ice covered. Soo Harbor was 20-30% ice covered, mainly with ice along the U.S. shore. There was shore ice behind the west boom, but the boom itself held only a small amount of broken ice. The east boom held large amounts of broken ice, but there were some open water areas. There was no ice in Little Rapids Cut and the channel was open almost to Frechette Point.

8 March 1984. The area for approximately 1/2 mile upstream of the compensating works was 60% ice covered, but there was no ice directly above the compensating works. The powerhouse headrace and tailrace and the St. Marys Rapids were ice free. Soo Harbor was only about 20-30% ice covered -- shore ice along the U.S. mainland and Sugar Island. There was shore ice behind the west boom. The boom itself held some broken ice, with open water above that. The area behind the east boom was 55% ice covered. Little Rapids Cut was ice free. The Lake Nicolet ice field was 2 miles below the ferry crossing.

16 March 1984. The ice conditions above Soo Harbor were essentially the same as those observed on 8 March. Soo Harbor retained only shore ice along the U.S. mainland and along Sugar Island. The area behind the west boom was covered with broken ice. Thin deteriorating ice covered above 60% of the area behind the east boom. There was no ice in Little Rapids Cut and the Lake Nicolet ice field was two miles below the ferry crossing.

26 March 1984. There was no ice above the compensating works. There was thin and broken ice in the lock approaches, 75% cover upstream and 100% cover downstream. Some ice remained in Soo Harbor along the Sugar Island shore. There was no ice behind the east boom and only a small amount of broken ice was being held by the west boom. There was no ice in Little Rapids Cut, and very little ice in the upper portion of Lake Nicolet.

APPENDIX C
DATA ANALYSIS

APPENDIX C
DATA ANALYSIS

TABLE OF CONTENTS

	<u>PAGE</u>
INTRODUCTION	C-1
WATER LEVELS AND FLOWS	C-1
FLOW DISTRIBUTION AROUND SUGAR ISLAND	C-5
ICE COVER	C-11
CONCLUSIONS	C-19

TABLES

C-1 Distribution of Flow Around Sugar Island as Measured at Frechette and Garden River Hydraulic Sections	C-9
C-2 Comparison of Cross Sectional Areas as Measured in 1969, 1978 and 1979 at Frechette and Garden River Sections	C-11
C-3 Measured Ice Thickness, East Center Pier	C-13
C-4 Measured Ice Thickness, Pittsburg Dock	C-14
C-5 Measured Ice Thickness, Head of Little Rapids	C-15
C-6 Measured Ice Thickness, Frechette Point	C-16
C-7 Measured Ice Thickness, Six Mile Point	C-17
C-8 Measured Ice Thickness, Upper Lake Nicolet	C-18
C-9 Maximum Ice Thickness, 1969-1984	C-20
C-10 Average Air Temperature, Sault Ste. Marie, MI	C-21

FIGURES

C-1 Location of Water Level Gage Stations	C-2
C-2 Average Pre- and Postboom Levels, at Selected Gage Sites on the St. Marys River	C-3
C-3 Average Pre- and Postboom Levels, on Lakes Superior and Michigan-Huron	C-4

TABLE OF CONTENTS
FIGURES (CONT.)

	<u>PAGE</u>
C-4 Average Quarter Month Levels Recorded at Selected Gage Sites for Preboom and Postboom Winter Seasons	C-6
C-5 Location of Hydraulic Sections Used to Measure Distribution of Flow Around Sugar Island	C-7
C-6 Flow Past Section, as a Percent of Total St. Marys River Flow	C-10
C-7 Location of Ice Measuring Stations	C-12

DATA ANALYSIS

INTRODUCTION

The St. Marys River - Little Rapids Cut ice boom is intended to stabilize the ice cover in Soo Harbor and to reduce the quantity of brash ice flowing into Little Rapids Cut. There was some fear that the boom would adversely affect the flow of water into the cut by increasing the build up of ice at the head of the cut. The effect of the ice boom on ice cover, water levels and flow patterns in the Soo Harbor and Little Rapids Cut area has been investigated and monitored by the Corps of Engineers each winter since its initial deployment in December 1975.

WATER LEVELS AND FLOWS

The recorded water levels in the lower St. Marys River were examined to determine the possible effects of the ice boom on levels and flows. The U.S. Slip, Little Rapids and Frechette Point water level gages were chosen for this analysis because of their locations relative to the ice boom (Figure C-1). The U.S. Slip gage represents the water levels in Soo Harbor above the boom while the Little Rapids gage records water level data immediately downstream of the boom. The Frechette Point gage records water level data below Little Rapids Cut. These three gages should reflect any effects on water levels and flows that might occur as a result of the ice boom, accumulated ice in Little Rapids Cut or ice in Lake Nicolet.

Figure C-2 shows plots of actual monthly mean water levels at the three river gages, averaged over two time periods: preboom, July 1968 to June 1975, and postboom, July 1975 to June 1983. Because the data recorded at the Little Rapids gage for the 1983-1984 winter were unreliable, as explained in the main report, none of the level data recorded during the 1983-1984 season were included in this analysis. The records at Frechette and U.S. Slip were reviewed in the main report. Figure C-3 shows Lake Superior water levels recorded at Marquette and Lake Michigan-Huron water levels recorded at Harbor Beach, averaged over the same periods. Comparing these values, there can be seen a definite rise in the water levels at the selected river gage sites, between December and February, that is not reflected in the seasonal fluctuation of the lakes, which show a steady decline into March. The winter rise in levels in the portion of the St. Marys River being monitored is the result of the retardation of flow by the ice field in Lake Nicolet and Little Rapids Cut. Flow retardation has the effect of raising water levels upstream of an obstruction (e.g., an ice field) while downstream levels decline. The retardation that is occurring appears to be a natural winter phenomenon in this reach, having occurred during both pre- and postboom winters.

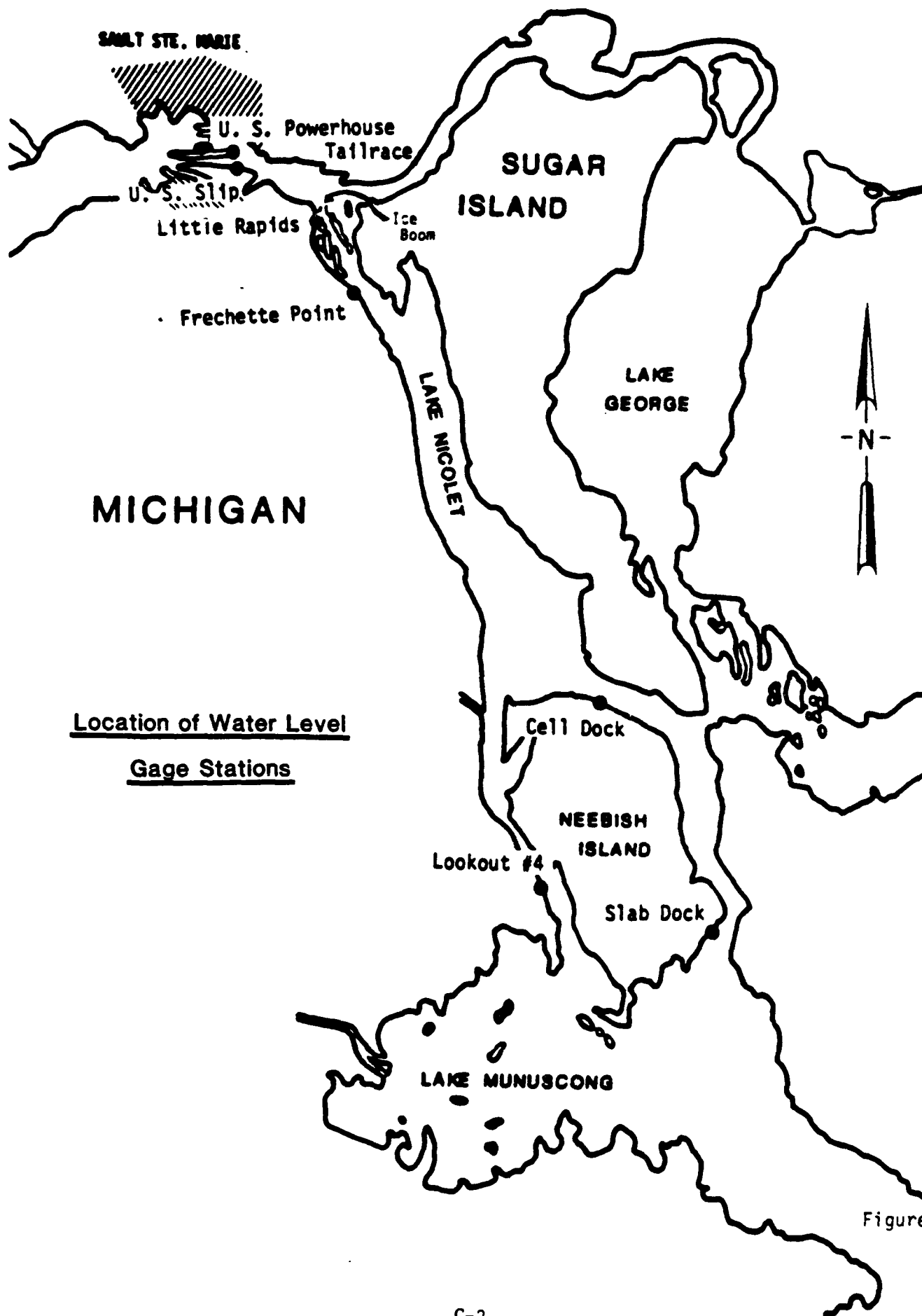


Figure C-1

AVERAGE PRE- AND POSTBOOM LEVELS
at Selected Gage Sites
on the St. Marys River

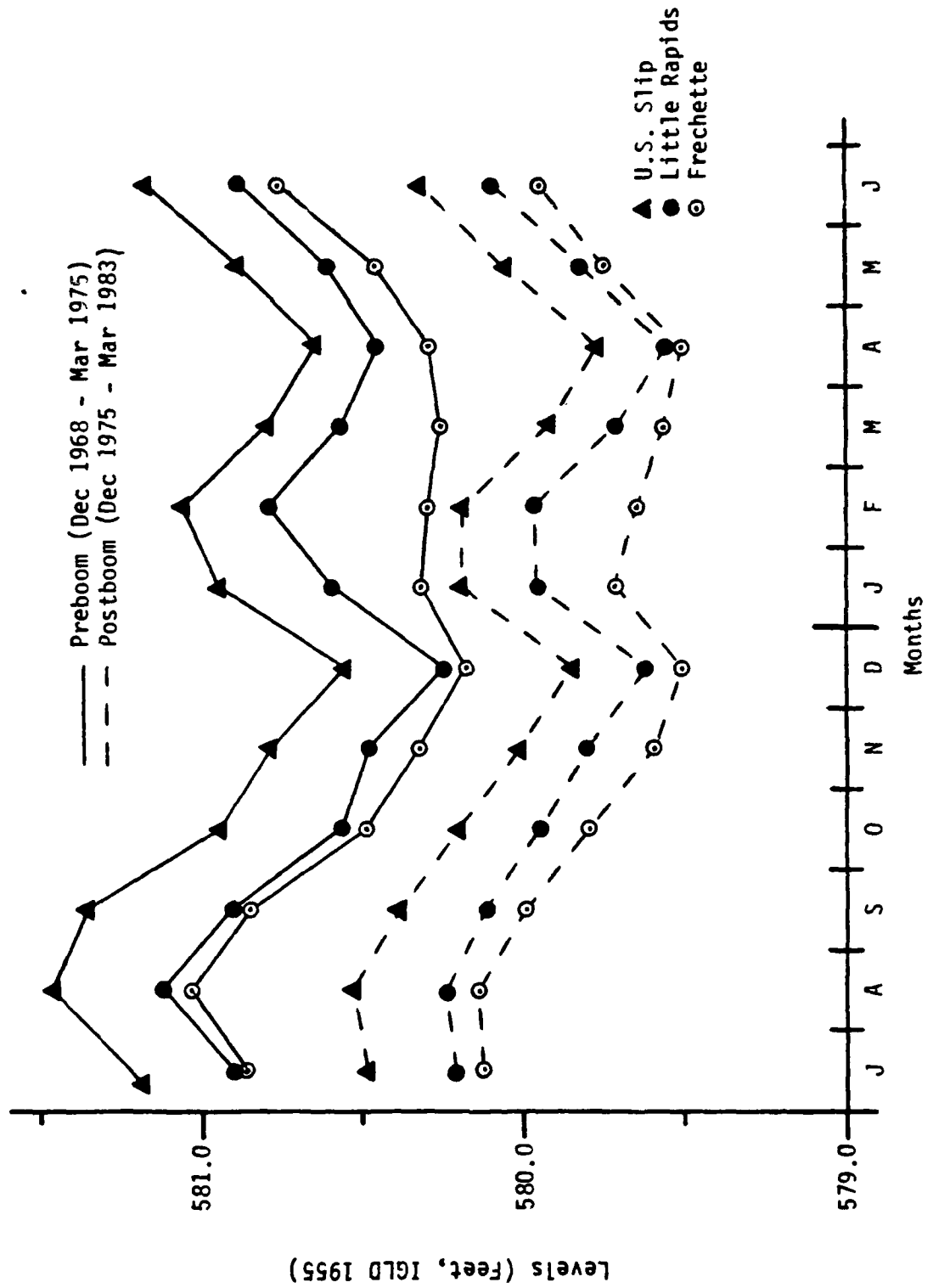


Figure C-2

Levels (Feet, IGLD 1955)

LAKE SUPERIOR
@ Marquette, MI

LAKE MICHIGAN-HURON
@ Harbor Beach, MI

Preboom (1969-75)
Postboom (1975-83)

Months

C-4

Figures C-4 gives a more detailed look at the winter months by showing quarter month average water levels¹ at the U.S. Slip, Little Rapids and Frechette Point gages for pre- and postboom periods. In mid to late December, generally all three gages are beginning to reflect the formation of ice in Lake Nicolet. By mid-January the ice field has usually advanced past Frechette Point and into Little Rapids Cut, as shown by the increased difference between the levels recorded at the Frechette Point and Little Rapids gages. Figure C-4 shows no significant difference in the U.S. Slip-Little Rapids relationship between the pre- and postboom periods. This would indicate that the ice boom has not altered the normal winter flow retardation at the head of Little Rapids Cut.

FLOW DISTRIBUTION AROUND SUGAR ISLAND

The St. Marys River splits around Sugar Island as it leaves Soo Harbor and flows down two major channels, the Old North Channel and the Little Rapids Channel. The distribution of flow around Sugar Island was first measured in 1965, as part of a study to determine the distribution of flow in various channels of the St. Marys River. Two hydraulic sections were established to make discharge measurements around Sugar Island. These are shown in Figure C-5.

The Frechette Section was located on the Little Rapids Channel, just below Little Rapids Cut. The section extended from Frechette Point on the Michigan mainland to Sugar Island. The Garden River Section was situated on the Old North Channel, approximately 2,500 feet downstream of the confluence of the Garden River.

The 1965 discharge measurements, made in September and October, were taken at the two sections on alternate days; i.e. one day at Frechette Section, the next day at Garden River Section. Shortly after the start of this series of measurements, seven gates were closed in the compensating works above the St. Marys Rapids, substantially altering the total flow in the river.

In September and October 1969, discharge measurements were again made on various channels of the St. Marys River, this time to provide data for the development of a mathematical model of the lower river. During this series, measurements were made simultaneously at the Frechette and Garden River Sections. At the beginning of October, 5-1/2 gates were closed in the compensating works resulting in a 1/2 gate open setting at the time of the October measurements.

¹Quarter month average water levels were computed by dividing the month into four quarters, as follows, and meaning the daily levels in each quarter month. Dec, Jan, and Mar: 1-8, 9-15, 16-23 and 24-31; Feb: 1-7, 8-14, 15-21 and 22-28 (22-29 in leap years).

AVERAGE QUARTER MONTH LEVELS
Recorded at Selected Gage Sites for
Preboom and Postboom Winter Seasons

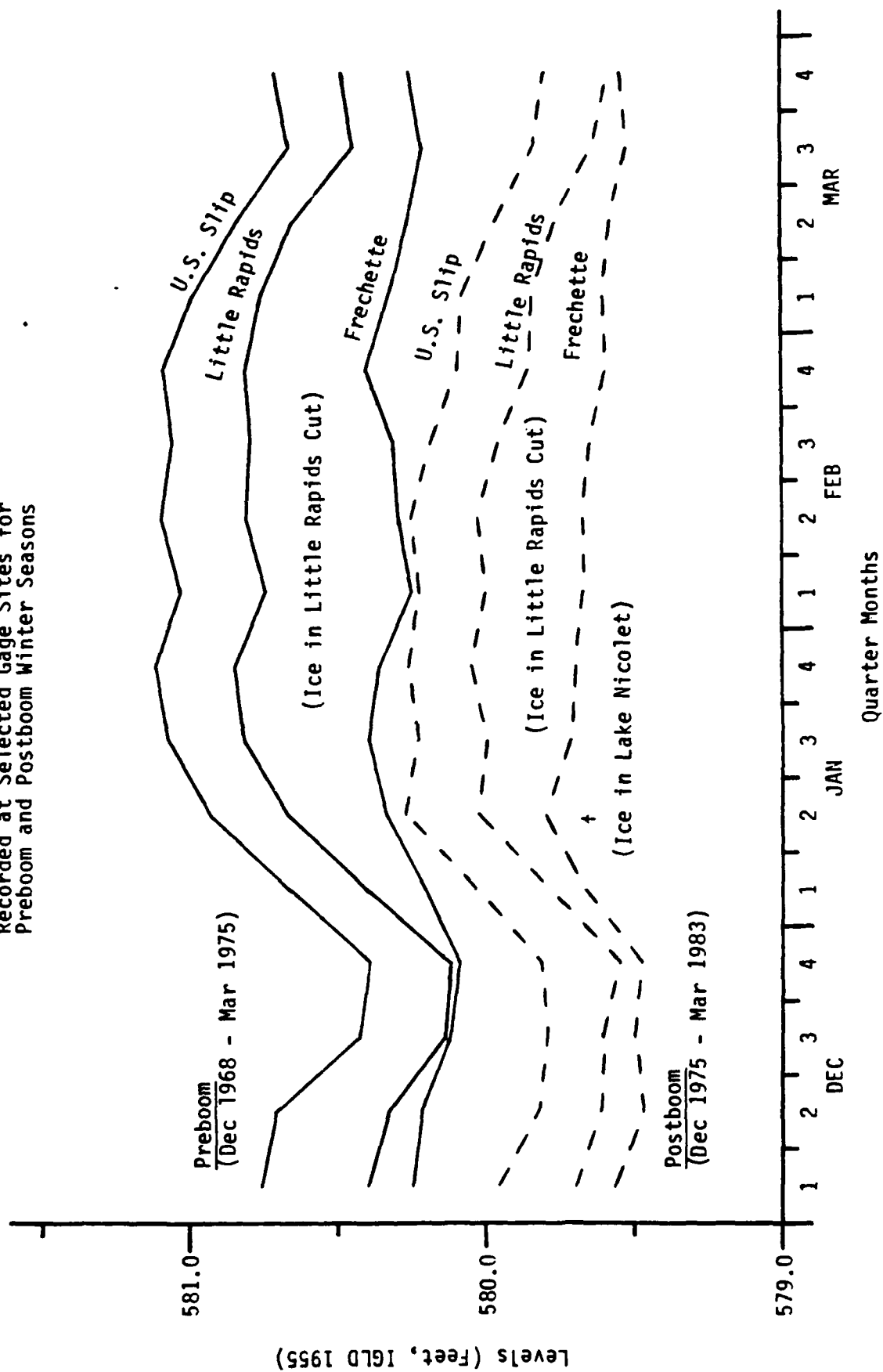
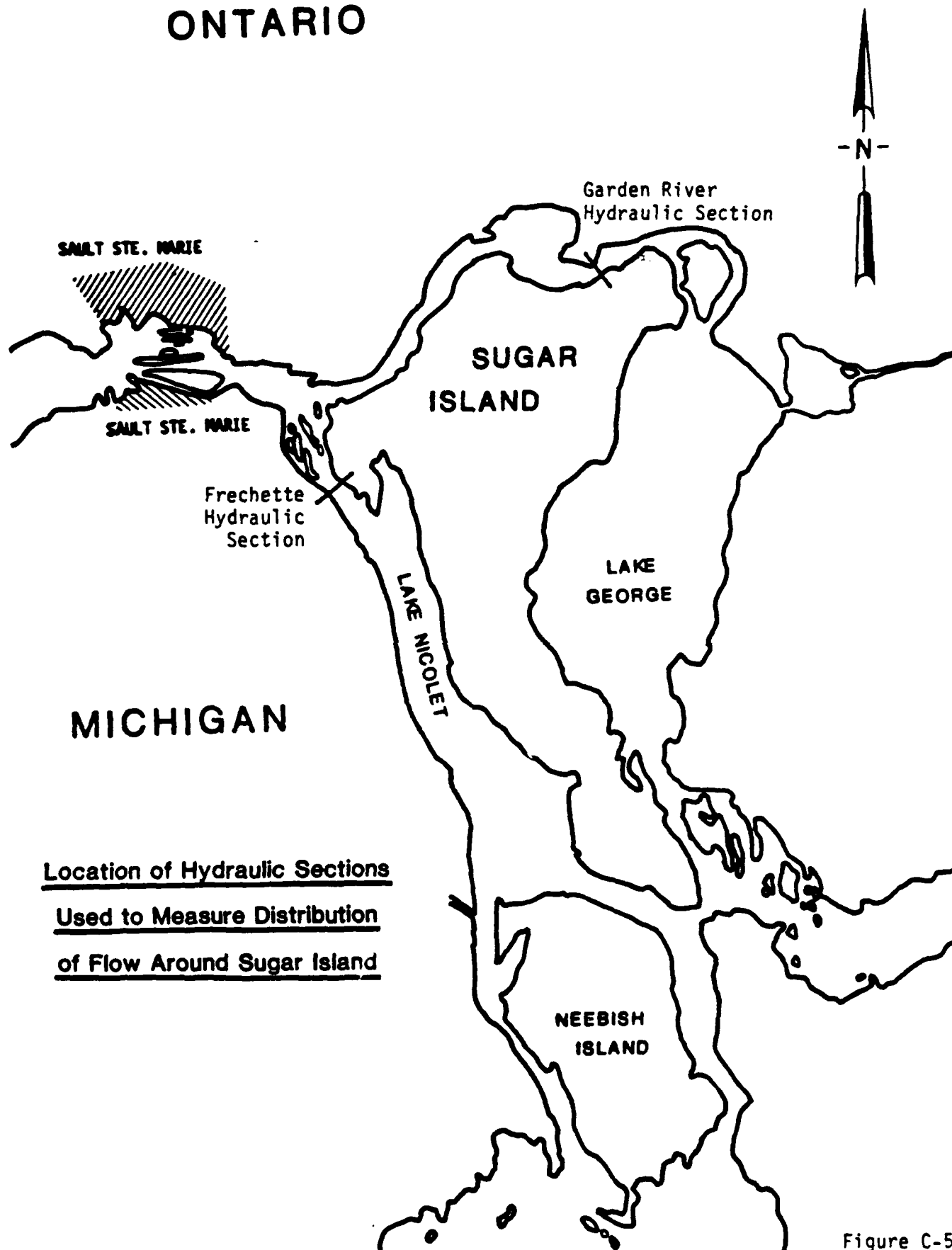


Figure C-4

ONTARIO



Location of Hydraulic Sections
Used to Measure Distribution
of Flow Around Sugar Island

Figure C-5

In 1971-1972, a survey was to be conducted to determine the effect an ice cover has on the St. Marys River flow around Sugar Island. Ice free measurements were made simultaneously at both Frechette and Garden River Sections in early December 1971. Measurements were also scheduled at both sections in February 1972, but only Frechette was metered. In February 1973, discharge measurements were made concurrently at both sections. At the time of these measurements, both sections were completely frozen over.

A short series of measurements were made at both sections in February 1976. This survey was made as part of a study to gather data on the effect of the ice boom at the head of Little Rapids Cut.

Discharge measurements were made at Frechette and Garden River Sections on 14 February and 6 September 1978, but due to insufficient data, these measurements were not considered. The last measurements of distribution of flow around Sugar Island were made in 1979. A series was made in February under winter conditions, and another set was made in June.

Table C-1 gives the results of the discharge measurements made at Frechette and Garden River Hydraulic Sections between 1965 and 1979. The distribution of flow around Sugar Island is exemplified by the flow past Frechette Section as a percent of the total flow measured.

There were three sets of discharge measurements made during winter periods. The 1973 series was made ten days after the close of the navigation season, and at the time of measurement both sections were frozen over. Navigation was continuing year round when the 1976 and 1978 measurements were made. The Garden River Section was never completely ice covered and the ice cover at Frechette Section was being continuously broken by ship traffic during the course of these measurements. The 1975-76 season was also the first winter in which the ice boom was installed at the head of Little Rapids Cut.

No conclusion can be made as to the effect of the ice boom on the flow distribution around Sugar Island during winter periods since there is only one preboom series of winter measurements for comparison, and that was made under conditions of total ice cover at both sections. There is, however, a noticeable change in the flow distribution around Sugar Island from winter to summer periods, see Figure C-6. When there is ice in the river a higher percentage of the total flow goes down the Old North Channel than during open water periods. This might be attributed to the fact that the Old North Channel has some reaches which rarely freeze over due to fast water velocities.

It should be noted, that in the course of taking discharge measurements at Frechette and Garden River Sections both sections showed an increase in total cross sectional area between 1969 and 1978. The sections were sounded in September 1969 and the resulting cross sectional areas were used to reduce the 1969, 1971, 1973 and 1976 measurements. The sections were not resounded until the summer of 1978, at which time the cross sectional areas were found to have changed substantially. The sections were again resounded in 1979 and this pattern persisted. The 1979 soundings were used to reduce the 1979 discharge measurements. Table C-2 gives a comparison of cross sectional areas. No explanation is offered for the change in cross sectional areas at

TABLE C-1
Distribution of Flow Around Sugar Island
as Measured at
Frechette and Garden River Hydraulic Sections

<u>Year & Month</u>	<u>Discharge (TCFS)</u>		<u>Total Measured Discharge</u>	<u>Flow at Frechette as % of Total</u>	<u>Daily Mean Water Level at U.S. Slip (feet, IGLD 1955)</u>
	<u>Frechette Section</u>	<u>Garden River Section</u>			
<u>1965</u>					
14 Sep - 18 Sep	89.0	30.5	119.5	74.5	579.65
20 Sep - 6 Oct	79.9	28.9	108.8	73.4	579.44
<u>1969</u>					
18 Sep	72.9	27.4	100.3	72.7	580.83
19 Sep	71.4	27.4	98.8	72.3	580.88
20 Sep	70.3	27.2	97.5	72.1	580.89
22 Sep	70.4	26.7	97.1	72.5	580.94
23 Sep	75.6	28.0	103.6	73.0	580.88
24 Sep	74.5	28.1	102.6	72.6	580.72
25 Sep	72.1	27.2	99.3	72.6	580.79
26 Sep	71.6	27.6	99.2	72.2	580.90
27 Sep	71.4	27.8	99.2	72.0	580.74
16 Oct	52.2	19.8	72.0	72.5	580.10
17 Oct	50.4	19.9	70.3	71.7	580.06
18 Oct	53.0	20.1	73.1	72.5	580.27
20 Oct	54.8	19.9	74.7	73.4	580.10
21 Oct	50.0	18.7	68.7	72.8	580.01
<u>1971</u>					
11 Dec	89.8	37.7	127.5	70.4	581.13
13 Dec	87.7	34.5	122.2	71.8	580.94
14 Dec	82.9	34.4	117.3	70.7	581.01
<u>1973</u>					
17 Feb	43.6	20.2	63.8	68.3	580.80
19 Feb	43.6	19.1	62.7	69.5	580.81
20 Feb	44.2	19.5	63.7	69.4	580.71
21 Feb	45.0	19.9	64.9	69.3	580.76
<u>1976</u>					
26 Feb	45.2	25.1	70.3	64.3	580.86
27 Feb	45.4	24.8	70.2	64.7	580.88
<u>1979</u>					
27 Feb	51.8	26.6	78.4	66.1	580.38
28 Feb	51.7	25.0	76.7	67.4	580.44
1 Mar	53.2	26.0	79.2	67.2	580.42
2 Mar	49.5	25.1	74.6	66.4	580.41
13 Jun	77.4	32.0	109.4	70.7	581.14
14 Jun	76.3	33.4	109.7	69.6	581.19
15 Jun	79.4	33.4	112.8	70.4	581.27
16 Jun	79.6	33.8	113.4	70.2	581.24

FLOW PAST FRECHETTE SECTION
AS A PERCENT OF TOTAL ST. MARYS RIVER FLOW

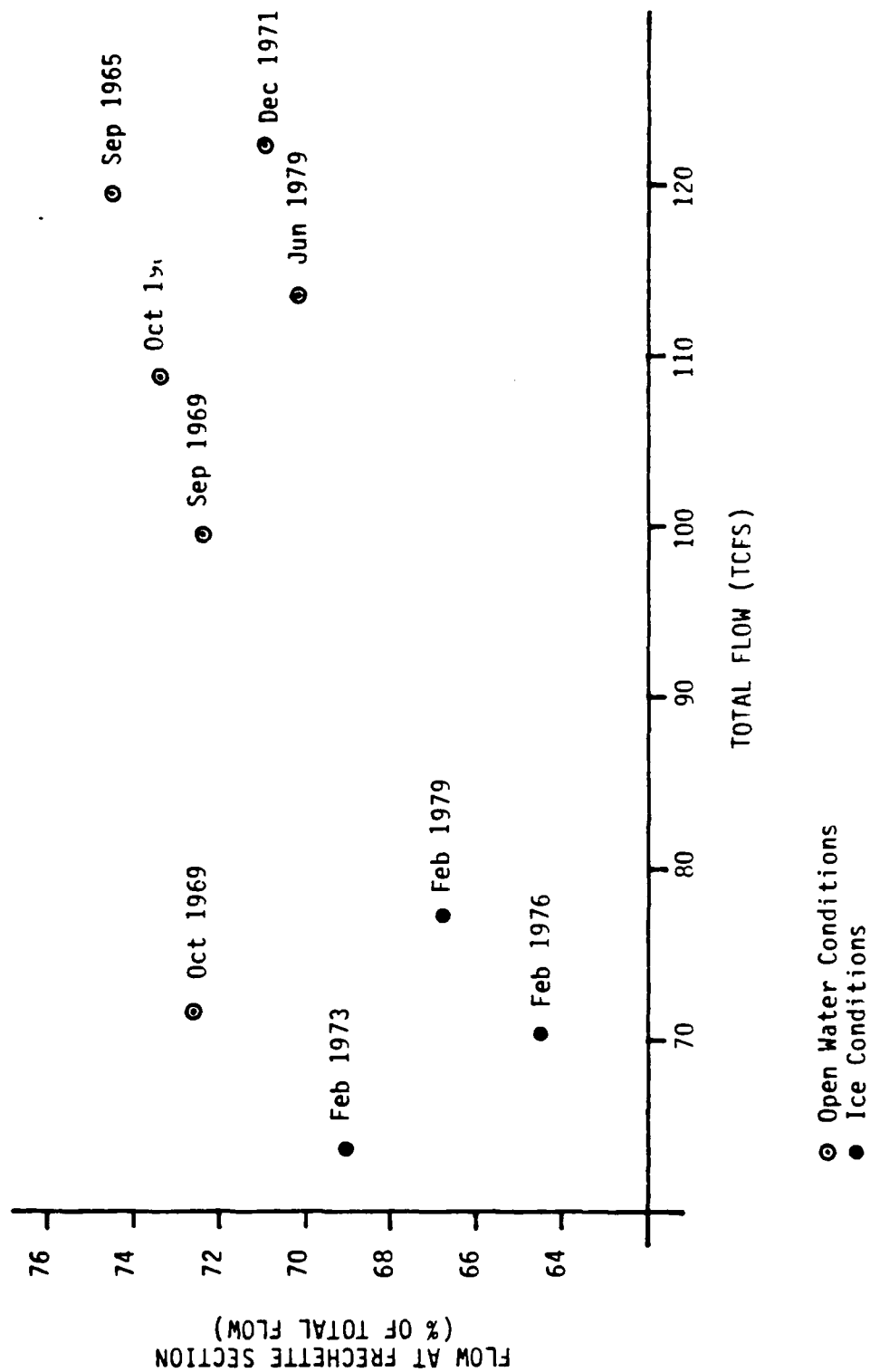


Figure C-6

the two sections. If this phenomena was progressive throughout the period 1969-1978, the results of flow measurements in 1971, 1973 and 1976 might be somewhat biased.

TABLE C-2
Comparison of Cross Sectional Areas
as Measured in 1969, 1978 and 1979
at Frechette and Garden River Sections

	<u>Cross Sectional Area* (sq. ft.)</u>			<u>Percent Increase in Area</u>	
	<u>1969</u>	<u>1978</u>	<u>1979</u>	<u>1969 to 1978</u>	<u>1978 to 1979</u>
Frechette	23,829	25,980	26,758	9.0	3.0
Garden River	11,809	12,291	12,381	4.1	0.7

*All cross sectional areas were computed as areas below Low Water Datum (577.50 feet at Frechette Section, 577.30 feet at Garden River Section).

ICE COVER

To determine whether or not the ice boom has had an effect on ice thickness in the river since its first installation in 1975, the ice thickness measurements made between 1969 and 1984 were reviewed. Summaries of the measurements made at the six sites (Figure C-7) are given in Tables C-3 to C-8.

The effect of the ice boom and stabilization islands on the ice cover at the head of Little Rapids Cut is readily discernible. Prior to December 1975, a solid ice cover at the head of the rapids is common, particularly in February. During the winter that the boom was first installed (1975-1976), the ice cover at the "Head of Little Rapids" measuring site was too unstable to measure and generally consisted of broken, drifted ice. With the placement of a sunken barge and crane weights during the following winter (these were replaced by permanent rock islands in October 1981), the "Head of Little Rapids" site has had no measurable ice cover. The ice boom and the stabilization islands have tended to stabilize the ice cover above the Cut. This factor, in conjunction with the swift current in Little Rapids Cut, has resulted in the head of the cut remaining essentially ice free throughout most of the winter.

Any conclusions about the thickness of the ice covers in Soo Harbor and below Little Rapids Cut are less apparent. The thickness of ice in the river is affected by many things, including air temperature, the presence or absence of the ice boom and whether or not there was winter navigation.

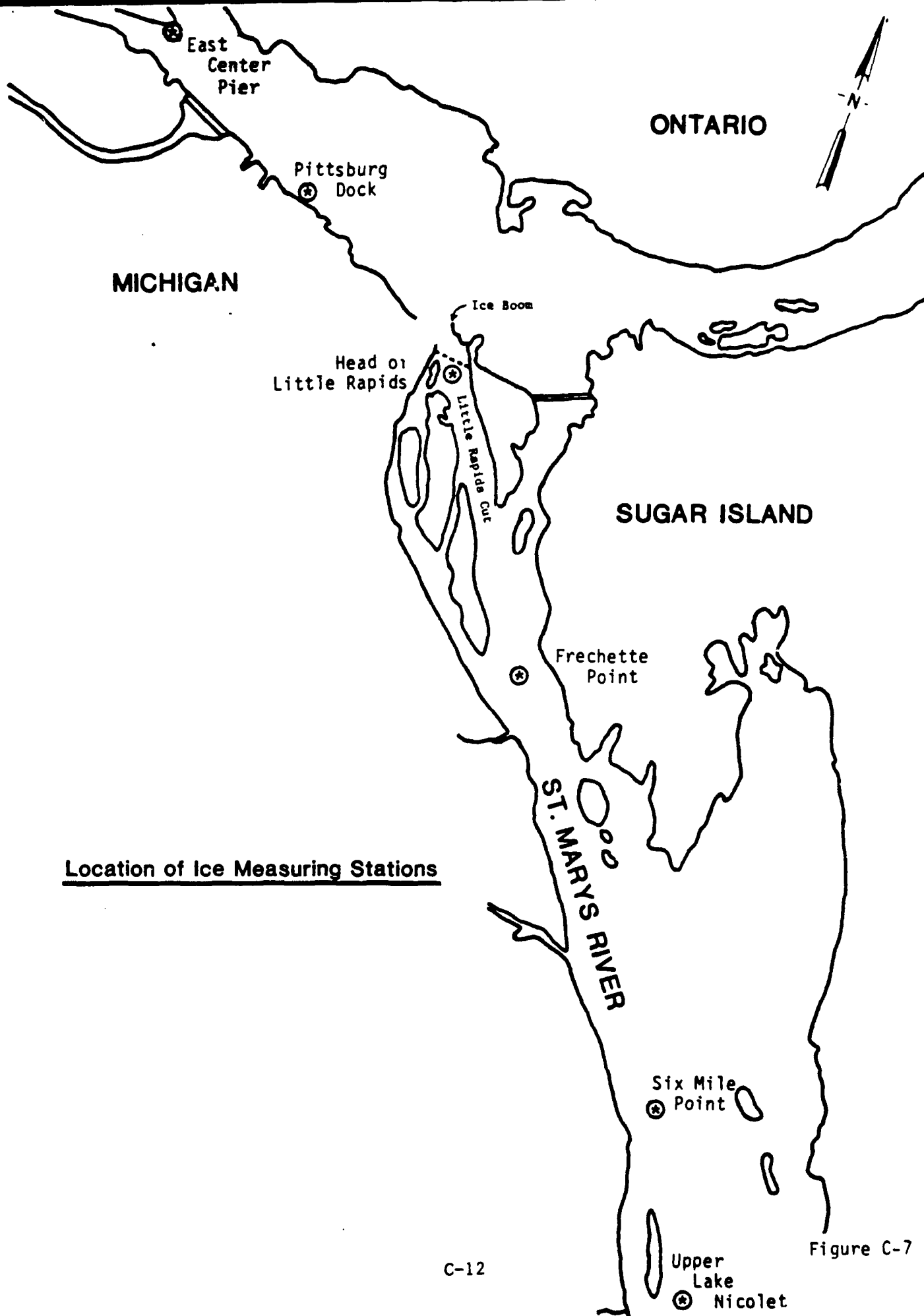


TABLE C-3
MEASURED ICE THICKNESS (INCHES)
EAST CENTER PIER
BY QUARTER MONTHS*

Year	Jan				Feb				Mar.				Winter Navigation
	3	4	1	2	3	4	1	2	3	4	1	2	
1969	7.5	10.0	11.5	14.5	14.75	15.5	15.5	16.5	16.0	O.W.			
1970	6.0	9.5	14.0	14.0	14.5	15.5	16.0	17.0	O.W.				
1971	O.W.	U.C.	U.C.	12.0	13.0	14.5	17.0	17.5	18.0	19.5			
1972	U.C.	U.C.	9.0	13.0	13.0	17.5	15.5	21.5	18.0	19.0			
1973	O.W.	U.C.	O.W.	5.5	10.5	9.0	11.0	O.W.					
1974	O.W.	O.W.	U.C.	10.5		13.0		O.W.	O.W.	O.W.			
1975	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.			
1976	U.C.	U.C.	U.C.	U.C.	U.C.	O.W.	O.W.	U.C.	U.C.	O.W.			
1977	13.0	14.0	16.0	21.0		19.5	17.0	O.W.	O.W.	O.W.			
1978	U.C.	O.W.	U.C.	U.C.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.			
1979	U.A.	U.A.	U.A.	U.A.	U.A.	U.A.	O.W.	O.W.	O.W.	O.W.			
1980	O.W.	U.A.	U.A.	U.A.	U.A.	O.W.		O.W.	O.W.				
1981	10.0	10.5	12.5	13.0	13.5	11.5	13.0	O.W.					
1982	10.0	14.0	16.0	20.0	18.0	17.0	17.0	20.0	21.0	U.A.			
1983		U.C.		U.A.	O.W.	O.W.	O.W.						
1984	10.5		17.0	17.0	14.5	13.0		16.5	O.W.				

O.W. = Open Water; U.C. = Unsafe Cover; U.A. = Unsafe Access

*When more than one measurement was made during a quarter month period they were averaged to give one value for the period.

TABLE C-4
MEASURED ICE THICKNESS (INCHES)
PITTSBURG DOCK
BY QUARTER MONTHS

Year	Jan				Feb				Mar			
	3	4	1	2	3	4	1	2	3	4	1	2
1969	3.5	5.5	8.5	12.0	13.5	13.0	13.0	12.0	4.5	O.W.		
1970	7.0	6.5	11.5	8.0	11.0	9.5	2.5	5.0	O.W.			
1971	O.W.	U.C.	10.0	12.5	14.0	17.0	18.0	16.0	15.0	14.0		
1972	U.C.	U.C.	9.0	13.0	13.0	17.5	15.5	21.5	18.0	19.0		
1973	O.W.	U.C.	U.C.	9.0	12.0	12.5	11.5	O.W.				
1974	O.W.	O.W.	U.C.	11.5		11.0		U.C.	O.W.	O.W.		
1975	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.		
1976	U.C.	U.C.	U.C.	U.C.	U.C.	O.W.	O.W.	U.C.	U.C.	O.W.		
1977	9.0	U.A.	U.A.	8.0		U.A.	U.A.	O.W.	O.W.	O.W.		
1978	U.C.	17.0	12.0	13.5	14.5	12.0	13.0	U.A.	O.W.	O.W.		
1979	U.A.	U.A.	13.0	17.0	20.0	18.0	13.0	U.A.	O.W.	O.W.		
1980	O.W.	U.A.	U.A.	U.A.	U.A.	O.W.		O.W.	O.W.			
1981	13.5	13.0	14.5	12.5	12.0	U.A.	O.W.	O.W.				
1982	9.0	14.0	17.0	20.0	22.0	18.0	15.0	15.0	17.0	U.A.		
1983		O.W.		U.A.	U.A.	U.A.	O.W.					
1984	10.0		14.0	13.0	9.0	O.W.		O.W.				

Winter
Navigation

Ice
Boom

TABLE C-5
MEASURED ICE THICKNESS (INCHES)
HEAD OF LITTLE RAPIDS
BY QUARTER MONTHS

Year	Jan				Feb				Mar			
	3	4	1	2	3	4	1	2	3	4	1	2
1969	O.W.	O.W.	U.C.	11.5	12.5	U.C.	U.C.	O.W.	O.W.	O.W.	U.C.	O.W.
1970	U.C.	U.C.	10.0	U.C.	11.0	12.0	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1971	O.W.	U.C.	O.W.	U.C.	U.C.	U.C.	U.C.	U.C.	O.W.	O.W.	O.W.	O.W.
1972	U.C.	U.C.	U.C.	15.0	15.0	18.0	16.5	17.0	11.0	U.A.	U.C.	U.C.
1973	O.W.	O.W.	U.C.	8.0	10.0	9.0	U.C.	O.W.	O.W.	O.W.	O.W.	O.W.
1974	O.W.	U.C.	O.W.	9.0	9.5	9.5	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1975	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1976	U.C.	U.C.	U.C.	U.C.	U.C.	U.C.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1977	U.C.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1978	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1979	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1980	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1981	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1982	O.W.	U.A.	O.W.	O.W.	U.A.	U.A.	U.A.	U.A.	U.A.	U.A.	U.A.	U.A.
1983	O.W.	O.W.	O.W.	O.W.	U.A.	U.A.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.
1984	O.W.	O.W.	U.A.	U.A.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.	O.W.

Winter
Navigation

Ice
Boom

TABLE C-6
MEASURED ICE THICKNESS (INCHES)
FRECHETTE POINT
BY QUARTER MONTHS

Year	Jan		Feb				Mar				Winter Navigation	Ice Boom
	3	4	1	2	3	4	1	2	3	4		
1969	3.5	10.0	12.5	16.0	15.75	12.5	12.0	9.0	4.0	O.W.		
1970	6.0	6.0	9.5	11.0	6.5	6.5	O.W.	O.W.	O.W.	17.5		
1971	U.C.	U.C.	16.0	18.0	20.5	21.0	20.5	18.5	18.0	20.0		
1972	U.C.	U.C.	12.0	15.5	14.5	14.5	18.0	15.0	13.0			
1973	U.C.	U.C.	U.C.	11.5	12.0	11.0	U.C.	O.W.				
1974	6.0	7.5	10.75	14.5	12.5	12.5		4.0	O.W.	O.W.		
1975	U.C.	U.C.	7.0	10.0	10.0	U.A.	U.A.	U.A.	U.A.	U.C.		
1976	4.0	11.0	14.5	15.0	15.0	16.0	16.0	19.0	20.0	O.W.		
1977	16.0	15.5	23.0	20.0		19.5	27.0	U.A.	O.W.	O.W.		
1978	U.C.	16.5	20.0	21.5	21.0	17.0	16.0	14.0	U.C.	O.W.		
1979	11.25	11.0	14.0	16.0	17.0	18.5	16.0	14.0	O.W.	O.W.		
1980	O.W.	U.A.	7.0	3.0	O.W.	2.5		O.W.	O.W.			
1981	15.0	14.0	15.0	14.5	12.0	O.W.	O.W.	O.W.				
1982	10.0	12.5	16.5	15.0	16.0	13.0	11.0	10.0	14.0	O.W.		
1983		O.W.		O.W.	O.W.	O.W.	O.W.					
1984	10.0		U.A.	U.A.	O.W.	O.W.		O.W.	O.W.			

Winter
Navigation

Ice
Boom

TABLE C-7
MEASURED ICE THICKNESS (INCHES)
SIX MILE POINT
BY QUARTER MONTHS

Year	Jan				Feb				Mar				Winter Navigation	Ice Boom
	3	4	1	2	3	4	1	2	3	4				
1969	8.0	10.5	11.5	13.5	14.75	14.5	13.0	13.0	13.0	9.75	O.W.			
1970	9.5	6.5	14.5	14.5	15.5	11.0	12.0	9.0	6.5					
1971	11.5	15.5	16.0	16.0	20.5	20.0	21.0	21.5	23.0	23.0				
1972	U.C.	10.5	9.5	13.0	13.5	16.5	14.5	23.0	13.0					
1973	8.5	10.5	14.0	15.0	15.5	15.5	15.0	U.C.						
1974	9.0	10.5	13.25	13.0	16.5	16.5	10.0	4.0	3.0					
1975	U.C.		4.0	8.5	9.0	12.5	11.5	14.5	12.0					
1976	6.5	9.5	14.0	12.0	13.0	17.0	16.0	18.0	23.0	20.0				
1977	13.0	14.5	11.0	16.75	17.75	17.75	19.5	6.0	U.A.	O.W.				
1978	14.75	16.0	21.0	23.0	24.5	26.5	26.0	28.0	U.A.	21.5				
1979	12.0	13.0	16.0	21.0	15.0	19.0	15.0	19.0	U.A.	U.A.				
1980	O.W.	U.A.	10.0	11.5	11.0	7.0		10.5	U.A.					
1981	14.0	14.0	16.0	17.0	16.0	12.0	U.A.	U.A.						
1982	12.0	14.0	18.0	17.0	17.0	15.0	16.0	18.0	19.0	U.A.				
1983		O.W.		7.0	8.0	U.A.	O.W.							
1984	11.0		12.0	19.5	5.0	O.W.		O.W.	O.W.					

TABLE C-8
MEASURED ICE THICKNESS (INCHES)
UPPER LAKE NICOLET
BY QUARTER MONTHS

Year	Jan				Feb				Mar			
	3	4	1	2	3	4	1	2	3	4	1	2
1969	7.0	9.5	12.0	14.0	16.75	16.5	16.5	16.5	15.5	12.25		
1970	11.0	10.0	16.0	14.5	13.0	12.5	17.0	13.0	14.5			
1971	10.5	12.5	18.2	17.5	19.0	21.5	21.5	23.0	23.0	20.0		
1972	8.0	7.5	9.0	14.0	13.0	18.5	18.0	17.0	13.5	17.0		
1973	11.75	12.5	17.0	18.5	19.5	20.2	18.0	U.C.				
1974	10.0	10.0	13.75	17.0	19.5	19.5	18.0	16.5	16.0	14.5		
1975	3.0	9.0	9.5	11.0	15.0	17.5	17.0	19.5	19.0	18.5		
1976	9.0	11.5	13.5	15.0	16.0	16.0	21.5	18.0	26.0	21.0		
1977	14.0	14.5	18.0	17.0	21.25	21.25	20.5	12.5	5.0	U.C.		
1978	8.25	13.0	15.0	19.5	18.0	19.5	20.5	19.0	20.0	21.5		
1979	13.5	13.0	15.0	16.0	19.0	18.0	15.0	20.0	16.0	18.0		
1980	U.A.	10.0	11.0	13.5	13.0	10.25		13.0	9.5			
1981	12.5	14.0	16.0	15.0	17.5	18.5	17.0	10.0				
1982	15.0	18.0	18.0	22.0	23.5	27.0	20.0	19.0	21.0	U.A.		
1983		U.C.		8.0	6.0	U.A.	O.W.					
1984	12.5		11.0	16.0	8.0	5.0		8.5	O.W.			

Winter
Navigation

Ice
Boom

2
3
4

The thickest ice covers recorded at five of the six sites occurred since the boom was installed (Table C-9), but those winters had some of the coldest air temperatures of the 16-year period (Table C-10).

In Soo Harbor the average ~~maximum~~ ice thickness was greatest for the period when there was no navigation and no ice boom. During the majority of winters with navigation on the river there was either open water or an unsafe

cover at the "East Center Pier" site. This was the result of ships breaking up the ice cover as they proceeded into and out of the navigation locks. The "Pittsburg Dock" site also had a more unstable ice cover since winter navigation and installation of the boom. This is due to ships using the docking facilities at Pittsburg Dock.

Since the discontinuation of winter navigation, the ice cover at the two Soo Harbor sites has dissipated sooner than it generally did before placement of the boom. This is probably due to the warmer temperatures experienced in the later part of the winter during the years the boom was in place.

Below Little Rapids Cut the average maximum ice thicknesses were greatest for the period when there was winter navigation. This period had the coldest December-March average temperature, but the thicker ice could also have been due to ship traffic. The three measuring sites below the cut are located near the navigation channel. When the ice cover in the channel was broken by ship passage the ice was pushed to the sides. This could and probably did affect the ice thickness at the sites.

Considering only the periods when there was no winter navigation, two things are apparent. Firstly, the average maximum ice thicknesses were greatest prior to installation of the boom. Because the boom has stabilized the ice above the cut, less ice from Soo Harbor enters and builds up in the river below the cut. Secondly, the ice cover reaches its greatest extent and thickness earlier and melts sooner, since placement of the boom. Looking at the monthly average temperatures for the two periods, while the December-March averages are about the same, the December and January temperatures were lower and the February and March temperatures were higher during the period the boom was installed.

An important factor affecting ice thickness in Soo Harbor appears to be winter navigation. The ice boom did have a significant effect on the ice cover at the head of Little Rapids Cut, virtually eliminating it. With less ice entering the cut and Lake Nicolet from Soo Harbor, since placement of the boom and discontinuation of winter navigation, ~~maximum~~ ice thicknesses below the cut have decreased.

CONCLUSIONS

There is no indication that the presence of the ice boom has adversely altered the retardation of flow caused naturally by ice in Soo Harbor and in and below Little Rapids Cut. There is, also, little evidence to indicate that the ice boom has changed the distribution of flow around Sugar Island. The placement of the ice boom and the two permanent rock islands have helped to keep ice out of the upper portion of Little Rapids Cut, and have reduced the amount of broken ice buildup downstream on the Lake Nicolet ice field.

TABLE C-9

Maximum Ice Thickness
(Inches)

	East Center Pier	Pittsburg Dock	Little Rapids	Frechette Point	Six Mile Point	Upper L. Nicolet	Average Dec-Mar Temperature
1969	17.5	14.0	13.0	18.0	15.0	17.0	17.2°F
1970	17.0	11.5	12.0	11.0	15.5	17.0	19.8°F
1971	19.5	18.0	UC	21.0	23.0	23.0	15.7°F
1972	19.0	21.5	18.0	18.0	23.0	18.5	17.6°F
1973	11.0	12.5	10.0	12.0	15.5	20.5	
1974	13.0	11.5	9.5	12.5	16.5	19.5	
1975	OW	OW	OW	10.0	14.5	19.5	
1976	UC/OW	UC/OW	UC/OW	20.0	23.0	26.0	
1977	22.0	8.0	OW	27.0	19.5	22.0	
1978	OW/UC	14.5	OW	21.5	28.0	20.5	
1979	UA/OW	20.0	OW	18.5	21.0	20.0	
1980	OW/UA	OW/UA	OW	7.0	11.5	13.5	
1981	13.5	14.5	OW	15.0	17.0	18.5	
1982	21.0	22.0	UA	16.5	19.0	27.0	
1983	OW/UA	OW/UA	OW	OW	8.0	8.0	
1984	17.0	14.0	OW	10.0	19.5	16.0	
Average							
NB/NWN	16.0	15.0	12.5	15.5	18.0	19.0	17.2°F
NB/WN	OW	OW	OW	10.0	14.5	19.5	19.8°F
B/WN	UC	14.0	OW	22.0	23.0	22.0	15.7°F
B/NWN	10.5	10.0	OW	9.5	15.0	16.5	17.6°F
NB - no boom							
B - boom							
NWN - no winter navigation							
WN - winter navigation							
UC - unsafe cover							
UA - unsafe access							
OW - open water							

TABLE C-10

AVERAGE AIR TEMPERATURE
SAULT STE. MARIE, MICHIGAN
(DEGREES FAHRENHEIT)

<u>Winter</u>	<u>Dec</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Dec-Mar Average</u>
1968-69	18.3	15.4	18.3	23.0	18.8
1969-70	19.6	9.7	10.2	20.2	14.9
1970-71	17.3	9.5	13.1	20.3	15.0
1971-72	22.0	13.8	10.7	19.0	16.4
1972-73	18.7	19.2	14.6	35.0	21.9
1973-74	19.3	14.3	9.6	21.9	16.3
1974-75	24.1	16.2	17.9	20.9	19.8
1975-76	19.8	10.4	18.8	22.9	18.0
1976-77	9.4	5.3	14.3	28.6	14.4
1977-78	19.8	10.8	11.1	20.4	15.5
1978-79	17.9	8.9	5.2	27.1	14.8
1979-80	24.0	15.0	12.4	22.5	18.5
1980-81	12.8	8.8	18.6	27.2	16.8
1981-82	21.7	4.7	11.5	21.6	14.9
1982-83	24.3	15.9	21.0	27.5	22.2
1983-84	11.2	7.3	23.7	20.9	15.8
NWS 30-Year Average	20.1	13.3	14.3	23.9	