

*Report to
The International Niagara Board of Control
On the 1999-2000 Operation of
The Lake Erie-Niagara River Ice Boom
By the International Niagara Working Committee
August 2000*

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RELATED INTERNET SITES

International Joint Commission	www.ijc.org
New York Power Authority	www.iceboom.nypa.gov
International Niagara Board of Control	http://huron.lre.usace.army.mil/ijc/niagara.html
COE, Buffalo District	www.lrb.usace.army.mil
COE, Detroit District	www.lre.usace.army.mil
Great Lakes Information Network	www.great-lakes.net
Great Lakes Information Management Resource	www.cciw.ca/glimr

Data in this report are in metric units followed by approximate English units (in parenthesis). The latter are provided for information purposes only. Water levels are based on the International Great Lakes Datum, 1985 (IGLD 1985).

1. Highlights

Installation of the Lake Erie - Niagara River ice boom's 22 spans began on 19 December and was completed on 29 December, 1999. The October 1999 change in the Commission's Order of Approval, providing that installation may begin on December 16, regardless of water temperature, was exercised. This change made it much easier to plan the installation and reduced safety risks. Ice did not form on eastern Lake Erie until the middle of January.

The boom was opened on 23 and 24 March.

During the 1999-2000 season there were no helicopter or fixed wing observation flights conducted by International Niagara Working Committee Representatives. Insufficient ice cover prevented ice thickness surveys by a helicopter. Ice charts, based primarily on RADARSAT data, provide information on ice cover.

Appendix "A" - Contains a description of the Lake Erie/Niagara River Area. Appendix "B" - gives background information on the ice boom.

2. Operation of the Ice Boom During the 1999-2000 Ice Season

2.1 Installation of the Boom

The two video cameras installed on the roof of the HSBC Center in Buffalo, New York used to monitor the ice boom were in service again for the 1999-2000 ice season. The Internet address to view images is <http://www.iceboom.nypa.gov>.

The marine radar system for monitoring surface ice coverage in the Chippawa-Grass Island Pool was again operated during the 1999-2000 ice season. Computer network links to the radar system enable staff at the New York Power Authority's (NYPA) Niagara Power Project, its Energy Control Center in Marcy, NY, its engineering staff in White Plains, NY and staff at Ontario Power Generation's (OPG) Niagara Falls generating stations and its headquarters office in Toronto, Ontario to view ice movement in the Chippawa-Grass Island Pool.

In accordance with condition (d) of the Commission's 5 October, 1999 Supplementary Order of Approval, installation of the Lake Erie-Niagara River Ice Boom's spans commenced on December 19, 1999. Installation may begin when the Lake Erie water temperature at Buffalo reaches 4 degrees Celsius (C) (39 degrees Fahrenheit (F)) or on 16 December, whichever occurs first.

Preparations for placement of the 22 spans began with positioning of floating barrels on 13 and 14 December. The strings of pontoons were removed from their summer storage area and placed inside the Buffalo Harbor breakwall over the following few days. Installation of 14 spans, extending from the Canadian shore, was accomplished on 19 December. A further 2 spans were installed extending from the U.S. shore on 20 December. Strong winds delayed further span placements for several days. Installation of the final 6 spans was completed on 29 December.

The October 1999 change in the Commission's Order of Approval providing that installation may begin on 16 December, regardless of water temperature, was exercised. This change made it much easier to plan the installation and reduced safety risks. Installation governed by criterion (d) of the 1984 Order, would not have begun this past winter until 27 December at the earliest. The Lake Erie water temperature, as measured at the Buffalo water intake, was 40°F (4°C) on 26 December and dropped to 36°F (2°C) on 27 December. A summary of dates when the water temperature reached 4°C (39°F) and dates of ice boom installation are shown in table 2-1.

Even though ice did not form on eastern Lake Erie until the middle of January, no damage to the steel pontoons occurred from the open winter conditions. There were no lake ice runs despite several winter storms with associated high winds from the southwest. The steel pontoon spans performed as intended, minimizing the amount of lake ice entering the Niagara River through increased resistance to ice overtopping.

2.2 Ice and Hydrometeorological Conditions

The average monthly air temperatures for November 1999 through April 2000, as measured at the Buffalo Niagara International Airport, are shown in Table 2-2.

The air temperatures for the period November 1999 through April 2000 averaged about 2.0°C (35.6°F). This is approximately 1.5°C (3°F) above average. This is the fourth year in a row that the air temperatures for this period of time were above average.

A summary of Lake Erie water temperatures (as measured at the Buffalo water intake) is contained in Table 3-1.

The first three weeks of December 1999, as characterized by the Buffalo office of the National Weather Service, were exceedingly mild followed by a sharp turn to colder temperatures for about a week and then a return to mild temperatures to end of the millennium. The December average temperature at Buffalo of 0°C (32°F) was about 2°C (3°F) above normal. January 2000 was split into two parts, a very mild and snowfree first half followed by a very cold and snowy second half. Although the monthly average temperature was normal at -5°C (24°F), the first 12 days were 7°C (12°F) above normal while the remaining 19 days were 4°C (9°F) below normal.

Ice first began forming behind the boom around 17 January. A build-up in the Maid-of-the-Mist Pool, below Niagara Falls, of river generated ice, formed an ice bridge on 24 January. By the end of the month, much of the eastern basin had a thin ice cover encompassing 3570 square kilometres (1380 square miles) or 70%. A trailing span of pontoons, span "M", was observed on 1 February. Inspection revealed that the span cable had failed near one end. A short length of replacement cable was spliced in between the anchor tie plate and the span cable. This repair was completed on 4 February.

Although February was normally cold through the first three weeks, an astoundingly warm final week resulted in a monthly average around -1°C (30°F) or 3°C (5°F) above normal. Six days of the final week of the month saw temperatures rise above 10°C (50°F) with 22°C (71°F) on the 26th being the warmest ever recorded in February in Buffalo. Although ice cover in the eastern basin was about 2850 square kilometres (1100 square miles) around 22 February, this had diminished to about 1185 square kilometres (460 square miles) by 3 March.

This year, March was the warmest in Buffalo in 27 years and the second warmest in the last 50 years. The average temperature was about 4°C (39°F) which is 3°C (6°F) above normal. The 20°C (60°F) reading on 9 March broke the old record for that day set back in 1878.

The ice cover on the eastern basin of Lake Erie continued to decrease. On 9 March, it was about 360 square kilometres (140 square miles). The warm weather also acted on the ice bridge below the Falls, resulting in its destruction on March 8. The broken and decaying ice cover began bypassing the ice boom via the northern entrance to Buffalo Harbor, and entered the Niagara River. However, no operational problems for power generation were experienced. By the 21st the lake ice cover on Lake Erie was estimated to be only 160 square kilometres (60 square miles), all located in the eastern end of the lake, immediately upstream of the ice boom.

2.3 Opening and Removal of the Ice Boom

Opening of the Lake Erie-Niagara River Ice Boom began on 23 March and was completed the next day. Following the opening of the boom, some rotten lake ice entered the river. This passed downstream through the Chippawa - Grass Island Pool, over Niagara Falls and onwards down river after passing through the Maid-of-the-Mist Pool. No operational problems were experienced. All of the boom's 22 spans were removed to the on-shore storage area by 27 March.

Upstream of Niagara Falls, a combination of the Power Entities' ice breaker work and lowering of the Chippawa-Grass Island Pool level was required periodically during the 1999-2000 winter. This assisted in moving shale and sheet ice, which had formed in the river, past the power plant intakes. Tolerances for operation of the Pool were suspended for seven days in January, 12 days in February and two days in March when the level was held low.

On 28 March, the vessel NIAGARA was the season's first commercial vessel transit of the St. Lawrence Seaway - Welland Canal Section. Navigation at Buffalo commenced on 10 May with the sailing of the KINSMAN INDEPENDENT.

Opening of the 1999-2000 navigation season at both the Welland Canal and Buffalo Harbor required no Canadian or U.S. Coast Guard ice breaker assistance.

The year 2000 voyages of the Maid-of-the-Mist Steamboat Co. began on 8 April. This matches last years second earliest start up of operations. 4 April 1998 was the earliest start in the company's 154 year history.

This is the third season since the ice boom has been in use that no helicopter (ice thickness) or fixed-wing (ice area) observation flights were conducted. The previous seasons were 1997-1998 and 1998-1999.

Table 2-1 Dates Water Temperature Reached 4° C (39° F) and Dates of Ice Boom Installation

Date Water Temperature Reached 4° C (39° F)	Installation of the Ice Boom	Date Water Temperature Reached 4° C (39° F)	Installation of the Ice Boom
7 Dec 1964	9 Nov to 15 Dec 1964	14 Dec 1980	22 - 30 Dec 1980
15 Dec 1965	8 Dec 1965	11 Dec 1981	19 - 23 Dec 1981
19 Dec 1966	8 Nov to 6 Dec 1966	4 Jan 1983	6 - 8 Jan 1983
29 Nov 1967	17 Nov to 5 Dec 1967	18 Dec 1983	19 - 21 Dec 1983
10 Dec 1968	25 Nov to 5 Dec 1968	26 Dec 1984	27 - 30 Dec 1984
9 Dec 1969	10 Dec 1969	17 Dec 1985	20 - 21 Dec 1985
15 Dec 1970	15 Dec 1970	15 Dec 1986	16 - 17 Dec 1986
25 Dec 1971	30 Nov to 10 Dec 1971	19 Dec 1987	19 - 26 Dec 1987
11 Dec 1972	11 Dec to 14 Dec 1972	12 Dec 1988	12 - 17 Dec 1988
18 Dec 1973	19 Dec 1973 to 9 Jan 1974	6 Dec 1989	7 - 8 Dec 1989
10 Dec 1974	11 Dec to 30 Dec 1974	27 Dec 1990	27 - 30 Dec 1990
20 Dec 1975	24 Dec 75 to 8 Jan 1976	19 Dec 1991	20 - 27 Dec 1991
24 Nov 1976	30 Nov to 18 Dec 1976	6 Dec 1992	13 - 14 Dec 1992
8 Dec 1977	31 Dec 1977	16 Dec 1993	17 - 28 Dec 1993
11 Dec 1978	19 Dec 1978	2 Jan 1995	7 - 10 Jan 1995
17 Dec 1979	22 Dec 1979	7 Dec 1995	13 - 16 Dec 1995
		4 Dec 1996	8 - 11 Dec 1996
		13 Dec 1997	17 - 18 Dec 1997
		1 Jan 1999	2 - 9 Jan 1999
		27 Dec 1999	19-29 Dec 1999

Note: Prior to the 1980-81 Ice Season, the International Joint Commission Orders required that complete closure of the ice boom shall not be accomplished before the first Monday in December. Starting with the 1999-2000 ice season, installation may begin when the Lake Erie water temperature at Buffalo reaches 4°C (39°F) or on 16 December, whichever occurs first.

Table 2-2 Air Temperature at the Buffalo Niagara International Airport

Month	°C (Celsius)			°F (Fahrenheit)		
	Average* 1961-1990	Recorded 1999-2000	Departure	Average* 1961-1990	Recorded 1999-2000	Departure
Nov. 1999	4.7	6.6	+1.9	40.5	43.9	+3.4
Dec. 1999	-1.6	0.0	+1.6	29.1	32.0	+2.9
Jan. 2000	-4.7	- 4.7	0.0	23.6	23.6	0.0
Feb. 2000	-4.2	-1.2	+3.0	24.5	29.8	+5.3
Mar. 2000	1.0	4.4	+3.4	33.8	40.0	+6.2
Apr. 2000	7.3	6.8	-0.5	45.2	44.2	-1.0
Ave =		2.0			35.6	

* Official U.S. National Weather Service averages are based on 30 years of record, 1961-1990.

Table 2-3 Estimated Loss of Energy Due to Ice for the Period of Record 1975 to Present

Winter Season of:	December	January	POWER LOSSES (in MWH)		April	May	Totals
			February	March			
1964-1974	No Data Available						
1974-1975	*	*	2/14-3/5 150,000	3/7-3/26 15,100	*	*	165,100
1975-1976	*	78,700	36,500	45,800	32,000	*	193,000
1976-1977	*	54,000	23,500	0	0	0	77,500
1977-1978	*	88,000	600	600	0	0	89,200
1978-1979	*	30,000	3,700	0	1,600	0	35,300
1979-1980	*	6,000	30,000	13,000	10,500	0	59,500
1980-1981	14,000	9,000	3,900	1,100	4,100	0	32,100
1981-1982	*	58,000	27,000	10,000	13,000	5,000	113,000
1982-1983	0	0	0	0	0	0	0
1983-1984	53,000	57,000	4,000	25,000	0	0	139,000
1984-1985	0	65,000	25,000	11,000	29,000	0	130,000
1985-1986	10,000	65,000	8,000	5,000	6,000	0	94,000
1986-1987	0	28,000	32,000	4,000	0	0	64,000
1987-1988	0	13,000	24,000	0	4,000	0	41,000
1988-1989	0	0	30,000	1,000	2,000	0	33,000
1989-1990	6,000	7,000	5,000	5,000	0	0	23,000
1990-1991	0	14,000	11,000	6,000	0	0	31,000
1991-1992	0	21,000	3,000	14,000	0	0	38,000
1992-1993	0	0	2,000	2,000	0	0	4,000
1993-1994	0	11,000	12,000	0	1,000	0	24,000
1994-1995	0	0	11,000	2,000	7,000	0	20,000
1995-1996	0	45,000	4,000	13,000	0	0	62,000
1996-1997	0	80,000	4,000	3,000	16,000	0	103,000
1997-1998	0	0	0	0	0	0	0
1998-1999	0	17,000	700	0	0	0	17,700
1999-2000	-	-	1,200	-	-	-	1,200

* No Data Published

3. Data Analyses 1999-2000

2.4 Estimated Power Losses

Some reduction in hydropower generation occurs virtually every year due to ice problems. However, the Power Entities (Ontario Power Generation and the New York Power Authority) estimate that the average annual savings to the existing hydropower facilities resulting from the use of the ice boom are approximately 414,000 megawatt-hours (MWH) of electric energy.

The losses of hydroelectric power generation for the Power Entities due to ice during the 1999-2000 season were 1,200 MWH. A summary of estimated loss of energy due to ice for the Period of Record 1975 to present is shown in Table 2-3.

2.5 Niagara River Shore Property Damages

As a result of the relatively thin and short duration ice cover on Lake Erie, and lack of any lake ice runs overtopping the boom and entering the river, no damages to shore properties along the Niagara River were experienced this past season.

2.6 Maintenance of the Ice Boom

The installation, removal and maintenance of the Lake Erie - Niagara River Ice Boom is undertaken by NYPA on behalf of both Power Entities. As a result of the studies conducted by NYPA and OPG, all of the timber pontoons have been replaced with 76cm (30 in.) diameter steel pontoons. This was done to improve the ice-overtopping resistance of the ice boom and reduce its maintenance costs. The replacement of the timbers with steel pontoons was completed in the fall of 1997, and the first all-steel-pontoon ice boom was used in the 1997-98 ice season.

As a result of the experience gained during the 1997-98 ice season, it was recommended that one steel pontoon from each of Spans A through J of the ice boom be removed to reduce the potential pontoon collisions in the future. Therefore, Spans A through J contained 10 instead of 11 steel pontoons beginning with the 1998-99 ice season. This modification greatly reduced damage to the pontoons in this reach.

The performance of the ice boom was closely monitored during the 1999-2000 ice season. This was the second year that an all steel-pontoon ice boom was used with ice present. As noted elsewhere in this report, a trailing span of pontoons, span "M", was observed on 1 February. Inspection revealed that the span cable had failed near one end. A short length of replacement cable was spliced in between the anchor tie plate and the span cable. This repair was completed on 4 February. No pontoons were damaged and no further repairs to the boom were necessary during the 1999-2000 ice season.

The planned summer 2000 maintenance will involve the routine change out of worn or damaged cables and hardware. The underwater inspection of all anchor cables was completed on 5 May 2000. As a result, three 152 metre (500 foot) anchor cables (#7, 13, & 14C) will be replaced.

3.1 Purpose

During the 1999-2000 winter season, the International Niagara Working Committee continued its program of collecting data and information related to ice boom operations to monitor conditions and determine when opening should begin. As part of the usual program, satellite imagery was analyzed and meteorological data from the U.S. National Weather Service Station at Buffalo were collected. However aerial surveys of the ice coverage in eastern Lake Erie and the Niagara River and ice thickness measurements in eastern Lake Erie were not conducted due to the lack of extensive ice cover.

Lake Erie water temperatures, as recorded at the Buffalo water intake, of the 1999-2000 ice boom reporting period are contained in Table 3-1. Observed dates of last ice for the period 1905 to present are presented in Table 3-2. Comparison of ice areas at time of ice boom opening are shown in Table 3-3.

3.2 Navigation at the Welland Canal in Ontario and at Buffalo, New York

On 28 March, the vessel NIAGARA made the first commercial vessel transit of the St. Lawrence Seaway - Welland Canal section. The first commercial transit from Buffalo was on 10 May, with the sailing of the vessel Kinsman Independent.

Opening dates for the ice boom and commencement of navigation at the Welland Canal and Buffalo Harbor for the period 1965 to 2000, are shown in Table 3-4.



Table 3-1 Lake Erie Water Temperatures as Recorded at the Buffalo Intake (1999-2000).

Month	December		January		February		March		April		May	
Date	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
1	7.8	46	2.2	36	0	32	0	32	4.4	40	7.2	45
2	7.2	45	2.8	37	0	32	0	32	4.4	40	7.2	45
3	7.2	45	2.8	37	0	32	0	32	4.4	40	7.8	46
4	6.7	44	2.2	36	0	32	0	32	4.4	40	7.2	45
5	6.7	44	2.8	37	0	32	0	32	4.4	40	8.3	47
6	7.2	45	2.2	36	0	32	0	32	4.4	40	9.4	49
7	7.2	45	2.2	36	0	32	0	32	4.4	40	10.0	50
8	7.2	45	2.2	36	0	32	0	32	4.4	40	10.6	51
9	6.7	44	2.8	37	0	32	0	32	4.4	40	11.1	52
10	7.2	45	3.3	38	0	32	0	32	4.4	40	11.7	53
11	7.2	45	2.2	36	0	32	0	32	5.0	41	12.2	54
12	7.2	45	2.2	36	0	32	0	32	4.4	40	12.8	55
13	7.2	45	2.8	37	0	32	0	32	4.4	40	11.7	53
14	7.2	45	2.8	37	0	32	0	32	4.4	40	11.7	53
15	6.7	44	2.8	37	0	32	0	32	5.0	41	12.8	55
16	6.7	44	1.7	35	0	32	0	32	5.6	42	12.8	55
17	6.1	43	1.1	34	0	32	0	32	5.0	41	12.2	54
18	5.6	42	1.1	34	0	32	0	32	5.6	42	12.2	54
19	6.1	43	0.6	33	0	32	0	32	5.6	42	12.2	54
20	6.1	43	1.1	34	0	32	0	32	5.6	42	12.2	54
21	6.1	43	1.1	34	0	32	1.1	34	5.6	42	12.2	54
22	6.1	43	0.6	33	0	32	1.1	34	5.6	42	11.7	53
23	5.0	41	0.6	33	0	32	1.1	34	5.6	42	12.2	54
24	4.4	40	0	32	0	32	2.8	37	5.6	42	12.8	55
25	4.4	40	0	32	0	32	2.8	37	5.6	42	12.8	55
26	4.4	40	0	32	0	32	2.8	37	6.1	43	13.3	56
27	2.2	36	0	32	0	32	3.9	39	6.1	43	13.3	56
28	2.8	37	0	32	0	32	3.3	38	6.1	43	12.8	55
29	2.2	36	0	32	0	32	3.3	38	6.7	44	13.3	56
30	2.8	37	0	32			3.3	38	6.7	44	13.3	56
31	2.2	36	0	32			3.9	39			13.3	56
Avg.	5.8	42.5	1.5	34.7	0.0	32.0	0.9	33.7	5.1	41.3	11.4	52.6

Table 3-2 Observed Dates of Last Ice, 1905 to Present

Year	Observed Date of Last Ice	Year	Observed Date of Last Ice	Year	Observed Date of Last Ice
1905	7 May	1941	21 April	1976	19 April
1906	22 April	1942	30 April	1977	13 May
1907	30 April	1943	20 May	1978	14 May
1908	9 May	1944	15 April	1979	3 May
1909	26 April	1945	9 April	1980	23 April
1910	30 April	1946	No Data	1981	30 April
1911	6 May	1947	No Data	1982	20 May
1912	29 April	1948	No Data	1983	23 Feb
1913	30 April	1949	No Data	1984	25 April
1914	28 April	1950	No Data	1985	1 May
1915	2 May	1951	15 April	1986	26 April
1916	11 May	1952	27 March	1987	9 March
1917	30 April	1953	Ice Free	1988	27 April
1918	20 April	1954	27 March	1989	9 April
1919	15 March	1955	5 April	1990	10 April
1920	20 May	1956	20 April	1991	28 March
1921	14 March	1957	11 March	1992	15 April
1922	11 April	1958	10 April	1993	16 April
1923	16 May	1959	8 May	1994	1 May
1924	20 April	1960	5 May	1995	18 April
1925	26 April	1961	15 April	1996	6 May
1926	31 May	1962	30 April	1997	29 April
1927	9 April	1963	11 May	1998	Ice-Free
1928	19 May	1964	27 April	1999	2 April
1929	2 May	1965*	14 May	2000	28 March
1930	7 May	1966	27 April		
1931	7 April	1967	13 April		
1932	21 April	1968	4 May		
1933	23 April	1969	26 April		
1934	23 April	1970	30 April		
1935	13 April	1971	31 May		
1936	31 May	1972	5 May		
1937	14 April	1973	15 March		
1938	14 April	1974	6 April		
1939	14 May	1975	8 April		
1940	19 May				

* 1965 First year the ice boom was used.

Average date of last ice for the period of record, 1905 - 2000 is 24 April (Ice free and no data years are excluded).

Table 3-3 Comparison of Ice Areas Near Time of Ice Boom Opening

Year	Areas of Ice in Eastern Lake Erie			Opening of Boom	
	Date of Observation	Square Kilometres	Square Miles	Start	Completed
1965	<i>No Data Collected</i>			21 March	27 March
1966				20 March	1 April
1967				22 March	29 March
1968				8 March	20 March
1969				26 March	3 April
1970	16 April	2590	1,000	23 April	30 April
1971	27 April	2850	1,100	3 May	14 May
1972	18 April	1300	500	20 April	25 April
1973	14 March	260	100	16 March	21 March
1974	18 March	320	125	26 March	1 April
1975	21 March	80	30	25 March	28 March
1976	15 April	130	50	19 April	21 April
1977	14 April	520	200	18 April	20 April
1978	27 April	710	275	1 May	8 May
1979	10 April	390	150	13 April	17 April
1980	1 April	700	270	2 April	7 April
1981	15 April	1220	470	18 April	22 April
1982	26 April	1090	420	27 April	2 May
1983	2 March	Trace	Trace	7 March	8 March
1984	5 April	780	300	7 April	10 April
1985	12 April	780	300	13 April	15 April
1986	7 April	1010	390	12 April	14 April
1987	5 March	130	50	6 March	6 March
1988	8 March	70	270	9 April	10 April
1989	27 March	340	130	30 March	6 April
1990	26 March	230	90	26 March	30 March
1991	25 March	50	20	27 March	30 March
1992	31 March	160	60	30 March	2 April
1993	3 April	540	210	5 April	6 April
1994	19 April	620	240	21 April	28 April
1995	28 March	420	160	30 March	17 April
1996	17 April	720	280	19 April	3 May
1997	24 April	65	25	25 April	28 April
1998	Ice-Free			5 March	5 March
1999	30 March	Trace	Trace	30 March	30 March
2000	21 March	160	60	23 March	24 March

Table 3-4 Comparative Data for Years Ice Boom Has Been in Place

Opening of Boom			Navigation Season Opened at:		NOTES
Year	Start*	Completed	Buffalo	Welland**	
1965	21 March	27 March	18 April	1 April	* Denotes opening of first boom span. Mobilization time precedes this date.
1966	20 March	1 April	12 April	4 April	
1967	22 March	29 March	9 April	1 April	
1968	18 March	20 March	8 April	1 April	
1969	26 March	3 April	8 April	1 April	
1970	23 April	30 April	7 April	1 April	1970 Commencement of flexible date for boom opening.
1971	3 May	14 May	18 April	29 March	
1972	20 April	25 April	9 April	29 March	
1973	16 March	21 March	20 March	28 March	
1974	26 March	1 April	24 March	29 March	
1975	25 March	28 March	22 March	25 March	** Usually, scheduled date is established well in advance and could be related to the Welland Canal repair schedule.
1976	19 April	21 April	10 April	1 April	
1977	18 April	20 April	11 April	4 April	
1978	1 May	8 May	23 April	28 March	
1979	13 April	17 April	13 April	28 March	
1980	2 April	7 April	3 April	24 March	Opening of the navigation season is not necessarily dependent on ice conditions.
1981	18 April	22 April	31 March	25 March	
1982	27 April	2 May	21 April	5 April	
1983	7 March	8 March	25 March	5 April	
1984	7 April	10 April	12 April	28 March	
1985	13 April	15 April	10 April	1 April	
1986	12 April	14 April	10 April	3 April	
1987	6 March	6 March	4 April	1 April	
1988	9 April	10 April	30 March	31 March	
1989	30 March	6 April	30 March	31 March	
1990	26 March	30 March	3 April	28 March	
1991	27 March	30 March	27 March	26 March	
1992	30 March	2 April	7 April	30 March	
1993	5 April	6 April	30 March	30 March	
1994	21 April	28 April	20 April	5 April	
1995	30 March	17 April	29 March	24 March	
1996	19 April	3 May	12 April	29 March	
1997	25 April	28 April	28 March	2 April	
1998	5 March	5 March	11 January	24 March	
1999	30 March	30 March	22 April	31 March	
2000	23 March	24 March	10 May	28 March	
1965 - 2000	4 April	9 April	5 April	30 March	
1970 - 2000	6 April	10 April	4 April	30 March	Average 31 year flexible boom opening date.

4. Findings, Conclusions and Recommendations

4.1 Findings and Conclusions

- a. Placement of the ice boom began on 19 December 1999. This date was 14 days earlier than for the 1998-99 ice season. This year's commencement of the boom installation equaled the most recent ten-year average date of 19 December.
- b. Water temperature, as recorded at the Buffalo Water Intake, did not reach the point when installation could have commenced prior to the October 1999 Supplemental Order until 27 December. This was the first year a cut off date (16 December) was allowed, and implemented, thereby reducing the risks associated with a late start.
- c. During the period that the ice boom was in place, all months averages were at or above normal air temperatures. This, along with an earlier start to installation, resulted in a relatively uneventful ice boom season. Other than span M's cable break, which is the same span that failed in the previous season, there were no other significant problems. With much warmer than normal temperatures for the last week in February and into March, very little ice (less than 130 square kilometres/50 square miles) remained at the time of ice boom opening.
- d. The ice boom was removed on 23 and 24 March 2000.
- e. Once conditions became favorable for removal, all of the boom's 22 spans were removed in two days. The average length of time required to open the ice boom for the period of record 1965 through 1999 is six days.
- f. Opening of the navigation season at both the Welland Canal and Buffalo Harbor required no ice breaker assistance.

4.2 Recommendations for 2000-2001 Operation

- a. The International Niagara Board of Control assessed the 1996-1997 field demonstration that evaluated replacing the timbers with steel pontoons and found it to be successful. Therefore, the Power Entities replaced all of the timbers with steel pontoons during the 1997-1998 ice season. As a result of the experience gained during the 1997-98 ice season, one steel pontoon from each of Spans A through J of the ice boom was removed prior to the 1998-99 season. This greatly reduced the potential pontoon collisions that had occurred during the open-water conditions of the previous season. The 1999-2000 season continued to show the increased effectiveness of the steel pontoons, notably during several days of strong southwest winds during the late part of February. Working Committee representatives should continue to monitor the performance of the ice boom.
- b. Continue to use RADARSAT for early reconnaissance of Lake Erie ice conditions, conduct ice thickness measurements, and conduct aerial ice surveys near the end of the season to evaluate the ice conditions with respect to identifying the proper time for removal of the ice boom.
- c. Continue to utilize Great Lakes ice cover maps prepared by the National Ice Center, Maryland and Canadian Ice Centre in Ottawa, Ontario and assess newly developed technologies and tools, such as RADARSAT, to determine the ice cover on Lake Erie.
- d. The Working Committee should continue utilizing and storing its ice maps. The computer generated ice maps are maintained in a storage and retrieval database structure for future use of the data. The most recent ice reconnaissance map is posted on the Internet at:
<http://www.lrb.usace.army.mil/levels/levels.html>
- e. The Working Committee should continue to liaise with the United States and Canadian Coast Guards regarding ice boom installation and opening operations.

Appendix A - Description of the Lake Erie-Niagara River Area

A.1 Hydraulics and Hydrology

The Niagara River, about 58 kilometres (36 miles) in length, is the natural outlet from Lake Erie to Lake Ontario (Figure 3). The elevation difference between the two lakes is about 99 metres (326 feet); half of this occurs at Niagara Falls. Over the period 1860-1998, the average Niagara River flow at Queenston, Ontario has been 5883 cubic metres per second (m^3/s) (207,760 cubic feet per second (cfs)). The Welland Canal carries a small portion of the Lake Erie outflow. The Great Lakes drainage basin upstream of the Niagara River is approximately 684000 square kilometres (264,000 square miles). Figure 3 is a map of the Niagara River.

The Niagara River, as described in the following paragraphs, consists of three major reaches: the upper Niagara River, the Niagara Cascades and Falls, and the lower Niagara River.

(a) Upper Niagara River

The upper Niagara River extends about 35 kilometres (22 miles) from Lake Erie to the Cascade Rapids which begin 1 kilometre (0.6 mile) upstream from the Horseshoe Falls. From Lake Erie to Strawberry Island, a distance of approximately 8 kilometres (5 miles), the channel width varies from 2740 metres (9,000 feet) at its funnel-shaped entrance to 460 metres (1,500 feet) at Squaw Island below the Peace Bridge. The average fall over this reach is around 1.8 metres (6 feet). In the upper 3.2 kilometres (2 miles) of the river, the maximum depth is approximately 6 metres (20 feet) with velocities as high as 3.7 metres per second (m/s) (12 feet per second (f/s)) in the vicinity of the Peace Bridge. Below Squaw Island the river widens to approximately 610 metres (2,000 feet) with velocities in the order of 1.2 to 1.5 m/s (4 to 5 f/s).

At Grand Island, the river divides into the west channel, known as the Canadian or Chippawa Channel, and the east channel, known as the American or Tonawanda Channel. The Chippawa Channel is approximately 17.7 kilometres (11 miles) in length and varies from 610 to 1220 metres (2,000 to 4,000 feet) in width. Velocities range from 0.6 to 0.9 m/s (2 to 3 f/s). The Chippawa Channel carries approximately 60% of the total river flow. The Tonawanda Channel is 24 kilometres (15 miles) long and varies from 460 to 610 metres (1,500 to 2,000 feet) in width above Tonawanda Island. Downstream thereof, the channel varies from 460 to 1220 metres (1,500 to 4,000 feet) in width. Velocities range from 0.6 to 0.9 m/s (2 to 3 f/s).

At the north end of Grand Island, the channels unite to form the 4.8 kilometre (3 mile) long Chippawa-Grass Island Pool. At the downstream end of the pool is the Chippawa-Grass Island Pool control structure. This structure extends from the Canadian shoreline to about halfway across the width of the river. The Niagara Falls are located about 1370 metres (4,500 feet) downstream of the structure. The average fall from Lake Erie to the Chippawa-Grass Island Pool is 2.7 metres (9 feet).

(b) Niagara Cascades and Falls

Below the control structure, the river falls 15 metres (50 feet) through the Cascade area and is divided into two channels by Goat Island. These channels convey the flow to the brink of the Canadian and American Falls. The Canadian or Horseshoe Falls is so named because the crest is horseshoe shaped. During non-tourist hours the minimum Falls flow is 1416 m^3/s (50,000 cfs). This produces a fall of about 57 metres (188 feet). Minimum Falls flow for tourist hours is 2832 m^3/s (100,000 cfs) which results in a fall of about 54 metres (177 feet). These minimum values are combined Horseshoe and American Falls flows. There are small accumulations of talus (rock debris) at the flanks. At the American Falls, water plunges vertically ranging from 21 to 34 metres (70 to 110 feet) to a talus slope at its base.

(c) Lower Niagara River

The Niagara Gorge extends from the Falls for 11 kilometres (7 miles) downstream to the foot of the escarpment at Queenston, Ontario. The upper portion of this reach is known as the Maid-of-the-Mist Pool, with an average fall of approximately 1.5 metres (5 feet). This reach is navigable for practically its entire length. The Maid-of-the-Mist Pool is bounded downstream by the Whirlpool Rapids, which extend a further 1.6 kilometres (1 mile). The water surface profile drops 15 metres (50 feet) in the Whirlpool Rapids where velocities can reach as high as 9 m/s (30 f/s). The Whirlpool, a basin 518 metres (1,700 feet) long and 365 metres (1,200 feet) wide with depths up to 38 metres (125 feet), is where the river makes a near right-angled turn. Below the Whirlpool, there is another set of rapids, which drop approximately 12 metres (40 feet). The river emerges from the gorge at Queenston, Ontario and subsequently drops 1.5 metres (5 feet) to Lake Ontario. At Queenston, the river widens to 610 metres (2,000 feet) and is navigable to Lake Ontario.

A.2 Hydro-Electric Installations and Remedial Works

A major portion of the Lake Erie outflow is utilized for power production and is diverted to hydro-electric plants by intake structures located above the Falls. A lesser portion is diverted for power via the Welland Canal. The high head plants, Sir Adam Beck Nos. 1 and 2 in Canada and the Robert Moses Niagara Power Project in the United States, withdraw water from the Chippawa-Grass Island Pool and return it to the lower Niagara River at Queenston, Ontario and Lewiston, New York, respectively. The Ontario Power Plant and the Canadian Niagara Power Plant, both located in Canada, divert water from the Cascade area and return it to the Maid-of-the-Mist Pool. The Ontario Power Plant is located at the base of the gorge near the head of the Maid-of-the-Mist Pool. Figure 4 shows the location of these diversion structures and hydro-electric power plants.

The amount of water that can be diverted for power generation is determined by a 1950 Treaty between the Governments of Canada and the United States concerning "The Diversion of the Niagara River," generally referred to as the "1950 Niagara Treaty." The Treaty requires the flow over Niagara Falls to be not less than 100,000 cfs (2832 m³/s during the daylight hours of the tourist season (0800 to 2200 hours local time 1 April to 15 September and 0800 to 2000 local time 16 September to 31 October). At all other times, the flow must be not less than 50,000 cfs (1416 m³/s). The Treaty also specifies that all water in excess of that required for domestic and sanitary purposes, navigation, and the Falls flow requirements, may be diverted for power generation.

Remedial works were constructed by the Power Entities in the 1950's, with the approval of the International Joint Commission, to maintain the Falls flows required by the Treaty and to facilitate power diversions. The remedial works consist of excavation and fill on both flanks of the Horseshoe Falls and a control structure extending about 0.8 kilometre (0.5 mile) into the river from the Canadian shore at the downstream end of the Chippawa-Grass Island Pool. The control structure has 13 gates, completed in 1957, and 5 additional gates completed in 1963. The Chippawa-Grass Island Pool control structure is operated jointly by the Power Entities and regulates the water level in the Chippawa-Grass Island Pool within limits set by the International Joint Commission. It also functions to adjust the Falls flow promptly from 2832 m³/s (100,000 cfs) to 1416 m³/s (50,000 cfs) and vice-versa during the tourist season. The operation of the control structure is under the supervision of the International Joint Commission's International Niagara Board of Control.

In 1964, with the International Joint Commission's approval, the Power Entities installed a floating ice boom in Lake Erie, near the head of the Niagara River. The boom has been installed early each winter and removed in the spring every year since. Its main purpose is to reduce the frequency and duration of heavy ice runs into the Niagara River which may lead to ice jams that could seriously hamper power diversions and damage shoreline installations. A more detailed description of the boom is contained in Section B.3.

A.3 Other Shore Installations

The Black Rock Canal parallels the upper reach of the Niagara River from Buffalo Harbor to the downstream end of Squaw Island. The canal provides an alternate route around the constricted, shallow and high velocity Peace Bridge reach of the upper Niagara River. Extending from Buffalo Harbor to above Strawberry Island, the canal is separated from the river at the upstream end by the Bird Island Pier, a stone and concrete wall and by Squaw Island at the downstream end. The Black Rock Lock, which has a lift of 1.5 metres (5 feet), is located near the lower end of the canal. A navigation channel extends from Squaw Island, via the Tonawanda Channel, to Niagara Falls, New York. The channel and canal are maintained to a depth of 6.4 metres (21 feet) below low water datum to North Tonawanda and then to a depth of 3.7 metres (12 feet) below low water datum to the city of Niagara Falls, New York.

The U.S. Government in 1985 and 1986 rehabilitated a portion of the Bird Island Pier. Prior to rebuilding, most of the pier was overtopped by water passing from the canal into the river at times of storm surge and/or high outflow from Lake Erie. Although the rebuilding raised the level of the pier slightly, culverts were incorporated into the structure to ensure unimpeded pre-project flow conditions that occurred over and through the pier.

Two bridges linking the Province of Ontario and State of New York span the upper Niagara River. The Peace Bridge (highway) crosses the head of the river and the Black Rock Canal near Lake Erie. The International Railway Bridge crosses the river and the canal 2.4 kilometres (1.5 miles) downstream from the Peace Bridge. The South and North Grand Island highway bridges traverse the Tonawanda Channel at Tonawanda and Niagara Falls, New York, respectively.

Docks for recreational craft are located at many points along the Niagara River, with a high concentration along the Tonawanda Channel. There are a few commercial docks for bulk commodities along the United States shoreline between the lower end of the Black Rock Canal and North Tonawanda, New York. A commercial operation for storing and distributing dredged sand is located at Queenston, Ontario. Several municipal and industrial water intakes and waste outfalls are located in the upper river. Some of these have structures extending above the water surface.

A.4 Ice Problems

Flow retardation due to ice in the Niagara River is a common winter event. During periods of high southwest winds, ice from Lake Erie sometimes enters the Niagara River and becomes grounded in shallow areas, such as the shoals near the head of the river and in the Chippawa-Grass Island Pool. During severe winter weather, ice originating in the river often adds to the problems caused by ice runs from the lake. These ice conditions can retard the flow in the Niagara River and occasionally lead to shore property damage and flooding. Accumulations of ice at the hydroelectric power intakes above Niagara Falls, or ice jams upstream, can reduce the amount of water diverted into these intakes. At times it is necessary to reduce these diversions to maintain a higher water elevation in the Chippawa-Grass Island Pool to facilitate ice passage.

Ice accumulations in the Maid-of-the-Mist Pool may pose potential hazards to the Ontario Power Plant and the Maid-of-the-Mist Steamboat Company facilities, both located downstream of the Falls on the Canadian shore. Heavy ice runs in the upper river, if added to a sizable volume of ice already in the Maid-of-the-Mist Pool, may, and on occasions have, severely damaged these installations.

Appendix B - Background Information on the Ice Boom

B.1 Authorization for Placement of the Ice Boom

The International Joint Commission authorized the Power Entities to install the ice boom on a test basis under an Order of Approval dated 9 June 1964. This Order has subsequently been modified by Supplementary Orders. The latest Order, dated 18 January 1984, states that the operation of the ice boom will be reviewed by the International Joint Commission when circumstances require, but no less than once every five years. On 13 April 1994 the International Joint Commission indicated that a review had been completed and that "the ice boom has performed as intended and that no changes to the Order are required". In 1997 the Commission modified its Order of Approval for the ice boom to remove any reference to the material required for the ice boom's pontoons. The most recent (5 October 1999) supplemental order modified (d) to include a cut off date along with the water temperature criteria.

Condition (d) regarding installation and Condition (e) regarding boom removal state, respectively:

"(d) Installation of the floating sections of the boom shall not commence prior to December 16 or prior to the water temperature at the Buffalo water intake reaching 4° C (39° F), whichever occurs first, unless otherwise directed by the commission."

"(e) All floating sections of the ice boom shall be opened by April 1, unless ice cover surveys on or about that date show there is more than 250 square miles (650 square kilometres) of ice east of Long Point. The ice boom opening may be delayed until the amount of ice east of Long Point has diminished to 250 square miles (650 square kilometres). Complete disassembly and removal of all remaining flotation equipment shall be completed within two weeks thereafter. Not with-standing any other provisions of this Order, the Commission retains the right to require retention, opening or removal of all or any part of the boom at any time because of the existence of an emergency situation."

B.2 Purpose of the Ice Boom

The ice boom accelerates the formation of the natural ice arch that normally forms near the head of the Niagara River every winter and stabilizes the arch once it has formed. The boom reduces the severity and duration of ice runs from Lake Erie into the Niagara River, thereby lessening the probability of large-scale ice blockages in the river. Such blockages could lead to both hydropower generation reductions and shoreline property flooding. In addition, it reduces the probability of ice damage to docks and other shore structures.

Once the ice arch is formed it bears the pressure of upstream ice. Subsequent storms may overcome the stability of the arch and force large masses of ice against the boom. The boom was designed to then submerge and allow the ice to override it until the pressure is relieved. After storm conditions subside, the boom resurfaces and restrains ice which otherwise would flow downriver. In the winter season, the ice boom facilitates stabilization of the broken ice cover during the refreezing process. In the spring, it minimizes the severity of ice runs by reducing the quantity of loose ice flows, which enter the river.

B.3 Description of the Ice Boom

When in position, the 2700 metre (8,800 foot) ice boom spans the outlet of Lake Erie and is located approximately 300 metres (1,000 feet) southwest of the water intake crib for the city of Buffalo. The boom is made up of 22 spans. Starting with the 1997-1998 season, the boom spans consisted of a series of 11 floating steel pontoons, anchored to the river bed at 122 metre (400 foot) intervals by a 6.4 centimetre (2.5 inch) diameter steel cable. Each pontoon is 76 centimetres (30 inches) in diameter and 9 metres (30 feet) long. Beginning in 1998-99, spans A through J contained 10 instead of 11 pontoons to reduce the potential for collisions during open water conditions. A map of eastern Lake Erie showing the location of the ice boom is included as Figure 5. Figure 6 is a map of the upper Niagara River. Figure 7 illustrates structural details and a plan view of the ice boom.

Plan View of Ice Boom and Sequence of Removal

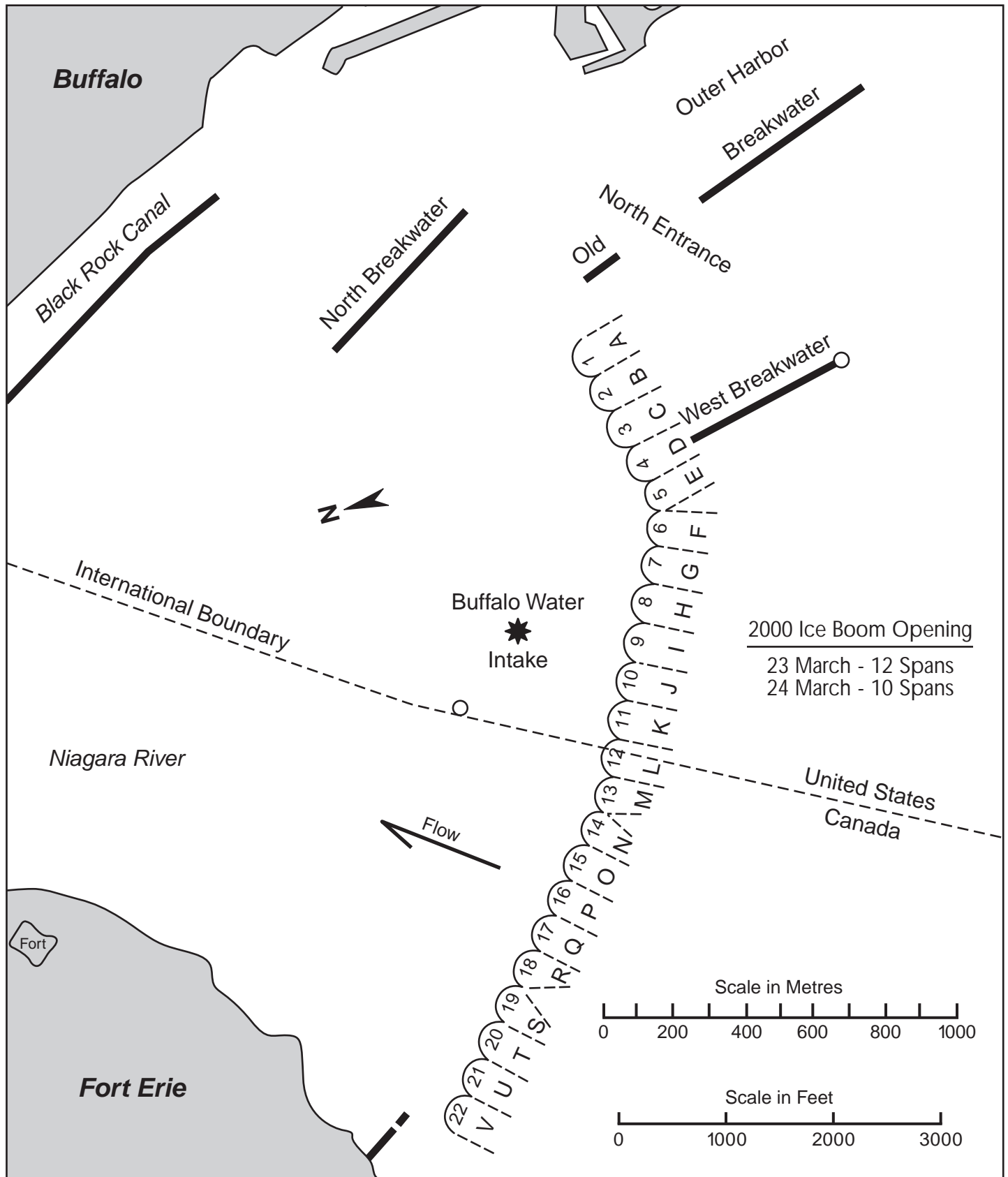


FIGURE 1

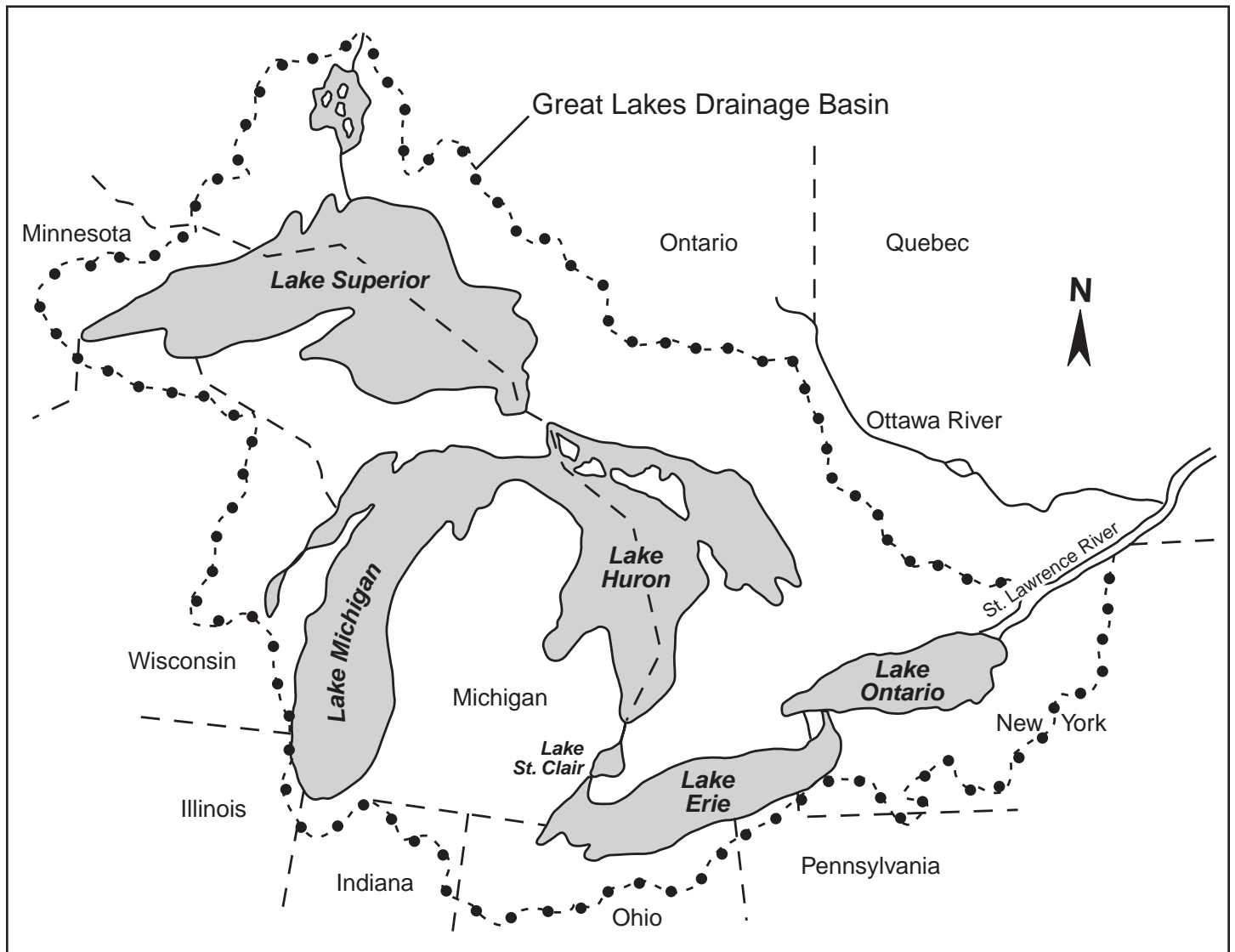


FIGURE 2

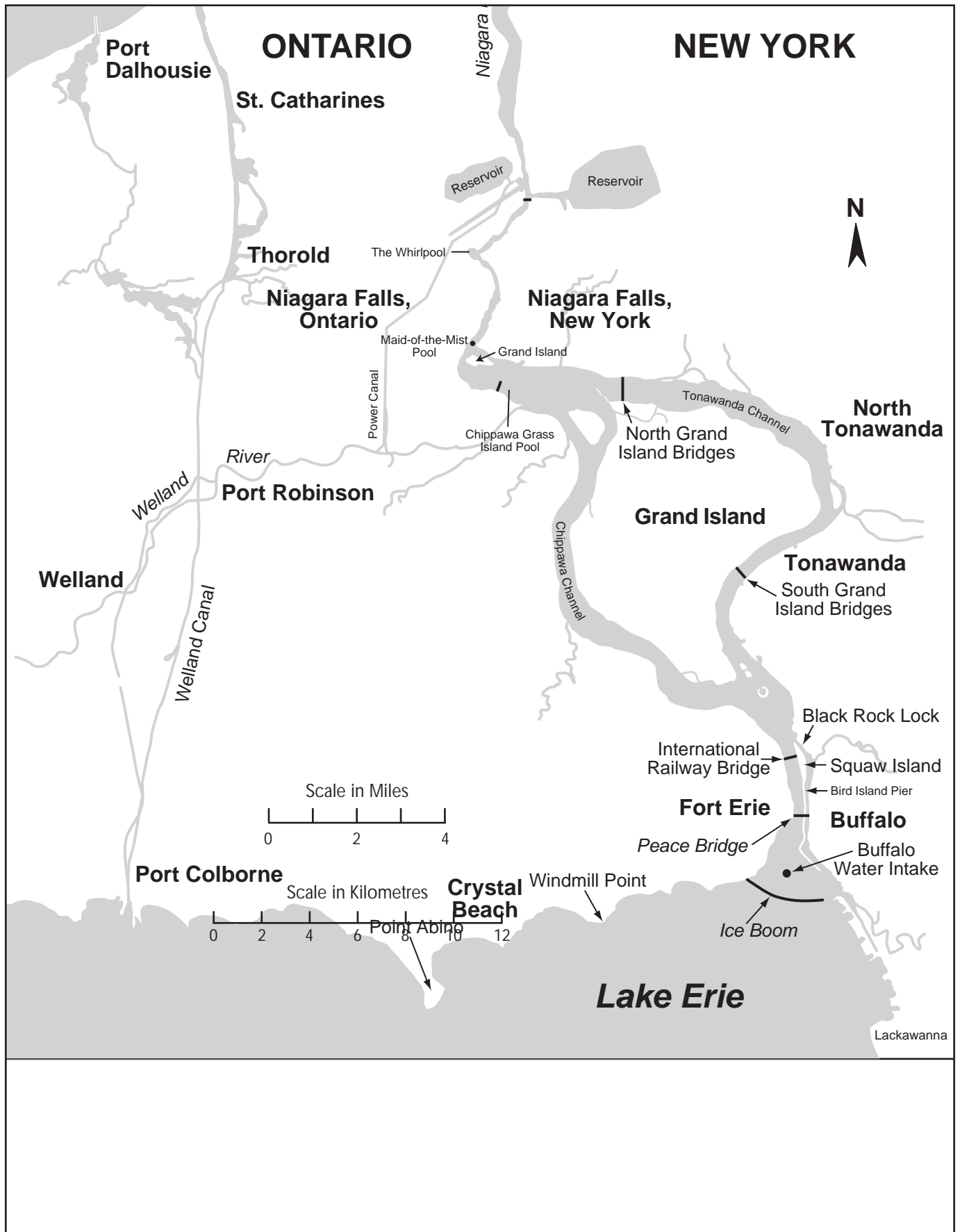


FIGURE 3

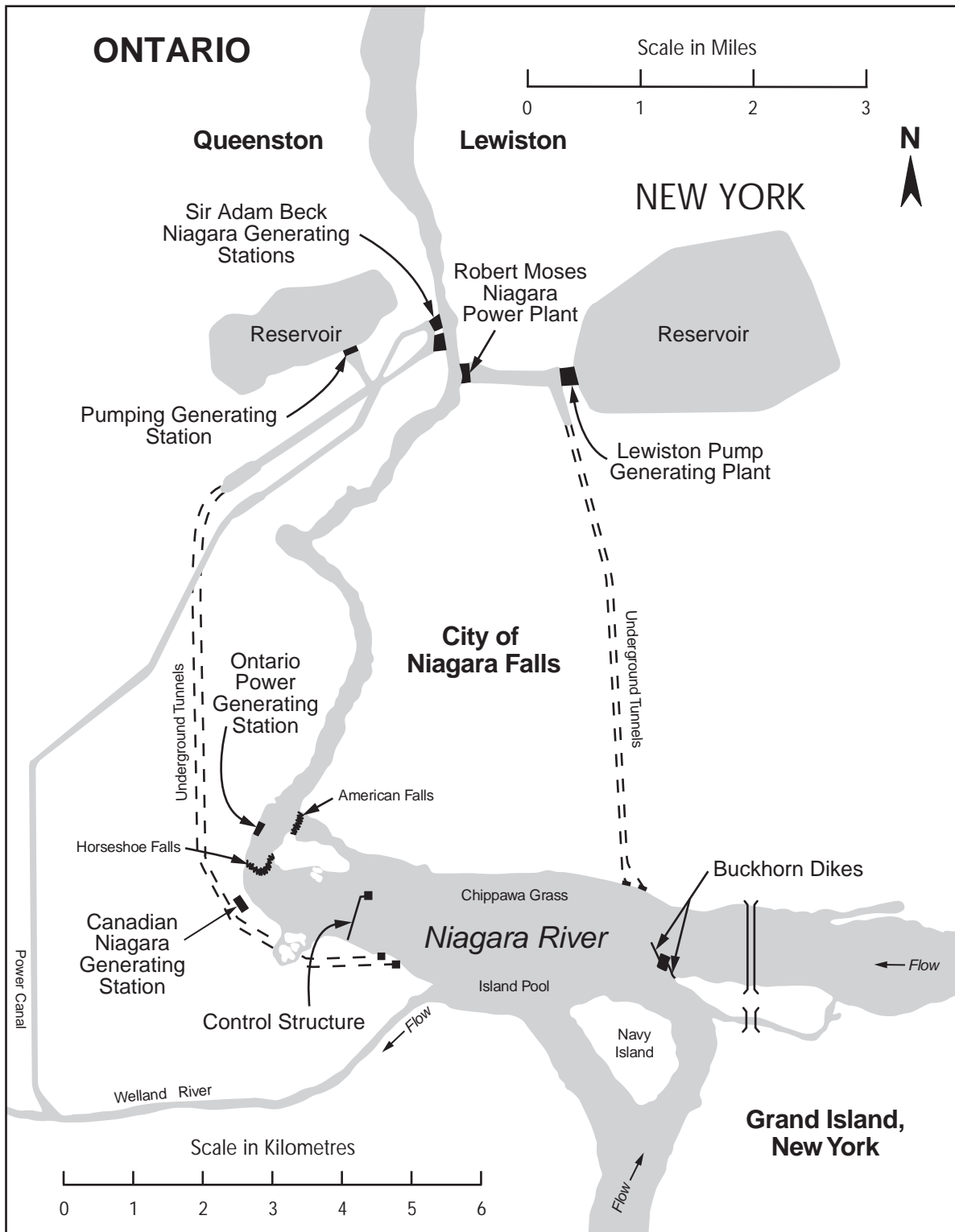


FIGURE 4

Map of Eastern Lake Erie

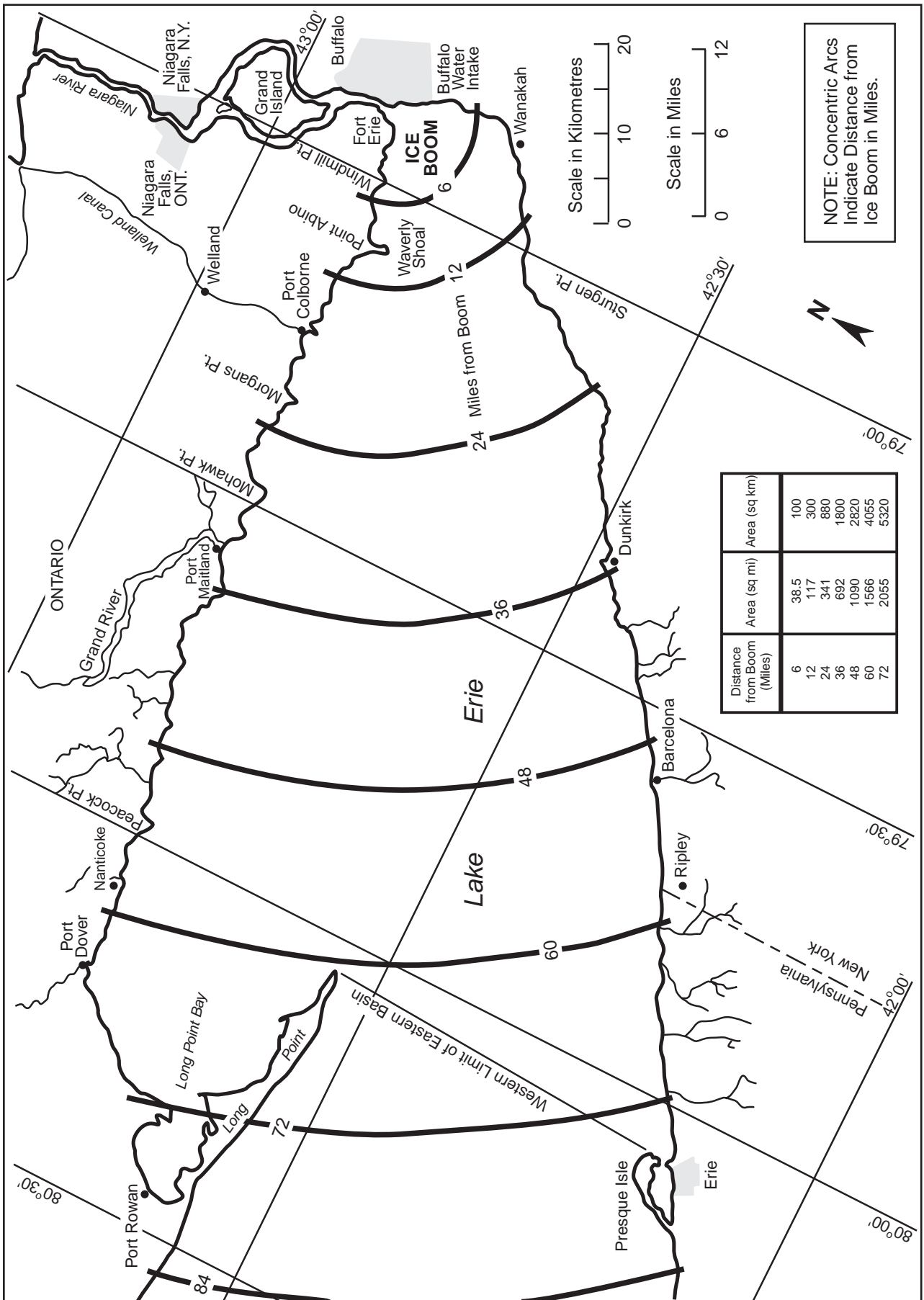


FIGURE 5

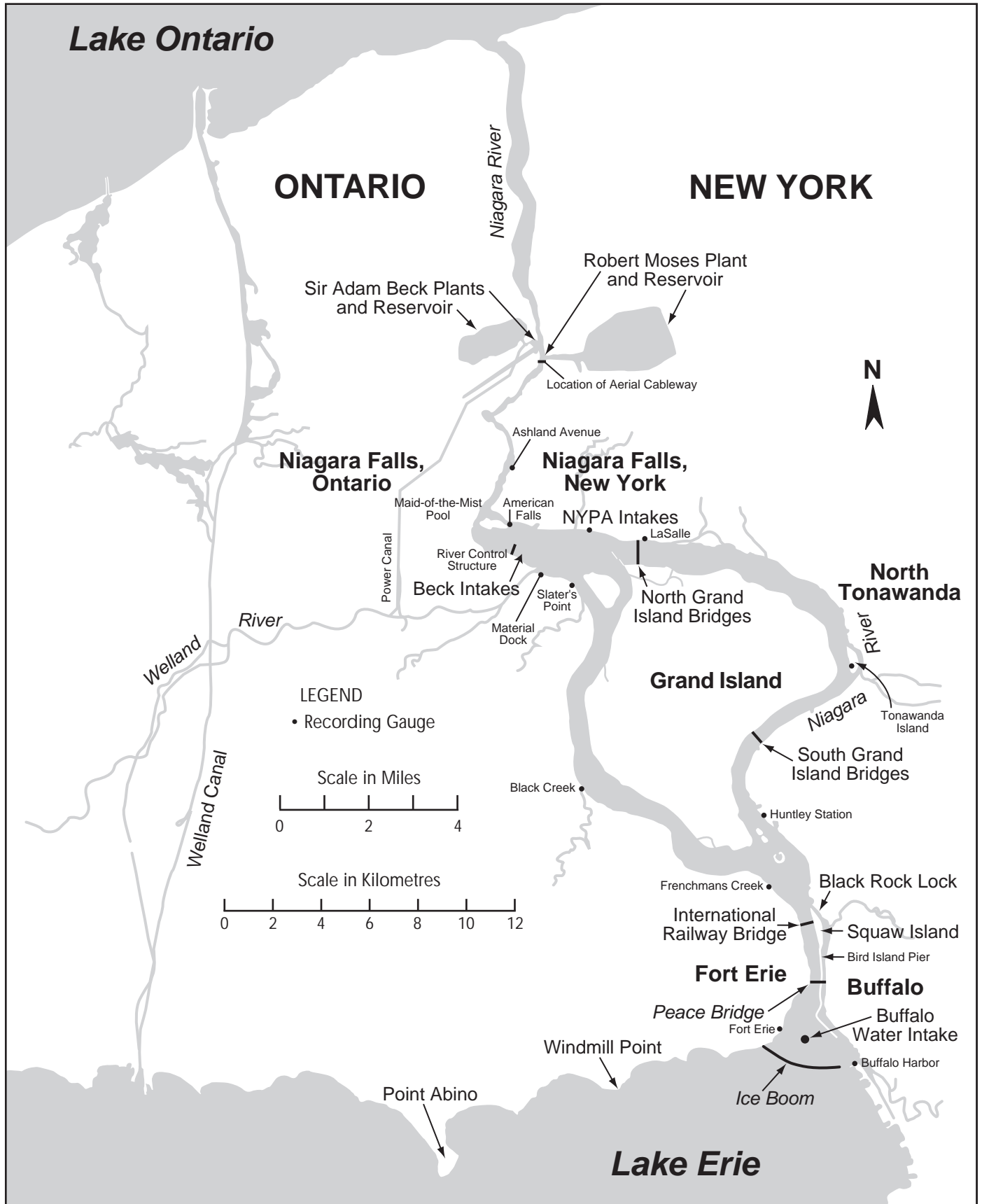


FIGURE 6

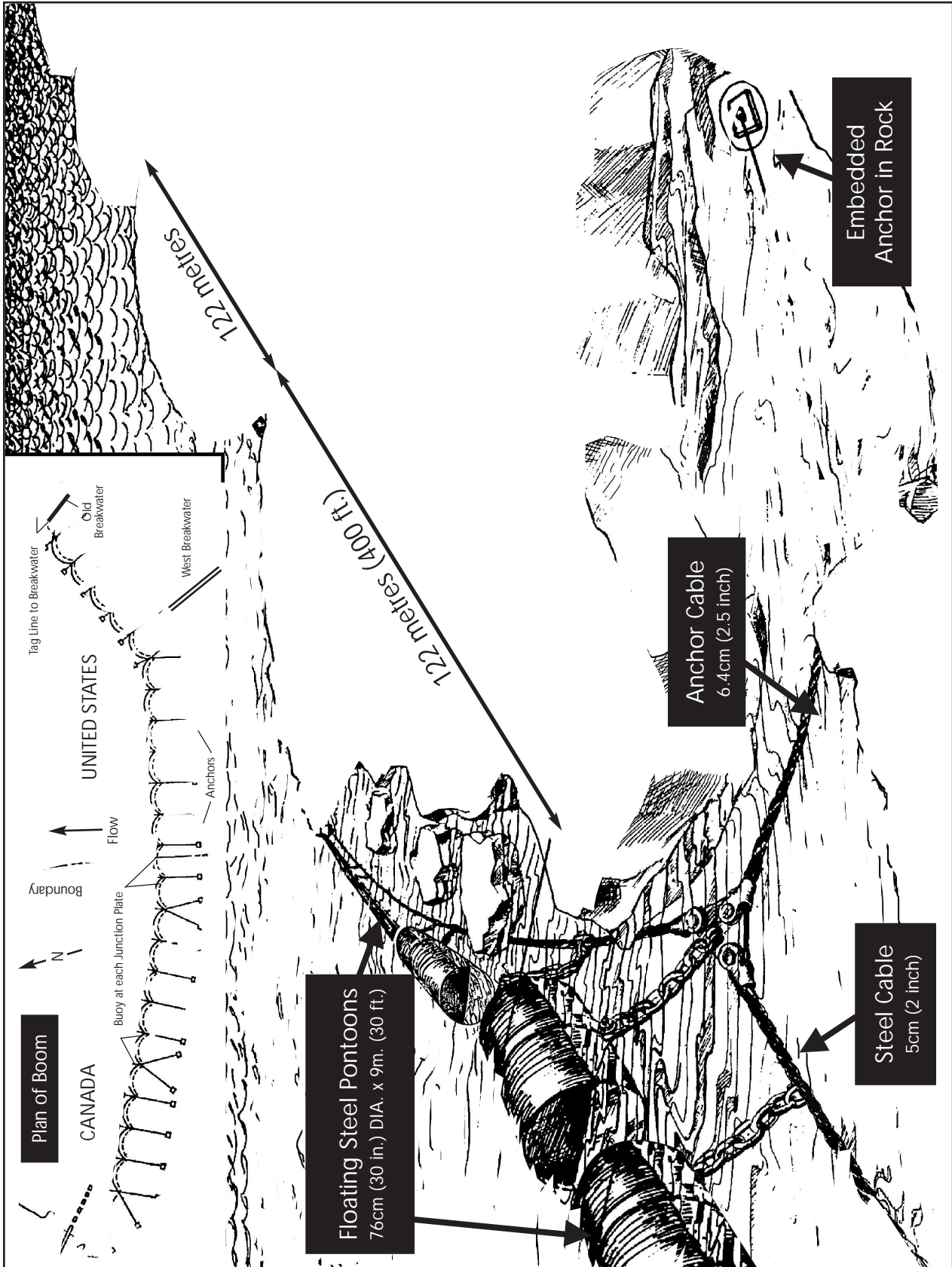


FIGURE 7