2005-06

Operation of the Lake Erie - Niagara River Ice Boom

A report to the
International Niagara Board of Control
by the
International Niagara Working Committee

October 2006

Report to
The International Niagara Board of Control
On the 2005-06 Operation of
The Lake Erie-Niagara River Ice Boom

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Great Lakes Information Network . . . . www.great-lakes.net
Our Great Lakes . . . . www.on.ec.gc.ca/water/greatlakes/intro-e.html

Data in this report are in metric units followed by approximate English units (in parentheses). 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 started on 14 December and was completed on 15 December, 2005.

An ice cover began forming behind the boom during the third week of February 2006.

A lake ice run from a storm in mid-March resulted in operation of the Power Entities' ice breakers at the Chippawa-Grass Island Pool.

Ice boom removal was accomplished on 20-21 March with all spans placed at their summer storage area by 24 March.

The Board's International Niagara Working Committee did not conduct any helicopter flights to measure ice thickness or fixed wing flights to observe ice conditions during the 2005-06 ice season.

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 2005-06 Ice Season

2.1 Installation of the Boom

A video system is used to monitor the ice boom. The Internet address for information on the ice boom as well as current images is:

http://www.iceboom.nypa.gov

The marine radar system for monitoring surface ice coverage in the Chippawa-Grass Island Pool (CGIP) was used by operators of the International Niagara Control Works during 2005-06. 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, and its engineering staff in White Plains, NY as well as staff at Ontario Power Generation's (OPG) Niagara Falls generating stations to monitor ice movement in the CGIP.

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 14 December 2005. The water temperature at Buffalo reached 4 degrees Celsius (°C) (39 degrees Fahrenheit (°F)) on 9 December. Installation may begin when the Lake Erie water temperature at Buffalo reaches 4 °C (39°F) or on 16 December, whichever occurs first.

Preparations for span placement began on 5 December when seven floatation barrels were installed. The remaining 16 barrels were installed on 8 December. The boom's anchor points at the bottom of the lake are connected by cables to junction plates. The 22 spans of the boom are attached to these plates. The plates, that spend the off season on the bottom of the lake, are lifted to the surface and held there by the floatation barrels to await installation of the spans between them. The strings of pontoons, which make up the booms spans and each contain either 10 or 11 pontoons, were pulled into the water from their summer storage area and placed inside the Buffalo Harbor breakwall by 14 December to await installation. (See section B.3 and Figure 7).

Installation of the ice boom's spans began on 14 December when 12 spans were placed starting from the Canadian side. The remaining 10 spans, continuing on towards the US shore, were installed the next day.

2.2 Ice and Hydrometeorological Conditions

The average monthly air temperature data for November 2005 through April 2006, as measured at the Buffalo Airport, are shown in Table 2-2. These were about 1.5°C (2.7°F) above average for the six month period.

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

The monthly Buffalo weather summary for November 2005 characterized it as running the gamut from windstorms and thunderstorms to record warmth and Thanksgiving chill. With a monthly average air temperature of 6.3°C (43.3°F), which was 1.7°C (3.1°F) above average, it was the sixth consecutive warm month. Combined with September and October it was the fifth warmest autumn in the 63 years of records at the National Weather Service airport location and followed Buffalo's warmest summer in recorded history! However, air temperatures plunged to mid-winter levels around the 23rd producing the coldest Thanksgiving in 100 years with the Lake Erie at Buffalo water temperature at month's end of 5.0°C (41°F) compared to 8.3°C (47°F) at the same time in 2004.

December reversed the warm trend with a monthly average of -2.7°C (27.1°F), 1.5°C (2.7°F) below average. There were no significant weather extremes for the month. The Lake Erie water temperature at Buffalo dropped steadily through the first half of the month but levelled off for the last half. At month's end, the temperature was 1.1°C (34°F) compared to 1.7°C (35°F) at the same time in 2004. Conditions were near average in terms of progress towards freeze-up.

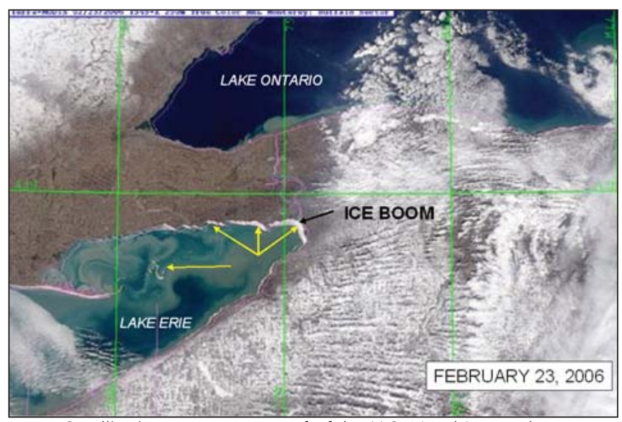
January 2006 was the warmest in 56 years at Buffalo with an average air temperature of 1.6°C (34.9°F), well above the average of -4.2°C (24.5°F). This consistent mildness over the region melted the ice cover that had formed at the western end of the Lake by the end of December. Lake Erie was ice free at the end of January.

Although the month of February was 1.1°C (1.9°F) above the average of -3.4°C (25.9°F), the Lake Erie water temperature at Buffalo remained above freezing until beyond mid-month with virtually no ice cover on the Lake. An extended cold period during the latter part of the month subsequently brought about a rapid formation of ice on the eastern basin.

Two major windstorms were experienced in the Buffalo area in February. With no ice cover formed until later in the month, the exposed spans of the ice boom suffered some damage from wind driven waves. Span E was observed on 8 February to be broken and was replaced on 10 February by the NYPA crew. Ends of pontoons adjacent to the broken span were badly dented indicating collisions with one another from strong wave action in the open water condition. On 13 February, it was noted that span F was broken. It was replaced with a spare span on 16 February.

The stresses exerted on the boom during storm events in both open water and ice conditions have resulted in some broken spans or trailing pontoons at various times throughout the boom's history. Occasional broken spans throughout the year are not unusual and do not adversely affect the function of the ice boom. They are normally replaced or repaired when the storm subsides.

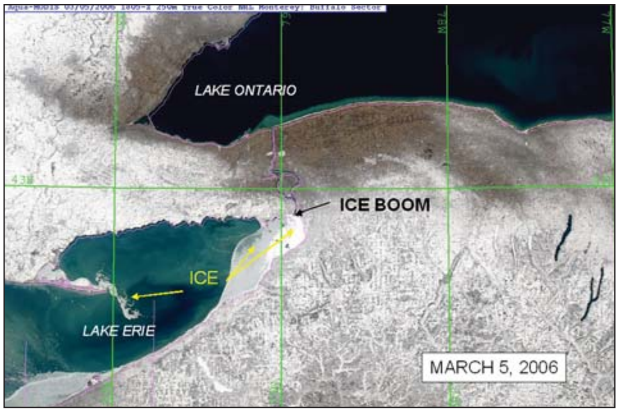
Ice began forming behind the ice boom and in the bays along the north shore of eastern Lake Erie around the third week of February as seen in this NEXSAT image.



Satellite imagery courtesy of of the U.S. Naval Research Laboratory/NPOESS NexSat project

The average air temperature for March was 0.5°C (0.9°F) above the average of 1.3°C (34.3°F). The first week of the month was colder than normal and continued to contribute to formation of an ice cover on the eastern end of the lake. The second week was above averagebut then came an 11 day stretch of cold followed by a dramatic warm up at the end of the month.

A break in span M, closest to the middle of the ice boom, was observed by the NPYA crew on 1 March. They completed a splice repair on 2 March. By 5 March, the ice cover on the eastern basin of Lake Erie reached its maximum as seen in the NEXSAT image below. It was determined to be 1390 square kilometres (540 square miles) or 27%.



An ice bridge formed in the Maid-of-the-Mist Pool on 27 February. A lake ice run which resulted from the storm on 14/15 March increased the ice cover below the Falls to almost 100%. This began to decrease as no further significant amount of ice exited the lake. The ice bridge broke apart on 26 March and the ice moved downstream without incident.

2.3 Ice Boom Opening

With warmer than average air temperatures during the second week in March, the ice cover on eastern Lake Erie began to diminish. A storm event on 14/15 March resulted in a lake ice run that required ice breaker activity at the Chippawa-Grass Island Pool. Two spans, H and I, were observed to be opened as the result of the storm. Only a small amount of ice remained in the extreme eastern end of Lake Erie by 17 March and so the Board issued a media advisory that, with favorable weather conditions, ice boom opening would begin on 20 March. The NYPA crew were able to remove the boom's 22 spans on 20 and 21 March.

The date of last ice in Lake Erie, based on satellite information, was 5 April.

The voyages of the Maid of the Mist Steamboat Company for the 2006 season began on 13 April. Last year's operations began on 21 April.

No helicopter (thickness) or fixed-wing (area) observation flights were conducted by the Board's representatives during the 2005-06 ice season.

2.4 Estimated Power Losses

Some reduction in hydropower generation occurs virtually every year due to ice problems. However, the Power Entities 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 2005-06 ice season were 32,900 Megawatt Hours (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

There were no reports of damages to shore properties from ice along the Niagara River.

2.6 Maintenance of the Ice Boom

The installation, removal and maintenance of the Lake Erie-Niagara River Ice Boom is undertaken by the New York Power Authority (NYPA) on behalf of both NYPA and Ontario Power Generation (the Power Entities). As a result of studies conducted by the Power Entities, all of the timber pontoons were replaced with 76 centimetre (30 inch) diameter steel pontoons. This was done to improve the ice-overtopping resistance of the ice boom and reduce its maintenance costs. The replacement of timbers with steel pontoons was completed in the fall of 1997 and the first all-steel-pontoon ice boom was used in the 1997-1998 ice season.

Based on experience gained during the 1997-1998 ice season, it was recommended that, in order to reduce the potential for damage to the ends of the pontoons from collisions due to storm induced wave action during open water periods, one steel pontoon from each of spans A through J of the ice boom be removed. Therefore, spans A through J contain 10 instead of 11 steel pontoons beginning with the 1998-1999 ice season. This modification greatly reduced damage to the pontoons in this reach.

Span E was observed on 8 February to be broken and was replaced on 10 February by the NYPA crew. Ends of pontoons adjacent to the broken span were badly dented indicating collisions with one another from strong wave action in the open water condition. On 13 February, it was noted that span F was broken. It was replaced with a spare span on 16 February. Two spans, H and I, were observed to be opened as the result of a storm event on 14/15 March. These were not repaired as ice boom opening and removal was about to begin.

As part of a routine summer ice boom maintenance program, hardware will be replaced where necessary.

3. DATA ANALYSIS 2005-06

3.1 Purpose

During the 2005-06 winter, 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 and mapping was analysed and meteorological data from the U.S. National Weather Service Station at Buffalo were collected.

Lake Erie water temperatures, as recorded at the Buffalo water intake, for the 2005-06 ice boom reporting period, are contained in Table 3-1. Observed dates of last ice for the period 1905 to present are contained in Table 3-2. Comparison of ice areas at the time of ice boom opening is shown in Table 3-3.

3.2 Navigation at the Welland Canal in Ontario

The Welland Canal opened to commercial shipping for its 177th consecutive year of service on 21 March. The up-bound transit of the Sea Eagle II / St. Mary's Cement II, loaded with cement bound for Detroit, marked the first time an integrated tug and barge unit has opened the Welland Canal.

Coast Guard ice breaker assistance was not required for commercial shipping on Lake Erie. Opening dates for the ice boom and commencement of navigation at the Welland Canal for the period 1965 to 2006 are shown in Table 3-4.

4. FINDINGS AND RECOMMENDATIONS

4.1 Findings and Conclusions

a) Water temperature at Buffalo reached 4°C (39°F) on 9 December.

b) The ice boom spans were installed during the period 14-15 December 2005 in accordance with the International Joint Commission's 1999 Supplementary Order of Approval.

c) Removal of the ice boom spans was accomplished on 20-21 March. The average length of time required to open and remove the ice boom spans for the period of record 1965 through 2006 is five days.

4.2 Recommendations for the 2006-07 Operation

a) The International Niagara Board of Control and its Working Committee should continue to monitor and assess the performance of the ice boom.

b) Utilization of Great Lakes ice cover maps prepared by the National Ice Center, Maryland and Canadian Ice Centre, Ottawa supplemented by ice thickness measurements and aerial ice surveys to evaluate ice conditions throughout the winter should continue. In particular, this will assist in determining when to remove the ice boom.

c) The Working Committee should continue to store ice area maps produced following aerial ice reconnaissance flights or determined from the composite ice maps. The computer generated 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:

www.lrb.usace.army.mil/levels/levels.html

d) The Working Committee should continue to liaise with the United States and Canadian Coast Guards regarding ice boom installation and removal operations.

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

Decade	Date Water Temperature Reached 4°C (39°F)	Installation of the Ice Boom
1960's	7 Dec 1964	9 Nov to 15 Dec 1964
	15 Dec 1965	19 Nov to 8 Dec 1965
	19 Dec 1966	8 Nov to 6 Dec 1966
	29 Nov 1967	17 Nov to 5 Dec 1967
	10 Dec 1968	25 Nov to 5 Dec 1968
	9 Dec 1969	15 Nov to 10 Dec 1969
1970's	15 Dec 1970	Completed 15 Dec 1970*
	25 Dec 1971	30 Nov to 10 Dec 1971
	11 Dec 1972	11 Dec to 14 Dec 1972
	18 Dec 1973	19 Dec 1973 to 9 Jan 1974
	10 Dec 1974	11 Dec to 30 Dec 1974
	20 Dec 1975	24 Dec 1975 to 8 Jan 1976
	24 Nov 1976	30 Nov to 18 Dec 1976
	8 Dec 1977	13 Dec to 31 Dec 1977
	11 Dec 1978	Completed 19 Dec 1978*
	17 Dec 1979	Completed 22 Dec 1979*
1980's	14 Dec 1980	22 Dec to 30 Dec 1980
	11 Dec 1981	19 Dec to 23 Dec 1981
	4 Jan 1983	6 Jan to 8 Jan 1983
	18 Dec 1983	19 Dec to 21 Dec 1983
	26 Dec 1984	27 Dec to 30 Dec 1984
	17 Dec 1985	20 Dec to 21 Dec 1985
	15 Dec 1986	16 Dec to 17 Dec 1986
	19 Dec 1987	19 Dec to 26 Dec 1987
	12 Dec 1988	12 Dec to 17 Dec 1988
	6 Dec 1989	7 Dec to 8 Dec 1989
1990's	27 Dec 1990	27 Dec to 30 Dec 1990
	19 Dec 1991	20 Dec to 27 Dec 1991
	6 Dec 1992	13 Dec to 14 Dec 1992
	16 Dec 1993	17 Dec to 28 Dec 1993
	2 Jan 1995	7 Jan to 10 Jan 1995
	7 Dec 1995	13 Dec to 16 Dec 1995
	4 Dec 1996	8 Dec to 11 Dec 1996
	13 Dec 1997	17 Dec to 18 Dec 1997
	1 Jan 1999	2 Jan to 9 Jan 1999
	27 Dec 1999	19 Dec to 29 Dec 1999
2000's	18 Dec 2000	16 Dec to 28 Dec 2000
	27 Dec 2001	17 Dec to 22 Dec 2001
	3 Dec 2002	11 Dec to 12 Dec 2002
	15 Dec 2003	16 Dec to 20 Dec 2003
	20 Dec 2004	17 Dec to 20 Dec 2004
	9 Dec 2005	14 Dec to 15 Dec 2005

* starting date unknown

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.

Table 2-2 Air Temperature at Buffalo Niagara International Airport

	°C (Celsius)			°F (Fahrenheit)		
Month	**Average* 1971-2000**	**Recorded 2005-06**	**Departure**	**Average* 1971-2000**	**Recorded 2005-06**	**Departure**
Nov. 2005	4.6	6.3	+1.7	40.2	43.3	+3.1
Dec. 2005	-1.2	-2.73	-1.5	29.8	27.1	-2.7
Jan. 2006	-4.2	1.6	+5.8	24.5	34.9	+10.4
Feb. 2006	-3.4	-2.3	+1.1	25.9	27.8	+1.9
Mar. 2006	1.3	-1.8	+0.5	34.3	35.2	+0.9
Apr. 2006	7.4	8.9	+1.5	45.3	48.0	+2.7

* Official U.S. National Weather Service averages are based on 30 years of record, 1971-2000.

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

Winter Season of:	POWER LOSSES (in MWH) December	January	February	March	April	May	Totals
1974-75	*	*	*(2/14-3/5) 150,000	*(3/7-3/26) 15,100	*	*	165,100
1975-76	*	78,700	36,500	45,800	32,000	*	193,000
1976-77	*	54,000	23,500	0	0	0	77,500
1977-78	*	88,000	600	600	0	0	89,200
1978-79	*	30,000	3,700	0	1,600	0	35,300
1979-80	*	6,000	30,000	13,000	10,500	0	59,500
1980-81	14,000	9,000	3,900	1,100	4,100	0	32,100
1981-82	*	58,000	27,000	10,000	13,000	5,000	113,000
1982-83	0	0	0	0	0	0	0
1983-84	53,000	57,000	4,000	25,000	0	0	139,000
1984-85	0	65,000	25,000	11,000	29,000	0	130,000
1985-86	10,000	65,000	8,000	5,000	6,000	0	94,000
1986-87	0	28,000	32,000	4,000	0	0	64,000
1987-88	0	13,000	24,000	0	4,000	0	41,000
1988-89	0	0	30,000	1,000	2,000	0	33,000
1989-90	6,000	7,000	5,000	5,000	0	0	23,000
1990-91	0	14,000	11,000	6,000	0	0	31,000
1991-92	0	21,000	3,000	14,000	0	0	38,000
1992-93	0	0	2,000	2,000	0	0	4,000
1993-94	0	11,000	12,000	0	1,000	0	24,000
1994-95	0	0	11,000	2,000	7,000	0	20,000
1995-96	0	45,000	4,000	13,000	0	0	62,000
1996-97	0	80,000	4,000	3,000	16,000	0	103,000
1997-98	0	0	0	0	0	0	0
1998-99	0	17,000	700	0	0	0	17,700
1999-2000	0	0	1,200	0	0	0	1,200
2000-01	700	3,600	500	100	0	0	4,900
2001-02	0	0	0	0	0	0	0
2002-03	0	35,000	11,500	1,500	0	0	48,000
2003-04	0	26,000	5,800	0	0	0	32,000
2004-05	0	7,000	13,100	8,500	0	0	28,600
2005-06	0	0	14,300	18,600	0	0	32,900

* No Data Published

Note: No Data Available for Period 1964-74.

Table 3-1 Lake Erie Water Temperatures as Recorded at the Buffalo Intake (Dec. 2005-May 06).

Month	December		January		February		March		April		May	
Date	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
1	6.1	43	1.1	34	1.7	35	0.0	32	2.8	37	8.3	47
2	6.1	43	1.1	34	1.7	35	0.0	32	2.8	37	8.3	47
3	6.1	43	1.7	35	1.7	35	0.0	32	3.9	39	8.3	47
4	5.6	42	2.2	36	1.7	35	0.0	32	3.9	39	8.3	47
5	5.6	42	2.2	36	1.7	35	0.0	32	3.9	39	9.4	49
6	5.0	41	1.7	35	1.7	35	0.0	32	5.6	42	10.0	50
7	4.4	40	1.7	35	1.1	34	0.0	32	5.0	41	10.0	50
8	4.4	40	1.7	35	1.1	34	0.0	32	5.0	41	10.0	50
9	3.9	39	1.7	35	0.6	33	0.0	32	5.0	41	10.0	50
10	3.9	39	1.7	35	0.6	33	0.0	32	4.4	40	10.0	50
11	3.3	38	2.2	36	0.6	33	0.0	32	4.4	40	10.6	51
12	3.3	38	2.8	37	0.6	33	0.0	32	4.4	40	11.1	52
13	3.3	38	1.7	35	0.6	33	0.0	32	4.4	40	11.1	52
14	2.8	37	1.7	35	0.6	33	0.0	32	4.4	40	11.1	52
15	2.2	36	1.7	35	0.6	33	0.0	32	4.4	40	10.6	51
16	2.2	36	1.7	35	0.6	33	1.7	35	5.0	41	10.6	51
17	2.2	36	1.7	35	0.6	33	1.7	35	5.0	41	10.6	51
18	2.2	36	1.7	35	0.0	32	1.7	35	5.6	42	11.7	53
19	1.7	35	1.1	34	0.0	32	1.7	35	5.6	42	11.7	53
20	1.1	34	1.1	34	0.0	32	1.1	34	6.1	43	11.7	53
21	0.6	33	1.1	34	0.0	32	1.7	35	6.1	43	11.7	53
22	1.7	35	1.1	34	0.0	32	1.1	34	6.7	44	11.1	52
23	1.1	34	1.1	34	0.0	32	1.1	34	6.7	44	11.1	52
24	1.1	34	1.7	35	0.0	32	1.1	34	7.2	45	11.1	52
25	1.1	34	1.7	35	0.0	32	1.1	34	7.8	46	11.1	52
26	1.7	35	1.7	35	0.0	32	3.3	38	7.8	46	11.1	52
27	0.6	33	1.7	35	0.0	32	5.0	41	7.8	46	11.7	53
28	1.1	34	1.7	35	0.0	32	5.6	42	7.8	46	11.7	53
29	1.1	34	1.7	35			2.8	37	7.8	46	11.7	53
30	1.7	35	1.7	35			2.8	37	8.3	47	13.9	57
31	1.1	34	1.7	35			2.8	37			13.9	57
Avg.	2.8	37.1	1.6	34.9	0.6	33.1	1.2	34.1	5.5	41.9	10.8	51.4

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	2001	27 April
1931	7 April	1967	13 April	2002	Ice-free
1932	21 April	1968	4 May	2003	22 April
1933	23 April	1969	26 April	2004	30 April
1934	23 April	1970	30 April	2005	11 April
1935	13 April	1971	31 May	2006	5 April
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.

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

	Areas of Ice in Eastern Lake Erie			Opening of Boom	
Year	Date of Observation	Square Kilometres	Square Miles	Start	Completed
1965	*No Data Collected*			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	1290	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 April	540	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	410	160	30 March	17 April
1996	17 April	730	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	410	160	23 March	24 March
2001	14 April	390	150	17 April	20 April
2002	Ice-Free			7 March	7 March
2003	10 April	490	190	10 April	11 April
2004	5 April	1110	430	6 April	7 April
2005	4 April	210	80	5 April	6 April
2006	20 March	70	30	20 March	21 March

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

	Opening of Boom		Navigation Season Opened at:	
Year	Start*	Completed	Welland**	NOTES
1965	21 March	27 March	1 April	* Denotes opening of first boom span. Mobilization time precedes this date.
1966	20 March	1 April	4 April	
1967	22 March	29 March	1 April	
1968	18 March	20 March	1 April	
1969	26 March	3 April	1 April	
1970	23 April	30 April	1 April	1970 Commencement of flexible date for boom opening.
1971	3 May	14 May	29 March	
1972	20 April	25 April	29 March	
1973	16 March	21 March	28 March	
1974	26 March	1 April	29 March	
1975	25 March	28 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	1 April	
1977	18 April	20 April	4 April	
1978	1 May	8 May	28 March	
1979	13 April	17 April	28 March	
1980	2 April	7 April	24 March	
1981	18 April	22 April	25 March	
1982	27 April	2 May	5 April	
1983	7 March	8 March	5 April	
1984	7 April	10 April	28 March	
1985	13 April	15 April	1 April	
1986	12 April	14 April	3 April	
1987	6 March	6 March	1 April	
1988	9 April	10 April	31 March	
1989	30 March	6 April	31 March	
1990	26 March	30 March	28 March	
1991	27 March	30 March	26 March	
1992	30 March	2 April	30 March	
1993	5 April	6 April	30 March	
1994	21 April	28 April	5 April	
1995	30 March	17 April	24 March	
1996	19 April	3 May	29 March	
1997	25 April	28 April	2 April	
1998	5 March	5 March	24 March	
1999	30 March	30 March	31 March	
2000	23 March	24 March	28 March	
2001	17 April	20 April	30 March	
2002	7 March	7 March	26 March	
2003	10 April	11 April	26 March	
2004	6 April	7 April	23 March	
2005	5 April	6 April	23 March	
2006	20 March	21 March	21 March	
1965 - 2006	4 April	8 April	30 March	Average for the post-ice boom period.
1970 - 2006	5 April	9 April	29 March	Average for the flexible boom opening period.

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 (Figures 2 and 3). The elevation difference between the two lakes is about 99 metres (326 feet); half of this occurs at Niagara Falls. Over the period 1860-2005, the average Niagara River flow at Queenston, Ontario has been 5864 cubic metres per second (m^3/s) (207,080 cubic feet per second (cfs)). The Welland Canal carries a small portion of the Lake Erie outflow. The total upper Great Lakes drainage basin upstream of the Niagara River is approximately 684,000 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 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 (ft/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 ft/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 ft/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 ft/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 International Niagara Control Works. This structure extends from the Canadian shoreline 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 (Figure 4). 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 ft/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 (Figure 4). 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. 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 2832 m^3/s (100,000 cfs) 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 1416 m^3/s (50,000 cfs). 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 m^3/s (100,000 cfs) to 1416 m^3/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, a combination of reduced diversions, manipulated water elevations in the Chippawa-Grass Island Pool and ice breaker activity is necessary 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 operation of the ice boom is reviewed by the International Joint Commission when circumstances require, but no less than once every five years. The most recent review was completed in 1999 and resulted in the Commission issuing a Supplementary Order which modified condition (d). A Supplementary Order was issued in 1997 to remove any reference to the material required for the ice boom's pontoons.

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 forms most winters near the head of the Niagara River 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 floes 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. Spans are anchored to the lake bed at 122 metre (400 foot) intervals by 6.4 centimetre (2.5 inch) diameter steel cables. As a result of studies conducted by the Power Entities, all of the timber pontoons were replaced with 76 centimetre (30 inch) diameter, 9 metre (30 foot) long steel pontoons. This was done to improve the ice-overtopping resistance of the ice boom and reduce its maintenance costs. The replacement of timbers with steel pontoons was completed in the fall of 1997 and the first all-steel-pontoon ice boom was used in the 1997-1998 ice season.

Based on experience gained during the 1997-1998 ice season, it was recommended that, in order to reduce the potential for damage to the ends of the pontoons from collisions due to storm induced wave action during open water periods, one steel pontoon from each of spans A through J of the ice boom be removed. Therefore, spans A through J contain 10 instead of 11 steel pontoons beginning with the 1998-1999 ice season. This modification greatly reduced damage to the pontoons in this reach. 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

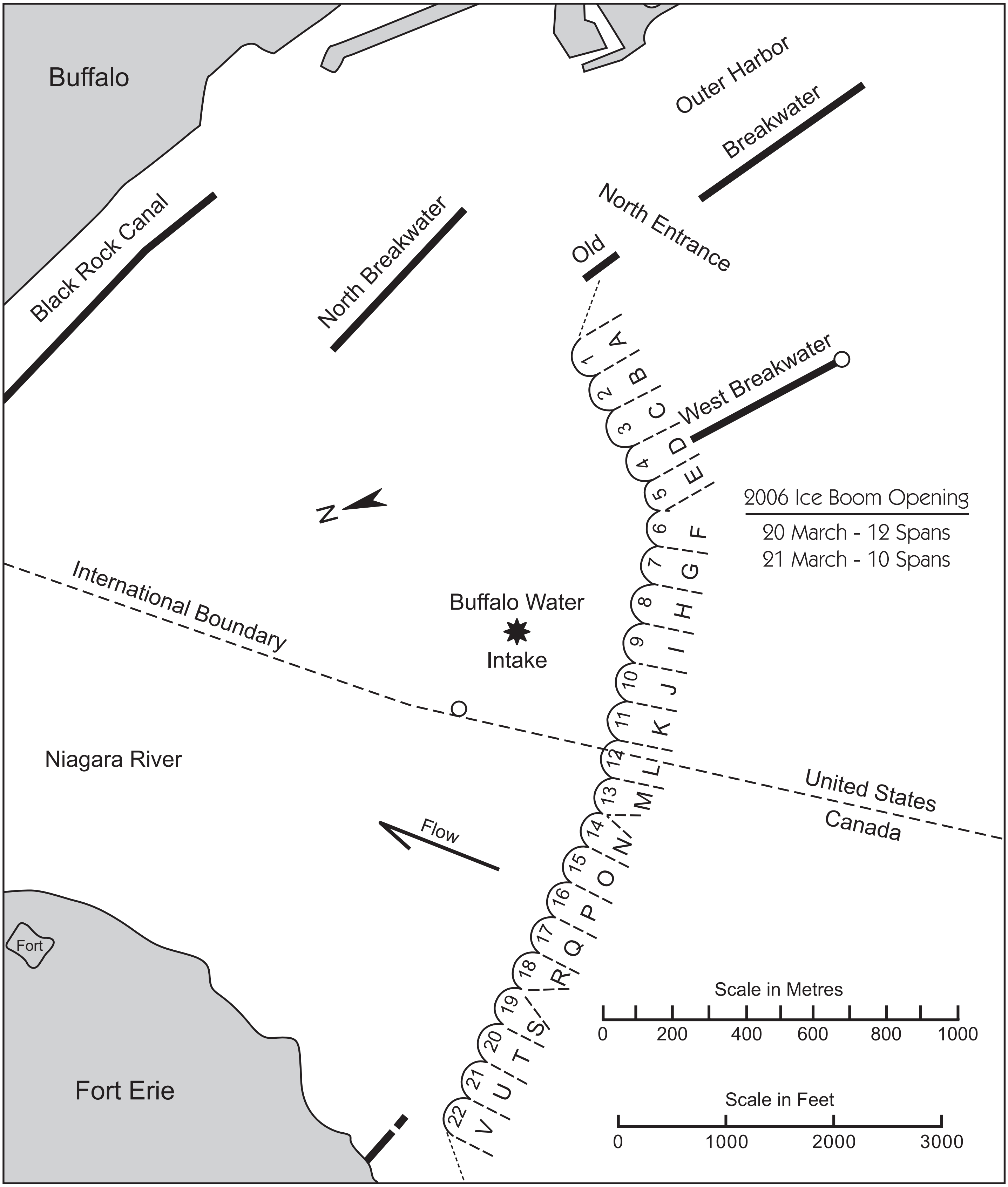


FIGURE 1

Great Lakes - St. Lawrence River Drainage Basin

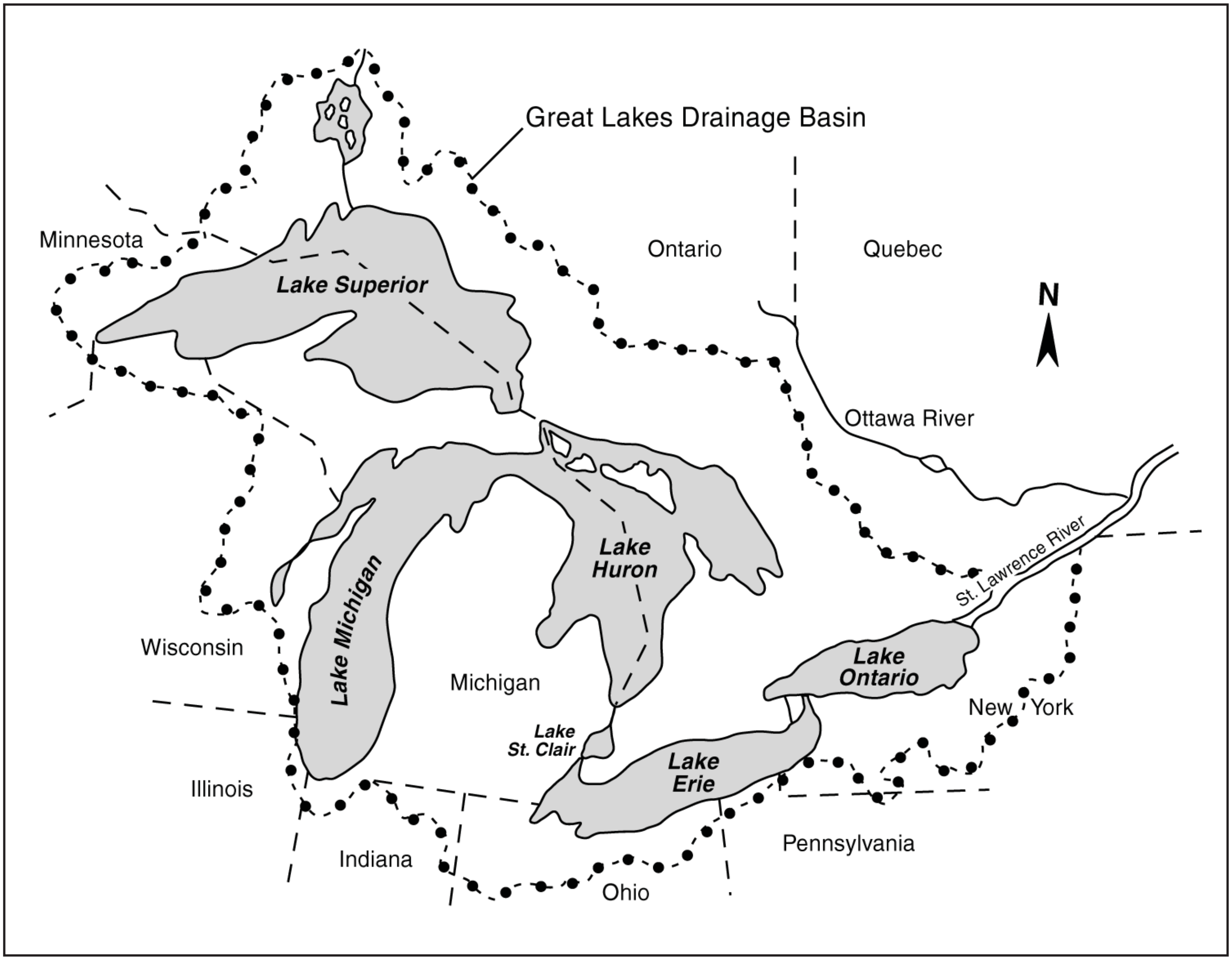


FIGURE 2

Niagara River - Location Map

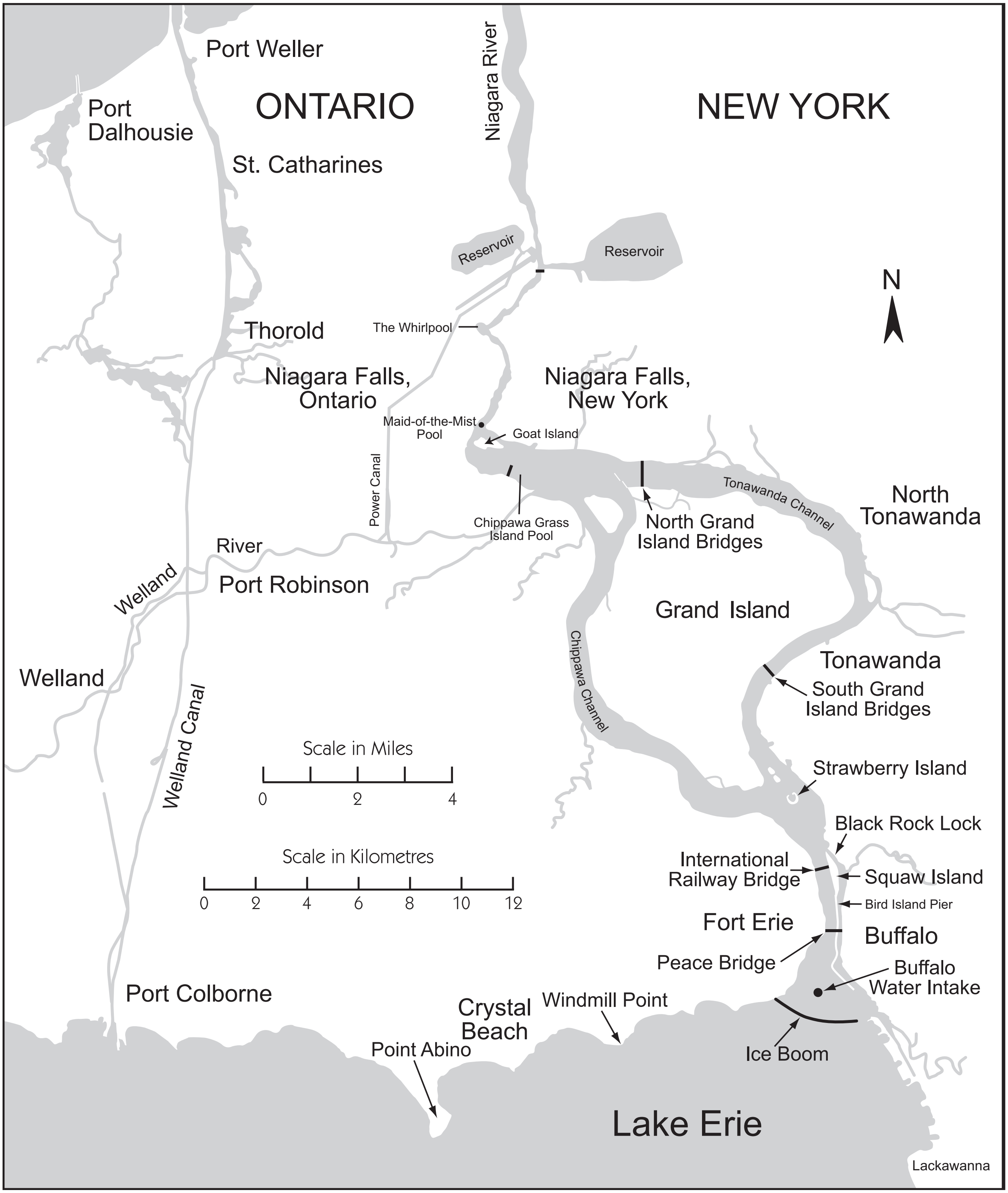


FIGURE 3

Niagara River Diversion Structures and Power Plants

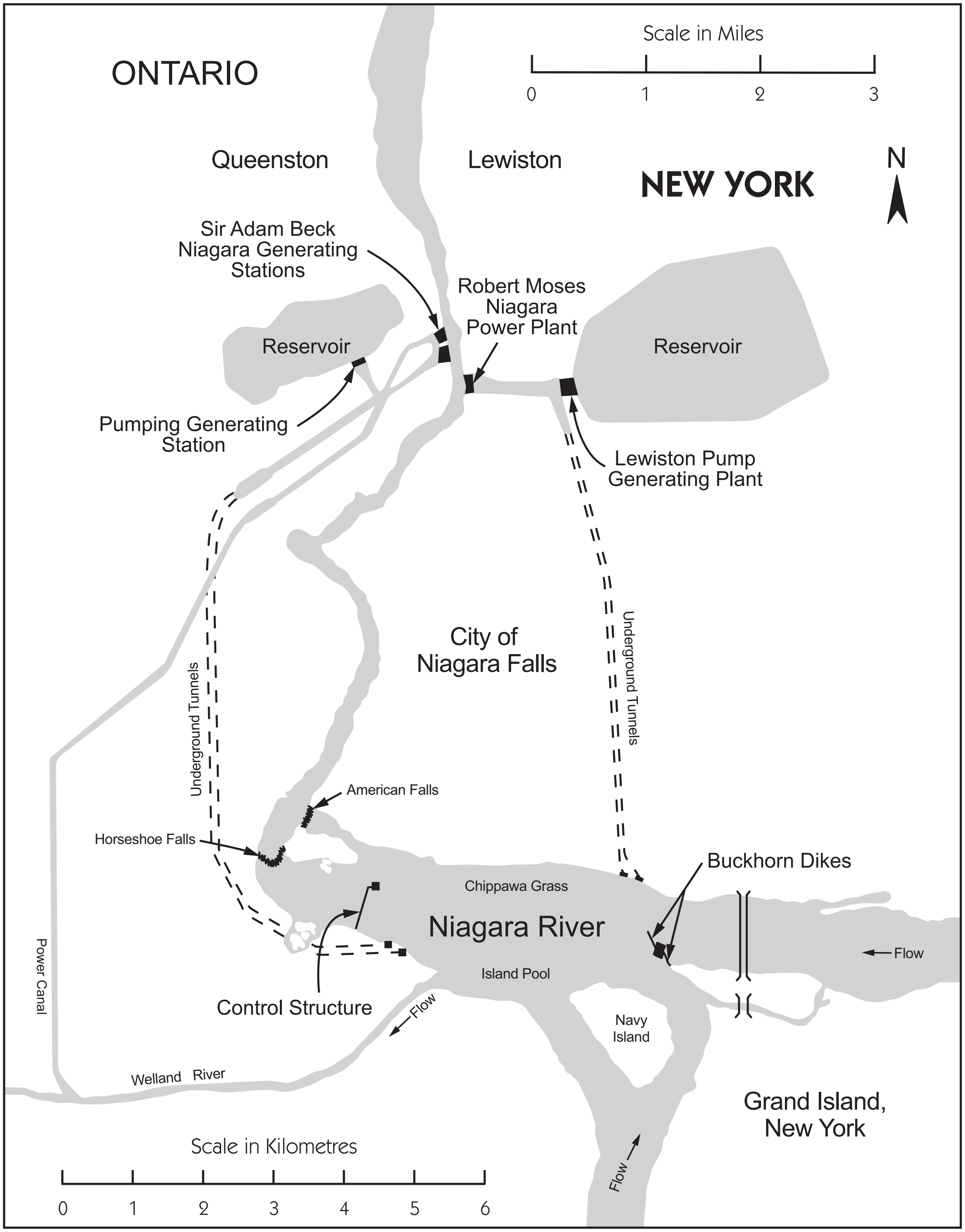
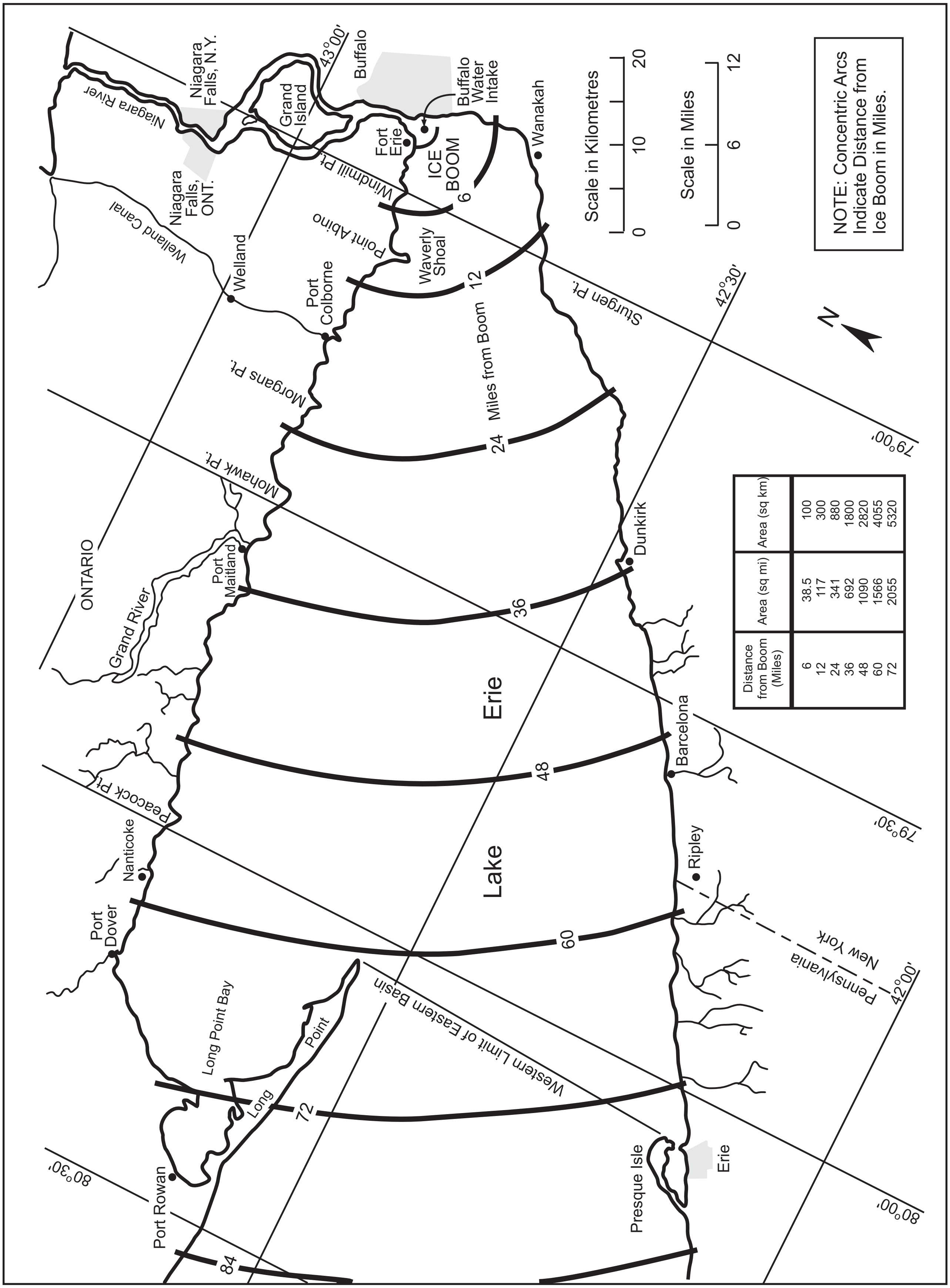


FIGURE 4

Map of Eastern Lake Erie



Distance from Boom (Miles)	Area (sq mi)	Area (sq km)
6	38.5	100
12	117	300
24	341	880
36	692	1800
48	1090	2820
60	1566	4055
72	2055	5320

FIGURE 5

Map of Upper Niagara River Showing Water Level Gauge Locations

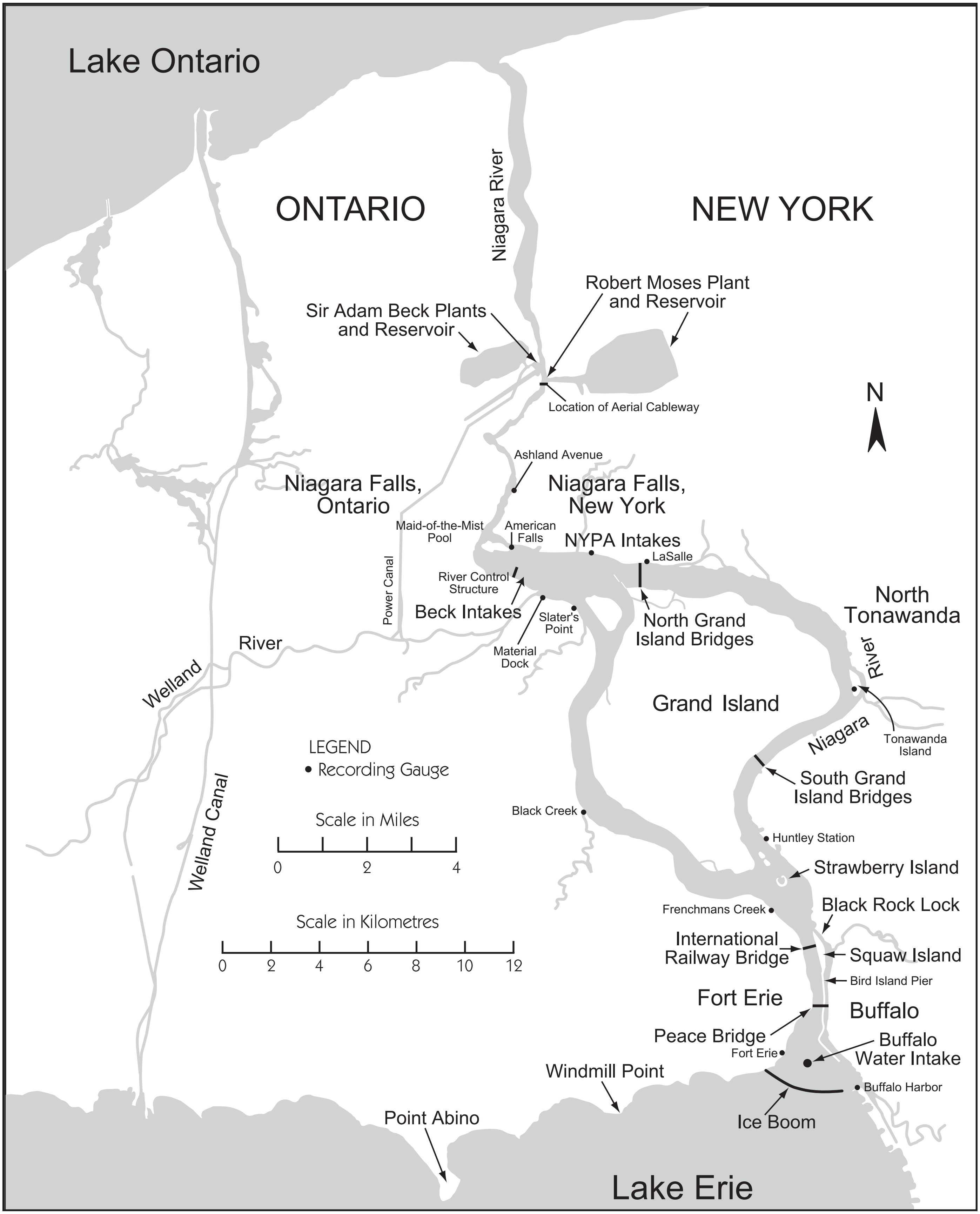


FIGURE 6

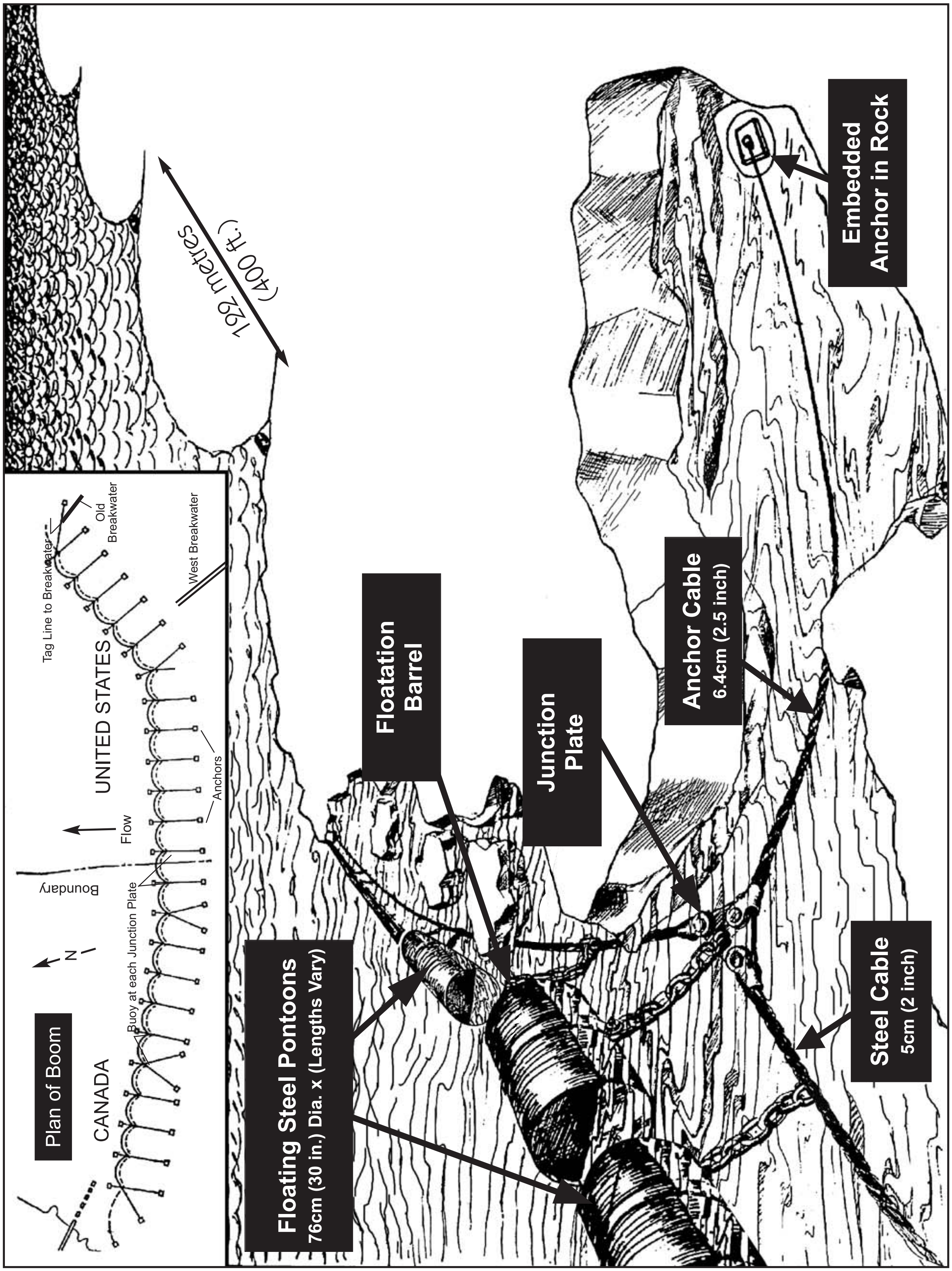

Plan of Boom
CANADA
UNITED STATES
Tag Line to Breakwater
Old Breakwater
West Breakwater
Anchors
Flow
Boundary
Buoy at each Junction Plate
N
122 metres
(400 ft.)
Embedded Anchor in Rock
Anchor Cable
6.4cm (2.5 inch)
Junction Plate
Floatation Barrel
Floating Steel Pontoons
76cm (30 in.) Dia. x (Lengths Vary)
Steel Cable
5cm (2 inch)

FIGURE 7