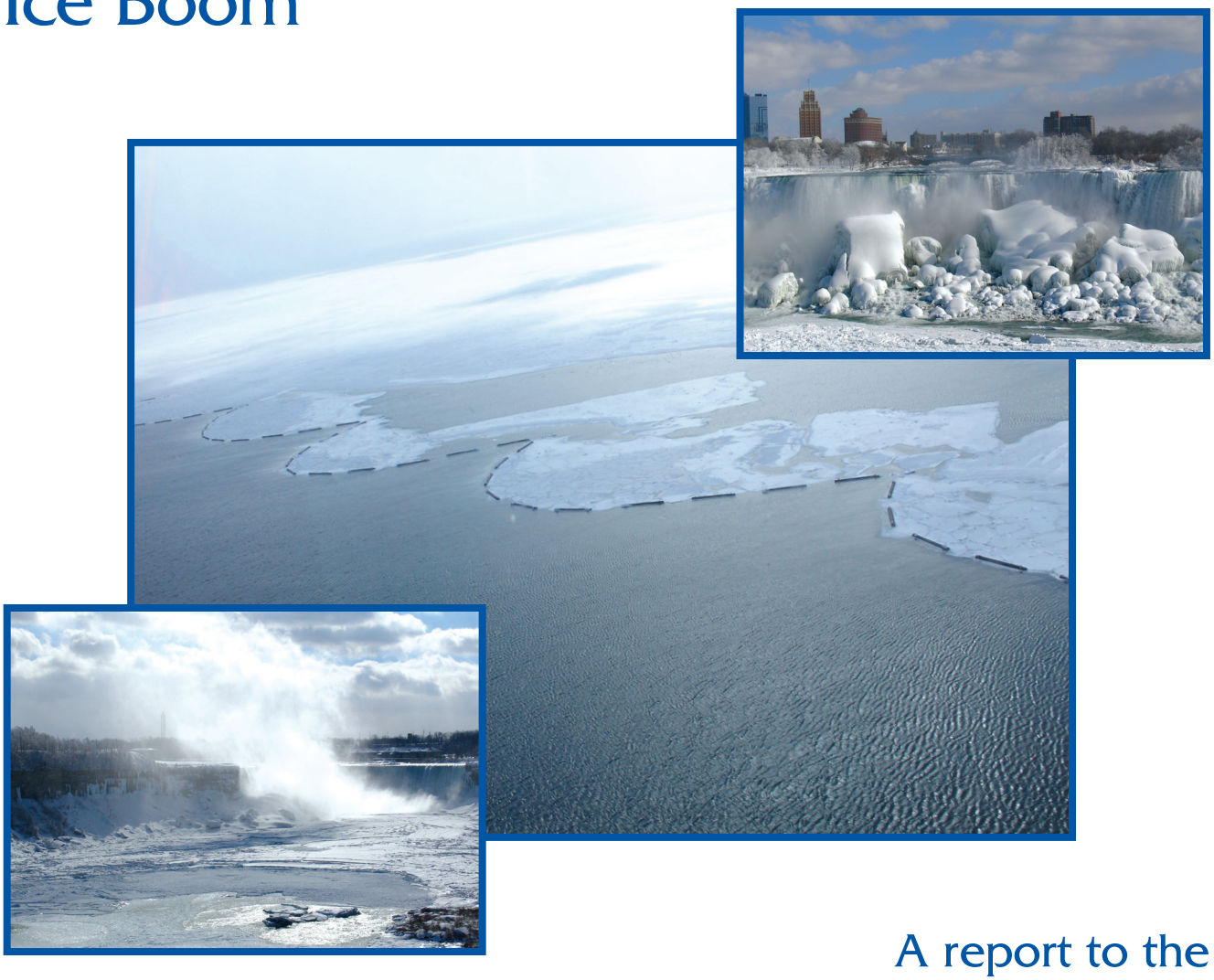
2010-11
Operation of the Lake Erie - Niagara River Ice Boom



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

September
2011

Report to
The International Niagara Board of Control
On the 2010-11 Operation of
The Lake Erie-Niagara River Ice Boom

By the International Niagara Working Committee

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Photos of Niagara Falls and the Ice Boom
(USACE Photos)

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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 . . . . . .www.ijc.org/conseil_board/niagara/en/niagara_home_accueil.htm
COE, Buffalo District . . . . . www.lrb.usace.army.mil
COE, Detroit District . . . . . .www.lre.usace.army.mil
Great Lakes Information Network . . . . . www.great-lakes.net
Environment Canada. . . . . www.ec.gc.ca/grandslacs-greatlakes/

1. Highlights

Installation of the Lake Erie - Niagara River ice boom's 22 spans started on 12 December and was completed on 16 December 2010.

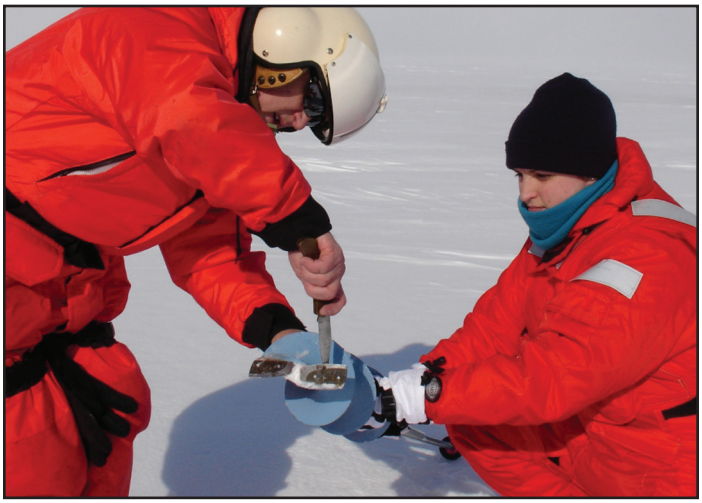
An ice cover began forming behind the boom in early January 2011.

Removal of the ice boom spans began on 12 April and was completed on 22 April.

The Board's International Niagara Working Committee conducted two helicopter flights to measure ice thickness and four fixed-wing flights to observe ice conditions during the 2010-11 ice season.

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

The date of last ice on Lake Erie was 24 April.



2. Operation of the Ice Boom During the 2010-11 Ice Season

2.1 Installation of the Ice 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:

www.iceboom.nypa.gov

Beginning on 29 November, the junction plates were raised from the bottom of the lake and floatation barrels were attached. This first phase of installation was completed on 4 December. The strings of pontoons were pulled from their new summer storage area, located about 3 kilometres (2 miles) upstream on the shore of the Buffalo River, and placed inside the Buffalo Harbor breakwall during the period 6 through 11 December, completing the second phase.

In accordance with Condition (d) of the International Joint Commission's 5 October 1999 supplementary Order of Approval, installation of the Lake Erie-Niagara River Ice Boom may begin when the Lake Erie water temperature reaches 4°C (39°F) or on 16 December, whichever occurs first. Lake Erie water temperature, as measured at the Buffalo Water Intake, reached 4°C (39°F) on 8 December. As a result, installation of the spans began on 12 December. Lake Erie water temperatures recorded at the Buffalo water intake, for the 2010-11 ice boom reporting period, are displayed in Table 1. Historical dates when the water temperature reached 4°C (39°F) and when the Ice Boom was installed are listed in Table 2.

Installation of the spans began on 12 December, with 9 spans placed starting from the Canadian side. For the next two days, unfavourable weather conditions temporarily stopped the installation. Installation resumed on 14 December with 1 span installed and continued on 15 December with 7 spans installed. The final 5 spans were placed on 16 December, completing the ice boom installation.

2.2 Ice and Hydrometeorological Conditions

The average monthly air temperature data for November 2010 through April 2011, as measured by the National Weather Service at the Buffalo Niagara International Airport, are shown in Table 3. The average of these temperatures was about 0.8°C (1.5°F) below normal for the six-month period.

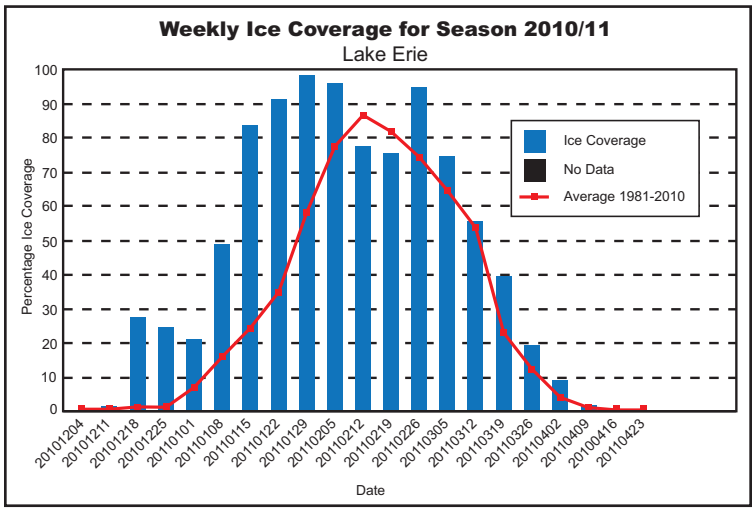
November was the 9th consecutive warmer than normal month for Buffalo, with an average temperature of 5.3°C (41.5°F), which was 0.7°C (1.3°F) above normal. December saw a dramatic change to cold, gloomy days with frequent snowfall. Phase two of boom installation (i.e. the pulling of strings from the storage area to the harbour breakwall) was delayed as snow had to be cleared from the lift bridges that span the Buffalo River under which the strings are towed.

December's average monthly temperature was -3.2°C (26.2°F) in Buffalo, 2.0°C (3.6°F) below normal. It was the coldest December in 10 years and the 3rd coldest in the last 21 years. Ice first appeared in the Chippawa-Grass Island Pool on 30 December.

The New York Power Authority's *Flood Warning Notification Plan in the Event of Ice-Affected Flooding on the Upper Niagara River* was tested on 20 December. A drill was conducted that simulated a flood event, along the U.S. shoreline in the vicinity of the North Grand Island Bridge, which was triggered by an ice jam upstream of the NYPA intakes.

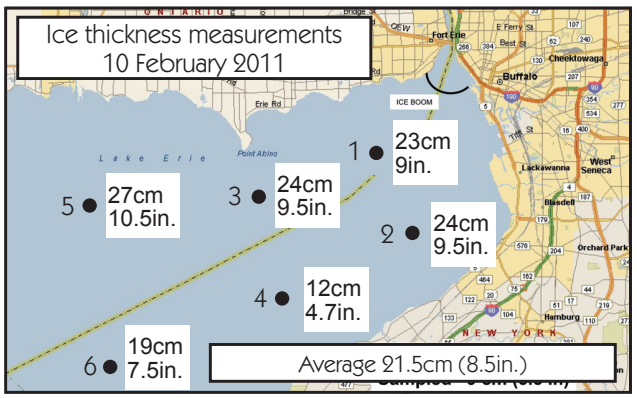
The average temperature for January 2011 was -5.9°C (21.3°F) which was 1.8°C (3.3°F) below normal. An ice bridge formed in the Maid-of-the-Mist Pool, below the Falls, during the night of 13-14 January. Ice began to accumulate behind the boom during the second week of the month. Ice breakers were used on several occasions to assist in keeping slush and sheet ice moving past the Power Entities' intakes in the Chippawa-Grass Island Pool.

As shown in this Canadian Ice Service graph, ice cover on Lake Erie peaked by the last week of January when it was about 97%. The average for this time of year is usually around 60% coverage.



February was another cold and snowy month for the Buffalo area. The average temperature was -4.1°C (24.6°F) or 0.7°C (1.3°F) below normal. Lake Erie ice cover decreased to around 75%, which was slightly below average. However, by the third week of February, the ice cover quickly increased to about 95%. By the end of February, the ice cover began to decrease again.

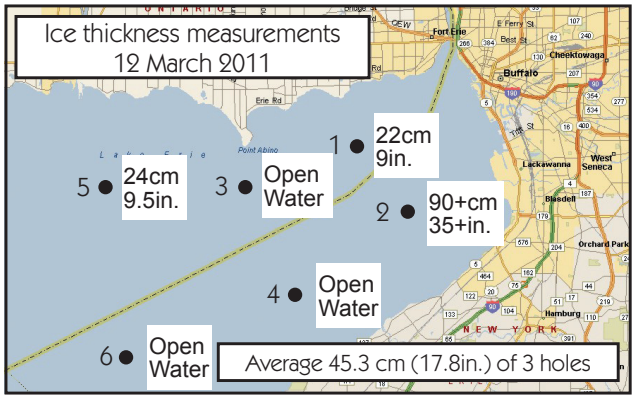
On 10 February, a helicopter flight was conducted to measure ice thickness on the eastern part of Lake Erie. Average thickness of the six sites sampled was 21.5 centimetres (8.5 inches). Similar measurements taken in mid-February 2010 resulted in an average of 9 centimetres (3.5 inches).



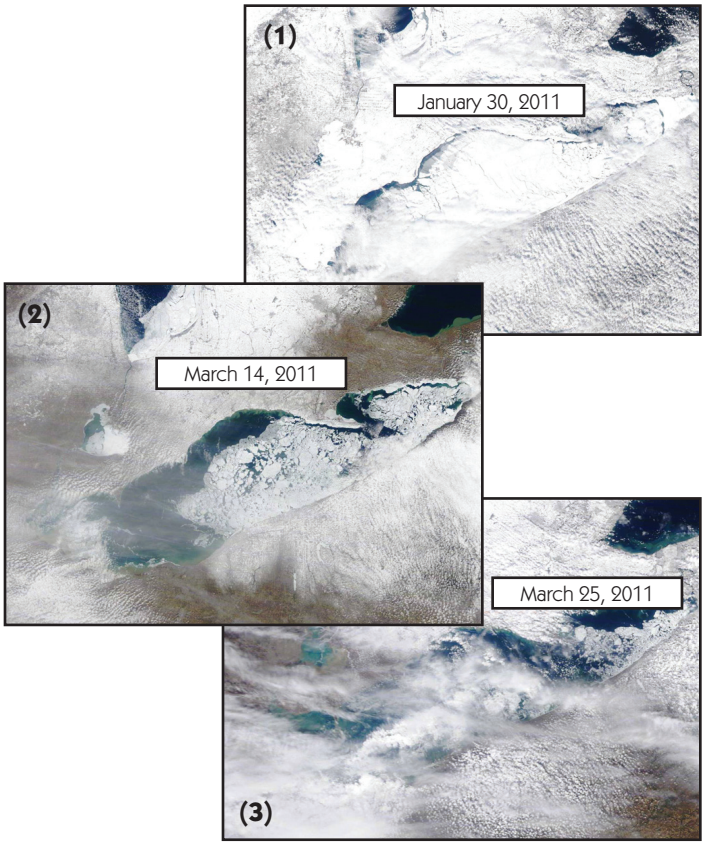
Western New York's meteorological winter (December through February) kept the region in constant cold temperatures and snowy conditions. Unusually, there were just two brief thaws all winter, lasting for only about two days each.

The weather in March was varied, as mid-month was mild but a return of more winter-like conditions caused a near-record cold spell near the end of the month. Temperatures failed to rise above freezing from 24 through 28 March, the longest stretch of late season cold temperatures since 1881. The average temperature was -0.1°C (31.9°F) which was 1.3°C (2.4°F) below normal.

The second helicopter flight of the season was conducted on 12 March 2011. Of the six sampling locations, three were open water, two of the northern sites averaged 23 centimetres (9 inches), and the site near the south-east end of the lake had in excess of 90 centimetres (35 inches) of ice. By mid-March, the ice cover on Lake Erie was about 40% compared to the average of 30% for that point in the season.



These MODIS images from the U.S. National Oceanic and Atmospheric Administration (NOAA) CoastWatch Great Lakes Program show the eastern basin of Lake Erie on (1) 30 January about the time when the most extensive ice cover was on the lake, on (2) 14 March as the ice cover was decreasing and on (3) 25 March the day after representatives of the International Niagara Board of Control conducted a fixed-wing flight to determine the extent of ice remaining on the eastern basin of Lake Erie. Although ice was continuing to dissipate, there was approximately 1380 square kilometres (530 square miles) or 27% of ice cover present. The Board advised the Commission that due to that amount of ice, a delay in ice boom opening beyond 1 April was expected.



2.3 Ice Boom Opening

Although the amount of ice cover on Lake Erie diminished over the next several days, as ice migrated eastward within the lake the cover on the eastern basin increased. The result was that on 30 March, ice cover on the eastern basin was observed to be 1580 square kilometres (610 square miles). By 6 April that amount had decreased to 670 square kilometres (260 square miles) and by 11 April, it was 230 square kilometres (90 square miles). Considering the amount of ice remaining and the absence of an ice buildup in the Maid-of-the-Mist Pool below Niagara Falls, the Board issued a media advisory on 11 April 2011 that preparations for boom opening were underway.

Boom opening operations began with two spans being opened on 12 April. One span was opened on 13 April, and five more were opened on 14 April. That same day, high winds forced lake ice over the remaining spans of the boom that were still in place, as well as

through the open section, causing a large amount of ice to enter the upper Niagara River. The boom opening was suspended as ice breaker efforts were needed to keep ice moving past the power entities' intakes in the Chippawa-Grass Island Pool. Removal operations were resumed on 19 April when six spans were opened. The final phase of the operation was completed on 22 April when the last eight spans were removed. The sequence of removal, by date, is shown in Figure 1 (following the appendices).

Floatation barrels were removed from the lake on 25 and 26 April. Both the Canadian and U.S. Coast Guards were then notified that this year's ice boom removal from the lake had been completed.

On 2 May, the New York Power Authority crew began towing the individual spans up the Buffalo River to the storage site, where the ground crew pulled them on shore. This operation, delayed for a few days due to high winds and equipment problems, resumed on 5 May and was completed on 11 May.

Based on satellite information, the date of last ice in Lake Erie was 24 April. Observed dates of last ice for the period 1905 to the present are contained in Table 4.

The voyages of the Maid of the Mist Steamboat Company for the 2011 season began on 4 May. Last year's operations began on 23 April.

2.4 Estimated Power Losses

Some reduction in hydropower generation occurs virtually every year due to ice problems. The Power Entities estimate that the use of the ice boom results in an average annual savings to the hydropower facilities of approximately 414,000 Megawatt Hours (MWh) of electric energy.

The 2010-11 ice season losses of hydroelectric power generation for the Power Entities were 29,500 MWh. A summary of estimated power losses due to ice for the period of record from 1975 to present is shown in Table 5.

2.5 Niagara River Shore Property Damages

There were no reports of damages to shore properties from ice along the Niagara River during the 2010-11 ice season.

2.6 Maintenance of the Ice Boom

As part of a routine summer ice boom maintenance program, hardware will be replaced where necessary. In addition, two anchor cables will be replaced.

3 DATA ANALYSIS 2010-11

3.1 Purpose

During the 2010-11 winter, the International Niagara Working Committee continued its program of collecting data and information related to ice boom operations. This data is used to monitor conditions of the ice boom, Lake Erie and to determine installation and removal dates of the ice boom. As part of the usual program, satellite imagery and mapping were analysed and meteorological data from the U.S. National Weather Service Station at Buffalo were collected.

Table 2 lists the historical record of the dates when the water temperature in Lake Erie reached 4°C (39°F) and the subsequent date of the ice boom installation. Comparison of historical ice coverage areas at the time of the ice boom opening is shown in Table 6. A historical comparison of the ice boom opening dates is provided in Table 7.

3.2 Navigation at the Welland Canal

The Welland Canal opened to commercial shipping this season on 22 March 2011 for its 182nd consecutive year of service with the passage of the Peter R. Cresswell. Commencement of navigation at the Welland Canal for the period 1965 to 2011 is shown in Table 7.

4 FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

4.1 Findings and Conclusions

Water temperature at Buffalo reached 4°C (39°F) on 8 December.

The ice boom spans were installed during the period 12-16 December and removed during the 12-22 April period in accordance with the International Joint Commission's 1999 Supplementary Order of Approval.

During the 2010-11 Season the ice boom functioned as intended.

The two helicopter (thickness) and four fixed-wing (area) observation flights conducted by the Board's representatives during 2010-11 supplemented the ice information available from remote sensing technology. The Board's water temperature and ice condition monitoring program, with the use of satellite images and observations using both helicopter and fixed-wing flights, is adequate to monitor ice conditions.

4.2 Recommendations for the 2011-12 Operation

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

Utilization of Great Lakes ice cover maps prepared by the National Ice Center in Maryland and the Canadian Ice Centre in Ottawa, supplemented by ice thickness measurements and fixed-wing aerial ice surveys to evaluate ice conditions throughout the winter, should continue.

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 the following website:

www.lrb.usace.army.mil/WhoWeAre/WaterMgmt/WaterMgmt.html

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

Table 1 Lake Erie Water Temperatures as Recorded at the Buffalo Intake (Dec 2010-May 2011)												
Month	**December**		**January**		**February**		**March**		**April**		**May**	
Date	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
1	7.2	45	0.6	33	0.0	32	0.0	32	0.6	33	4.4	40
2	7.2	45	0.6	33	0.0	32	0.0	32	0.6	33	5.0	41
3	6.7	44	0.6	33	0.0	32	0.0	32	0.6	33	6.7	44
4	6.7	44	0.6	33	0.0	32	0.0	32	0.6	33	5.0	41
5	6.1	43	0.6	33	0.0	32	0.0	32	0.6	33	5.6	42
6	4.4	40	0.6	33	0.0	32	0.0	32	0.6	33	7.2	45
7	4.4	40	0.0	32	0.0	32	0.0	32	0.6	33	6.7	44
8	4.4	40	0.0	32	0.0	32	0.0	32	1.1	34	6.7	44
9	3.9	39	0.0	32	0.0	32	0.0	32	1.1	34	7.2	45
10	3.9	39	0.0	32	0.0	32	0.0	32	1.1	34	6.7	44
11	3.9	39	0.0	32	0.0	32	0.0	32	1.1	34	7.8	46
12	3.9	39	0.0	32	0.0	32	0.0	32	1.1	34	8.9	48
13	3.9	39	0.0	32	0.0	32	0.0	32	0.6	33	7.8	46
14	3.3	38	0.0	32	0.0	32	0.0	32	1.1	34	6.7	44
15	2.2	36	0.0	32	0.0	32	0.0	32	0.6	33	7.8	46
16	1.7	35	0.0	32	0.0	32	0.0	32	0.6	33	6.7	44
17	1.1	34	0.0	32	0.0	32	0.0	32	1.1	34	6.1	43
18	1.7	35	0.0	32	0.0	32	0.0	32	1.7	35	7.2	45
19	1.7	35	0.0	32	0.0	32	0.0	32	1.7	35	6.1	43
20	1.7	35	0.0	32	0.0	32	0.0	32	2.8	37	6.1	43
21	1.7	35	0.0	32	0.0	32	0.0	32	3.3	38	6.1	43
22	1.7	35	0.0	32	0.0	32	0.0	32	2.8	37	7.8	46
23	1.7	35	0.0	32	0.0	32	0.0	32	3.9	39	8.9	48
24	1.1	34	0.0	32	0.0	32	0.0	32	3.9	39	9.4	49
25	1.1	34	0.0	32	0.0	32	0.0	32	3.3	38	10.0	50
26	1.1	34	0.0	32	0.0	32	0.0	32	3.3	38	10.0	50
27	1.1	34	0.0	32	0.0	32	0.0	32	3.3	38	10.0	50
28	1.7	35	0.0	32	0.0	32	0.0	32	3.9	39	11.1	52
29	0.6	33	0.0	32			0.0	32	7.2	45	10.0	50
30	0.6	33	0.0	32			0.0	32	6.1	43	10.0	50
31	0.6	33	0.0	32			0.6	33			10.6	51
Avg:	3.0	37	0.1	32	0.0	32	0.0	32	2.0	36	7.6	46

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

Date Water Temperature Reached 4°C (39°F)		Installation of the Ice Boom
7 Dec 1964	1	9 Nov to 15 Dec 1964
15 Dec 1965	9	19 Nov to 8 Dec 1965
19 Dec 1966	6	8 Nov to 6 Dec 1966
29 Nov 1967	0's	17 Nov to 5 Dec 1967
10 Dec 1968		25 Nov to 5 Dec 1968
9 Dec 1969		15 Nov to 10 Dec 1969
15 Dec 1970		Completed 15 Dec 1970*
25 Dec 1971		30 Nov to 10 Dec 1971
11 Dec 1972	1	11 Dec to 14 Dec 1972
18 Dec 1973	9	19 Dec 1973 to 9 Jan 1974
10 Dec 1974	7	11 Dec to 30 Dec 1974
20 Dec 1975	0's	24 Dec 1975 to 8 Jan 1976
24 Dec 1976		30 Nov to 18 Dec 1976
8 Dec 1977		13 Dec to 31 Dec 1977
11 Dec 1978		Completed 19 Dec 1978*
17 Nov 1979		Completed 22 Dec 1979*
14 Dec 1980		22 Dec to 30 Dec 1980
11 Dec 1981		19 Dec to 23 Dec 1981
4 Dec 1982	1	6 Jan to 8 Jan 1983
18 Nov 1983	9	19 Dec to 21 Dec 1983
26 Dec 1984	8	27 Dec to 30 Dec 1984
17 Dec 1985	0's	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 Nov 1988		12 Dec to 17 Dec 1988
6 Dec 1989		7 Dec to 8 Dec 1989
27 Dec 1990		27 Dec to 30 Dec 1990
19 Dec 1991	1	20 Dec to 27 Dec 1991
6 Dec 1992	9	13 Jan to 14 Jan 1993
16 Dec 1993	9	17 Dec to 28 Dec 1993
2 Jan 1995	0's	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 Jan 1997		17 Dec to 18 Dec 1997
1 Dec 1999		2 Jan to 9 Jan 1999
27 Nov 1999		19 Dec to 29 Dec 1999
18 Dec 2000		16 Dec to 28 Dec 2000
27 Dec 2001	2	17 Dec to 22 Dec 2001
3 Dec 2002	0	11 Dec to 12 Dec 2002
15 Dec 2003	0	16 Dec to 20 Dec 2003
20 Dec 2004	0's	17 Dec to 20 Dec 2004
9 Dec 2005		14 Dec to 15 Dec 2005
19 Jan 2007		18 Dec to 19 Dec 2006
9 Dec 2007		13 Dec to 17 Dec 2007
5 Dec 2008		10 Dec to 11 Dec 2008
12 Dec 2009		17 Dec to 19 Dec 2009
8 Dec 2010	2	12 Dec to 16 Dec 2010
	0	
	1	
	0's	

* 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 3 Air Temperature at Buffalo Niagara International Airport

	°C (Celsius)			°F (Fahrenheit)		
Month	Normal* 1971-2000	Recorded 2010-11	Departure	Normal* 1971-2000	Recorded 2010-11	Departure
Nov. 2010	4.6	5.3	0.7	40.2	41.5	1.3
Dec. 2010	-1.2	-3.2	-2.0	29.8	26.2	-3.6
Jan. 2011	-4.1	-5.9	-1.8	24.5	21.3	-3.3
Feb. 2011	-3.4	-4.1	-0.7	25.9	24.6	-1.3
Mar. 2011	1.3	-0.1	-1.3	34.3	31.9	-2.4
Apr. 2011	7.4	7.6	0.2	45.3	45.7	0.4
Average	0.8	-0.1	-0.8	33.4	31.9	-1.5

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

Table 4 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-Apr	1977	13-May
1906	22-Apr	1942	30-Apr	1978	14-May
1907	30-Apr	1943	20-May	1979	3-May
1908	9-May	1944	15-Apr	1980	23-Apr
1909	26-Apr	1945	9-Apr		
1910	30-Apr	1946	No data	1981	30-Apr
		1947	No data	1982	20-May
1911	6-May	1948	No data	1983	23-Feb
1912	29-Apr	1949	No data	1984	25-Apr
1913	30-Apr	1950	No data	1985	1-May
1914	28-Apr			1986	26-Apr
1915	2-May	1951	15-Apr	1987	9-Mar
1916	11-May	1952	27-Mar	1988	27-Apr
1917	30-Apr	1953	Ice-free	1989	9-Apr
1918	20-Apr	1954	27-Mar	1990	10-Apr
1919	15-Mar	1955	5-Apr		
1920	20-May	1956	20-Apr	1991	28-Mar
		1957	11-Mar	1992	15-Apr
1921	14-Mar	1958	10-Apr	1993	16-Apr
1922	11-Apr	1959	8-May	1994	1-May
1923	16-May	1960	5-May	1995	18-Apr
1924	20-Apr			1996	6-May
1925	26-Apr	1961	15-Apr	1997	29-Apr
1926	31-May	1962	30-Apr	1998	Ice-free
1927	9-Apr	1963	11-May	1999	2-Apr
1928	19-May	1964	27-Apr	2000	28-Mar
1929	2-May	1965*	14-May		
1930	7-May	1966	27-Apr	2001	27-Apr
		1967	13-Apr	2002	Ice-free
1931	7-Apr	1968	4-May	2003	22-Apr
1932	21-Apr	1969	26-Apr	2004	30-Apr
1933	23-Apr	1970	30-Apr	2005	11-Apr
1934	23-Apr			2006	5-Apr
1935	13-Apr	1971	31-May	2007	29-Apr
1936	31-May	1972	5-May	2008	23-Apr
1937	14-Apr	1973	15-Mar	2009	16-Apr
1938	14-Apr	1974	6-Apr		
1939	14-May	1975	8-Apr	2010	29-Mar
1940	19-May	1976	19-Apr	2011	24 Apr

* 1965 First year ice boom was used

Table 5 Estimated Power Losses Due to Ice for Period of Record 1975 to Present							
Winter Season of:	**December**	**January**	**February**	**March**	**April**	**May**	**Totals**
1974-75	*	*	150,000	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
2006-07	0	2,500	37,600	3,800	7,800	0	51,700
2007-08	0	15,000	153,900	1,300	500	0	171,200
2008-09	0	4,700	17,600	0	2,400	0	24,700
2009-10	0	36,700	3,000	0	0	0	39,700
2010-11	0	8,400	5,800	0	15,300	0	29,500

* No Data Published

Note: No data available for period 1964-74

Table 6 Comparison of Ice Areas Near Time of Ice Boom Opening

	Areas of Ice in Eastern Lake Erie			Opening of Ice Boom			Areas of Ice in Eastern Lake Erie			Opening of Ice Boom	
Year	Date of Observation	Square KMs	Square Miles	Start	Completed	Year	Date of Observation	Square KMs	Square Miles	Start	Completed
1965				21-Mar	27-Mar	2000	21-Mar	410	160	23-Mar	24-Mar
1966				20-Mar	1-Apr	2001	14-Apr	390	150	17-Apr	20-Apr
1967				22-Mar	29-Mar	2002	Ice-free			7-Mar	7-Mar
1968				8-Mar	20-Mar	2003	10-Apr	490	190	10-Apr	11-Apr
1969	No Data Collected			26-Mar	3-Apr	2004	5-Apr	1110	430	6-Apr	7-Apr
1970	16-Apr	2590	1000	23-Apr	30-Apr	2005	4-Apr	210	80	5-Apr	6-Apr
1971	27-Apr	2850	1100	3-May	14-May	2006	20-Mar	80	30	20-Mar	21-Mar
1972	18-Apr	1300	500	20-Apr	25-Apr	2007	7-Apr	620	240	10-Apr	18-Apr
1973	14-Mar	260	100	16-Mar	21-Mar	2008	14-Apr	310	120	15-Apr	19-Apr
1974	18-Mar	320	125	26-Mar	1-Apr	2009	6-Apr	100	40	6-Apr	13-Apr
1975	21-Mar	80	30	25-Mar	28-Mar	2010	18-Mar	570	220	22-Mar	24-Mar
1976	15-Apr	130	50	19-Apr	21-Apr	2011	11- Apr	230	90	12 Apr	22Apr
1977	14-Apr	520	200	18-Apr	20-Apr						
1978	27-Apr	710	275	1-May	8-May						
1979	10-Apr	390	150	13-Apr	17-Apr						
1980	1-Apr	700	270	2-Apr	7-Apr						
1981	15-Apr	1220	470	18-Apr	22-Apr						
1982	26-Apr	1090	420	27-Apr	2-May						
1983	2-Mar	Trace	Trace	7-Mar	8-Mar						
1984	5-Apr	780	300	7-Apr	10-Apr						
1985	12-Apr	780	300	13-Apr	15-Apr						
1986	7-Apr	1010	390	12-Apr	14-Apr						
1987	5-Mar	130	50	6-Mar	6-Mar						
1988	8-Apr	700	270	9-Apr	10-Apr						
1989	27-Mar	340	130	30-Mar	6-Apr						
1990	26-Mar	230	90	26-Mar	30-Mar						
1991	25-Mar	50	20	27-Mar	30-Mar						
1992	31-Mar	160	60	30-Mar	2-Apr						
1993	3-Apr	540	210	5-Apr	6-Apr						
1994	19-Apr	620	240	21-Apr	28-Apr						
1995	28-Mar	410	160	30-Mar	17-Apr						
1996	17-Apr	730	280	19-Apr	3-May						
1997	24-Apr	60	25	25-Apr	28-Apr						
1998	Ice-free			5-Mar	5-Mar						
1999	30-Mar	Trace	Trace	30-Mar	30-Mar						

Table 7 Comparative Data for Years Ice Boom Has Been in Place

	Opening of Ice Boom				Opening of Ice Boom		
Year	**Start***	**Completed**	**Welland****	**Year**	**Start***	**Completed**	**Welland****
1965	21-Mar	27-Mar	1-Apr	2000	23-Mar	24-Mar	28-Mar
1966	20-Mar	1-Apr	4-Apr	2001	17-Apr	20-Apr	30-Mar
1967	22-Mar	29-Mar	1-Apr	2002	7-Mar	7-Mar	26-Mar
1968	18-Mar	20-Mar	1-Apr	2003	10-Apr	11-Apr	26-Mar
1969	26-Mar	3-Apr	1-Apr	2004	6-Apr	7-Apr	23-Mar
1970	23-Apr	30-Apr	1-Apr	2005	5-Apr	6-Apr	23-Mar
1971	3-May	14-May	29-Mar	2006	20-Mar	21-Mar	21-Mar
1972	20-Apr	25-Apr	29-Mar	2007	10-Apr	18-Apr	20-Mar
1973	16-Mar	21-Mar	28-Mar	2008	15-Apr	19-Apr	20-Mar
1974	26-Mar	1-Apr	29-Mar	2009	6-Apr	13-Apr	31-Mar
1975	25-Mar	28-Mar	25-Mar	2010	22-Mar	24-Mar	25-Mar
1976	19-Apr	19-Apr	1-Apr	2011	12-Apr	22-Apr	22-Mar
1977	18-Apr	20-Apr	4-Apr				
1978	1-May	8-May	28-Mar				
1979	13-Apr	17-Apr	28-Mar				
1980	2-Apr	7-Apr	24-Mar				
1981	18-Apr	22-Apr	25-Mar				
1982	27-Apr	2-May	5-Apr				
1983	7-Mar	8-Mar	5-Apr				
1984	7-Apr	10-Apr	28-Mar				
1985	13-Apr	15-Apr	1-Apr				
1986	12-Apr	14-Apr	3-Apr				
1987	6-Mar	6-Mar	1-Apr				
1988	9-Apr	10-Apr	31-Mar				
1989	30-Mar	6-Apr	31-Mar				
1990	26-Mar	30-Mar	28-Mar				
1991	27-Mar	30-Mar	26-Mar				
1992	30-Mar	2-Apr	30-Mar				
1993	5-Apr	6-Apr	30-Mar				
1994	21-Apr	28-Apr	5-Apr				
1995	30-Mar	17-Apr	24-Mar				
1996	19-Apr	3-May	29-Mar				
1997	25-Apr	28-Apr	2-Apr				
1998	5-Mar	5-Mar	24-Mar				
1999	30-Mar	30-Mar	31-Mar				
1965-2011	4-Apr	8-Apr	29-Mar	Average for post-ice boom period			
1970-2011	6-Apr	10-Apr	29-Mar	Average for the flexible boom opening period.			

1970 Commencement of flexible date for boom opening.

* Denotes opening of first boom span. Mobilization time precedes this date.

** Opening date is usually established in advance and may relate to Welland Canal repair schedule.

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); and about half of this occurs at Niagara Falls. Over the period 1860-2010, the average Niagara River flow at Queenston, Ontario has been 5859 cubic metres per second (m^3/s) (206,910 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

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 ranging from 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). North of Grand Island, the channels unite to form the 4.8 kilometre (3 mile) long Chippawa-Grass Island Pool (Pool). At the downstream end of the Pool is the International Niagara Control Works. This gate control 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 Pool is 2.7 metres (9 feet).

(b) Niagara Cascades and Falls

Below the gate 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 the 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 flow 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 100 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 extends 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, 365 metres (1,200 feet) wide and 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 Lake Erie outflow is utilized for power production and is diverted to hydroelectric 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 than 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 no less than 2832 m^3/s (100,000 cfs) during the daylight hours of the tourist season. The tourist season is from 0800 to 2200 hours local time from 1 April to 15 September and then from 16 September to 31 October the hours are 0800 to 2000 local time. 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. River levels are monitored using water level gauges located throughout the Niagara River. Gauge locations are referenced on the map in Figure 6.

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 consists 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 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 then. 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.

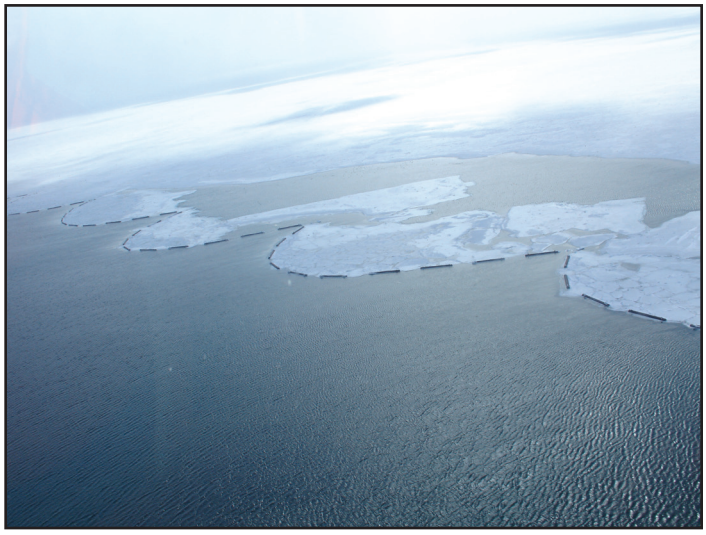
The U.S. Government rehabilitated a portion of the Bird Island Pier in 1985 and 1986. Prior to rebuilding, most of the pier was overtopped by water passing from the Canal into the Niagara River at times of storm and/or high outflow from Lake Erie. Although the rebuilding raised the lever of the pier 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 close to 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. 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 Maid-of-the-Mist Steamboat Company facilities located downstream of the Falls. Heavy ice runs in the upper river, if added to a large volume of ice already in the Maid-of-the-Mist Pool, have severely damaged this installation on occasion.



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 2009. A 1999 review resulted in the Commission issuing a Supplementary Order which modified condition (d). A 1984 Order of Approval established the current conditions for ice boom opening modifying condition (e). 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 provision 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 also stabilizes the arch once it has formed. A map of eastern Lake Erie indicating the location of the ice boom is shown in Figure 5. 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 blockage 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, the ice boom bears the pressure of upstream ice. Seasonal 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 again restrains the ice. Throughout 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 feet) 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. Figure 7 illustrates structural details and a plan view of the ice boom. 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 replacement 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 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 the spans A through J be removed. Therefore beginning with the 1998-1999 ice season, spans A through J contain 10 instead of 11 steel pontoons. 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 Niagara River showing key features. Figure 7 illustrates the structural details and a plan view of the ice boom.

Plan View of Ice Boom and Sequence of Removal

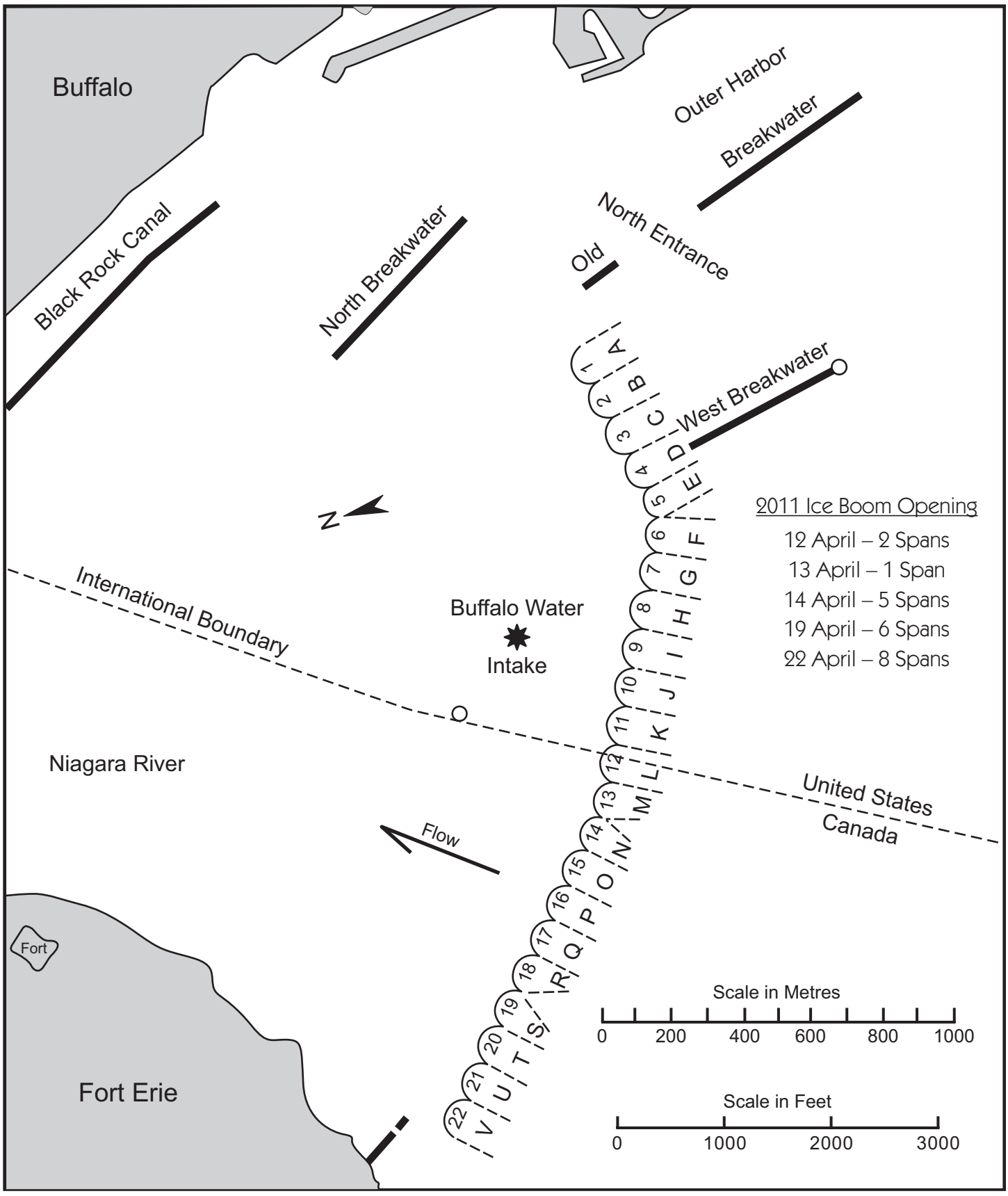


Figure 1

Great Lakes - St. Lawrence River Drainage Basin

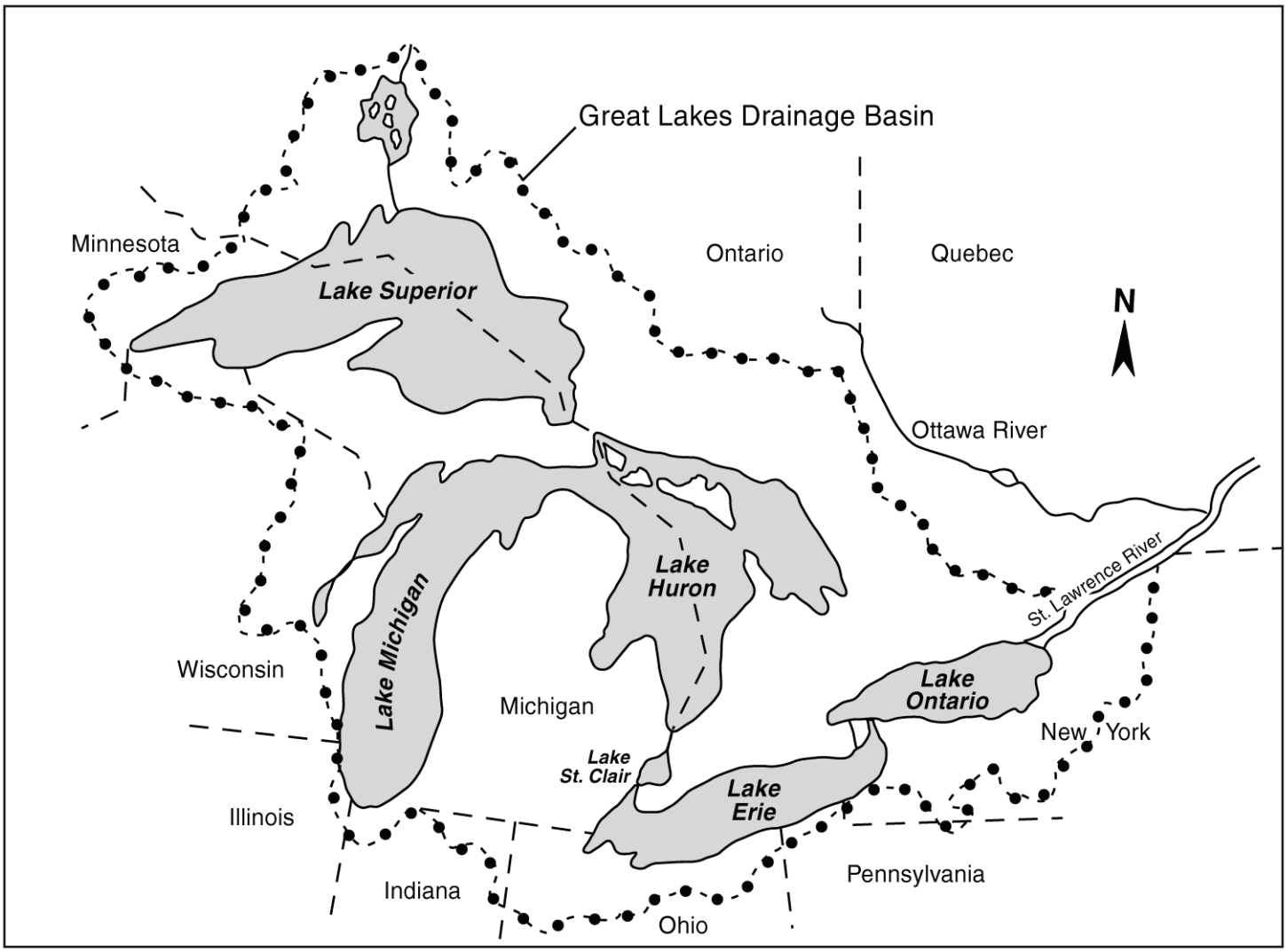


Figure 2

Niagara River - Location Map

Figure 3

Niagara River Diversion Structures and Power Plants

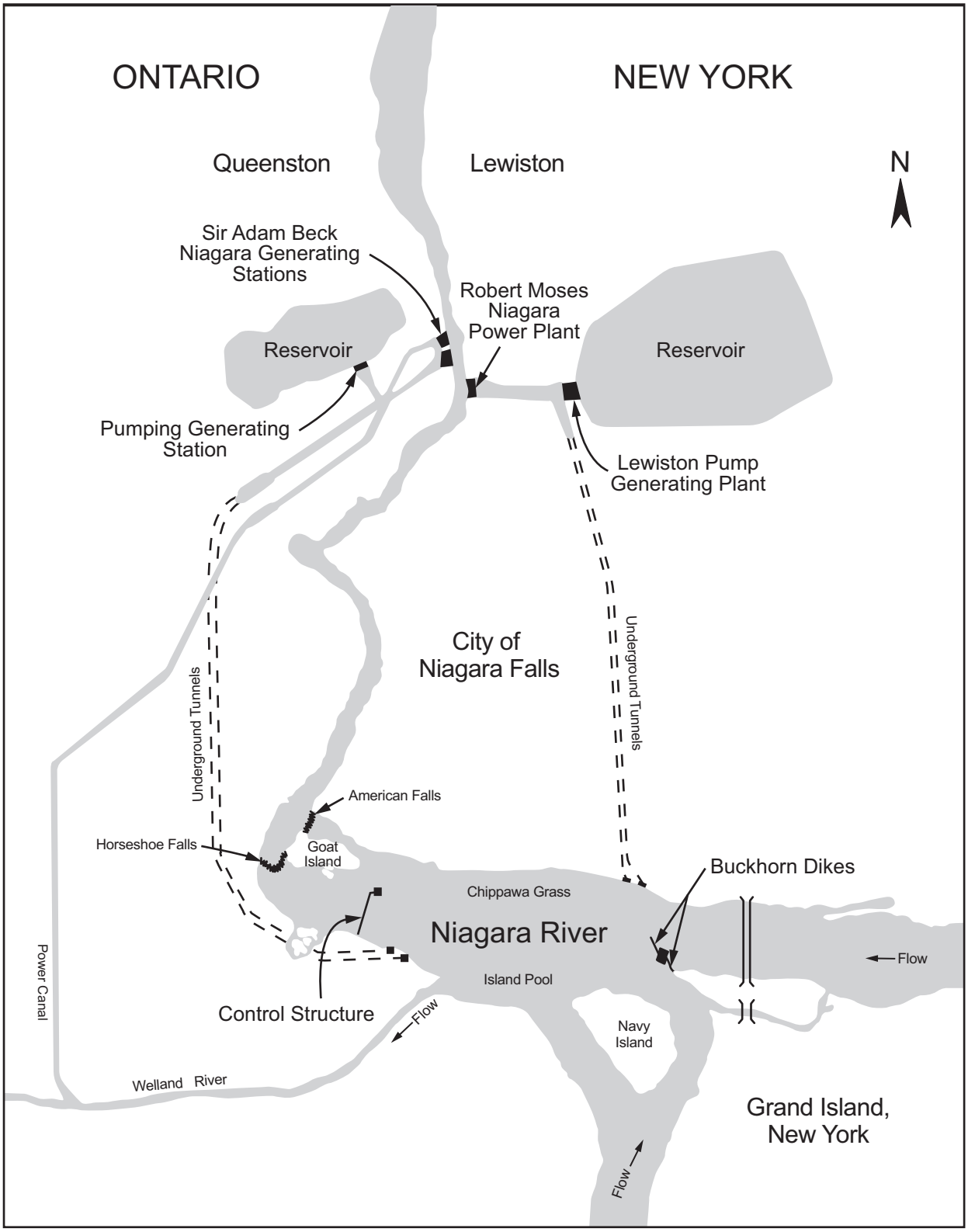


Figure 4

Map of Eastern Lake Erie

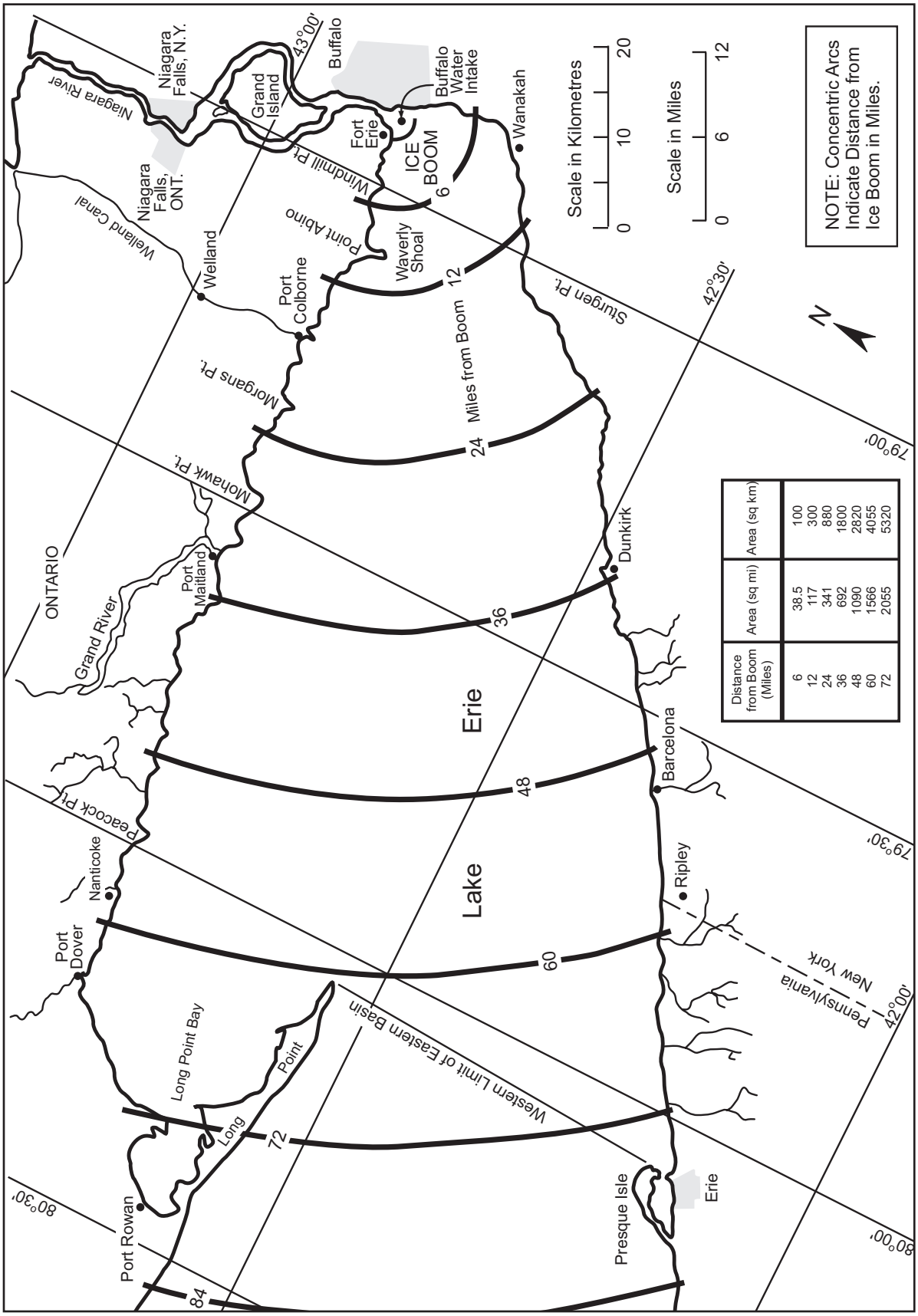


Figure 5

Map of Niagara River Showing Water Level Gauge Locations

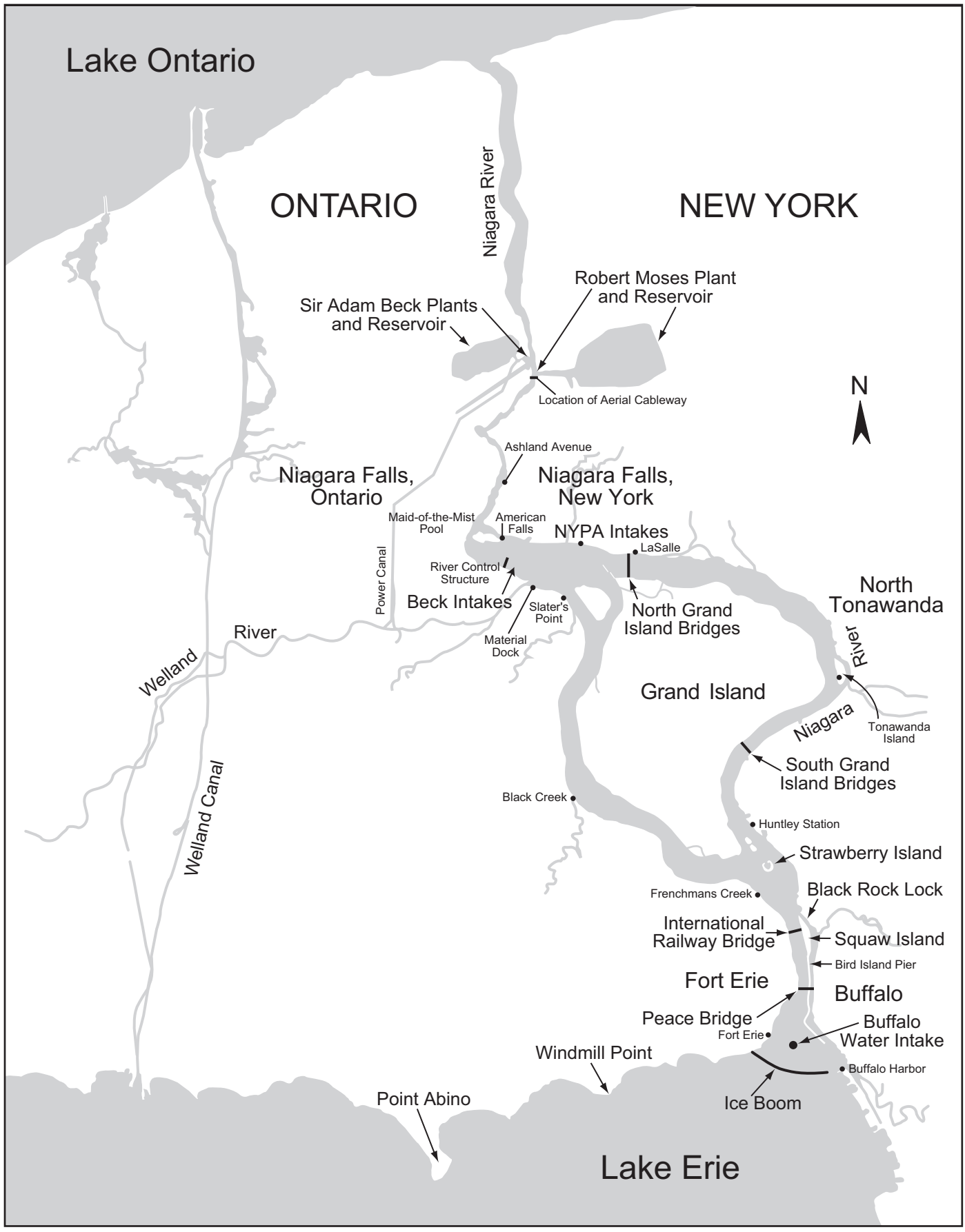


Figure 6

Structural Details of the Ice Boom

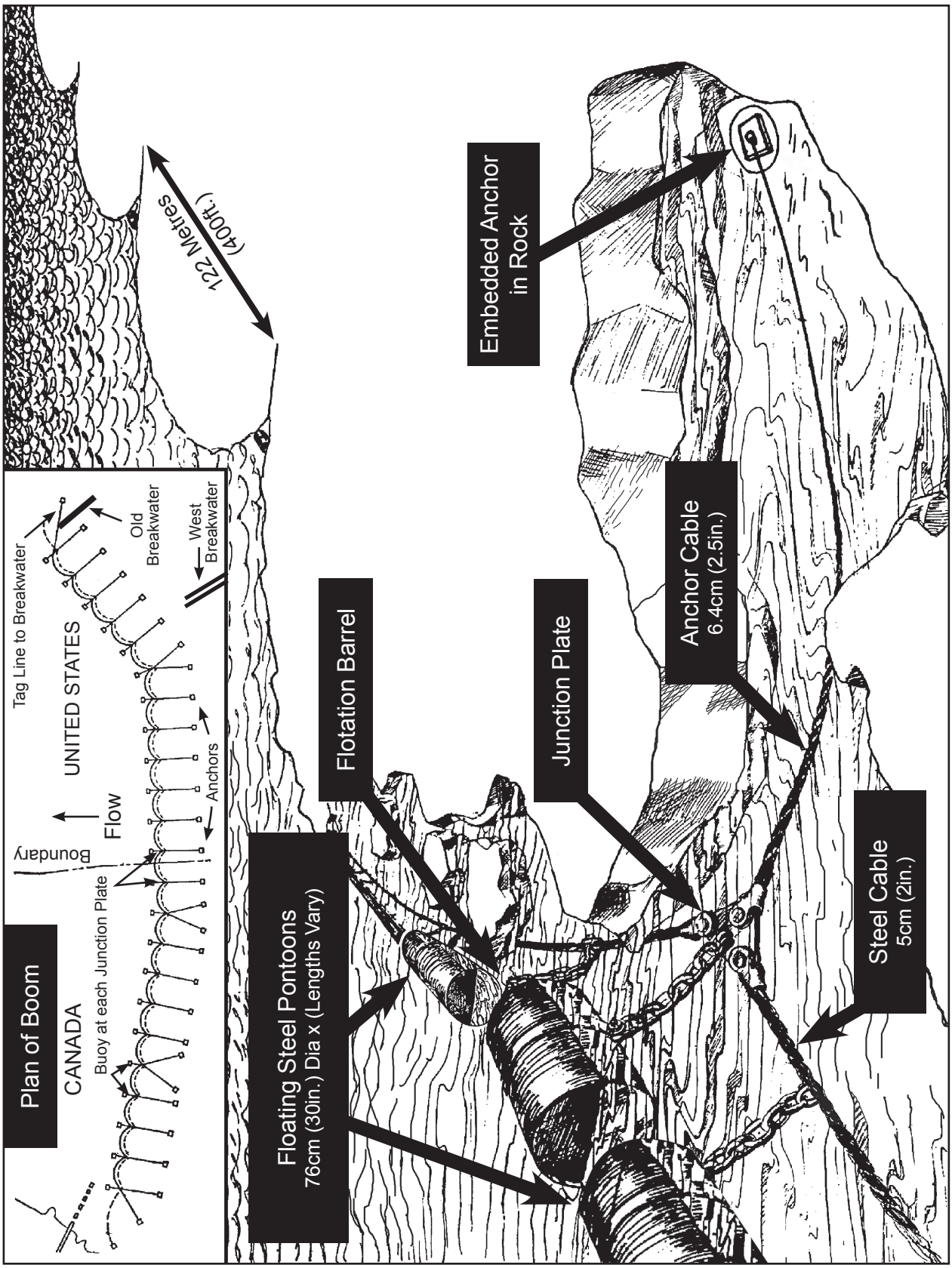


Figure 7