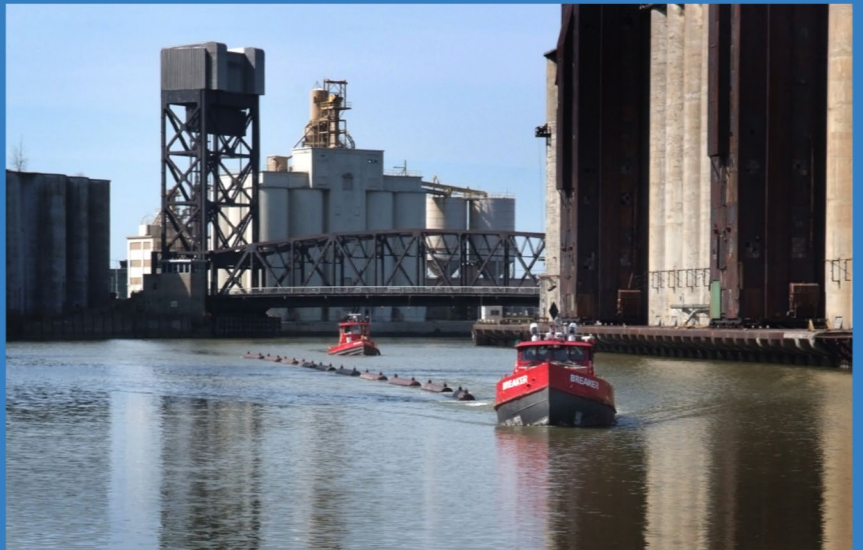


2019-2020 Operation of the Lake Erie-Niagara River Ice Boom



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

October 2020



Report to
The International Niagara Board of Control
On the 2019–20 Operation of
The Lake Erie–Niagara River Ice Boom
By the International Niagara Working Committee

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1. PURPOSE

The Lake Erie–Niagara River Ice Boom (ice boom) reduces the amount of ice passing from Lake Erie to the Niagara River. This prevents ice blockages from reducing hydropower production and reduces ice damage to shoreline property. The Power Entities, New York Power Authority (NYPA) and Ontario Power Generation (OPG) are authorized by the International Joint Commission (IJC) to use the ice boom. The International Niagara Board of Control (the Board) oversees the installation, operation and removal of the ice boom. This report is prepared by the Board's International Niagara Working Committee (INWC) from information provided by the Power Entities. Information collected by the INWC is used to inform the Board of ice boom operation for the 2019-2020 ice season. Further description of the Lake Erie–Niagara River system can be found in Appendix A.

2. HIGHLIGHTS

The winter of 2019-2020 was a very mild season for the Buffalo area. Meteorologically it was the 9th warmest winter on record for the Buffalo area and the 6th warmest for the continental United States. Precipitation for the winter season was well below average, ranking amongst the top 30 driest winters for the area. The winter season was bookended with temperatures below normal for November and April. The Buffalo area experienced above average temperatures for December, January, February, and March. The average temperature for the Buffalo area was 2.2°C (36°F).

In accordance with condition (d) of the International Joint Commission Order of Approval, installation of the Lake Erie–Niagara River Ice Boom may begin when Lake Erie's water temperature reaches 4°C (39°F) or on 16 December, whichever occurs first. On 16 December 2019 a media advisory was released stating that the ice boom installation would begin the following day. Ice boom installation began 17 December and was completed by 21 December 2019. Water temperature, as measured at the Buffalo Water Intake, reached 4°C (39°F) on 18 December 2019.

Temperatures for the Buffalo area were much warmer than average for the winter of 2019-2020. Lake Erie water temperature hit the freezing mark for only one day this ice season, on 1 March 2020, thus not allowing for an ice arch to form behind the boom. Ice coverage peaked at 9% the first week of March.

On 17 February 2020 ice boom crews located a break due to high winds at Span M. The span was repaired on 19 February 2020.

During the winter of 2019-2020 members of the INWC deemed it unnecessary to conduct any helicopter flights to measure ice thickness or fixed wing flights to measure lake area ice assessment as it was considered an ice-free year. The INWC used satellite imagery to observe the ice conditions in the eastern basin of Lake Erie.

Due to above freezing temperatures for much of this winter season, no notable ice cover formed on Lake Erie for the 2019-2020 ice season. The Power Entities informed the INWC that removal operations would begin as early as 2 March 2020 subject to safe on-water working conditions. The Board issued a public media advisory in the morning of 2 March 2020 and removal of boom spans began the same afternoon. Opening of the Ice Boom was completed by 5 March 2020 with all strings removed from the navigation section of Lake Erie and tied off to the Buffalo Harbor breakwall. As the COVID-19 pandemic emerged, NYPA modified their field operations and placed additional ice boom removal phases on hold. 17 of the 23 buoy barrels remained attached to their anchor cables until 20 April 2020, when NYPA completed Phase 2 of the ice boom removal. All boom components were put into dry storage and Phase 3 was completed on 4 June 2020. The INWC continues efforts to monitor Lake Erie ice cover, and regular updates are provided on the Board's website at <https://ijc.org/en/nbc/watershed/ice-boom>.

Data in this report are in metric units followed by the 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).

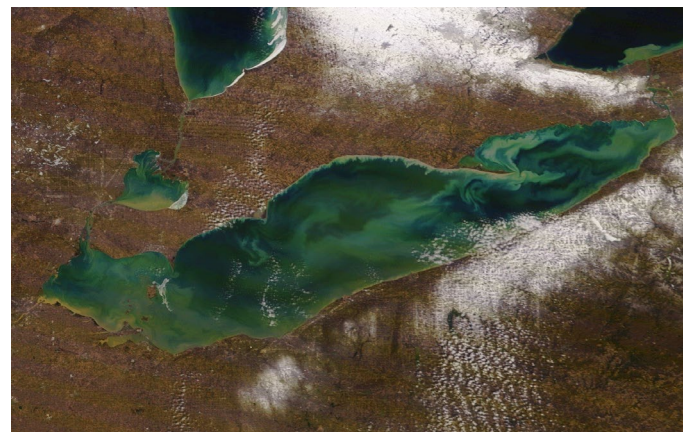


Figure 1: MODIS Satellite Imagery from the (NOAA) Coast Watch Great Lakes Program, 1 March 2020

3. HYDROMETEOROLOGICAL AND ICE CONDITIONS

During the winter of 2019-2020, the INWC continued its program of collecting data related to ice boom operations. An ice arch never formed behind the ice boom and ice formation for Lake Erie never exceeded 10% total coverage. These data were used to monitor the conditions of Lake Erie, but were not a factor for the installation and removal dates of the ice boom during the 2019-2020 ice season. As part of the program, satellite imagery of Lake Erie was analyzed, and meteorological data from the U.S. National Weather Service Station at Buffalo were collected.

Average monthly air temperature data for November 2019 through April 2020, as measured by the National Weather Service at the Buffalo Niagara International Airport, are located in Table 1.

For the second consecutive year the ice boom season started with a cold November. The average monthly temperature for November was below normal at 1.7°C (35.8°F) making it the 12th coldest November on record. The month also recorded five days below freezing, which tied the November of 2014, and fell two days short of the record of seven days which occurred in November 1951. Three daily temperature records were set during a mid-month cold spell. November 12th saw two records set. The highest temperature reached was -3.9°C (25.0°F), breaking the record of -0.6°C (31.0°F) from 1931. Also the lowest temperature of -8.9°C (16.0°F) broke the record of -5.6°C (22.0°F) from 1921. The following day the mercury dropped to -10.0°C (14.0°F) setting a daily record low, previously set back in 1986 at -8.9°C (16.0°F). Precipitation for November 2019 was well below normal. Only 5.0 cm (1.97 in) was recorded for the month, well below the average of 10.1 cm (3.98 in). Lake Erie's water temperature dropped from 13.3°C (56.0°F) to 6.7°C (44.0°F) by the beginning of December.

December 2019 started in typical fashion but ended unusually warm. Cool air moved into the Buffalo area the first week, with lake effect snow arriving mid-month. The temperature for the final two weeks of 2019 averaged above normal and were snow free. The average temperature for December was 0.7°C (33.0°F), which is 1.8°C (3.2°F) above average. Precipitation for the last month of the decade was measured at 13.6 cm (5.35 in), much of it falling as rain. Lake Erie's water temperature dropped during December from 7.2°C (45.0°F) to 2.8°C (37.0°F).

January 2020 was an uneventful and mild month for the Buffalo-Niagara area. All but four days recorded temperatures above normal. The average temperature for January 2020 was 0.6°C (33.0°F). Two temperature records were set for January 2020. On 10 January the warmest minimum temperature recorded was 0.6°C (33.0°F), and on 11 January the temperature rose to 19.4°C

(67.0°F), breaking the old record of 16.1°C (61.0°F) set in 2018. Very little precipitation fell during the month with a total of 6.91 cm (2.72 in). On 12 and 18 January high winds swept across Lake Erie causing two seiche events. With above average temperatures, Lake Erie remained ice free with the exception of some shore ice. Water temperature for Lake Erie dropped from 7.2°C (45.0°F) to 2.8°C (37.0°F).

The mild temperatures continued throughout the month of February. The average temperature for the leap year February was 1.4°C (35.0°F) making it the 9th warmest on record. Colder temperatures arrived later in the month. The temperature drop allowed for minor ice formation on Lake Erie by the first week of March. Precipitation for February averaged near normal with 6.35 cm (2.50 in). With the mild temperatures, Lake Erie was wide open with water temperatures between 0.6°C (33.0°F) and 2.2°C (36.0°F).

The 9th warmest February on record was followed by the 7th warmest March on record. The average temperature for March was 5.2°C (41.3°F). March 2020 was also the first time since 2015 that its average temperature was warmer than the previous month. The first three months of 2020 had 72 of 90 days with above normal average daily temperatures. March had 15 days with temperatures above 10.0°C (50.0°F). Total precipitation for the month was 8.13 cm (3.2 in). Ice cover for Lake Erie was virtually absent. The winter of 2020 was the 6th warmest winter since 1927 that had little or no ice on Lake Erie. The other years were 1953, 1983, 1998, 2002, and 2012. The first day of March saw Lake Erie's water temperature hit the freezing mark of 0.0°C (32.0°F). This would mark the only day Lake Erie would hit freezing before warming to 5.0°C (41.0°F) by the beginning of April.

For the second year in a row April had temperatures well below normal. The average temperature for the month was 6.3°C (43.0°F), which is 1.4°C (2.5°F) warmer than average. On 29 April the mercury hit 20.6°C (69.0°F) making this the second warmest day of 2020 until this point. 17 of 30 days in April had measurable precipitation, bringing the total precipitation to 9.0 cm (3.54 in), with twice as much snow falling this month than in March. Lake Erie's water temperature increased to 6.7°C (44.0°F) by the end of the month.

The daily Lake Erie water temperature, as measured at the Buffalo Water Intake, for the period December 2019 through May 2020, are provided in Table 2.

The first ice of the season was observed in the Chippewa Grass Island Pool (CGIP) on 21 February 2020. As shown in Figure 2, Lake Erie remained almost ice free, with minimal amounts of shore ice during the winter of 2019-2020. Ice coverage peaked at 9% the first several days of March before quickly dissipating for the season. The INWC deemed the two routine helicopter flights for ice thickness measurements, and one fixed wing flights for lake ice area assessment in the eastern basin of Lake Erie,

unnecessary during the winter of 2019-20 due to the lack of ice identified from satellite imagery and reported by the Canadian Ice Service. These flights, supplemented by ice information available from satellite imagery, are typically used to make decisions on the operation and removal of the Lake Erie-Niagara River Ice Boom.

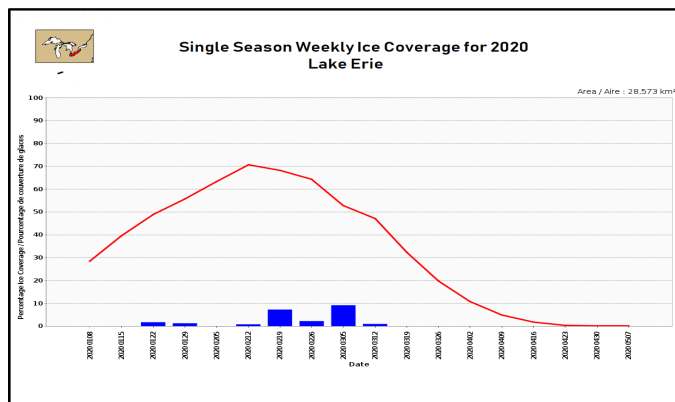


Figure 2: Single Season: Weekly Ice Coverage for 2019-2020 provided by the Canadian Ice Service

Due to the mild winter season, the lake remained open and navigable for the 2019-20 winter season. Historical dates of last ice can be seen in Table 3.

4. OPERATION OF THE ICE BOOM DURING THE 2019–20 ICE SEASON

The following sections provide a description of key operations of the ice boom in the 2019-20 ice season as they relate to the Order of Approval. Further background information on the ice boom can be found in Appendix B.

4.1 Installation of the Boom

A video surveillance system is used to monitor the ice boom. The web cam and information on the ice boom is available at: www.iceboom.nypa.gov and the Board's web site at <https://ijc.org/en/nbc/watershed/ice-boom>.

Phase 1 - Ice Boom Installation Preparation (the raising of the junction plates and attaching of the floatation buoy barrels) began on 21 November 2019. Beginning near the breakwall on the American side and extending across to the Buffalo Water Intake, crews were able to install 3 of 23 buoy barrels on 21 November 2019. From 25-28 November another six barrels were deployed, bringing the total to 10 of 23 barrels. The remaining barrels were placed 28 November 2019. NYPA used a new barrel system,

deploying Edgetech pop up barrels, as seen in Figure 3.



Figure 3: Edgetech pop up barrel recovery system

With Phase 1 complete, crews began Phase 2 – Ice Boom Installation Preparation, on 9 December 2019. NYPA crews towed out 5 spans from their storage facility at 100 Katherine Street, Buffalo, NY, located along the shore of the Buffalo River about 3 km (2 mi) upstream from Lake Erie. The first two spans were secured at the U.S. Coast Guard Station while the remaining three spans were placed at the Buffalo Harbor Break wall. The following day, 10 December 2019, another six spans were secured at the breakwall. High wind and waves delayed further preparations until 12 December, on which another five spans were towed out and secured with the others, bringing the total to 19 of 24 total spans. On 16 December 2019 the last five strings were pulled out.

The Lake Erie water temperature is taken at the Buffalo Water Treatment Plant located at the head of the Niagara River. The reading is taken at a depth of 9.1 m (30 ft). 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 (i.e. Phase 3 which is the placement of ice boom spans on Lake Erie as shown in Enclosure 6) will not begin before the Lake Erie water temperature reaches 4°C (39°F) or before 16 December, whichever occurs first.

Lake Erie water temperature did not drop to the required temperature for installation before 16 December. NYPA informed the INWC that installation would begin as soon as 17 December 2019, subject to safe working conditions. The Board issued a media advisory on 16 December 2019 informing the public, and installation (Phase 3) of the ice boom began 17 December 2019 as crews installed four spans (Spans V to S) on the Canadian side of the Niagara River (refer to Enclosure 6 for span layout). Inclement weather delayed installation efforts until 19 December as another 11 spans (Spans R to H) were installed. Work was halted until 21 December 2019 as ice boom crews

completed Phase 3 as the remaining 7 spans (Spans G to A) were installed on the American side.

Table 4 provides the dates from 1964 to the present year, when the Lake Erie water temperature, as measured at the Buffalo Water Intake, reached 4°C (39°F) and the dates of ice boom installation.

4.2 Ice Boom Operation

Lake Erie water temperatures only dropped to 4°C (39°F) for one day this ice season. An ice arch never formed behind the ice boom. An ice arch helps to stabilize the ice boom, helping to protect it from the changing conditions of open water.

High winds events on 12 and 18 January tested the integrity of the ice boom. The only damage reported for the ice season of 2019 – 20 was a trailing pontoon at Span M, the closest span to the Canadian shoreline. NYPA crews repaired Span M on 19 February 2020. NYPA crews at work can be seen from ice boom camera (Figure 4).

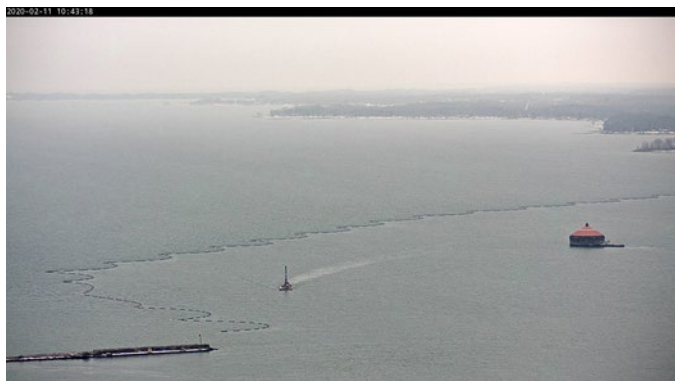


Figure 4: View from the NYPA Ice Boom Camera, 11 February 2020

4.3 Ice Boom Opening

Lake Erie ice coverage peaked at 9% the week of 5 March 2020. Lake Erie water temperature at the Buffalo Water Treatment Plant intake only dropped to 0.0°C (32.0°F) for one day on 1 March 2020.

Due to above freezing temperatures for much of this winter season, no notable ice cover formed on Lake Erie for the 2019-2020 ice season. On February 27, 2020 the water temperature near the ice boom was 1.1°C (34°F). Considering the lack of ice cover on Lake Erie and the absence of ice in the Maid-of-the-Mist Pool below Niagara Falls, the Power Entities informed the INWC that removal operations would begin as early as 2 March 2020 subject to safe on-water working conditions. The Board issued a public media advisory in the morning of 2 March 2020.

NYPA crews mobilized the afternoon of 2 March 2020 beginning removal by towing three spans (Spans A-C) and securing them to the Buffalo Harbor breakwall. Opening of the Ice Boom was completed on 5 March 2020 with all strings removed from the navigation section of Lake Erie and tied off to the Buffalo Harbor breakwall.

During the span removal (Phase 1) NYPA also initiated Phase 2, removal of the buoy barrels, by removing 6 buoy barrels on 5 March 2020. NYPA reported wave conditions making on-water working conditions unsafe suspending further boom operations and on 17 March 2020 NYPA suspended ice boom operations as precautions were initiated due to COVID-19. This left 17 buoy barrels remaining on the surface of Lake Erie.

On 20 March 2020 NYPA crews exercised due diligence during a COVID-19 shut down and removed the remaining 17 buoy barrels, completing Phase 2 and leaving the surface of Lake Erie unobstructed. This left all of the ice boom spans secured to the Buffalo Harbor Breakwall.

On 23 April 2020, one the spans broke free from the breakwall. It was later secured with a minimal crew. NYPA continued to inspect the secured spans using drone technology.

Ice boom operations resumed when safe work procedures for work under COVID-19 had been developed, and those protocols could be adhered too. On 1 June 2020 Phase 3 - Preparation for Storage began as NYPA crews removed and towed five of the 152 metre (500 ft) long spans up the Buffalo River to the Katherine Street storage facility where they were pulled onto shore. The following day another 8 spans were brought to the storage facility, on 3 June 7 more spans were put into storage. The Lake Erie Niagara River Ice Boom season effectively came to a close on 4 June 2020 as the last 4 spans were detached from the breakwall and brought in for storage.

4.4 Ice Boom Maintenance

As part of a routine summer maintenance program, hardware will be replaced where necessary. During the summer of 2020 NYPA used divers to fix or replace various anchor cables. The cables are anchored to the bedrock at the bottom of Lake Erie. NYPA crews replaced over 365 m (1200 ft.) of cable.

As part of a routine summer maintenance program, hardware will be replaced where necessary. During the summer of 2020 many cables had splice repairs completed. Also various anchor chains were replaced.

5. POWER LOSSES, FLOODING, AND NAVIGATION DURING THE 2019-20 ICE SEASON

5.1 Estimated Power Losses

Even with the installation of the ice boom, some reduction in hydropower generation can be expected virtually every year due to ice conditions where ice flows over top the ice boom or when ice is generated in the river itself. The Power Entities estimate that the ice boom provides an average annual savings to the hydropower facilities of approximately 414,000 Megawatt Hours (MWh) of electric energy.

The Power Entities did not experience any loss of hydroelectric power generation due to ice during the 2019–2020 ice season. A summary of estimated loss of energy due to ice for the period of record, 1975 to present, is shown in Table 6.

5.2 Niagara River Shore Flooding and Property Damages

The NYPA's Flood Warning Notification Plan, which is activated in the event of Ice-Affected Flooding on the Upper Niagara River, was not activated during the 2019-2020 ice season.

5.3 Navigation at the Welland Canal

The Welland Canal opened to commercial shipping this season on 24 March 2020 for its 191st consecutive year of service. A comparison of the dates of boom opening and the commencement date of navigation at the Welland Canal for the period 1965 to 2020 as shown in Table 7.

6. FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Findings and Conclusions

The winter of 2019-2020 was very mild. Ice formation for Lake Erie was minimal with only small amounts of thin shore ice observed. Lack of ice kept the lake wide open for the duration of the ice season. These types of open Lake Erie conditions last occurred during the winter of 2012. Two high wind events in January 2020 tested the integrity of the ice boom. On 19 February the only repair for the season took place on Span M at the Canadian shoreline.

The lack of ice resulted in an early ice boom removal date. Ice boom removal commenced on 5 March but the entire process took much longer than normal due to complications

brought on by the COVID-19 pandemic. The ice boom season officially ended on the 4 June 2020.

6.2 Recommendations for the 2020–21 Operation

The Board and the INWC should continue to monitor and assess the performance of the ice boom.

The Power Entities should continue to ensure that they monitor the ice boom and have adequate materials to repair multiple breakages in a timely manner, should they occur.

Utilization of Great Lakes ice information maps prepared by the Canadian Ice Centre and the United States National Ice Center, NOAA satellite imagery, and helicopter and fixed wing aerial ice surveys should continue to be used, as required, to evaluate ice conditions throughout the winter. In addition, the availability and applicability of additional, alternate forms of satellite-based remote sensing information should be investigated.

The INWC should continue to store ice area maps produced from aerial reconnaissance flights or composite ice maps in electronic format for future reference.

Table 1: Air Temperature at Buffalo Niagara International Airport

	°C (Celsius)			°F (Fahrenheit)		
Month	Average* 1981-2010	Recorded 2019-20	Departure	Average* 1981-2010	Recorded 2019-20	Departure
Nov. 2019	4.8	2.1	-2.7	40.7	35.8	-4.9
Dec. 2019	-1.1	0.7	1.8	30.1	33.3	3.2
Jan. 2020	-3.9	0.6	4.5	24.9	33.0	8.1
Feb. 2020	-3.2	1.4	4.6	26.3	29.4	3.1
Mar. 2020	1.1	5.2	4.1	34.0	41.3	7.3
Apr. 2020	7.7	6.3	-1.4	45.9	43.4	-1.1
Average	0.9	2.2	1.3	33.7	36.0	2.3

* Official U.S. National Weather Service averages are based on 30 years of record, 1981-2010.

Table 2: Lake Erie Water Temperatures as Recorded at the Buffalo Intake (Dec 2019 - May 2020)*

Month	December		January		February		March		April		May	
Date	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
1	7.2	45	3.3	38	2.2	36	0.0	32	3.9	39	6.7	44
2	6.1	43	2.8	37	2.2	36	0.6	33	3.9	39	6.7	44
3	6.1	43	3.3	38	2.2	36	1.1	34	3.9	39	7.2	45
4	6.1	43	3.3	38	2.2	36	1.1	34	4.4	40	7.2	46
5	6.1	43	3.3	38	2.2	36	1.1	34	5.0	41	7.2	45
6	5.6	42	3.3	38	2.2	36	1.1	34	5.0	41	7.2	45
7	5.6	42	3.3	38	2.2	36	1.1	34	5.0	41	7.2	45
8	5.6	42	3.3	38	1.7	35	1.1	34	5.0	41	7.2	45
9	6.1	43	2.8	37	1.7	35	1.7	35	5.0	41	7.2	45
10	5.0	41	2.8	37	1.7	35	1.7	35	6.1	43	7.2	45
11	5.6	42	2.2	36	1.7	35	1.7	35	6.1	43	7.2	45
12	5.0	41	2.8	37	1.7	35	2.2	36	5.6	42	7.2	45
13	4.4	40	2.8	37	1.7	35	2.2	36	5.6	42	6.7	44
14	4.4	40	3.3	38	1.1	34	2.2	36	6.1	43	7.2	45
15	4.4	40	2.8	37	1.1	34	2.2	36	6.1	43	7.2	45
16	4.4	40	2.8	37	1.1	34	2.2	36	6.1	43	7.8	46
17	4.4	40	2.8	37	1.1	34	2.2	36	6.1	43	8.3	47
18	3.9	39	2.8	37	1.1	34	2.2	36	5.6	42	8.3	47
19	2.8	37	2.8	37	1.1	34	2.2	36	5.6	42	8.3	47
20	3.3	38	2.8	37	1.1	34	2.8	37	5.6	42	8.3	47
21	3.3	38	2.8	37	1.1	34	2.8	37	5.6	42	8.9	48
22	2.8	37	2.2	36	1.1	34	2.8	37	6.1	43	9.5	49
23	2.8	37	2.8	37	0.6	33	2.8	37	6.1	43	8.9	48
24	3.3	38	2.2	36	1.1	34	2.8	37	5.6	42	10.0	50
25	2.8	37	2.2	36	1.1	34	2.8	37	5.6	42	10.6	51
26	3.3	38	2.2	36	1.1	34	2.8	37	6.1	43	11.7	53
27	3.3	38	2.2	36	1.1	34	3.3	38	6.1	43	12.2	54
28	3.3	38	2.2	36	0.6	33	3.3	38	6.1	43	12.2	54
29	3.3	38	2.2	36	0.6	33	3.3	38	6.1	43	12.8	55
30	3.3	38	2.2	36			3.9	39	6.7	44	13.3	56
31	3.3	38	1.7	35			5.0	41			13.3	56
Average:	4.4	40	2.7	37	1.4	35	2.2	36	5.5	42	8.7	48
Hi:	7.2	44	3.3	38	2.2	36	5.0	41	6.7	44	13.3	56
Low:	2.8	37	1.7	36	0.6	33	0.0	32	3.9	39	6.7	44

* Water temperatures at Buffalo are reported in Fahrenheit. The Celsius values provided are based on the equivalent values in Fahrenheit converted to Celsius and given to the nearest tenth of a degree.

Table 3: 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		1944	15-Apr		1982	20-May
1906	22-Apr		1945	9-Apr		1983	23-Feb
1907	30-Apr		1946	No data		1984	25-Apr
1908	9-May		1947	No data		1985	1-May
1909	26-Apr		1948	No data		1986	26-Apr
1910	30-Apr		1949	No data		1987	9-Mar
1911	6-May		1950	No data		1988	27-Apr
1912	29-Apr		1951	15-Apr		1989	9-Apr
1913	30-Apr		1952	27-Mar		1990	10-Apr
1914	28-Apr		1953	Ice-free		1991	28-Mar
1915	2-May		1954	27-Apr		1992	15-Apr
1916	11-May		1955	5-Apr		1993	16-Apr
1917	30-Apr		1956	20-Apr		1994	1-May
1918	20-Apr		1957	11-Apr		1995	18-Apr
1919	15-Mar		1958	10-Apr		1996	6-May
1920	20-May		1959	8-May		1997	29-Apr
1921	14-Mar		1960	5-May		1998	Ice-free
1922	11-Apr		1961	15-Apr		1999	2-Apr
1923	16-May		1962	30-Apr		2000	28-Mar
1924	20-Apr		1963	11-May		2001	27-Apr
1925	26-Apr		1964	27-Apr		2002	Ice-free
1926	31-May		1965*	14-May		2003	22-Apr
1927	9-Apr		1966	27-Apr		2004	30-Apr
1928	19-May		1967	13-Apr		2005	11-Apr
1929	2-May		1968	4-May		2006	5-Apr
1930	7-May		1969	26-Apr		2007	29-Apr
1931	7-Apr		1970	30-Apr		2008	23-Apr
1932	21-Apr		1971	31-May		2009	16-Apr
1933	23-Apr		1972	5-May		2010	29-Mar
1934	23-Apr		1973	15-Mar		2011	24-Apr
1935	13-Apr		1974	6-Apr		2012	Ice-free
1936	31-May		1975	8-Apr		2013	9-Apr
1937	14-Apr		1976	19-Apr		2014	8-May
1938	14-Apr		1977	13-May		2015	20-Apr
1939	14-May		1978	14-May		2016	6-Mar
1940	19-May		1979	3-May		2017	17-Mar
1941	21-Apr		1980	23-Apr		2018	16-Apr
1942	30-Apr		1980	23-Apr		2019	16-Apr
1943	20-May		1981	30-Apr		2020	9-Mar

Table 4: 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	1960's	9 Nov to 15 Dec 1964	6-Dec-1992	1990's	13 Dec to 14 Dec 1992
15-Dec-1965		19 Nov to 8 Dec 1965	16-Dec-1993		17 Dec to 28 Dec 1993
19-Dec-1966		8 Nov to 6 Dec 1966	2-Jan-1995		7 Jan to 10 Jan 1995
29-Nov-1967		17 Nov to 5 Dec 1967	7-Dec-1995		13 Dec to 16 Dec 1995
10-Dec-1968		25 Nov to 5 Dec 1968	4-Dec-1996		8 Dec to 11 Dec 1996
9-Dec-1969		15 Nov to 10 Dec 1969	13-Dec-1997		17 Dec to 18 Dec 1997
15-Dec-1970	1970's	Completed 15 Dec 1970*	1-Jan-1999	2000's	2 Jan to 9 Jan 1999
25-Dec-1971		3 Dec to 10 Dec 1971	27-Dec-1999		19 Dec to 29 Dec 1999
11-Dec-1972		11 Dec to 18 Dec 1972	18-Dec-2000		16 Dec to 28 Dec 2000
7-Jan-1974		19 Dec 1973 to 9 Jan 1974	27-Dec-2001		17 Dec to 22 Dec 2001
10-Dec-1974		11 Dec to 30 Dec 1974	3-Dec-2002		11 Dec to 12 Dec 2002
20-Dec-1975		24 Dec 1975 to 8 Jan 1976	15-Dec-2003		16 Dec to 20 Dec 2003
24-Dec-1976		30 Nov to 18 Dec 1976	20-Dec-2004		17 Dec to 20 Dec 2004
8-Dec-1977		13 Dec to 31 Dec 1977	9-Dec-2005		14 Dec to 15 Dec 2005
11-Dec-1978		Completed 19 Dec 1978*	19-Jan-2007		18 Dec to 19 Dec 2006
17-Nov-1979		Completed 22 Dec 1979*	9-Dec-2007		13 Dec to 17 Dec 2007
14-Dec-1980	1980's	22 Dec to 30 Dec 1980	5-Dec-2008	2010's	10 Dec to 11 Dec 2008
11-Dec-1981		19 Dec to 23 Dec 1981	12-Dec-2009		17 Dec to 19 Dec 2009
4-Jan-1982		6 Jan to 8 Jan 1983	8-Dec-2010		12 Dec to 16 Dec 2010
18-Dec-1983		19 Dec to 21 Dec 1983	28-Dec-2011		17 Dec to 18 Dec 2011
26-Dec-1984		27 Dec to 30 Dec 1984	28-Dec-2012		18 Dec to 20 Dec 2012
17-Dec-1985		20 Dec to 21 Dec 1985	10-Dec-2013		14 Dec to 16 Dec 2013
15-Dec-1986		16 Dec to 17 Dec 1986	5-Dec-2014		15 Dec to 16 Dec 2014
19-Dec-1987		19 Dec to 26 Dec 1987	6-Jan-2016		16 Dec to 28 Dec 2015
12-Nov-1988		12 Dec to 17 Dec 1988	15-Dec-2016		17 Dec to 22 Dec 2016
6-Dec-1989		7 Dec to 8 Dec 1989	15-Dec-2017		16 Dec to 17 Dec 2017
27-Dec-1990	1990's	27 Dec to 30 Dec 1990	12-Dec-2018		13 Dec to 18 Dec 2018
19-Dec-1991		20 Dec to 27 Dec 1991	18-Dec-2019		17 Dec to 21 Dec 2019

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 date unknown.

Table 5: 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	No Data Collected			21-Mar	27-Mar	2001	14-Apr	390	150	17-Apr	20-Apr
1966				20-Mar	1-Apr	2002	Ice-free			7-Mar	7-Mar
1967				22-Mar	29-Mar	2003	10-Apr	490	190	10-Apr	11-Apr
1968				8-Mar	20-Mar	2004	5-Apr	1110	430	6-Apr	7-Apr
1969				26-Mar	3-Apr	2005	4-Apr	210	80	5-Apr	6-Apr
1970	16-Apr	2590	1000	23-Apr	30-Apr	2006	20-Mar	80	30	20-Mar	21-Mar
1971	27-Apr	2850	1100	3-May	14-May	2007	7-Apr	620	240	10-Apr	18-Apr
1972	18-Apr	1300	500	20-Apr	25-Apr	2008	14-Apr	310	120	15-Apr	19-Apr
1973	14-Mar	260	100	16-Mar	21-Mar	2009	6-Apr	100	40	6-Apr	13-Apr
1974	18-Mar	320	125	26-Mar	1-Apr	2010	18-Mar	570	220	22-Mar	24-Mar
1975	21-Mar	80	30	25-Mar	28-Mar	2011	11-Apr	230	90	12-Apr	22-Apr
1976	15-Apr	130	50	19-Apr	21-Apr	2012	Ice-free			28-Feb	2-Mar
1977	14-Apr	520	200	18-Apr	20-Apr	2013	25-Mar	228	88	25-Mar	28-Mar
1978	27-Apr	710	275	1-May	8-May	2014	28-Apr	622	240	29-Apr	7-May
1979	10-Apr	390	150	13-Apr	17-Apr	2015	19-Apr	218	84	20-Apr	25-Apr
1980	1-Apr	700	270	2-Apr	7-Apr	2016	Ice-free			8-Mar	23-Mar
1981	15-Apr	980	300	18-Apr	22-Apr	2017	Ice-free			6-Mar	13-Mar
1982	26-Apr	1090	420	27-Apr	2-May	2018	10-Apr	181	70	10-Apr	19-Apr
1983	2-Mar	Trace	Trace	7-Mar	8-Mar	2019	17-Apr	746	288	29-Apr	7-May
1984	5-Apr	780	300	7-Apr	10-Apr	2020	Ice-free			2-Mar	5-Mar
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						
1999	21-Mar	160	60	23-Mar	24-Mar						
2000	21-Mar	160	60	23-Mar	24-Mar						

Table 6: Estimated Power Losses In MW-hours 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
1999-00	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	31,800
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	15,500	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
2011-12	0	0	0	0	0	0	0
2012-13	0	0	2,900	21,600	9,100	0	33,600
2013-14	0	93,300	0	0	0	0	93,300
2014-15	0	32,800	6,200	0	0	0	39,000
2015-16	0	0	10,500	0	0	0	10,500
2016-17	1,100	0	0	0	0	0	1,100
2017-18	0	95,700	10,500	0	25,300	0	131,500
2018-19	0	61,700	56,600	6,300	9,900	0	134,500
2019-20	0	0	0	0	0	0	0

*No Data Published

Note: No Data available for period 1964-74

Table 7: Ice Boom and Welland Canal Opening Dates*

	Opening Date				Opening Date		
Year	Ice Boom Start**	Ice Boom Completed	Welland***	Year	Ice Boom Start*	Ice Boom 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	21-Apr	1-Apr	2011	12-Apr	22-Apr	22-Mar
1977	18-Apr	20-Apr	4-Apr	2012	28-Feb	2-Mar	22-Mar
1978	1-May	8-May	30-Mar	2013	25-Mar	28-Mar	22-Mar
1979	13-Apr	17-Apr	28-Mar	2014	29-Apr	7-May	28-Mar
1980	2-Apr	7-Apr	24-Mar	2015	20-Apr	25-Apr	2-Apr
1981	18-Apr	22-Apr	25-Mar	2016	8-Mar	23-Mar	21-Mar
1982	27-Apr	2-May	5-Apr	2017	6-Mar	28-Mar	20-Mar
1983	7-Mar	8-Mar	5-Apr	2018	10-Apr	10-May	29-Mar
1984	7-Apr	10-Apr	28-Mar	2019	2-Mar	4-Jun	24-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				
1965-2020	3-Apr	7-Apr	28-Mar	Average for post-ice boom period			
1970-2020	5-Apr	9-Apr	28-Mar	Average for the flexible boom opening period			

1970 commencement of a flexible date for boom openings.

*For years that ice boom has been in operation.

**Denotes opening of first boom span. Mobilization time precedes this date. Total time for removal is dependent on wind, wave and other safety considerations for removal crews.

*** 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 km (36 mi) in length, is the natural outlet from Lake Erie to Lake Ontario (Enclosure 3). The elevation difference between the two lakes is about 99 m (326 ft); and about half of this occurs at Niagara Falls. Over the period 1860-2019, the average Niagara River flow at Queenston, Ontario has been 5,883 m³/s (207,760 cfs). The Welland Canal carries a small portion of the Lake Erie outflow. The total upper Great Lakes drainage basins upstream of the Niagara River is approximately 684,000 km² (264,000 mi²). Enclosure 2 shows a detailed 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 km (22 mi) from Lake Erie to the Cascade Rapids, which begin 1 km (0.6 mi) upstream from the Horseshoe Falls. From Lake Erie to Strawberry Island, a distance of approximately 8 km (5 mi), the channel width varies from 2,740 m (9,000 ft) at its funnel-shaped entrance to 460 m (1,500 ft) at Unity Island below the Peace Bridge. The fall over this reach is around 1.8 m (6 ft). In the upper 3.2 km (2 mi) of the river, the maximum depth is approximately 6 m (20 ft), with velocities as high as 3.7 m/s (12 ft/s) in the vicinity of the Peace Bridge. Below Unity Island, the river widens to approximately 610 m (2,000 ft), 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 km (11 mi) in length and varies from 610 to 1,220 m (2,000 to 4,000 ft) in width. Velocities range from 0.6 to 0.9 m/s (2 to 3 ft/s). The Chippawa Channel carries approximately 60 percent of the total river flow. The Tonawanda Channel is 24 km (15 mi) long and varies from 460 to 610 m (1,500 to 2,000 ft) in width above Tonawanda Island. Downstream thereof, the channel varies from 460 to 1,220 m (1,500 to 4,000 ft) 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 km (3 mi) long Chippawa-Grass Island Pool (CGIP). At the downstream end of the CGIP is the International Niagara Control Works (INCW). This gate control structure extends from the Canadian shoreline about halfway across the width of the river. The Niagara Falls are located about 1,370 m (4,500 ft)

downstream of the structure. The average fall from Lake Erie to the CGIP is 2.7 m (9 ft).

(b) Niagara Cascades and Falls

Below the INCW, the river falls 15 m (50 ft) 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 (Enclosure 3). The Canadian or Horseshoe Falls is so named because the crest is horseshoe shaped. During the non-tourist hours, the minimum Falls flow is 1,416 m³/s (50,000 cfs). This produces a fall of about 57 m (188 ft). Minimum Falls flow for tourist hours is 2,832 m³/s (100,000 cfs), which results in a fall of about 54 m (177 ft). 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 m (70 to 100 ft), to a talus slope at its base.

(c) Lower Niagara River

The Niagara Gorge extends from the Falls for 11 km (7 mi) 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 (M-O-M Pool), with an average fall of approximately 1.5 m (5 ft). This reach is navigable for practically its entire length. The M-O-M Pool is bounded downstream by the Whirlpool Rapids, which extends a further 1.6 km (1 mi). The water surface profile drops 15 m (50 ft) in the Whirlpool Rapids, where velocities can reach as high as 9 m/s (30 ft/s). The Whirlpool, a basin 518 m (1,700 ft) long, 365 m (1,200 ft) wide and depths up to 38 m (125 ft), is where the river makes a near right-angled turn. Below the Whirlpool, there is another set of rapids which drop approximately 12 m (40 ft). The river emerges from the gorge at Queenston, Ontario and subsequently drops 1.5 m (5 ft) to Lake Ontario. At Queenston, the river widens to 610 m (2,000 ft) 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 (Enclosure 3). 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 CGIP and return it to the lower Niagara River at Queenston, Ontario and Lewiston, New York, respectively. Enclosure 3 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 no less than 2,832 m³/s (100,000 cfs) during the daylight hours of the tourist season. The tourist season is defined as 8:00 a.m. to 10:00 p.m. local time from 1 April to 15 September and 8:00 a.m. to 8:00 p.m. local time from 16 September to 31 October. At all other times, the flow must be not less than 1,416 m³/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 along the Niagara River. Gauge locations are referenced on the map in Enclosure 2.

Remedial works were constructed by the Power Entities in the 1950's, with the approval of the International Joint Commission (IJC), to maintain the Falls flow 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 the INCW structure extending about 0.8 km (0.5 mi) into the river from the Canadian shore at the downstream end of the CGIP. The INCW has 13 gates that were completed in 1957 and 5 additional gates which were completed in 1963. The INCW is operated jointly by the Power Entities and regulates the water level in the CGIP within limits set by the International Niagara Board of Control. It also functions to adjust Falls flow promptly from 2,832 m³/s (100,000 cfs) to 1,416 m³/s (50,000 cfs) and vice-versa during the tourist season. In 1964, with the IJC's approval, the Power Entities installed a floating ice boom in Lake Erie, near the head of the Niagara River. The ice 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 Unity 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 Unity Island at the downstream end. The Black Rock Lock, which has a lift of 1.5 m (5 ft), is located near the lower end of the canal. A navigation channel extends from Unity Island via the Tonawanda Channel to Niagara Falls, New York. The channel and canal are maintained to a depth of 6.4 m (21 ft) below low water datum to North Tonawanda and then

to a depth of 3.7 m (12 ft) 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 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 close to Lake Erie. The International Railway Bridge crosses the river and the canal 2.4 km (1.5 mi) 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 CGIP. 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 CGIP and ice breaker activity is necessary to facilitate ice passage. Ice accumulations in the M-O-M Pool may pose potential hazards to the boat tour companies' facilities located downstream of the Falls. In the past, heavy ice runs in the upper river, combined with a large volume of ice already in the M-O-M Pool, have occasionally damaged these facilities.

Appendix B – Background Information on the Ice Boom

B.1 Authorization for Placement of the Ice Boom

The IJC 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 IJC when circumstances require, but no less than once every five years. The most recent review was completed in 2014. 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 by 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 mi² (650 km²) 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 mi² (650 km²). Complete disassembly and removal of all remaining flotation equipment shall be completed within two weeks thereafter. Notwithstanding 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 Enclosure 4. 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 arch 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

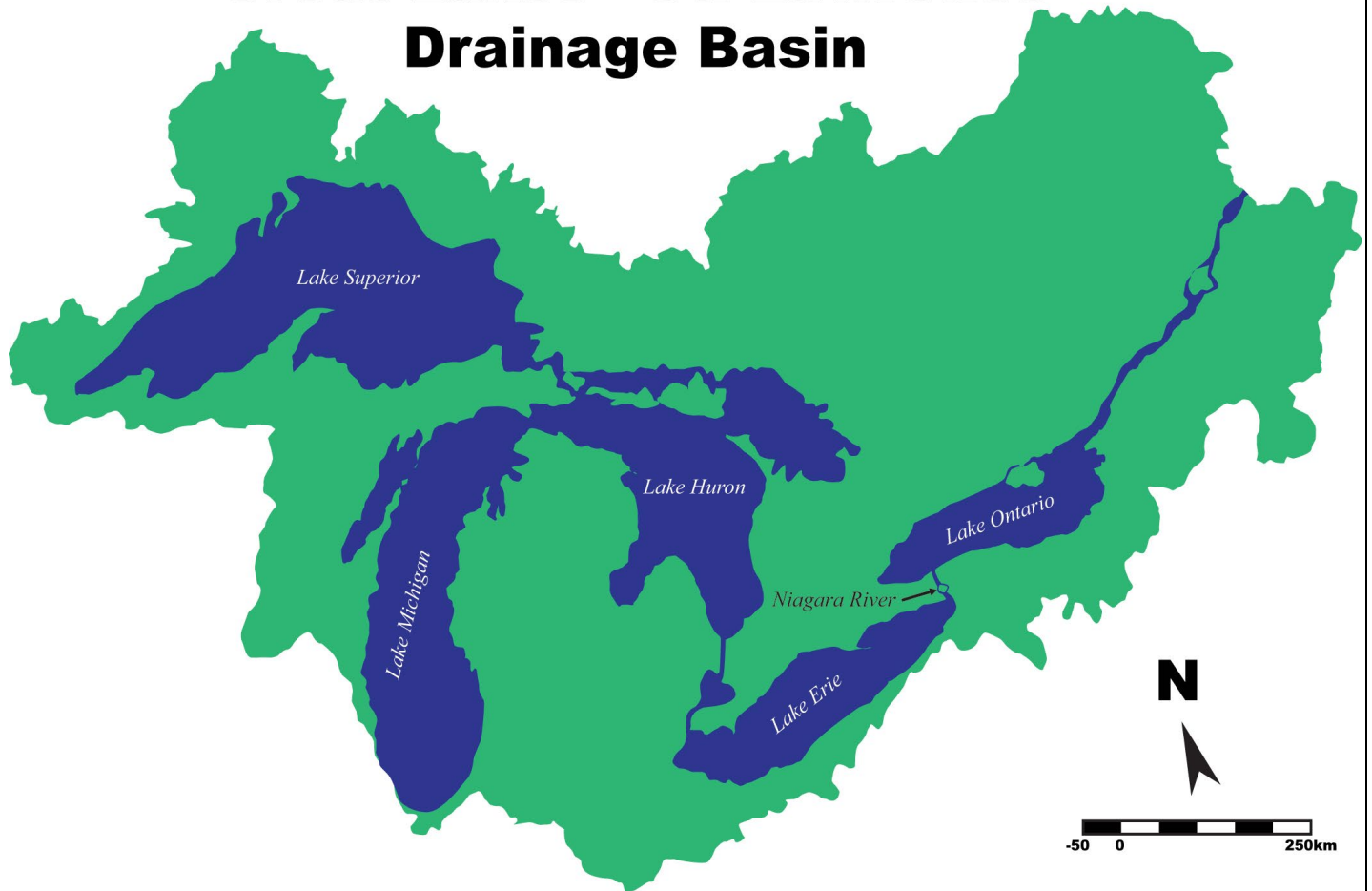
When in position, the 2,700 m (8,800 ft) ice boom spans the outlet of Lake Erie and is located approximately 300 m (1,000 ft) southwest of the water intake crib for the city of Buffalo. The boom is made up of 22 spans. Spans are anchored to the lake bed at 122 m (400 ft) intervals by 6.4 cm (2.5 in) diameter steel cables. Enclosure 5 illustrates structural details and a plan view of the ice boom is shown in Enclosure 6. As a result of studies conducted by the Power Entities, all of the timber pontoons were replaced with 76 cm (30 in) diameter, 9 m (30 ft) 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 1997-98 ice season.

Based on experience gained during the 1997-98 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 1998-99 ice season, spans A through J contain 10 instead of 11 steel pontoons. This modification greatly reduced damage to the pontoons in this reach.

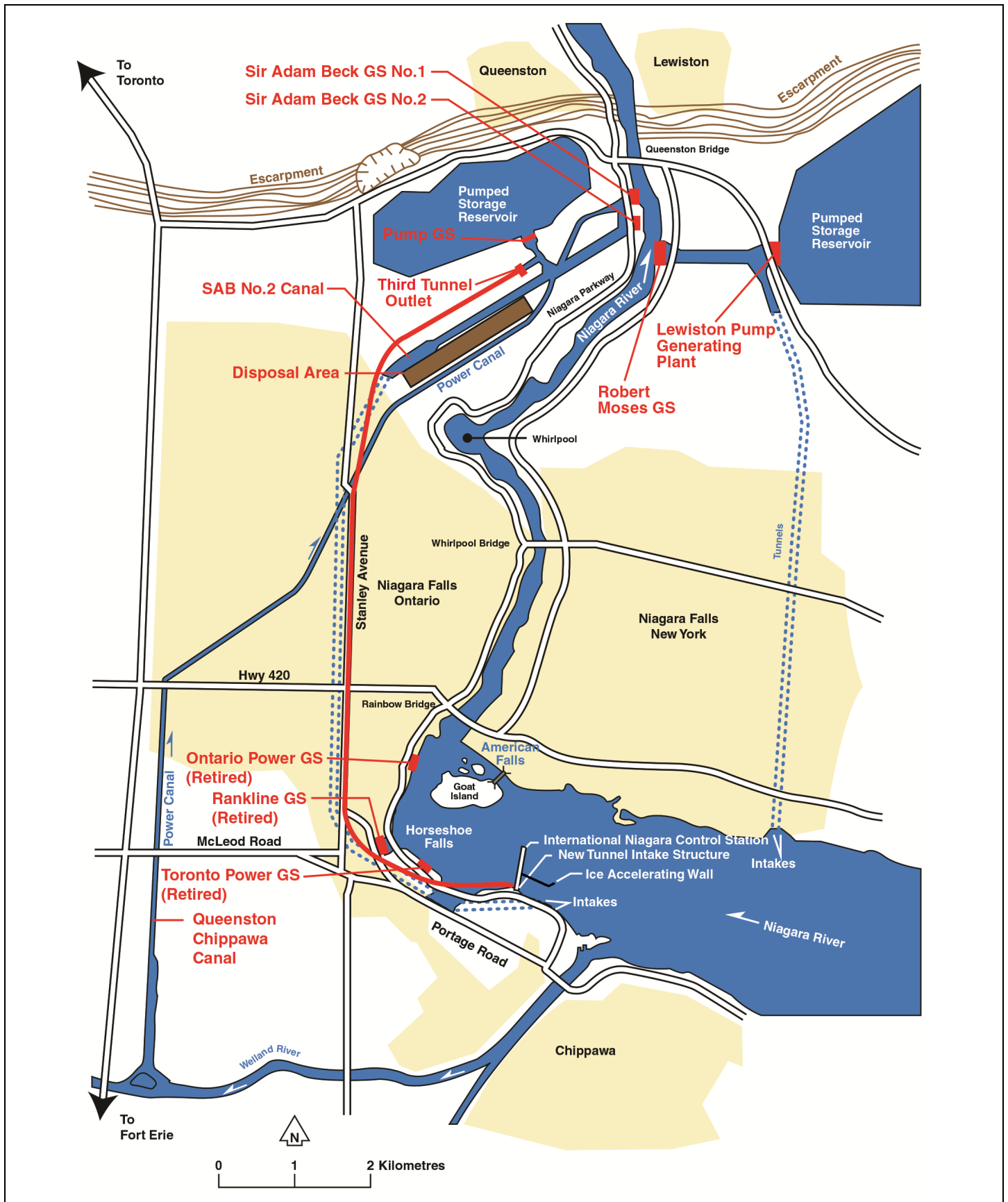
To further reduce the pontoon end cap damage and reduce the fatigue of the span cables between the inner and outer break walls (i.e. Spans A through D), the number and length of pontoons were changed to sixteen 4.6 m (15 ft) long mini pontoons per 152 m (500 ft) span, during the 2000-01 ice season. As per maintenance protocol, and to further reduce damage to the ends of the pontoons, sections K-P were reduced from 11 to 10 pontoons per sections at the start of the 2001-02 ice season. Remaining sections Q-V were reconfigured to 10 pontoons per span at the beginning of the 2002-03 ice season.

Enclosure 6 shows the plan view of the ice boom on Lake Erie. Enclosure 7 shows the span configuration using the typical 9 m (30 ft) pontoon and the 4.6 m (15 ft) mini pontoons.

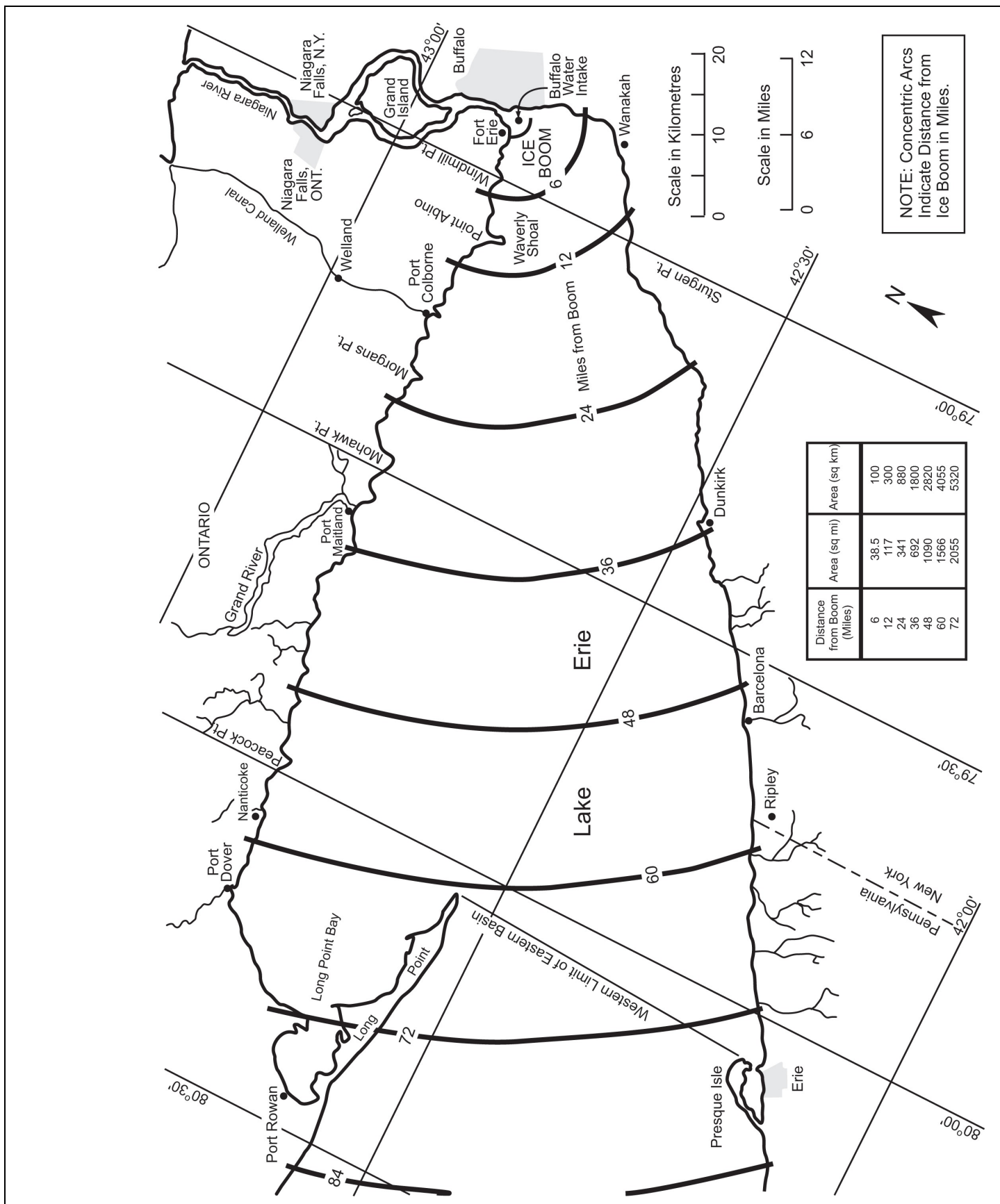
Great Lakes - St. Lawrence Drainage Basin



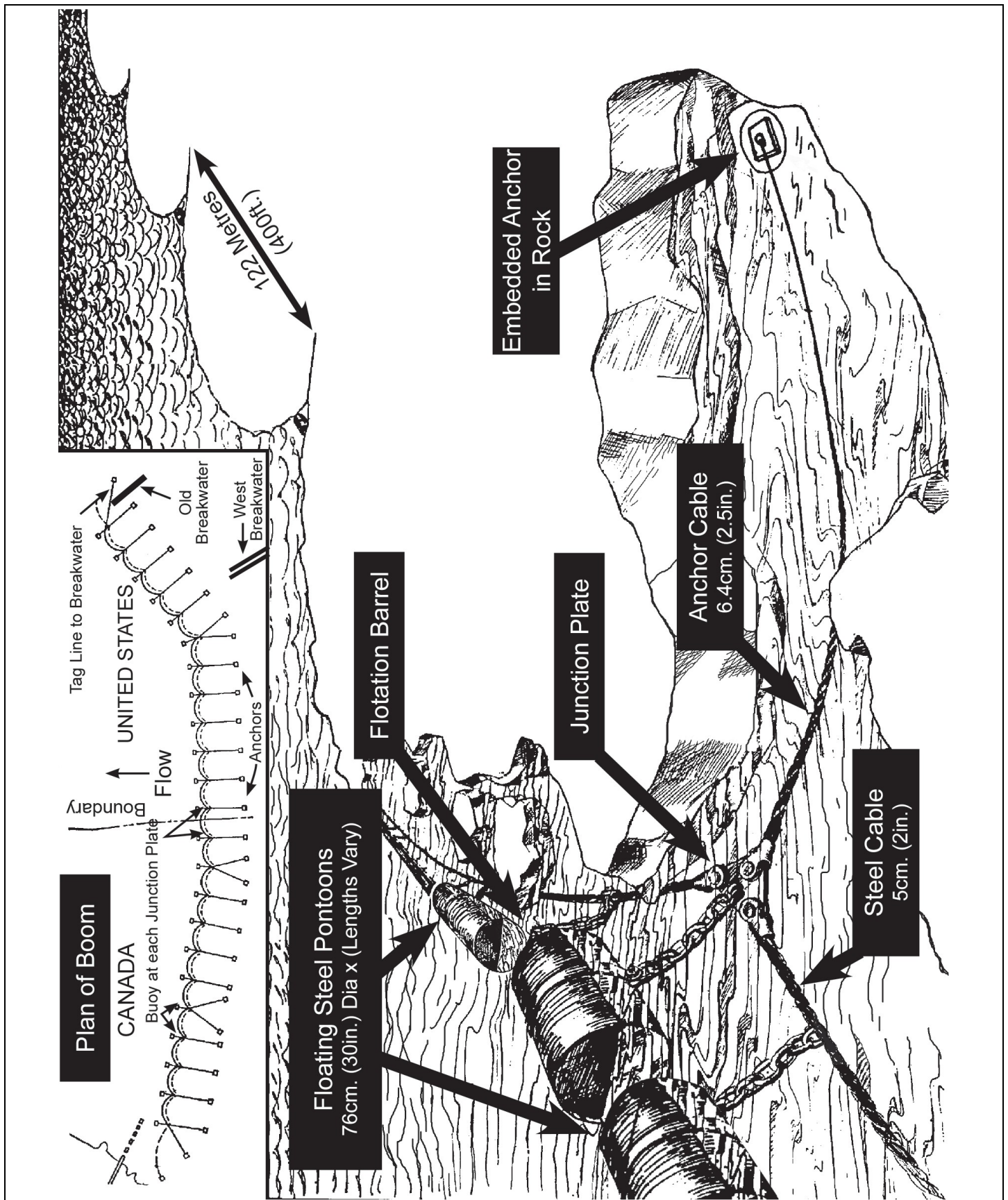
Enclosure 1: Great Lakes – St. Lawrence Drainage Basin



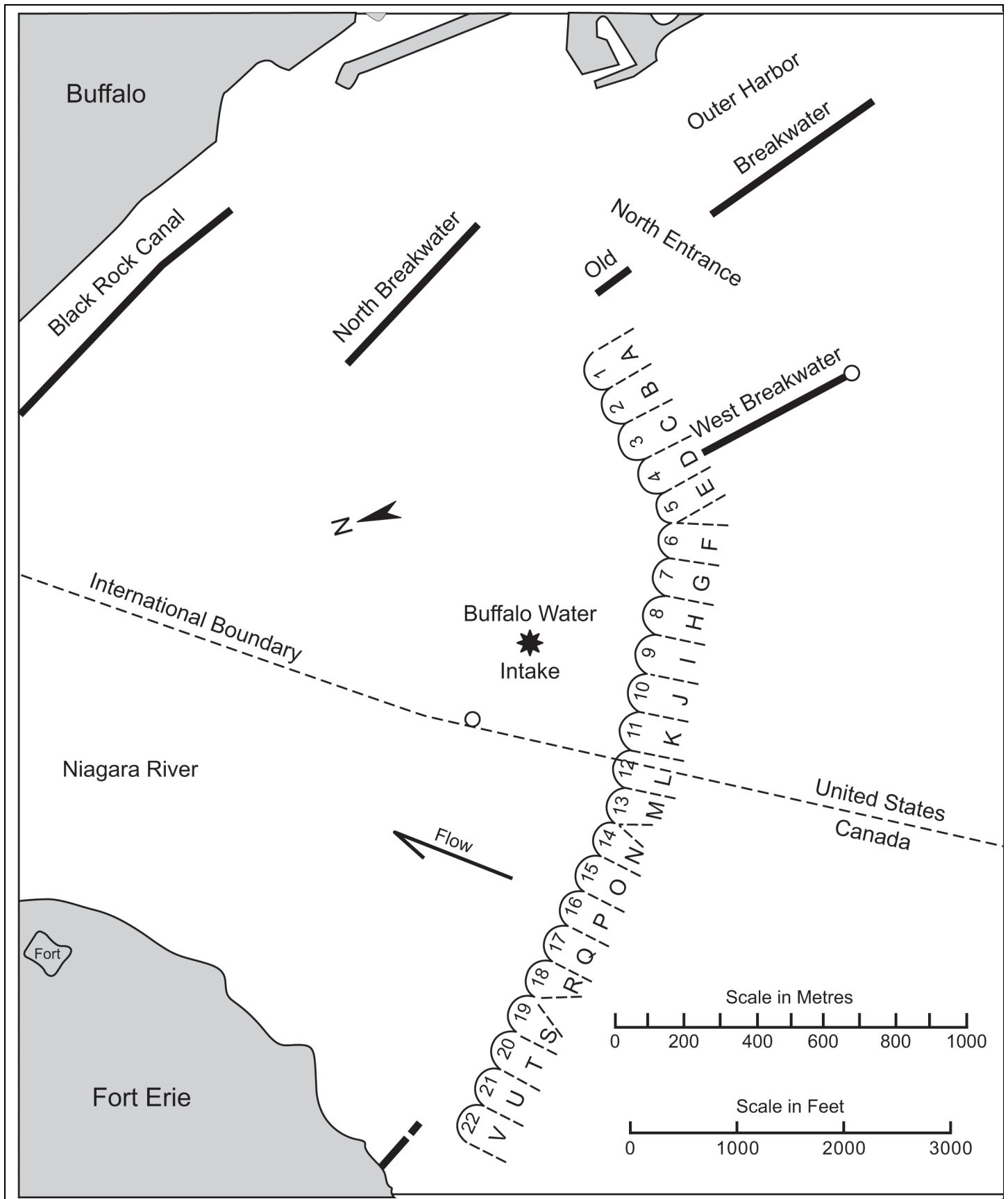
Enclosure 3: NYPA and OPG Power Projects



Enclosure 4: Map of Eastern End of Lake Erie



Enclosure 5: Ice Boom Detail



Enclosure 6: Plan View of Ice Boom

