US Army Corps
f Engineers
North Central Division

GREAT LAKES LEVELS

Update Letter No. 81 April 2, 1992

Niagara River Hydropower

The Niagara River, only 36 miles long, drains 4 of the 5 Great Lakes--an area equal to about one-twelfth of the continental United States. The river's flow averages about 202,000 cubic feet per second (cfs), with little variation throughout the year, making it among the world's most dependable sources of water supply. This Update Letter will focus on how this dependable source of water has been used for over 200 years to generate power.

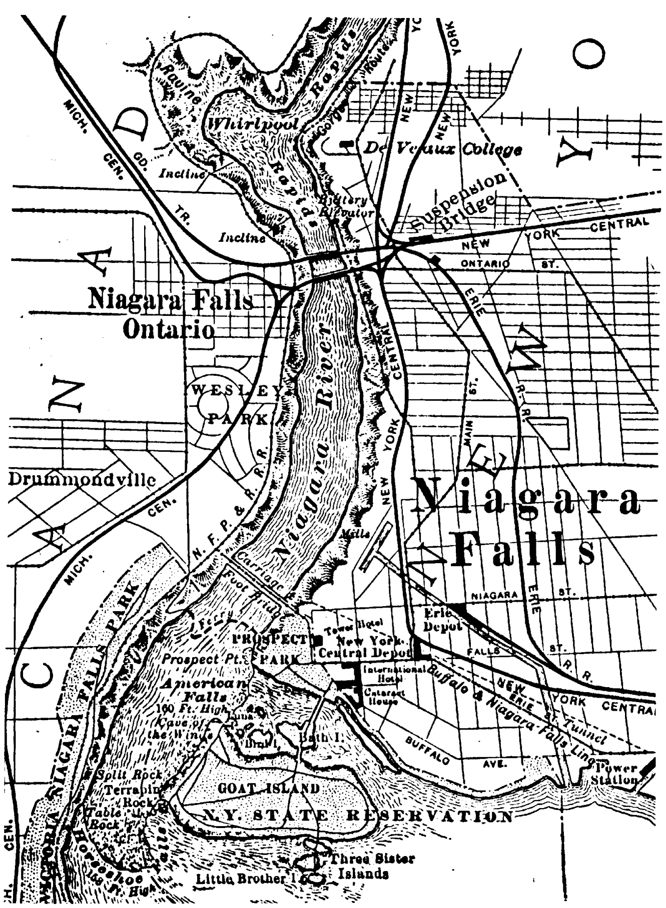

Figure 1. Map of Niagara Falls Area, 1901.

Early History

As early as 1757, a small mill-race, no more than 6 feet wide and 4 feet deep, was constructed by Chabert Joncaire. The mill-race took water from above the Niagara Falls (Falls), rejoining the river a short distance downstream. The water powered an overshot wooden water wheel for a small sawmill located above the Falls near the area of the present American Rapids Bridge. The canal and mill were abandoned, but were later repaired and put into operation in 1760 by John Steadman, the master of the portage. Other water-powered mills were constructed during the late 1700s, but they only harnessed a very small portion of the river's potential.

United States Development

During the early 1800s, industrialists, engineers, and others began formulating plans to construct major power projects at the Falls. Augustus Porter, a 26-year-old surveyor from Connecticut, explored and settled in the Falls region with his brother, Peter. They considered the Falls an untapped resource with power enough to turn all the mill wheels in America. In 1805, when New York offered land (including riparian rights and the title to the water power) along the Niagara River at public auction, the Porters and others were able to obtain lots which included the American Falls, the rapids above them, and the beginning of the gorge below. They constructed a grist mill and tannery on the site previously

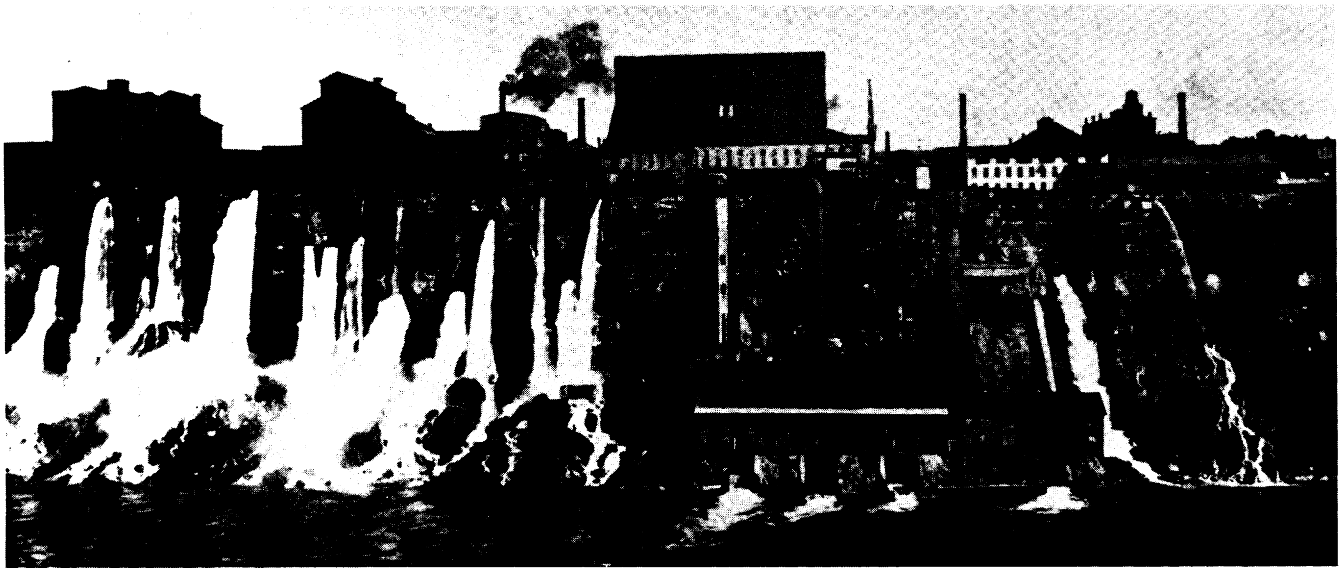

Figure 2. The Niagara Falls Power Company Generating Station in 1907.

1,000 households = approximately 2-3 MW

Hydraulic Head = the difference in height between the top of the intake tunnel or penstock and its discharge point. This difference produces water pressure due to gravity.

occupied by Joncaire's saw mill. Over the next 72 years, the Porters, their heirs, several industrialists, the Niagara Falls Canal Company, and others pursued efforts to construct a reservoir and canal capable of furnishing water power for manufacturing plants being built in the area. By 1877, construction had reached the point that water could be diverted from the Niagara River to generate mechanical power for a flour mill. When creditors forced the sale of the property, the mill and canal were acquired at public auction by Joseph Schoellkopf, a Buffalo manufacturer, who formed the Niagara Falls Hydraulic and Manufacturing Company. By 1882, the canal was enlarged and a small electric generating station, known as Station One, had been built at the site of the old mill. Seven additional mills also drew water from the canal.

By 1889, no fewer than five companies were granted franchises to develop hydropower on the U.S. side of the Niagara River. Similarly, leases at the Canadian Falls were granted to two American companies - the Canadian Power Company (later the Ontario Power Company), and the Canadian Niagara Power Company (subsidiary of the Niagara Power Company) - - and to a Canadian syndicate.

Between 1890 and 1905, the science of electrical engineering and technology advanced to a point where large-scale hydroelectric projects became feasible. The first success in the Nation of such magnitude was accomplished by the Niagara Falls Power Company with their construction of the Edward Dean Adams Station above the Falls. Construction began in 1890, was completed in 1900, and it began operations in 1895. The station used a short intake canal connected to a tunnel running under the City of Niagara Falls. The tunnel connected to a vertical shaft, dropping 135 feet to operate turbines rated at 3.7 megawatts (MW). The first commercial production of power from the plant occurred on the night of November 15, 1896, when the mayor of Buffalo, NY, threw a switch for transmission of power to the city. A second plant began producing power in 1902. It was completed in 1904, by which time both stations generated 82.4 MW. Figure 1 is a map of the Niagara Falls area in 1901 (The Niagara Book, Havells, W.D., et al., Doubleday, 1901). Figure 2 is the Niagara Falls Power Company generating station in 1907.

While construction continued on the Adams Station, the Niagara Falls Hydraulic Power and Manufacturing Company (builders of Station One) constructed a second station, completed in 1896. Shortly afterwards, the company completed the first section of the Schoellkopf Station in the gorge below the Falls. From 1905 to 1914, the company expanded to 97 MW, under full hydraulic head development.

While this hydropower expansion was occurring, the Burton Act of 1906 was passed by Congress, limiting U.S. diversions to 15,600 cfs. This act had no effect on Canadian water use. In 1909, the joint regulation of the diversions from the Niagara River was established under terms of a treaty between the United States and Great Britain (made in behalf of Canada). U.S. diversions were limited to 20,000 cfs and Canadian diversions to 36,000 cfs.

As the diversion limit was approached, it was realized that the only way to secure a much needed power increment was by united action. This was accomplished by consolidating the Niagara Falls Power Company and the Niagara Falls Hydraulic Power and Manufacturing Company. By abandoning a number of less efficient units, aggregating 42.2 MW, and using the available water in new developments, the new Niagara Falls Power Company increased their in-service capacity to 421.5 MW. This was accomplished with the 1924 completion of a new Schoellkopf Plant at the bottom of the gorge, about 3,000 feet downstream from the American Falls. Its hydraulic capacity was about 23,400 cfs in 1955.

In 1956, the southern two-thirds of the Schoellkopf Plant was destroyed by a spectacular rockfall (see Figure 3) on June 7, 1956. Throughout that day, workers attempted to stop water seepage coming through the back wall of the plant. As the day went on, cracks developed, water leakage increased, and one piece of the floor of the powerhouse buckled. Workers continued to battle the increasing flow until the walls and ceiling started to collapse. The employees ran for safety, but one was killed. The northern section of the remaining plant was repaired and placed into operation.

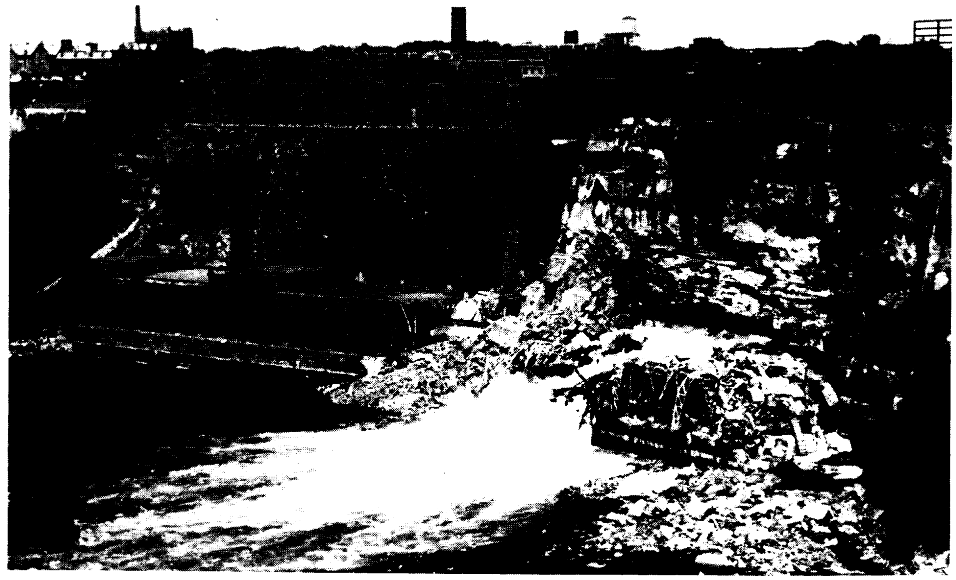

Figure 3. The Collapse of the Schoellkopf Plant occurred on June 7, 1956.

Figure 4. Robert Moses Power Plant, Lewiston Pump Generating Plant and Reservoir.

The U.S.-Canadian Treaty of 1950 increased the amount of water which could be taken from the river for power, while still ensuring an adequate flow over the Falls for scenic purposes. To alleviate power shortages and fully utilize the additional U.S. portion of power diversions from the Niagara River, the Power Authority of the State of New York undertook a major redevelopment of U.S. hydropower facilities. This took from 1958 to 1962. The resulting Robert Moses Niagara Power Plant (Figure 4) is one of the world's largest hydroelectric facilities.

The Robert Moses Plant takes water from the Niagara River above the Falls through two conduits approximately 46 feet wide and 66 feet high. These run under the City of

Niagara Falls and Town of Lewiston, NY, and then into an open canal between the Lewiston Pump-Generating Plant and the Robert Moses Plant.

The water supplied to the Robert Moses Plant falls about 305 feet to 13 turbines. The turbines drive 150 MW generators, having a combined capacity of 1,950 MW. Water is discharged into a tailrace channel which leads to the lower Niagara River.

The Lewiston Pump-Generating Plant consists of 12 motor-generators directly connected to 12 hydraulic pump-turbines. Each unit is rated at 28 MW as a motor and 20 MW as a generator. The facility can produce 240 MW of power. This provides an added degree of flexibility by storing water for optimum power generation. The water is pumped during off-peak hours to a pumped-storage reservoir which covers about 1,900 acres and can hold about 20 billion gallons of water. The water is re-used through the generating units at the Moses plant.

Upon completion of the Robert Moses facility, both the Schoellkopf and Edward Dean Adams plants were retired in 1961 and were demolished by 1963.

Canadian Development

The Canadian Niagara Power Company obtained the right to use Niagara River water, on the condition that they have their initial generating station in operation by May 1, 1897, and would have 7.5 MW ready for use by November 1, 1898. The plant was only partially completed when the franchise lapsed. After renegotiations in 1899, the company was authorized to install a total capacity of 74.6 MW. The forebay for the powerhouse was constructed from a portion of the river which ran around Cedar Island. The tailrace water flowed through a tunnel into the lower Niagara River just below the Horseshoe Falls. The tunnel was cut through solid rock and lined with concrete and brick. The plant began operations in 1905, and is still in use today. During this construction, franchises were granted to the Ontario Power Company (1902) and the Electrical Development Company (1903) for construction of facilities along the river bank south of the Canadian Niagara Plant.

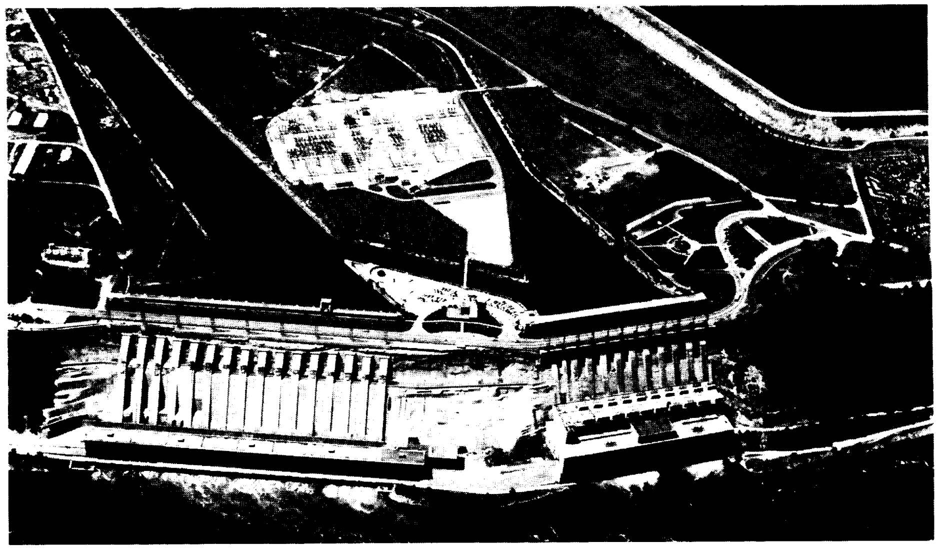

Figure 5. Sir Adam Beck Generating Stations 1 and 2 and Pump Generating Plant with Reservoir.

The Ontario Power Company facility, the largest of the early projects, was constructed between 1902 and 1905. The power generation facility, located almost at river level near the foot of the Horseshoe Falls, utilizes water from the river at the entrance to Dufferin Island. A gathering weir in the river diverted water to three conduits. All conduits carried water underground for a distance of about 6,500 feet to a location at the top of the escarpment just below the Canadian Falls. From this point the water falls through penstocks to the power house. The plant originally had an installed capacity of 132.5 MW from 15 units. The plant still operates today and maintains 12 units in service, generating approximately 101 MW. (Three units were retired in 1968,) Two of the three original conduits remain in use.

The plant constructed by the Electrical Development Company between 1903-1906, today known as the Toronto Powerhouse, is located sixth-tenths of a mile above the Horseshoe Falls. The plant was constructed on what was previously riverbed and originally utilized 11 vertical turbines for power production. The turbines discharged into parallel tunnels, which combined into one long tailrace tunnel 13 feet in diameter, which emptied into the river under the Horseshoe Falls. The plant had a total capacity of 102.6 MW when originally built and began providing power in 1906. The plant ceased operation in February 1974.

The next Canadian project was the Queenston-Chippawa project, then heralded as the world's largest. Now known as the Sir Adam Beck-Niagara Generating Station No. 1, construction began in 1917 and was completed in 1922 (see Figure 5). The plant is set at the top of the 300-foot cliffs overlooking the Niagara Gorge. Water is diverted through an intake structure at the mouth of the Welland River at Chippawa, Ontario. The diverted water flows through the Welland River to an 8-1/2 mile long canal to the forebay. The plant opened in 1921, with nine generating units; a tenth unit was added in 1930 to provide a total capacity of 415 MW.

No further Canadian development took place until the Niagara Treaty of 1950 was signed. The increased diversion justified Ontario Hydro's largest project, the Sir Adam Beck Generating Station No. 2.

Construction began in 1950, and was completed in 1958. It is located about 2-1/2 miles below the Falls, just upstream of Sir Adam Beck No. 1. The project includes a control structure on the Niagara River, upstream of the Falls; two intake structures; two tunnels 5-1/2 miles long and 45 feet in diameter; an open canal 200-feet wide and 2-1/4 miles long; a large forebay and headworks at the top of the gorge; 16 penstocks 19 feet in diameter; a powerhouse containing 16 generating units, with turbines rated at 78.3 MW; and, a pumped-storage facility. The plant's total installed capacity is 1,400.3 MW.

A unique feature of the project was the construction of the Chippawa-Grass Island Pool Control Structure, shown in Figure 6. The control structure, completed in 1957, located above the Falls, extends 1,482 feet into the river from the Canadian shore. The structure assists in controlling flows over the Falls to meet the requirements of the 1950 Treaty, while allowing optimal diversion of water for power generation.

In addition to facilities on the Niagara River, Ontario Hydro operates the DeCew Falls Plants on the Welland River, with a total capacity of 147 MW. DeCew Falls Plant No. 1 began power generation in 1898, with 6 units at 266 feet of hydraulic head, and a rated capacity of 32 MW. DeCew Falls Plant No. 2 began operation in 1943, with a capacity of 115 MW. Water is withdrawn from the Welland Canal and discharged into a tributary of Lake Ontario.

Figure 6. International Control Structure, 1963. Designed to control the flow of water over the Falls.

Present Power Facilities

Presently, the U.S. and Canada operate nine hydroelectric generating facilities on or near the Niagara River. A map locating these facilities is shown in Figure 7. The facilities are listed in Table 1.

The Robert Moses and Sir Adam Beck plants, referred to as high-head plants, divert flow from the upper Niagara River where the river elevation is about 50 feet higher than the brink of the Falls, and return the flow to the lower river at a point about 5 to 6 feet above the level of Lake Ontario. Consequently, each of these plants has a total hydraulic head of about 300 feet. The remaining older hydroelectric plants divert water essentially from the brink of the Falls near the Canadian shoreline and discharge it to the Maid-of-the-Mist Pool near the base of the Falls. The operating hydraulic head for these older two plants is less than 200 feet. Because of their age and small capacities, they routinely use only small amounts of diversion water.

Future Expansion of Power

Ontario Hydro is proposing to install an additional hydroelectric station at the Sir Adam Beck complex. The new station, Sir Adam Beck No. 3, would be located just downstream of the Sir Adam Beck No. 1 facilities. It would obtain water from the existing forebay. It would also require additional facilities to divert flow from the upper Niagara River. These facilities would include new diversion intakes located at the control structure and two diversion tunnels constructed deep below the existing tunnels. The tunnels would follow the alignment of the existing Sir Adam Beck No. 2 tunnels under the City of Niagara Falls, Ontario, and would surface through outlet structures on the north side of the Sir Adam Beck No. 2 canal.

Based on study results, a 600 MW development alternative would include locating the headworks at forebay level, widening of the Sir Adam Beck No. 1 canal, and operation of the new station in base-loaded rather than peaking mode. The scenic Falls flow requirements will still be met under post-project conditions. The project is still in its planning phase and is undergoing evaluation in accordance with the Ontario Environmental Assessment Act (EA).

The New York Power Authority is also expanding its facilities by upgrading the existing generating units at the Robert Moses Plant and at the Lewiston Plant. The proposed upgrade to the 13 Robert Moses Plant units would increase the maximum power by 325 MW. Similarly, the upgrade of the 12 Lewiston Plant units is expected to increase the maximum power by 60 MW. The expansion will allow more efficient use of its allotment of Niagara River flow, by increasing the project's output during times of peak demand.

IJC Reference Study Update

The Levels Reference Study Board met in Chicago on March 25-26, to review the status of a number of technical studies that are underway. These include erosion processes; development of water-level regulation scenarios, wetlands investigations associated with fluctuating water levels, and detailed site and shoreline reach studies. The Study Board will next meet on March 22-24, 1993, in Washington, D.C., in conjunction with the semiannual appearances before the International Joint Commission.

Progress Review Meetings, which combine daytime technical workshops with evening public review sessions, are being planned. Three such sessions are scheduled for May. Dates, locations, and subject matter are listed below:

*May 4-5 1992, Baraga, Michigan Natural Resource Impacts;

*May 12-13 1992, Toledo, Ohio Regulation Scenarios, Crises Conditions, and Land Use and Management; and

*May 27-28, 1992, Burlington, Ontario, Potential Damages and Erosion Processes.

Greetings from the New Commanding General

I would just like to say how pleased I am to be the new Commanding General of the North Central Division. I am looking forward to serving all the great people of this region.

Russell L. Fuhrman
Brigadier General, U.S. Army
Commanding General and
Division Engineer

TABLE 1

Development	In Service Date	No. of Units	Diversion Capacity (cfs)	Normal Head (ft)	Discharge Capacity (cfs)	Generating Capacity (MW)
Canadian Plants						
DeCew No. 1	1901	6	-	266	2034(3)	34
Rankine (CNP)	1904	11	10000	133	10000	75
Ontario Power	1905	12	8260	205	8260	104
Sir Adam Beck No. 1	1922	10	22075	292	21260	488
DeCew No. 2	1943	2	6887(1)	283	6804(3)	144
Sir Adam Beck No. 2	1954	16	42384	291	59504	1264
Sir Adam Beck PGS	1954	6	-	80	31950	150
		63	89606		139812(2)	2259
United States Plants						
Robert Moses	1961	13	109491	300	10207	2275
Lewiston PGS	1962	12	-	85	46975	360
		25	109491		57182	2635

Note (1) Normal diversion to supply DeCew No. 1 and DeCew No. 2.
(2) Pumping-Generating Station (PGS) discharge is to Generating Station forebay only and has been excluded from totals.
(3) The maximum allowable flow in the tailrace below the DeCew Plants is 7800 cfs (combined plant outflow).

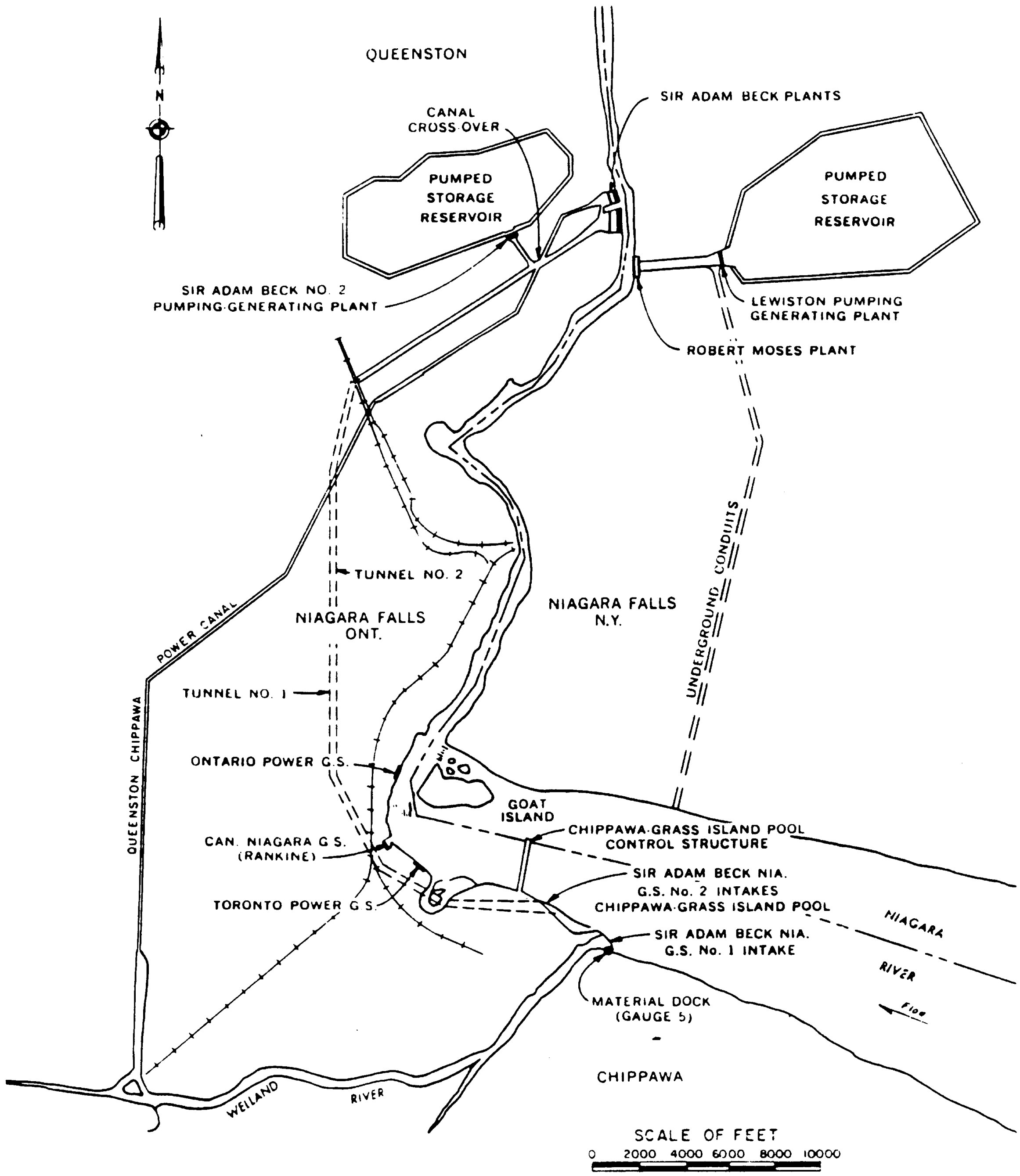

Figure 7. Niagara River - Detail Location of Hydroelectric Power Plants and Diversion Works.

Great Lakes Basin Hydrology

The precipitation, water supplies, and outflows for the lakes are provided in Table 1. Precipitation data include the provisional values for the past month and the year-to-date and long-term averages. The provisional and long-term average water supplies and outflows are also shown.

Table 2
Great Lakes Hydrology[1]

PRECIPITATION								
BASIN	MARCH				YEAR-TO-DATE			
	1992*	AVG.**	DIFF.	% OF AVG.	1992*	AVG.**	DIFF.	% OF AVG.
Superior	1.1	1.8	-0.7	61	3.8	5.2	-1.4	73
Michigan-Huron	2.4	2.2	0.2	109	5.8	6.0	-0.2	97
Erie	2.8	2.8	0.0	100	7.4	7.3	0.1	101
Ontario	3.3	2.6	0.7	127	7.9	7.7	0.2	103
Great Lakes	2.2	2.2	0.0	100	5.7	6.1	-0.4	93

LAKE	MARCH WATER SUPPLIES***		MARCH OUTFLOW[3]	
	CFS[2]	AVG.[4]	CFS[2]	AVG.[4]
Superior	18,000	45,000	77,000	66,000
Michigan-Huron	144,000	184,000	180,000[5]	170,000
Erie	57,000	72,000	206,000[5]	193,000
Ontario	70,000	75,000	232,000	233,000

*Estimated (inches) **1900-90 Average (inches)
***Negative water supply denotes evaporation from lake exceeded runoff from local basin.

[1]Values (excluding averages) are based on preliminary computations.
[2]Cubic Feet Per Second [3]Does not include diversions [4]1900-89 Average (cfs)
[5]Reflects effects of ice/weed retardation in the connecting channels.

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