Construction of Niagara River Remedial Works

REPORT

TO THE

INTERNATIONAL JOINT COMMISSION

UNITED STATES AND CANADA

BY THE

INTERNATIONAL NIAGARA BOARD OF CONTROL

WASHINGTON 30 September, 1960 OTTAWA

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SECTION I

INTRODUCTION

1. PURPOSE AND SCOPE OF REPORT. — This report describes the construction of the Niagara Remedial Works, which was accomplished in the interval between June 1954 and July 1957 by The Hydro-Electric Power Commission of Ontario, hereinafter referred to as "Ontario Hydro", and the Corps of Engineers, U.S. Army, under the supervision of the International Niagara Board of Control. The report includes a summary of the conditions prior to construction and of the plans and objectives adopted by the International Niagara Falls Engineering Board and the International Joint Commission. It also contains a statement of the cost of construction and a discussion of the degree of attainment of the objectives.

2. The report has been prepared in compliance with a directive of the International Joint Commission dated 19 August 1953, described in paragraph 5 following, and to meet the requirements of the Commission as conveyed to the Board orally in the Commission's Executive Meeting of 2 October 1957.

3. THE TREATY OF 1950. — A treaty between the United States and Canada, concerning the uses of the waters of the Niagara River, was signed 27 February 1950 at Washington, D.C., approved 14 June 1950 by the Canadian Parliament, ratified 9 August 1950 by the United States Senate, and put into force 10 October 1950 by an exchange of ratifications between the two Governments. The initial paragraph of the treaty states that the two Governments recognize "their primary obligation to preserve and enhance the scenic beauty of the Niagara Falls and River." Article II of the treaty states, "The United States of America and Canada agree to complete in accordance with the objectives envisaged in the final report submitted to the United States of America and Canada on December 11, 1929, by the Special International Niagara Board, the remedial works which are necessary to enhance the beauty of the Falls by distributing the waters so as to produce an unbroken crestline on the Falls. The United States of America and Canada shall request the International Joint Commission to make recommendations as to the nature and design of such remedial works and the allocation of the task of construction as between the United States of America and Canada. Upon approval by the United States of America and Canada of such recommendations the construction shall be undertaken pursuant thereto under the supervision of the International Joint Commission and shall be completed within four years after the date upon which the United States of America and Canada shall have approved the said recommendations. The total cost of the works shall be divided equally between the United States of America and Canada."

4. REPORT OF INTERNATIONAL JOINT COMMISSION. — In accordance with Article II of the 1950 treaty and the Reference of 10 October 1950 to the International Joint Commission, the Commission submitted its report to the two Governments on 12 May 1953, with recommendations as to the nature and design of remedial works and as to the allocation of the task of construction. The report quotes the reference and describes the action taken thereunder including the appointment of the International Niagara Falls Engineering Board to make the necessary investigation of the Niagara Falls and River and to set forth its findings and recommendations. The Engineering Board's report, dated 1 March 1953, is attached to and constitutes a part of the Commission's report of 12 May 1953. On 21 July 1953, the Commission was notified that its recommendations had been approved and was advised to undertake construction of the remedial works.

5. INTERNATIONAL NIAGARA BOARD OF CONTROL. — The International Joint Commission, in a directive dated 19 August 1953, ordered that:

(a) The International Niagara Board of Control be established, to consist of two members each from the United States and Canada; and

(b) Under the supervision of the Commission, the duties of the Board shall be:

(1) To review and approve the design of the remedial works and to exercise general direction of their construction;

(2) To exercise control over the maintenance and operation of the remedial works as construction progresses to insure certain objectives;

(3) To collaborate with designated representatives of the two Governments in determining the amounts of water available for the purposes of the 1950 treaty and in recording the amounts used;

(4) To submit reports to the Commission as directed and to keep the Commission informed of the progress of construction of the works; and

(5) To make representations to the Commission in regard to any matter affecting construction and operation of the remedial works.

6. The original members of the Board were:

For Canada:

T. M. PATTERSON, *Chairman* —
Chief, Water Resources Division,
Department of Resources and Development; and

A. A. ANDERSON —
Assistant Chief Engineer,
Department of Public Works.

For the United States:

COLONEL W. P. TROWER, *Chairman* —
Division Engineer, Great Lakes Division,
Corps of Engineers; and

FRANCIS L. ADAMS —
Chief, Bureau of Power,
Federal Power Commission.

7. Colonel Trower's title was later changed to Division Engineer, North Central Division. He has been succeeded, in that position and on the Board by Brigadier General P. D. Berrigan, Major General Louis J. Rummaggi, Colonel Harry O. Fischer, and Brigadier General Thomas DeF. Rogers, who is the present Chairman of the United States Section of the Board. Mr. Adams was succeeded on the Board by W. R. Farley, Chief, Division of Licensed Projects, Federal Power Commission.

8. Mr. Patterson's title was changed to Director, Water Resources Branch, Department of Northern Affairs and National Resources. Mr. Anderson was succeeded on the Board in turn by G. H. Thurber and G. T. Clarke, both of the Department of Public Works. Mr. Clarke, Chief Engineer, Development Engineering Branch, Department of Public Works, is the present member.

9. WORKING COMMITTEE. — At its first meeting, in Ottawa, Canada, on 6 and 8 October 1953, the Board of Control established a Working Committee, to consist of two members each from the United States and Canada, to assist the Board in the discharge of its assigned responsibilities.

10. The original members of the Committee were:

For Canada:

C. G. CLINE, *Chairman* —
Hydraulic Engineer, Water Resources Division,
Department of Resources and Development; and

C. W. MORGAN —
District Engineer, Harbours and Rivers,
Department of Public Works.

For the United States:

COLONEL PHILIP R. GARGES, *Chairman*—
District Engineer, Buffalo District,
Corps of Engineers; and

W. R. FARLEY —
Chief, Division of Licensed Projects,
Bureau of Power, Federal Power Commission.

11. Colonel Garges was succeeded in turn as District Engineer and Chairman of the United States Section of the Committee by Colonel Loren W. Olmstead and Colonel Earle B. Butler. Mr. Farley was succeeded by H. M. Hay, Division of Licensed Projects, Bureau of Power, Federal Power Commission.

12. The title of Mr. Cline's agency was changed to Water Resources Branch, Department of Northern Affairs and National Resources. Mr. Morgan was succeeded in his position and on the Committee by R. P. Henderson.

SECTION II

PLAN OF REMEDIAL WORKS

13. Objectives in Design. — The 1950 treaty referred to the objectives envisaged in the 1929 report of the Special International Niagara Board to the Governments of Canada and of the United States of America. The International Niagara Falls Engineering Board (a Board of the International Joint Commission, described in paragraph 4) considered these objectives, changes in conditions since 1929, and changes expected to occur as a result of the increased diversions of water for power permitted by the 1950 treaty. The report of the Engineering Board, dated 1 March 1953 and constituting a part of the 1953 report by the International Joint Commission, established the following criteria to be met by the remedial works:

(a) A dependable flow of water over the American Falls and Rapids and in the vicinity of Three Sisters Islands, approximating the satisfactory intensity experienced under existing conditions;

(b) A dependable and ample flow of water over both flanks of the Horseshoe Falls to provide an unbroken crestline, the intensity of the flank flows to be such as to satisfy the following requirements:

(1) When the total flow over the Falls is 100,000 cubic feet per second, the remedial works should produce a flow per foot of crest length of six to eight cubic feet per second over the Goat Island flank and 10 to 12 cubic feet per second over the Canadian flank; and

(2) When the total flow over the Falls is 50,000 cubic feet per second, the remedial works should produce an unbroken curtain from shore to shore;

(c) Maintenance of the present relationship between the total river flow and the level of the Chippawa-Grass Island Pool; and

(d) Ability to meet promptly the changes in permissible power diversions while assuring flows of either 50,000 or 100,000 cubic feet per second over the Falls.

14. General Plan. — The remedial works proposed by the International Niagara Falls Engineering Board are discussed in Section VI of that Board's report dated 1 March 1953. The plan included three major features which are described below in paragraphs headed: *Chippawa-Grass Island Pool Control Structure, Excavation and Fill on Goat Island Flank*, and *Excavation and Fill on Canadian Flank.* The general locations of these features are shown on Plate 1 of this report. The major features were constructed essentially as proposed; variations in minor detail are noted hereinafter in *Section IV, Construction of Remedial Works.* Two water-level recording stations, which had not been mentioned in the Engineering Board report, were found to be needed for operation of the works and were added to the plan during the construction period.

15. Chippawa - Grass Island Pool Control Structure. — The structure was designed to extend 1,550 feet into the river from the Canadian shore. Except for a short approach fill, the structure designed consists of 13 sluices, each 100 feet wide, separated by concrete piers. A bascule-type gate controls flows through each sluice. A service bridge spans the piers to provide access for operation and maintenance. The dimensions of sluices and piers, and type of gate were selected to minimize interference with the passage of floating ice. The structure need not extend entirely across the river, since some water will be passed at all times for flow over the Falls. The number of sluices was selected on the basis of model studies, but the Board expressed the opinion that a more precise determination of the ultimate length of the control structure should be based on operating experience with completed increments of the structure.

16. Excavation and Fill on Goat Island Flank. — In order to provide adequate flows along the Goat Island flank of the Falls, a deepened channel was designed, leading from the naturally deep channel along the international boundary toward the flank and extending to the brink of the Falls. In the design for improvements on the Goat Island flank, a stone-faced concrete wall incloses a triangular area with a base about 400 feet long on Goat Island, a side of about 300 feet along the brink of the Falls, and the other about 500 feet along the new deep channel. This area is filled with excavated material and landscaped to provide additional viewing space.

17. Excavation and Fill on Canadian Flank. — In order to divert water to an area of inadequate flow on the Canadian flank of the Horseshoe Falls, a deepened channel was designed, extending from the naturally deep channel on the Canadian side of the Cascades to the brink of the Falls. In the design for improvements on the Canadian flank, a stone-faced concrete wall extends along the brink of the Falls for about 100 feet from the old shore line and then continues upstream to meet the old shore about 100 feet above the Falls. The area between the walls and the shore is filled with excavated material to provide additional space for viewing the Falls.

18. Construction Schedule. — The Engineering Board recommended that construction of the control structure be started at the earliest possible date, and be coordinated with increasing diversions so as to reduce to a minimum any adverse effects of the increased diversions. It was also recommended that only one of the two excavations and fill programs, one on each side of the Cascades, be under way at any time.

19. Allocation of Construction. — The Board recommended the following allocation of the task of construction:

(a) To be done by Canada:

(1) Construction of the control structure;

(2) Construction of the excavation and fill on the Canadian flank of the Horseshoe Falls; and

(b) To be done by the United States:

(1) Construction of the excavation and fill on the Goat Island flank of the Horseshoe Falls.

20. Water Level Recording Stations. — Flow over Niagara Falls is determined by measurement of flow through the Maid-of-the-Mist pool below the Falls and subtraction therefrom of measured flows through three Canadian and two United States plants which discharge into the pool. Before the construction of the Sir Adam Beck No. 2 plant, the measurement of the flow through the pool was made by using a stage-discharge relationship which had been established for a water level gauge maintained by the Department of Northern Affairs and National Resources at the foot of Morrison Street on the Canadian side of the river. This gauge was connected to an indicator in the office of the operating superintendent of Ontario Hydro. However, because the increased diversions to be made around the pool on both sides of the river would cause pool elevations to be lower, it would have been necessary to have a deeper well at the Morrison Street site. Because that site is difficult of access, it was decided, rather than deepen the present well or dig a new one near it, to build a new well and gauge house adjacent to the sewage treatment plant at the foot of Ashland Avenue on the United States side of the river, where an elevator is available. The new well was made deep enough to allow for the lower pool elevation that will result when all the proposed diversions are in effect.

21. The project also includes a water level recording station on the United States mainland near the head of the channel leading to the American Falls. The records of this station will provide a basis for determining whether or not flows in this channel are meeting the criterion set by the Engineering Board (paragraph 13(a), above).

22. Since both recording stations were to be constructed in the United States, the task of constructing them was assigned to the United States.

SECTION III

DIVERSIONS FOR POWER

23. Conditions in 1953. — In 1953, before construction of the remedial works was started, water was being diverted directly from Niagara River for power at two points in the United States and at four points in Canada. Both United States diversions were from the Chippawa-Grass Island Pool, one through the Adams plant, the other through a canal and a parallel tunnel to the Schoellkopf plant. In Canada, water was diverted from the Chippawa-Grass Island Pool through a canal to the Sir Adam Beck No. 1 plant, and from the Cascades at three points to the Ontario, Toronto, and Canadian Niagara plants. Plate 1 shows the locations of these intakes.

24. Changes During the Construction Period. — The first of the two new tunnels supplying the Sir Adam Beck No. 2 plant was opened 26 June 1954 and the second was opened in October of that year. Flows in the canal supplying the Sir Adam Beck No. 1 plant were reduced or shut off for short periods in the latter part of 1954 to permit inspection and repairs.

25. On 7 June 1956, a rock fall destroyed part of the Schoellkopf plant and damaged the remainder. Flow through the tunnel was shut off and a cofferdam was built to close the canal. The former diversion of 23,400 cfs ceased entirely until early in 1957. The damaged units were gradually returned to service and the diversion was increased to 6,000 cfs by August 1957. The Adams plant was closed for repairs in July and August 1957 and its diversion of 8,800 cfs was shut off temporarily.

26. Later Changes. — The Power Authority of the State of New York is constructing two parallel conduits from the Chippawa - Grass Island Pool near Conners Island to the new Lewiston plant. At the time the plan for remedial works was developed, it was expected that the Schoellkopf plant would continue to divert 20,000 cfs and that the remainder of the United States share of diversions would pass through the new conduits. However, under the United States Public Law 85-159 approved 21 August 1957 (71 Stat. 401) and the Federal Power Commission license issued 20 January 1958 to the Power Authority of the State of New York, the entire diversion will be made through the new conduits and no diversion will normally be made through the Schoellkopf and Adams plants.

SECTION IV

CONSTRUCTION OF REMEDIAL WORKS

27. GENERAL. — As noted in paragraph 5, the International Joint Commission assigned to the International Niagara Board of Control the responsibility for general direction of construction of the remedial works. The works were constructed essentially as had been proposed by the International Niagara Falls Engineering Board, recommended by the Commission and approved by the two Federal Governments. There were, however, certain items which had not been designed in detail and other items which required modification as the work progressed. This section of the report discusses the actual construction of the remedial works.

28. Ontario Hydro and the Buffalo District, Corps of Engineers, began development of detailed plans and specifications for the work to be done in their respective countries immediately after the works were approved by the two Federal Governments in July 1953. Actual construction of the remedial works project commenced in October 1953 with excavations at the Canadian shore of Niagara River, in which to start cofferdams for construction of the control structure. All works approved for construction were completed to the extent that they were fully operational as of 21 July 1957. The work then remaining consisted of a few minor items such as installation of railing on the bridge of the control structure; lettering on the south facade of the control house; fencing, grading, and general cleanup and landscaping of the area adjacent to the shore end of the control structure. These items were completed prior to the dedication ceremony on 28 September 1957. The excavations and fills on the flanks of the Horseshoe Falls had been completed prior to 21 July 1957. At the direction of the Board of Control, the works were inspected by the Chairmen of the Board's Working Committee on 22 July 1957 and copies of their inspection report were forwarded to the Commission 20 August 1957.

29. CONTROL STRUCTURE. — Specifications for the gates and operating equipment were prepared for Canada by Ontario Hydro and reviewed for the United States by the Corps of Engineers. Tenders for design and manufacture were requested from selected firms with a closing date of 2 November 1953. On 7 January 1954 the Board approved award of a contract in the amount of $1,787,567 to Canadian Vickers, of Montreal, who, working with Maschinenfabrik Augsberg-Nurnberg AG (M.A.N.) of Germany, had offered equipment meeting the specifications and generally similar to a design proposed in the 1953 report.

30. Detailed drawings and design analysis for the gates were approved by the Board of Control 16 March 1954. The manufacturers then furnished details of bedded parts so that preliminary designs of piers and rollways could be modified to accommodate them. A model of a sluice was constructed at Islington, Ontario, to check the hydraulic performance of the gate and to compare the hydraulic effects of various shapes of pier noses.

31. Since unwatering for construction of the structure would occur in successive stages, and since the river bottom was nearly bare and level rock, the cofferdam was designed to be re-used. It consisted of steel cribs loaded with 6-ton concrete blocks and faced with steel sheet piling. After tests of frames fabricated by Ontario Hydro, a design was adopted and orders for volume production were placed with Standard Steel and Dominion Bridge Company. Deliveries started 16 March 1954. Concrete blocks were cast by Ontario Hydro forces, 30 at a time.

32. Construction of the cofferdam started in October 1953. Approximately 4,500 cubic yards of earth were excavated to form two pockets in the river bank in which to start the ends of the first stage of the cofferdam. Rock-filled timber cribs, 30 feet wide, were built, 95 feet long for the upstream leg and 65 feet for the downstream leg, with a total volume of approximately 3,000 cubic yards.

33. The cofferdam frames were kept in alignment by rollers on each frame which fitted into guides attached to the frame previously placed. After a frame was in position, heavy steel H-section columns were driven through it a few inches into the limestone of the river bed. After any projecting parts of the columns had been cut off, a cap beam was placed across them at the level of the top of the frame to support the precast concrete blocks, of which 30, each 10 x 2½ x 3 feet, were placed on each 10 x 30-foot frame. The load was carried solely by the columns and the frame served to distribute the water pressure to the columns.

Steel sheet piling on the river face of the cofferdam was driven to penetrate two or three inches into the river bed. Earth fill was then placed along the base of the piling to complete a watertight seal. Each stage of the cofferdam was pumped dry in one day. After unwatering, struts were installed to strengthen the upstream side of the cofferdam against possible ice pressure.

34. This method of construction provided a roadway on top of the concrete blocks, extending all around each work area in turn. Within each stage of the cofferdam except the first, a ramp was constructed to permit access from the roadway to the construction area on the river bottom. After each pier was built, a temporary trestle of Bailey bridging was extended across to the downstream end from the previous pier. The trestle provided access across the completed sluices to the later stages of concrete construction and also provided access to the pier tops for cranes used in setting gates and girders for the service bridge. As soon as the concrete deck set, the service bridge itself was also used for access. Photograph 1 shows the cofferdam arrangement for stages 1 and 2 of the program, as indicated on Plate 3. Photograph 2 shows construction within that cofferdam. Photograph 3 shows the portion of the control works completed in stages 1 and 2 and the cofferdam arrangements for stages 3 and 4. It demonstrates also the temporary trestle across the downstream ends of the completed piers and the ramp arrangement leading into the stage 3 cofferdam. Photograph 4 records construction progress in stages 3 and 4. Photograph 5 shows the portion of the works completed in the first four stages and the cofferdam and ramp arrangement for the final stage.

35. On 1 June 1954, the Board of Control presented the International Joint Commission a revised construction plan which would have changed from a four-stage to a six-stage construction program. Work could then have been shut down in the winter and construction costs would have been reduced, but the construction period would have been longer than the four years specified in the 1950 treaty. The revised plan was not approved, principally because of the treaty provision.

36. In practice, there was little trouble from ice and work was carried on continually. The last two stages were combined, four gates being built in a single cofferdam and thus the work was completed on time. The construction schedule actually followed is shown in Plate 3. Photographs 6 and 7 show the completed structure in operation.

37. A diamond drill test hole at the site of the structure confirmed that rock conditions there were similar to those at nearby structures where it had been found necessary to grout the rock before excavating it. After the area in the first stage cofferdam was unwatered in June 1954, it was blanketed to permit excavation to at least 4 feet below the existing river bottom. About 4,000 linear feet of drilling and 15,600 bags of cement were needed.

38. Each pier of the control structure was designed to resist an ice thrust of 560,000 pounds in addition to hydrostatic loads. Piers are 91 feet long, with a sloping cut-water upstream, and 14 feet wide at the base. A portion of each pier is widened on both sides at the top to form a cantilever extension 14 feet long, used as part of the service deck and as a support for the service bridge. Each span of the bridge consists of six precast, prestressed concrete girders, with a clear span of 72 feet, connected by cast-in-place diaphragms and roadway slabs. Girders, diaphragms, and slabs were prestressed laterally to assure proper load distribution. The Stress-steel system was used in all prestressing. The deck was designed to carry a 70-ton crawler crane or to support the loads from a 45-ton crane working on it at any point. Oil pressure pipes, power cables, and control cables are carried below the deck between the girders.

39. Plate 2 shows a cross section taken between two adjacent piers of the control structure, in which the general shape and positioning of the fishbelly type gate is illustrated. The body of the gate is secured at its lower edge to the sill of the sluice by 18 hinges, spaced at regular intervals, which transmit horizontal loads from the gate to the structure. In the fully closed position, the gate extends 10.5 feet above the sill. In the fully open position, the highest point of the gate is level with the sill. Rubber seals on each end act against stainless-steel-clad plates embedded in the piers to prevent water flowing around the ends of the gate.

40. The rollway of each sluice measures 64 feet between upstream and downstream edges. The gate sill is at the same elevation as the crest of the submerged rock weir upstream. The downstream portion of the rollway has a bucket shape to disperse the energy of the water flowing through the sluice and so reduce erosion of the rock bottom downstream. Model tests by the manufacturer showed that water flowing over a gate in an unbroken curtain would produce a partial vacuum behind the gate affecting the discharge capacity and increasing the force required to raise the gate. This difficulty was overcome by introducing air back of the gate by means of flow splitters on the crest and breather pipes of 20-inch diameter embedded in the piers and extending above water level.

41. Each gate is rotated on its hinges by trunnions passing into the piers at each end of the gate, connected to driving levers inside the piers. These are in turn connected to hydraulic pistons. The gate is normally operated from both ends at once, but it is rigid enough to operate from either end alone under normal hydrostatic load.

42. Each gate has its own hydraulic system. A 40-horsepower motor-driven pump forces oil from a sump tank into hydraulic cylinders in adjacent piers to move pistons and raise the gate. The gate is lowered by releasing oil from the cylinders to the tank. The system normally operates at 400 pounds per square inch, but can be operated safely at pressures up to 1,000 pounds per square inch if necessary to overcome ice loads. If, because of ice pressure or for some other reason, pressure in the hydraulic system should exceed 1,000 pounds per square inch, breakable pressure heads would rupture and release oil from the operating cylinders through emergency discharge lines to the sump. The gate would start to drop, but its movement would gradually close a valve in the discharge line so that it would reach the open position gradually, without damage.

43. Each gate also has a central electric heating system of 110-kilowatt capacity, which circulates hot oil to the seal plates on the sides of the piers and to seals and hinges at the gate sill, to prevent icing. The heating system is controlled automatically by outside air temperatures.

44. Control Building. — Gates are operated from the second floor of a two-storey stone-faced concrete building at the inner end of the structure. The lower floor contains control equipment and lockers for the operators. The control room provides views of the structure and of the river upstream and downstream. A panel on the river side shows the positions of all gates and contains operating switches. Photograph 8 shows the building and Photograph 9, the control panel. Each gate can also be operated from an individual panel in an adjacent pier. This method was used during the construction period and could be used in emergencies if the central controls were not operable.

45. Excavation and Fill on Goat Island Flank. — Plans and specifications for the work, prepared by the Buffalo District of the Corps of Engineers, were approved by the Board 8 January 1954. After bids were opened 2 March 1954 a contract was awarded to McLain Construction Corporation of Buffalo, 15 March. A plan is shown in Plate 4.

46. The Contractor submitted a plan for unwatering all but a length of approximately 100 feet at the upstream end in the first stage and the remainder in the second. Photograph 10 shows the first 200 feet of steel sheet piling in the first stage cofferdam, which was completed 2 August 1954. Photograph 11 shows the lower end of this cofferdam. The second stage was completed 30 September 1954.

47. A detailed survey of the area unwatered in the first stage showed appreciable deviations from the survey on which the 1953 report was based. In the upstream portion of the excavated area, actual elevations were two feet higher than expected. Soundings taken outside the upper part of the cofferdam with a 3,000-pound weight suspended from the boom of a crane also showed the river bottom to be two feet higher than expected. In accordance with the recommendations of the Working Committee, the Board approved, 31 August 1954, a minor adjustment at the upper end of the excavation area and two additional small cuts at the southwest corner of the excavation area adjacent to the brink of the Falls.

48. In order to approximate the roughness of the natural river bed and to provide for turbulence in the water flowing over the excavated area, the Board, at the same meeting, also approved Committee recommendations to leave several small areas at their existing elevations to form small islands; and to retain a number of large boulders near the lower end of the excavation area.

49. After excavation had been ostensibly completed by the Contractor, a survey showed that elevations in some places were still higher than called for by the contract. When the models were revised to this condition and tested, it was found that insufficient water would reach the crest to supply the required flow at some points. The tests also indicated that one of the small islands and several of the boulders, which the Contractor had been instructed to leave in place, would have to be removed. A plan for additional excavation, developed by model studies and followed carefully in the field, finally produced the required depths of flow at the crest and also produced sufficient turbulence to give a satisfactory scenic spectacle. Photographs 12 and 13 show progress of the excavation near the lower end of the work area. Photograph 14 shows the lower end of the work area after excavation was finished. Photograph 15 shows removal of the cofferdam.

50. On 5 August 1954, after the flank of the Falls was unwatered, an inspection of the bluff was made by geologists of the Corps. It was found that the cap rock near the crest was undercut and broken, with open seams along the major planes of fracture. In view of this unstable condition, the Board approved, 31 August 1954, the recommendation of the Committee to locate the wall, designed to retain the fill, farther from the crest than originally planned. The location finally adopted, averaging about 30 feet upstream from the original position, is shown on Plate 5. This change was approved by the Division of Parks of the New York State Conservation Department.

51. Model testing to determine the final excavation conditions accentuated the fact that the area between the excavated channel and Goat Island would be above the water line at a flow of 100,000 cubic feet per second. This part of the old river bed was strewn with boulders. The Working Committee was assigned the development of a plan to make the area harmonize with the park landscaping, and on 22 December 1954 the Committee submitted a plan for using rock from the cofferdam to bring this area above the water line at little cost except for topsoil and final grading.

52. The Committee also developed a plan for treatment of the fill area inside the retaining wall. Plate 5 shows the arrangement of walks and stepped ramps leading from Goat Island to paved areas adjacent to the wall. The plan also included placing topsoil and grading preparatory to seeding. The plan was approved by the Board of Control 31 August 1954 and later was accepted by the Division of Parks. The final result is shown in Photograph 16, which also shows the short wall which was built from the main wall to the crest of the Falls to keep water from the area between the latter wall and the dry bluff. The International Joint Commission inspected this end of the Horseshoe Falls 13 April 1955 and approved its appearance. The fill area was turned over to the Division of Parks 3 November 1955.

53. Excavation and Fill on Canadian Flank. — This work was accomplished by Ontario Hydro, starting in April 1955. A plan is shown in Plate 6. Removal of 70,000 cubic yards of rock was completed 1 September 1955. After completion of the excavation, models at Islington and Vicksburg were revised to the new topography. Tests then showed that flow conditions would be satisfactory at discharges of 100,000 and 50,000 cubic feet per second. At a meeting 12 September 1955, the Board of Control received the reports of the tests and inspected the site, then authorized removal of the cofferdam. Photograph 17 shows the areas with the cofferdam partly removed.

54. The stone-faced concrete wall, originally planned to extend along the brink of the Falls for about 100 feet out from the old shore line, was actually extended to a point only 55 feet out. This modification was made since the model results showed an ample coverage of water over the longer crest line and since the shorter extension of the wall assured Canadian park authorities that the outlook portal from their tunnel under the Falls would not be unwatered by the remedial works and that the increased water curtain would improve this tourist attraction.

55. On 4 October 1955, the Board approved the request of Canadian park authorities that the ornamental stone wall be extended from the observation point at Table Rock upstream to meet the stone wall below the Canadian Niagara Power Plant, as a safety measure against the increased hazard resulting from the excavation and the increased flow of water along the Canadian shore in that area.

56. Photographs 18 and 19 show conditions after completion of work at the Horseshoe Falls. The combined flow over the Falls 24 November 1955, in Photograph 18, was 95,000 cubic feet per second. In Photograph 19, 19 March 1956, the flow was 63,000 cubic feet per second. For comparison, Photograph 20, taken 5 December 1950 before construction was started, shows a flow of 107,000 cubic feet per second.

57. Water Level Recording Station for Maid-of-the-Mist Pool. — This water level gauge is located at the downstream side of the Niagara Falls, New York, sewage treatment plant, near the foot of Ashland Avenue, and is accessible at all times through the plant, to which it is connected by new steel stairways and walkways. The principal feature of the gauge station is a reinforced concrete well, five feet square on the inside. The well penetrates about 25 feet into thin bedded shales and sandstones overlain by 10 feet of rock fragments. Ladder rungs in one wall provide access to the well. The well is connected to the river by a six-inch pipe about 73 feet long, sloping down at 1 on 20 from the well. The highest point of the intake will be below the pool surface at all flows permitted by the treaty. At the river end, a section of pipe 1.75 feet long is attached by a short radius 90-degree elbow and points downstream. This section is plugged, but contains 64 holes and serves as an intake and screen. It was first intended to drive the long pipe from the well but, when difficulties were encountered in penetrating the layer of rock fragments, a trench was dug and backfilled after the pipe was placed.

58. The six-inch pipe fills the well through a three-inch pipe controlled by a valve operated from the gauge house. The smaller pipe is also connected to a pump-filled 60-gallon flush tank, operated from the house.

59. The gauge house is a concrete structure located over the well. The building is lighted and heated electrically. It contains two recording gauges operated by the United States Lake Survey which record at the site, and two telemeter gauges operated by Ontario Hydro which transmit the record to its office in Niagara Falls, Ontario. Photograph 21 shows the exterior of the building.

60. The structure was constructed under contract by Herbert F. Darling. Work was started 8 August 1956 and completed 2 July 1957. The International Niagara Committee, created by Article VII of the 1950 treaty, approved a rating for the Ashland Avenue gauge, based on the old Morrison Street relation plus 0.26 foot, and the operators were instructed to change over to this new rating at 1:00 a.m., 17 June 1958.

61. Water Level Recording Station for American Channel. — This station is located near the head of the channel. It is a hexagonal stone structure, with a maximum outside dimension of 8 feet, superimposed on a reinforced concrete well of the same shape, 10 feet deep. The floor of the well is about 3 feet below the general rock surface at the site. The well is connected to the river by a six-inch pipe laid in a trench in the rock. In the riverward end of the trench, this pipe is inside a twelve-inch pipe and the space between is filled with spun-glass insulation. The trench is back-filled with concrete around the larger pipe. Electric heating is also provided to reduce the possibility of ice forming at the outer end of the pipe. Arrangements are provided for flushing the pipe.

62. The building is lighted and heated electrically and contains a gauge operated by the United States Lake Survey. Photograph 22 shows the exterior of the building.

63. The structure was constructed under contract by McLain Construction Corporation. It was completed in May 1955.

SECTION V

COSTS

64. Expenditures in each country with respect to the units of the remedial works located in that country are shown in the tabulation below. Owing to the fact that the control structure is located on the Canadian side of the boundary, the bulk of the construction occurred in Canada. However, costs were divided equally between the two countries, monthly, on the basis of the exchange rates current at the time of payment.

Feature	Costs in Canadian Dollars for Items Constructed in or by Canada	Costs in U.S. Dollars for Items Constructed in or by U.S.
Direct cost		
Control structure	$ 8,287,203.63	—
Canadian Flank of Horseshoe Falls	418,676.00	—
U.S. Flank of Horseshoe Falls	—	$ 757,142.78
Gauging stations	12,244.51	107,539.85
Indirect costs, including temporary construction facilities, engineering, construction supervision and administrative costs	1,931,688.77	358,244.89
	$ 10,649,812.91	$ 1,222,927.52

The total cost of constructing the works was $11,844,433 in Canadian currency or $12,107,152 in United States currency. The original estimate, shown in the 1 March 1953 report of the International Niagara Falls Engineering Board, was that the total cost of constructing the project would be $17,536,000.

65. Each of the three principal items of the remedial works was constructed at a cost materially less than the original estimate. The Board here records its commendation to The Hydro-Electric Power Commission of Ontario and the Buffalo District, Corps of Engineers, U.S. Army, for performance of their assigned tasks with outstanding records of efficiency and safety.

66. The tabulation in paragraph 64 shows the total direct and indirect costs for construction of the remedial works. The item of engineering in the indirect costs includes only the engineering work directly associated with the construction. It does not include the costs incurred by the International Niagara Falls Engineering Board in developing the plans for the project, nor those for operation and maintenance of the completed project. Expenditures by the Engineering Board were reported to the International Joint Commission by a letter dated 5 May 1953, which contained the recommendation that, since such expenditures were nearly equal, each country should absorb its own costs. The Canadian expenditure was $225,359.53 in Canadian currency; the United States expenditure was $239,164.20 in United States currency.

67. Prior to July 1957, when the works became completely operable, charges for operation and maintenance were included in the construction costs. Since that date, the annual expenditure for operation and maintenance has averaged about $98,000 in Canadian currency or $101,000 in United States currency. The International Niagara Falls Engineering Board estimated the annual cost of these items at approximately $100,000. Costs for operation and maintenance since July 1957 have been divided equally between the two countries, on the same basis as the construction costs.

SECTION VI

OPERATION DURING CONSTRUCTION

68. Operating Instructions. — The International Niagara Board of Control was assigned the responsibility by the International Joint Commission of exercising control over the maintenance and operation of the remedial works as construction progressed to insure certain objectives. Operating instruction and requirements for records and reports were contained in a letter, dated 30 June 1955, from the Board of Control to Niagara Mohawk Power Corporation and The Hydro-Electric Power Commission of Ontario, which is quoted in full in Appendix A to this report. The instructions were revised, with regard to tolerances for levels of the Chippawa-Grass Island Pool, in a letter dated 2 October 1956, also quoted in the appendix.

69. Records of Diversions and Pool Levels. — Changes in diversion rates during the construction period are described in paragraph 24, above. Plates 8 and 9 show graphically Canadian and United States diversions and the total diversion from the Chippawa-Grass Island Pool, day by day for the years 1954-1957, inclusive. During these years, flows over the Falls met the requirements of the 1950 treaty, except for a few short periods when errors in transmission of readings from the Morrison Street gauge led to slight excesses in diversion.

70. Plates 10 and 11 show the combined effect of the diversions and the construction work on the elevation of the Chippawa-Grass Island Pool at the Slaters Point gauge near the upper end of the pool. The zero line on these plates represents stages computed by a formula which applied in March 1954 before the control structure cofferdam was started:

Computed G.H. = 560.49 + 0.301 (Q — 160,000)/10,000, where Q is the discharge through the Maid-of-the-Mist Pool. The estimated average effect of weeds on pool stages has been plotted as a broken line above the zero line, showing how much pool stages are usually raised for this reason at various times of the year. The broken line where shown and the zero line at other times represent stages which would have been expected under March 1954 conditions, which will be referred to as normal conditions. The difference between the normal stage and the observed stage is the net change in water level as a result of the combined effects of increased diversion, and construction and operation of the control structure. It is not possible to predict the effect of ice runs and no attempt has been made to adjust normal stages to show such effects.

71. Similar equations have been derived for other gauges in the pool. The Slaters Point gauge has been used here to show the effect at the upper end of the pool, but in the absence of telemetering equipment there, the record of the Material Dock gauge, farther downstream, is used in operation of the control structure.

72. Operations. — Until the first stage of the control structure cofferdam was removed so that gates could be operated, there was no effective control of pool elevations. During the early summer of 1954 the water level at Slaters Point rose gradually as shown in Plate 10 and reached a maximum of 0.3 foot above normal gauge height by June. Then the gradual increase in Canadian diversion, as shown in Plate 8, brought the pool back to the normal elevation by the end of the year.

73. During the early months of 1955, as shown in Plate 10, the pool was kept near the computed elevations except that ice runs caused it to rise an extra one foot during the last week in January and two feet during the last half of March. The gradual increase in Canadian diversion during the spring lowered the pool until by June, it was 0.4 foot lower than normal.

74. By 25 July 1955, the first cofferdam had been removed and gates 1 and 2 could be operated. By 15 September, gates 3 and 4 were also in use. In a letter dated 30 June 1955, the Board instructed the power entities to start operating the gates 16 July or as soon thereafter as they were ready, so as to keep the average water level as close as possible to the normal stage. To meet the needs of practical operation, the Board

established tolerances of: plus or minus 0.5 foot for the daily mean elevation; and plus or minus 0.3 foot for the monthly mean. The placing of the third stage cofferdam early in September could have raised the pool above normal elevations but, by opening the completed gates, it was possible to keep it well within the specified tolerances for the rest of the year, as shown in Plate 10.

75. During the first five months of 1956, the pool was kept close to the normal elevations, as shown in Plate 11, the variations being well within the tolerances set by the Board except for one day during the spring ice run. During the latter part of May, special permission was granted by the Board to draw the pool down to facilitate removal of the third stage cofferdam. After the closing of the Schoellkopf plant in June, the pool was consistently high during the rest of year even with all gates wide open. In its 30 June 1955 letter, the Board had included a statement that it would allow an extra plus tolerance of a reasonable amount during the construction period if all gates were open. In view of the change in diversion, the Board, on 2 October 1956, made this extra allowance definite by modifying the original directive to establish new plus tolerance for the daily and monthly means of 0.7 foot and 0.5 foot, respectively, during periods when all available gates were open. This change was effective until the last four gates came into operation 22 July 1957.

76. Plate 11 shows conditions in 1957. Until the last cofferdam was removed, the pool remained above normal elevations but never exceeded the new tolerances set by the Board except during the ice runs in January, March and April. After 22 July, the pool was close to computed elevations except for the period when the Adams station was shut down, but, even then, it never exceeded the permitted tolerances.

SECTION VII

PUBLIC RELATIONS

77. GENERAL. — At its meeting in Ottawa in October 1953, the International Joint Commission granted the request of the Board of Control that the latter be empowered to determine and execute a program of public relations during the period when construction activity would focus tourist attention on the changes being made in the appearance of the Falls. This program, which was developed in cooperation with the construction agencies, included the establishment of suitable exhibits on both sides of the river with attendants to explain and illustrate the need for, and the results to be expected from, the construction activities. The approved program also included the making of documentary 16-mm. coloured film of the entire construction with interim films suitably edited for release at intervals. These measures, together with news releases to the press, and radio and television programs, were successful in forestalling unguided speculation which might have led to unfavourable publicity.

78. CEREMONIES. — On 2 June 1954, the International Joint Commission held ceremonies on Goat Island to mark the start of excavation there, and on the Canadian side at the site of the control structure to mark the start of construcion. There was a smaller ceremony at Niagara Falls, Ontario, 13 April 1955, at the start of work at the Canadian end of the Horseshoe Falls. An appropriate ceremony was held 3 November 1955 when the Terrapin Point fill area was turned over to the New York State Division of Parks.

79. A dedication ceremony at the control structure 28 September 1957, followed by a luncheon, marked completion of the structure and the remedial works as a whole. The principal speakers were the Honorable Wilber M. Brucker, Secretary of the Army, for the United States; and the Honorable Alvin Hamilton, Minister of Northern Affairs and National Resources, for Canada.

80. PLAQUE. — Photograph 23 shows the aluminum plaque which has been attached to the gate post at the entrance to the parking lot at the control structure. This plaque commemorates the action of the two Governments and the responsibility of the International Joint Commission in the preservation and enhancement of the scenic beauty of Niagara Falls under the Treaty of 1950.

SECTION VIII

MODEL AND PROTOTYPE TESTS OF COMPLETED STRUCTURE

81. HYDRAULIC MODELS. — The hydraulic model of the upper river and Falls which the Corps of Engineers built at its Waterways Experiment Station at Vicksburg, Mississippi, and the hydraulic model of the Chippawa-Grass Island Pool and Falls which Ontario Hydro built at Islington, Ontario, for the design studies under the International Niagara Falls Engineering Board were made available to the Board of Control for testing purposes. Photograph 24 shows a view of the model at Vicksburg and Photograph 25 shows the model at Islington.

82. PURPOSE OF MODEL TESTS. — In January 1959 the Board of Control decided that additional tests in the hydraulic models were needed to determine the adequacy of the control structure, as built, to maintain desired water surface elevations in the Chippawa-Grass Island Pool. The tests conducted in the models to determine the length of control structure for the purposes of the 1953 report of the International Joint Commission, hereinafter referred to as the 1953 tests for convenience of reference, used a somewhat different plan of power development on the United States side of the river than is now under construction. Also, it was considered that a more accurate determination of the length of control structure required, under conditions to be met in the full range of flows and diversions, could be made with the models adjusted to conform to the actual performance of the prototype in November 1957 with the completed control structure in place and operating. A program of tests was devised to determine separately the effects of verifying the models to the November 1957 prototype performance, the change in plan for the Conners Island intake from that used in the 1953 tests to that now under construction, and the change in the pattern of diversions from that used in the 1953 tests to the present plan to divert all of the United States share of the waters through the Conners Island intake. For ease in later reference, the intake used in the 1953 tests is referred to as the 1953 intake and the pattern of diversions used in the 1953 tests is referred to as the 1953 diversions. The 1953 diversions contemplated that the first 20,000 cfs of the United States share of the waters would be diverted through the Schoellkopf intake, and the remainder up to a maximum of 75,000 cfs would be diverted through the Conners Island intake.

83. MODEL TEST PROGRAM. — A series of tests designated as Group 4 was conducted to obtain the stage-discharge relation at the Material Dock gauge using the 1,550-foot long control structure with all gates closed. The 1953 intake and the 1953 diversions were used for this series so that the resulting stage-discharge relation could be compared directly with the same item developed during the 1953 tests and shown in Table G-5 of the 1953 report. The difference between the two ratings is then attributable entirely to the re-adjustment of the models to conform to the November 1957 prototype performance.

84. Another series of tests designated as Group 6 was conducted to obtain the stage-discharge relation at the Material Dock gauge with the Conners Island intake changed to conform with the one now under construction by the Power Authority of the State of New York and all other conditions the same as the Group 4 tests. Any difference between this rating and the one obtained in the Series 4 tests is attributable to the change in the intake plan.

85. A series of tests designated as Group 8 was run to obtain the rating at the Material Dock gauge with the pattern of diversions changed to that presently proposed and all other conditions the same as in the Group 6 tests. The change consists of shifting 20,000 cfs of diversion from the Schoellkopf intake to the Conners Island intake, a change in the maximum United States diversion from 95,000 to 100,000 cfs, and a shift of a small amount of diversion from the Sir Adam Beck intakes to Canadian Cascades' intakes for low river flows. The difference between the rating so obtained and the one for Group 6 is attributable to the change in the pattern and amounts of diversion.

86. For each of the three groups referred to above, additional tests were run with the same diversions and intake plan to determine the number of gates in addition to the thirteen in the completed structure, if any, which would be required to hold the water surface in the Chippawa-Grass Island Pool at the levels prescribed by the Board.

87. Results of Model Tests. — All of the tests described in the preceding paragraphs were conducted in the model at the Waterways Experiment Station, Vicksburg, Mississippi, but only the Group 8 tests were run in the Islington, Ontario, model. Pertinent test results are shown in tabular form below and plotted rating curves are shown in Plate 7.

Water surface elevations at Material Dock Gauge — in feet, U.S.L.S. 1935 datum:

Condition	River flow in cfs				
	170,000	200,000	220,000	230,000	240,000
Prescribed by Board of Control	561.9	562.8	563.4	563.7	564.0
1953 Tests —					
Vicksburg	562.2	562.9	563.3	563.5	563.7
Islington	561.8	562.8	——	——	563.9
Group 4	562.00	562.54	562.90	563.14	563.32
Group 6	561.88	562.48	562.90	563.14	563.32
Group 8 —					
Vicksburg	561.88	562.48	562.78	562.84	562.90
Islington	561.75	562.45	562.85	562.85	562.90

88. The 1953 tests had indicated that the 1,550-foot long control structure would result in water-surface elevations at Material Dock gauge somewhat lower than the levels prescribed by the Board for river flows of 220,000 cfs or greater; the deficiency being up to 0.3 foot at a river flow of 240,000 cfs. Group 4 tests show that the deficiency would be greater ranging from 0.68 foot at a river flow of 240,000 cfs to no deficiency at 170,000 cfs. Comparison of Group 6 and Group 4 tests wherein flow conditions were the same and other physical conditions differed only by the use of different intakes, shows that the type of intake has very little effect on the stage-discharge curve.

89. Comparison of Group 8 and Group 6 tests wherein all physical conditions were the same except the pattern and volume of diversion, shows an additional decrease in levels ranging from 0.42 foot for a flow of 240,000 cfs to no lowering at 200,000 cfs. In none of the tests was there any evident adverse effect on the flows in the vicinity of Three Sisters Islands or the distribution of flow around the crest of the Horseshoe Falls.

90. Prototype Tests. — Analysis of model study results included consideration of a possible distortion effect on the model, which could make pool elevations indicated by model tests lower than actually would occur in the prototype under corresponding conditions. In view of this possibility, which had been indicated by a demonstration on the Islington model, the Board arranged for measurements of river flow and Chippawa-Grass Island Pool levels with all gates in the control structure closed. The measurements were made during the period 11-15 December 1959 by Ontario Hydro in cooperation with the Power Authority of the State of New York and the Board's Working Committee.

91. Measurements of river flows and pool levels encompassed four periods of several hours each, wherein flow and level conditions were substantially stable. These measurements provide points on a rating for flow past the control structure with all gates closed, as do the data from the model tests (Groups 4, 6 and 8). Flows past the structure in the prototype tests ranged from about 100,000 to 110,000 cfs, whereas those in the model tests ranged from 51,000 to 81,000 cfs. Despite the difference in flow ranges between the prototype and model tests, it appears, from plottings of rating curves for flows past the closed control structure against

pool levels at the Material Dock and Slaters Point gauges, that the two series of data, one from the prototype and the other from the model, align fairly well. There is no indication that the model produces pool levels which are lower than can be expected in the prototype.

92. Discussion of Test Results. — The control structure as built is of insufficient length to hold the level of the Chippawa-Grass Island Pool at the levels prescribed by the Board of Control under all conditions. During the daylight hours of the tourist season, there should be no difficulty in holding the pool at the prescribed levels while diverting for power all the water permitted by the 1950 treaty. During the non-tourist season and the night hours of the tourist season, if all the water permitted by the treaty is drawn for power purposes, the deficiency in the level of the pool at Material Dock gauge will range from 1.1 feet at a river flow of 240,000 cfs to none at 170,000 cfs. The addition of three sluices to the control structure would make it possible to maintain the levels prescribed by the Board while diverting all the water permitted by the Treaty.

93. The change in the plan for the Conners Island intake has no effect on the stage-discharge relations at the Material Dock gauge. The shift of 20,000 cfs of diversion from the Schoellkopf to the Conners Island intake and the increase in the maximum diversion capacity by the United States plants will reduce the level of the pool by 0.4 foot at a river flow of 240,000 cfs. Any future improvements which would increase the capacity to divert water from the pool will cause a further decrease in levels which can be estimated roughly at 0.05 foot for each additional 1,000 cfs so diverted.

SECTION IX

CONCLUSIONS

94. On the basis of operating experience since completion of the remedial works, and model tests of the works as built, it is concluded that the items (a), (b), and (d) of the objectives listed in paragraph 13 have been met. With regard to objective (c), when the power development now under construction in the United States by the Power Authority of the State of New York is completed, the results of the model tests indicate that the Chippawa-Grass Island Pool can not be maintained at the presently prescribed levels if the power entities divert all the water permitted by the 1950 treaty during the non-tourist season or the night hours of the tourist season, except during periods of very low river flows. Under present operating instructions, the maintenance of authorized pool levels will require reduction of diversions. No estimates are available as to the volume or value of water that may be lost to power, nor whether such loss, if any, would warrant an extension of the control structure. It is considered that these are matters for study by the power entities concerned. Any proposal for an extension of the control structure would need to be analyzed carefully as to the effect of the longer structure on ice formation and the passage of ice.

SECTION X

ACKNOWLEDGMENT

95. In connection with its investigations for this report the Board acknowledges the high degree of cooperation it has had from the Waterways Experiment Station of the Corps of Engineers, Ontario Hydro, the Power Authority of the State of New York, and members of their staffs in hydraulic model studies and from these two power organizations and Niagara Mohawk Power Corporation in the prototype tests conducted by Ontario Hydro for the Board in the period 11 to 15 December 1959.

INTERNATIONAL NIAGARA BOARD OF CONTROL

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MR. T. M. PATTERSON —
Director, Water Resources Branch,
Department of Northern Affairs and
National Resources,
Ottawa, Ontario.

MR. G. T. CLARKE —
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North Central, Corps of Engineers,
Chicago, Illinois.

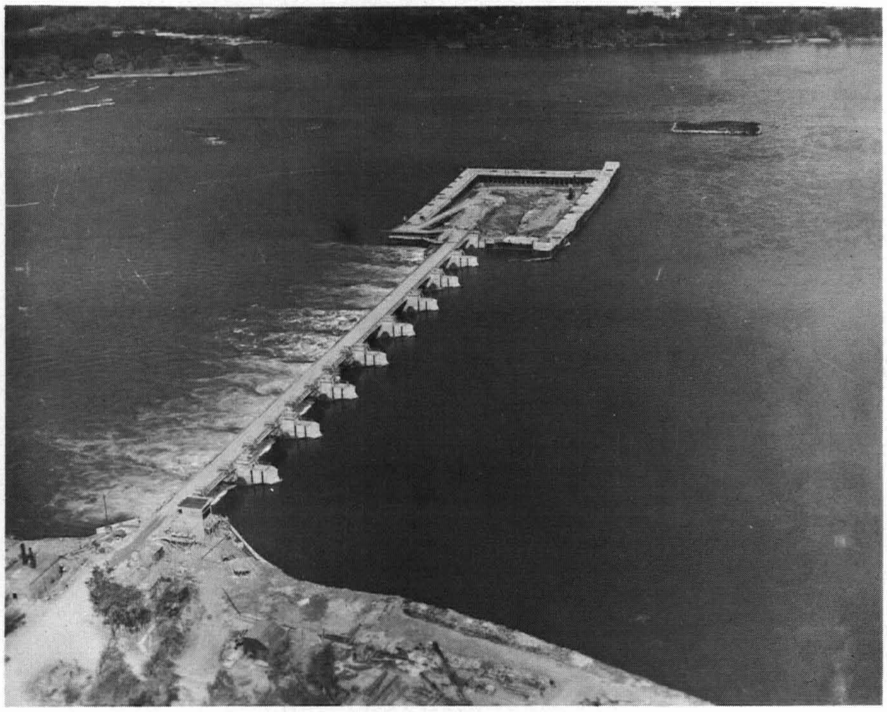
MR. WILLIAM R. FARLEY —
Chief, Division of Licensed Projects,
Bureau of Power, Federal Power Commission,
Washington, D.C.

Photograph 1. Cofferdam for first four gates, control structure, 7 January, 1955.

Photograph 2. Erection of piers for first four gates, control structure, 10 March, 1955

Photograph 3. First four gates in operation, stages 3 and 4 unwatered, control structure, 27 September, 1955.

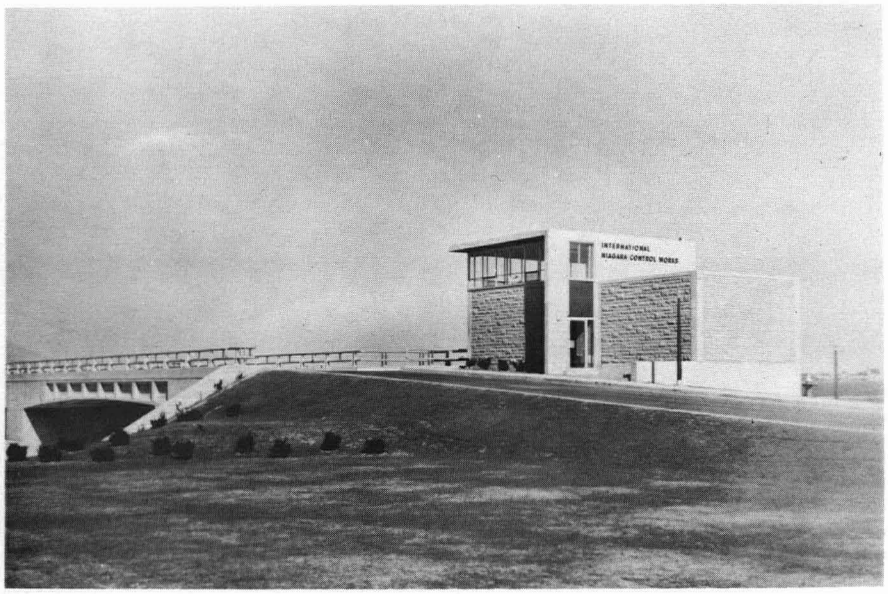
Photograph 4. Five gates in various stages of completion, control structure, 19 March, 1956.



Photograph 5. Nine gates in operation, last cofferdam unwatered, control structure, 25 September, 1956.

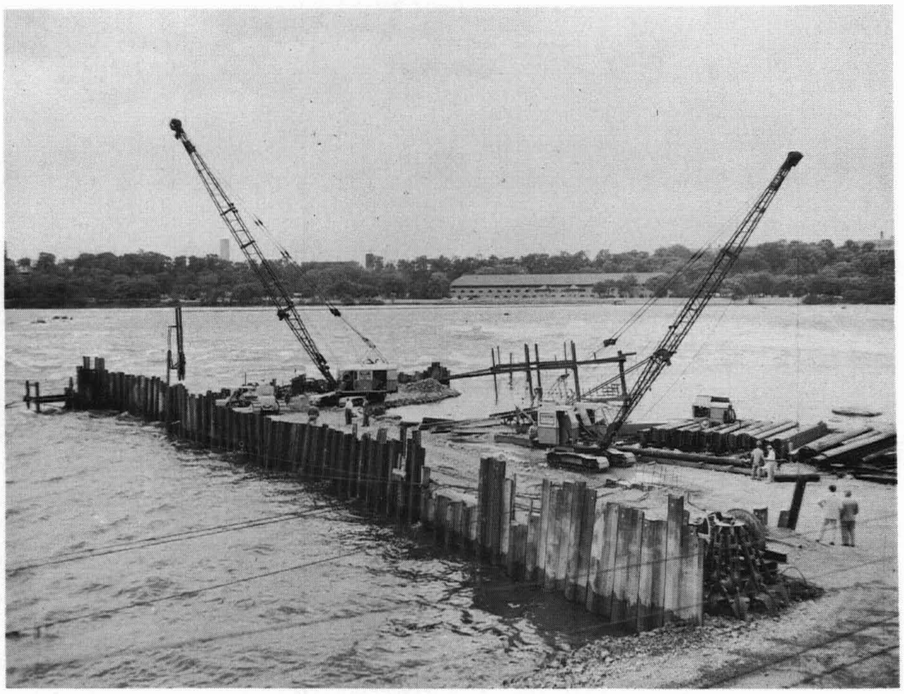
Photograph 6. Airplane view of completed control structure, 23 July, 1957.

Photograph 7. Control structure from Falls View, 21 October, 1957.

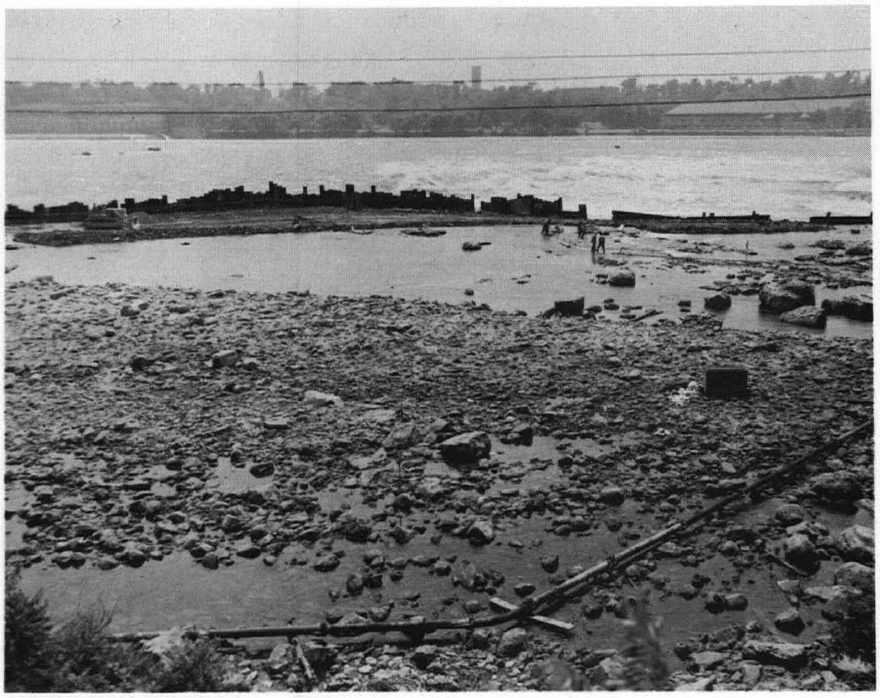


Photograph 8. Control building, 21 October, 1957.

Photograph 9. Control panel, 18 March, 1957.

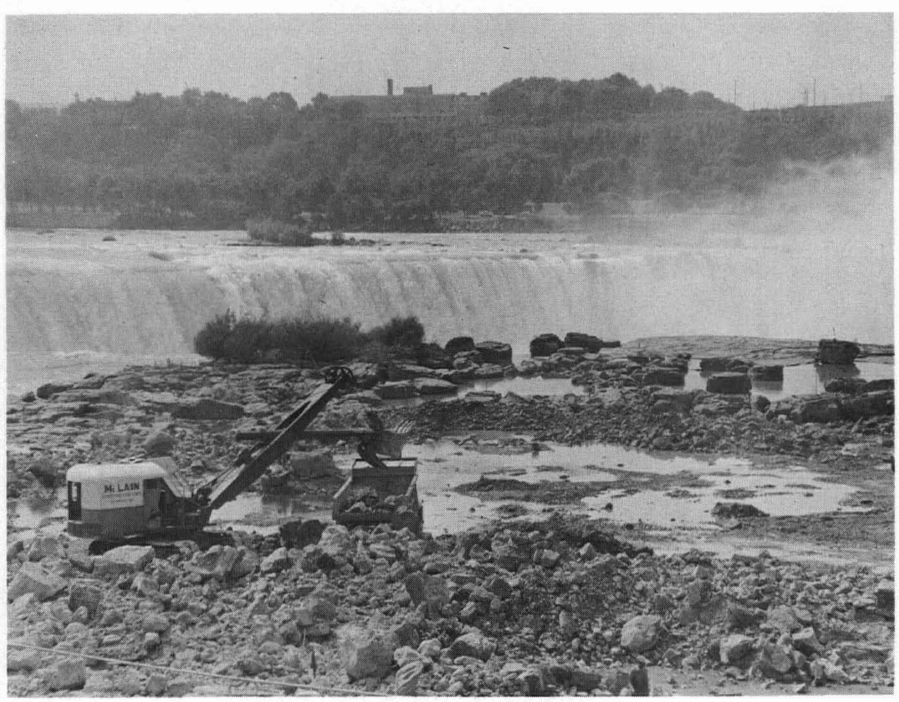


Photograph 10. Upper end of cofferdam, Goat Island, 16 July, 1954.



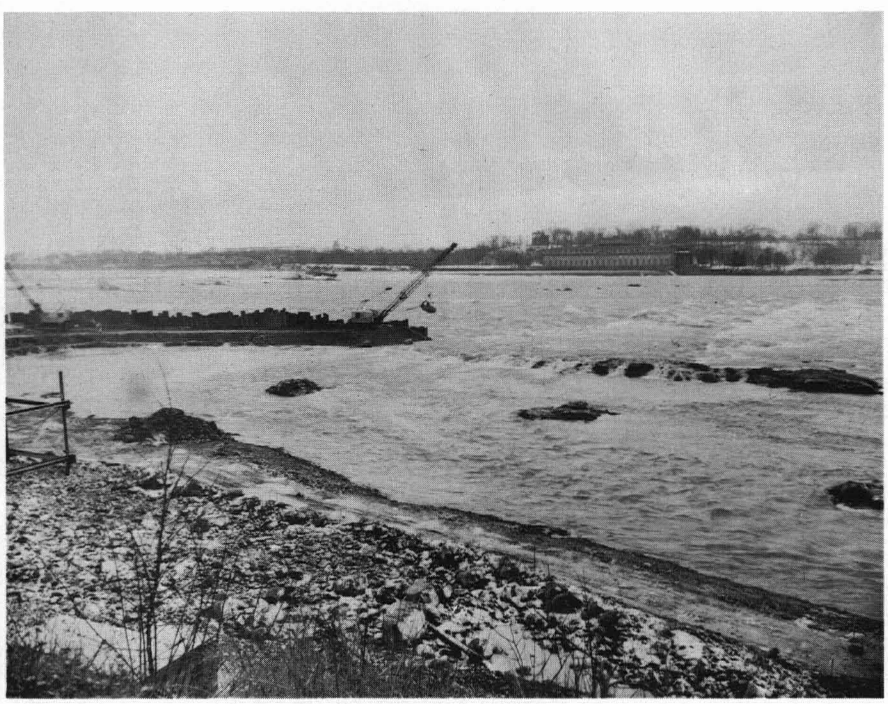
Photograph 11. Lower end of cofferdam, Goat Island, 6 August, 1954.

Photograph 12. Lower part of work area, Goat Island, 2 September, 1954.



Photograph 13. Lower end of work area, Goat Island, 9 September, 1954.

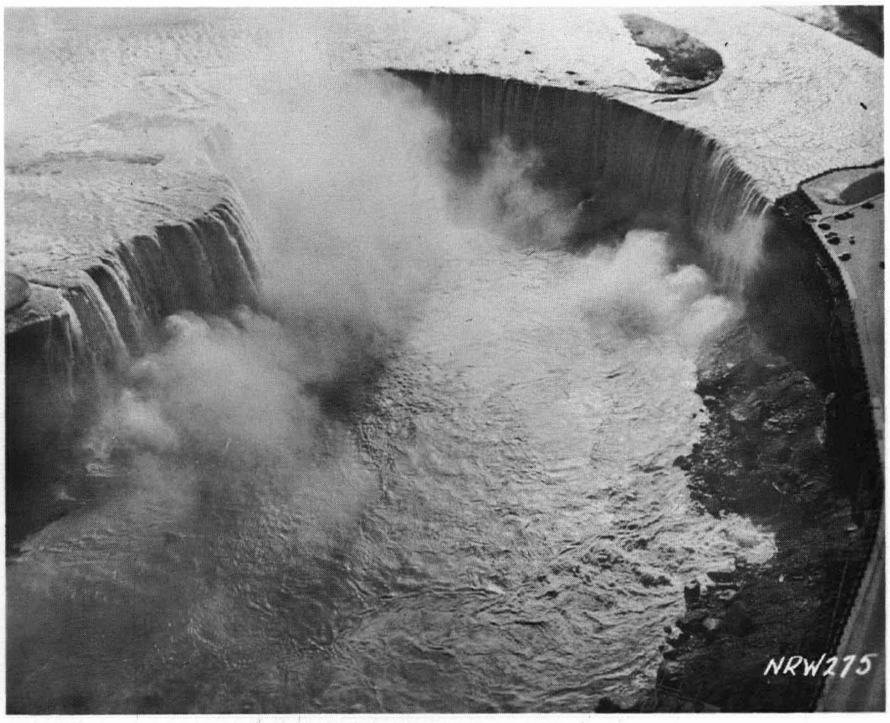
Photograph 14. Lower end of work area, Goat Island, 2 December, 1954.



Photograph 15. Removing cofferdam, Goat Island, 16 December, 1954.

Photograph 16. Terrapin Point, 27 September, 1955.

Photograph 17. Removal of cofferdam, Canadian end of Falls, 27 September, 1955.



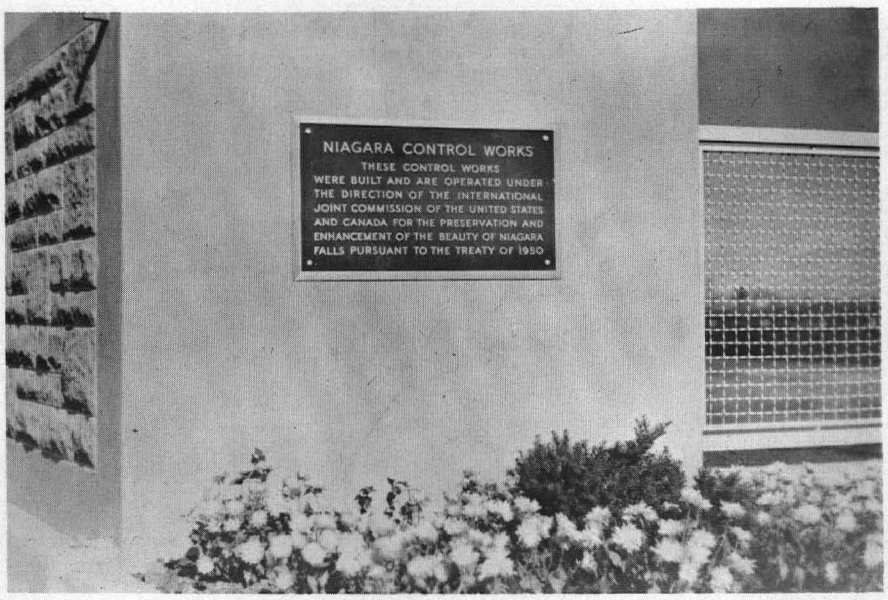
Photograph 18. Horseshoe Falls after remedial work, 24 November, 1955.
Combined flow over Falls, 95,000 cfs.

Photograph 19. Horseshoe Falls after remedial work, 19 March, 1956.
Combined flow over Falls, 63,100 cfs.

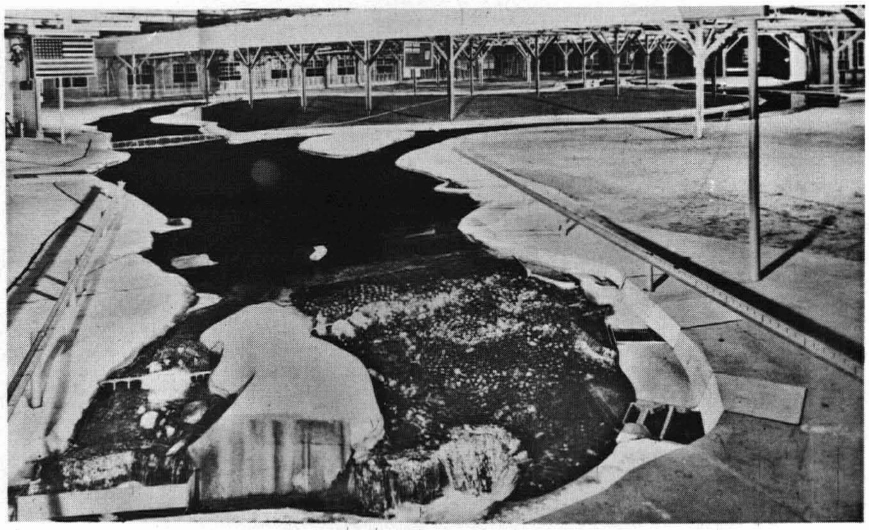
Photograph 20. Horseshoe Falls before remedial works, 5 December, 1950.
Combined flow over Falls, 107,000 cfs.

Photograph 21. Water level recording station, near foot of Ashland Avenue.

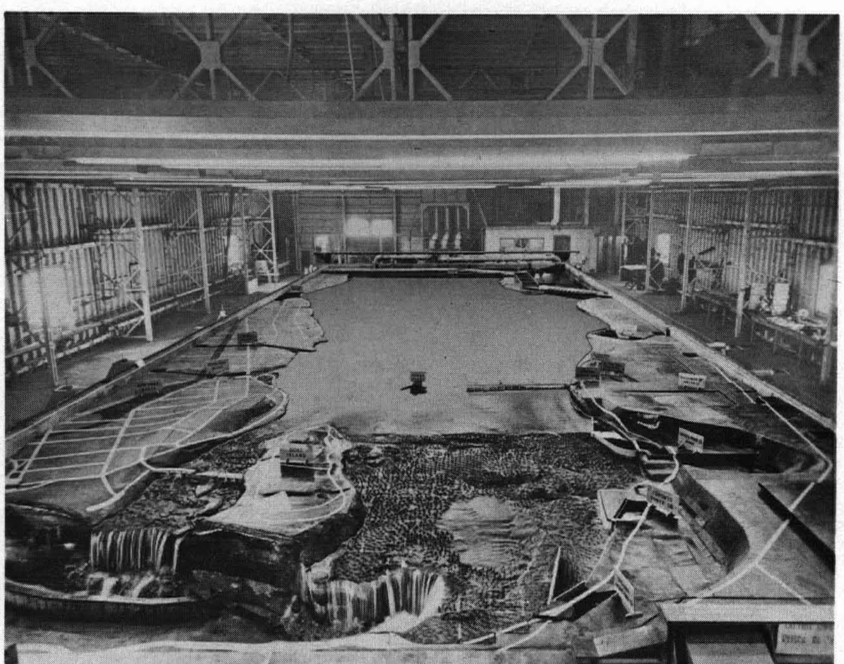
Photograph 22. Water level recording station, near head of American Channel.



Photograph 23. Aluminum plaque on gatepost at control structure, 21 October, 1957.



Photograph 24. Model at Vicksburg, Mississippi.



Photograph 25. Model at Islington, Ontario.

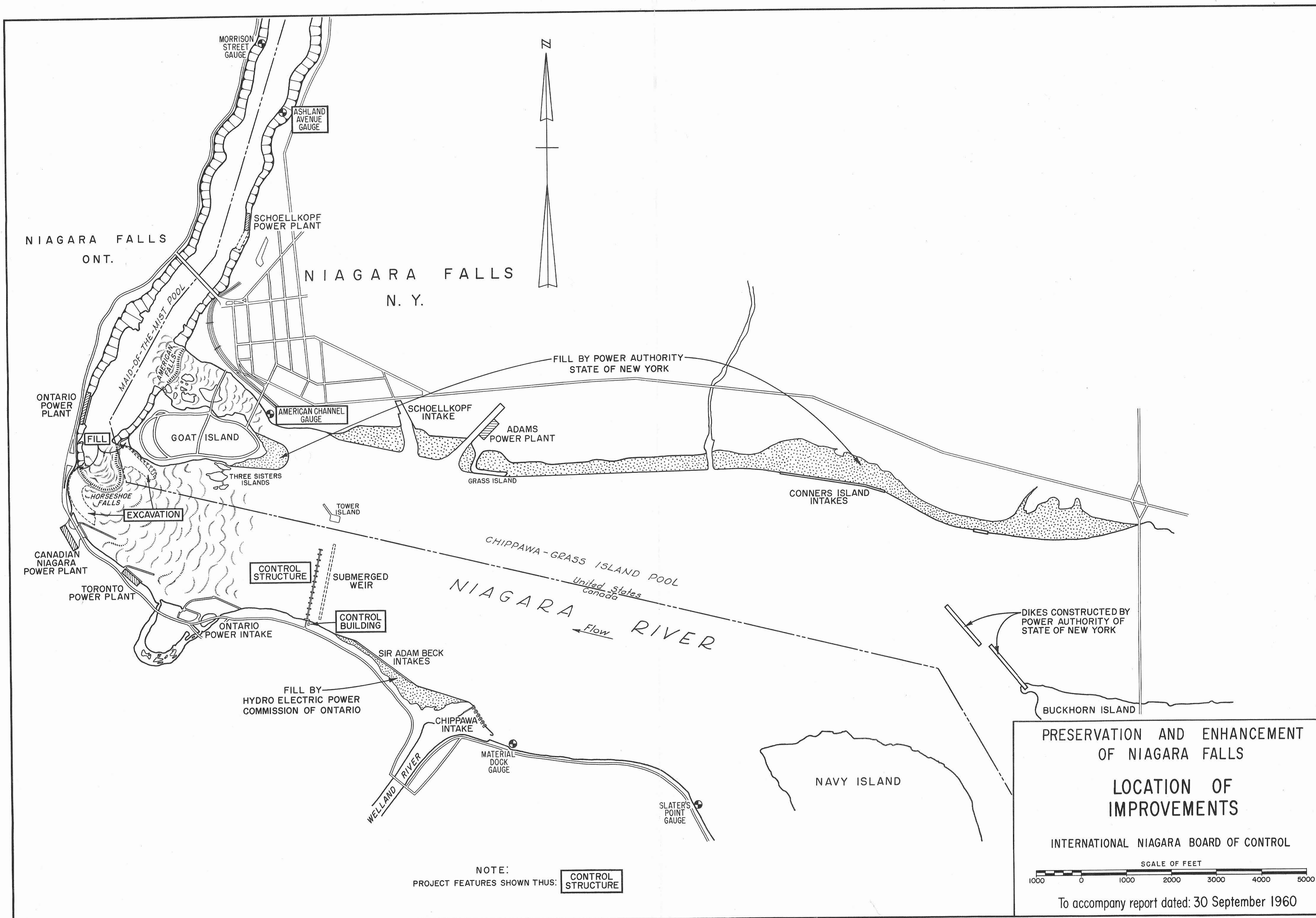
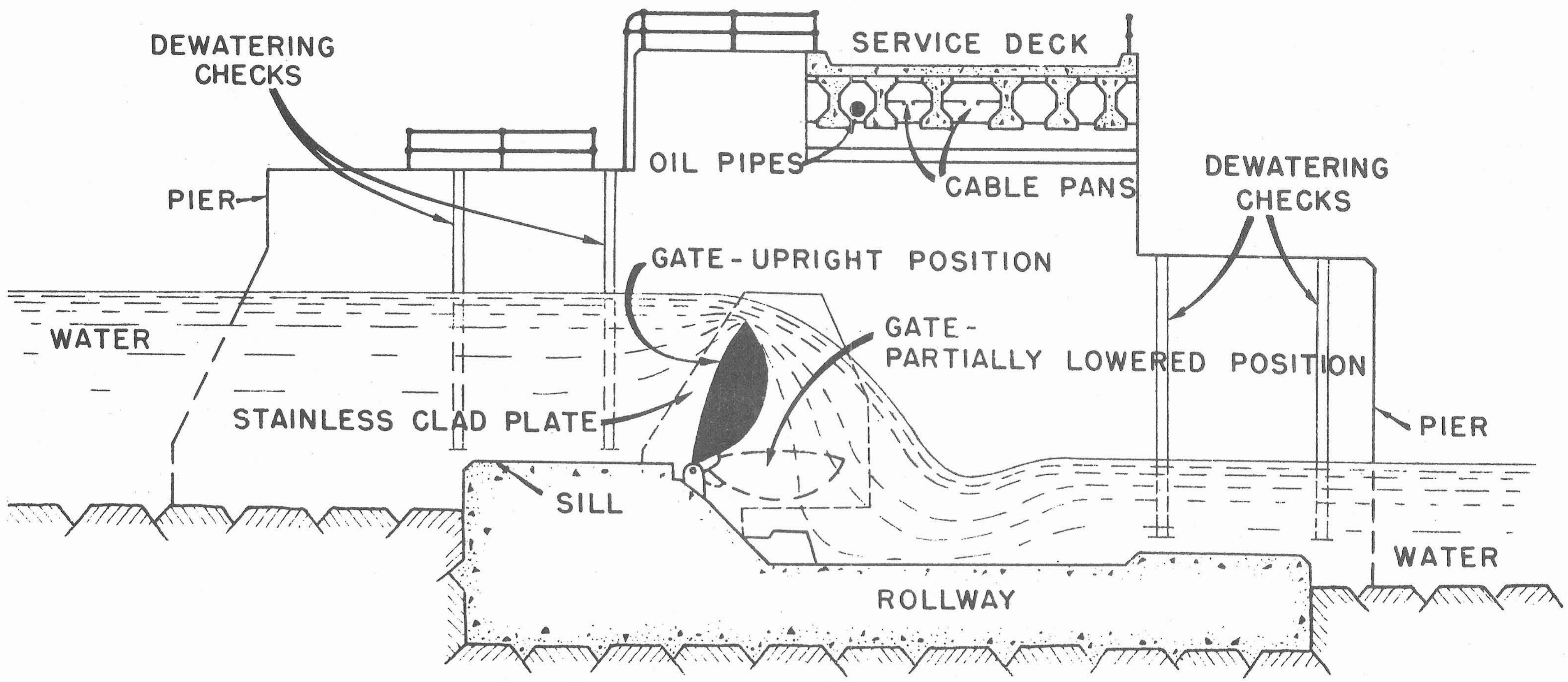

MORRISON STREET GAUGE
ASHLAND AVENUE GAUGE
N
SCHOELLKOPF POWER PLANT
NIAGARA FALLS ONT.
NIAGARA FALLS N. Y.
MAID-OF-THE-MIST POOL
AMERICAN FALLS
FILL BY POWER AUTHORITY STATE OF NEW YORK
ONTARIO POWER PLANT
AMERICAN CHANNEL GAUGE
SCHOELLKOPF INTAKE
ADAMS POWER PLANT
FILL
GOAT ISLAND
THREE SISTERS ISLANDS
GRASS ISLAND
HORSESHOE FALLS
EXCAVATION
TOWER ISLAND
CONNERS ISLAND INTAKES
CANADIAN NIAGARA POWER PLANT
CHIPPAWA - GRASS ISLAND POOL
United States
Canada
CONTROL STRUCTURE
SUBMERGED WEIR
TORONTO POWER PLANT
NIAGARA RIVER
CONTROL BUILDING
Flow
DIKES CONSTRUCTED BY POWER AUTHORITY OF STATE OF NEW YORK
ONTARIO POWER INTAKE
SIR ADAM BECK INTAKES
FILL BY HYDRO ELECTRIC POWER COMMISSION OF ONTARIO
BUCKHORN ISLAND
CHIPPAWA INTAKE
MATERIAL DOCK GAUGE
WELLAND RIVER
NAVY ISLAND
SLATER'S POINT GAUGE
NOTE:
PROJECT FEATURES SHOWN THUS: CONTROL STRUCTURE
PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS
LOCATION OF IMPROVEMENTS
INTERNATIONAL NIAGARA BOARD OF CONTROL
SCALE OF FEET
1000 0 1000 2000 3000 4000 5000
To accompany report dated: 30 September 1960

PLATE I



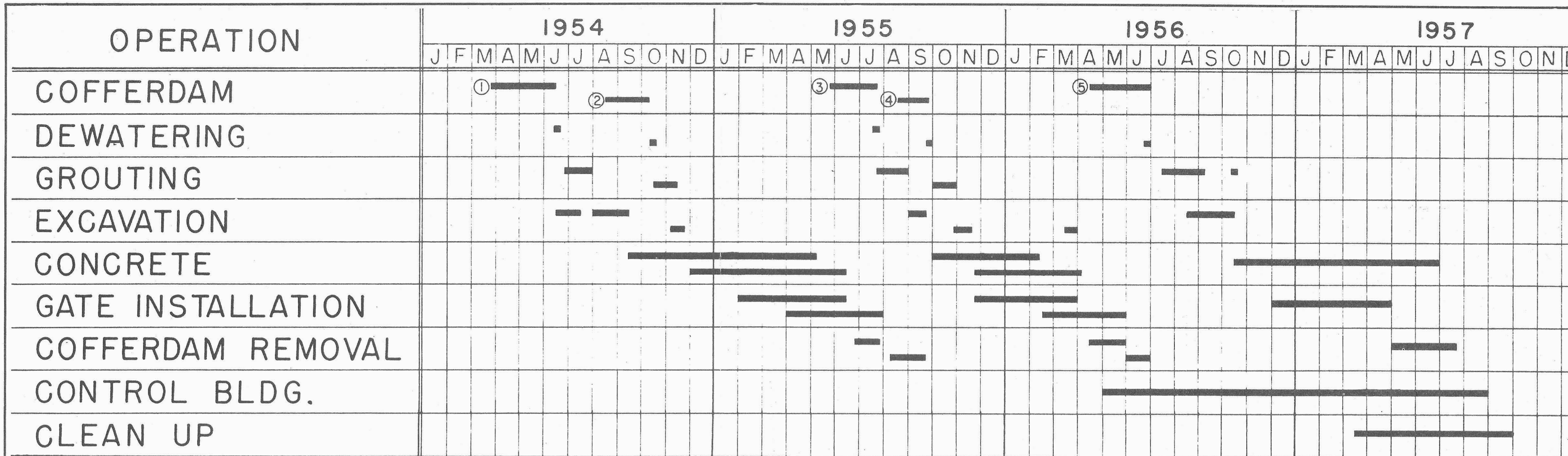
PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS

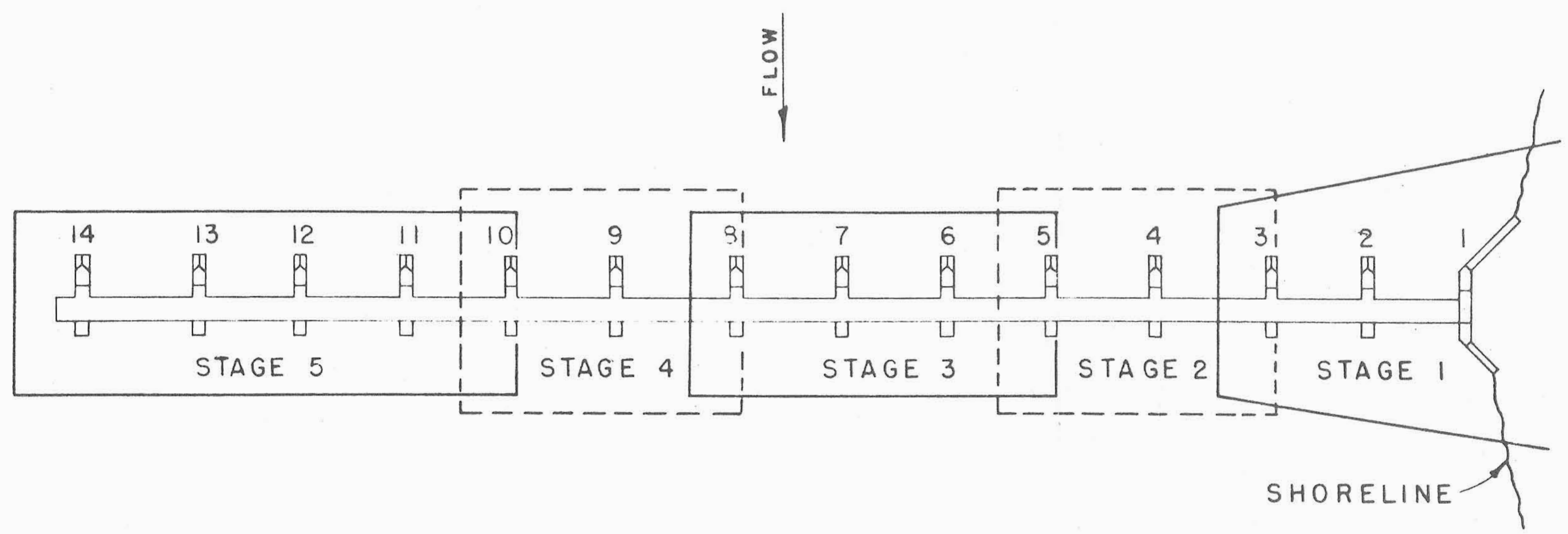
CROSS SECTION OF CONTROL STRUCTURE

INTERNATIONAL NIAGARA BOARD OF CONTROL

To accompany report dated: 30 September 1960

PLATE 2





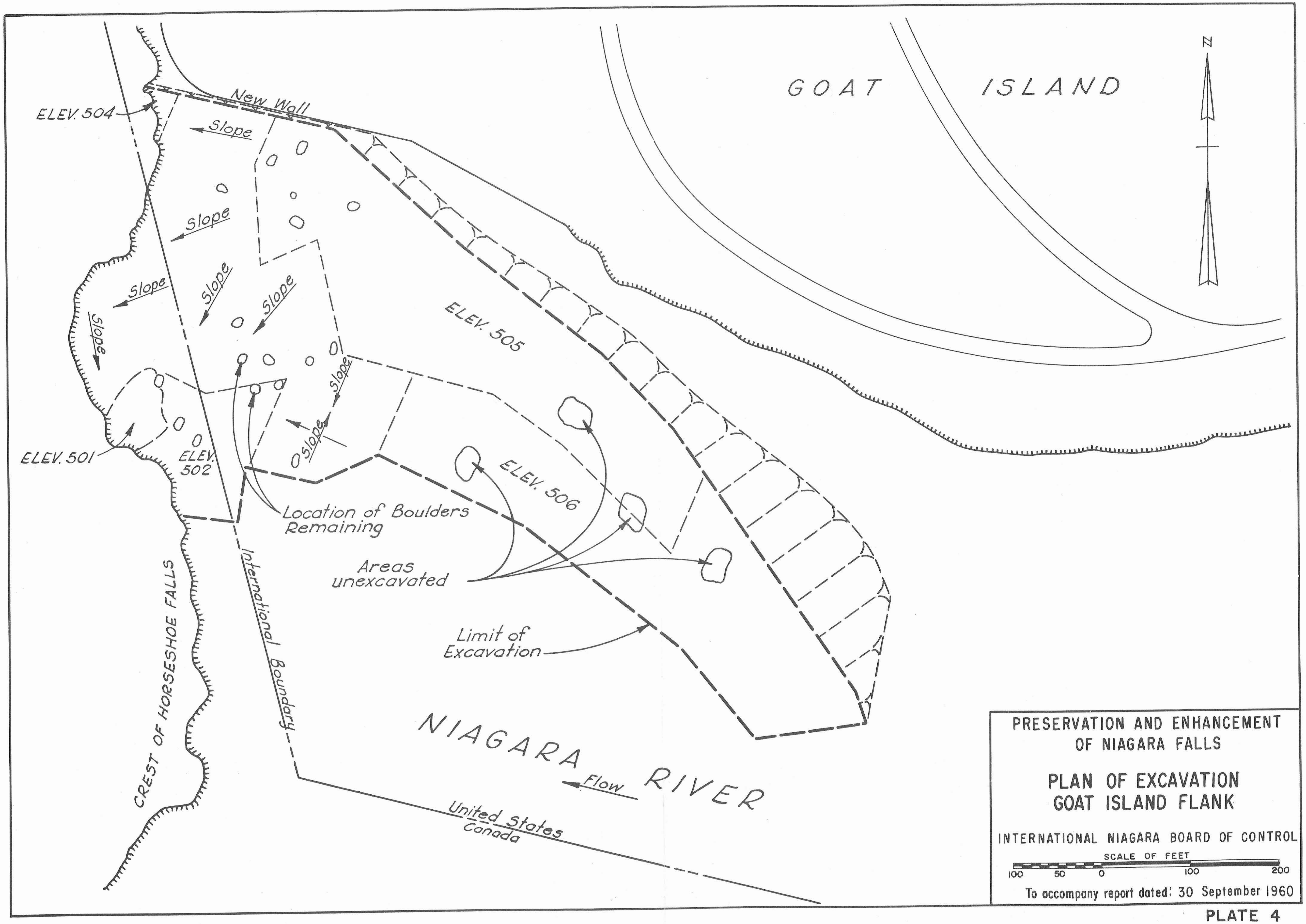
PLAN

PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS

CONSTRUCTION SCHEDULE FOR CONTROL STRUCTURE

INTERNATIONAL NIAGARA BOARD OF CONTROL

To accompany report dated: 30 September 1960



PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS

PLAN OF EXCAVATION GOAT ISLAND FLANK

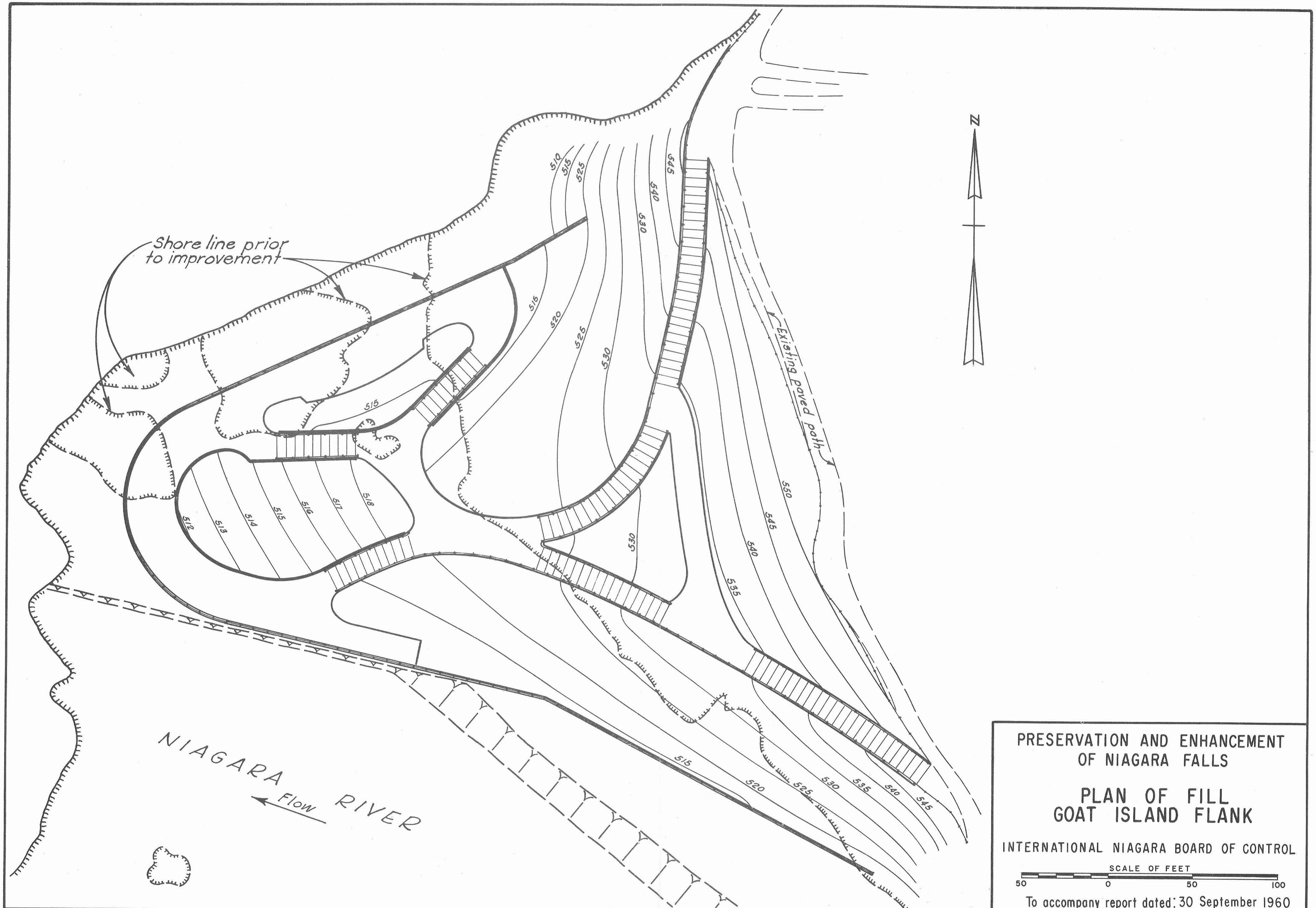
INTERNATIONAL NIAGARA BOARD OF CONTROL

SCALE OF FEET

100 50 0 100 200

To accompany report dated: 30 September 1960

PLATE 4

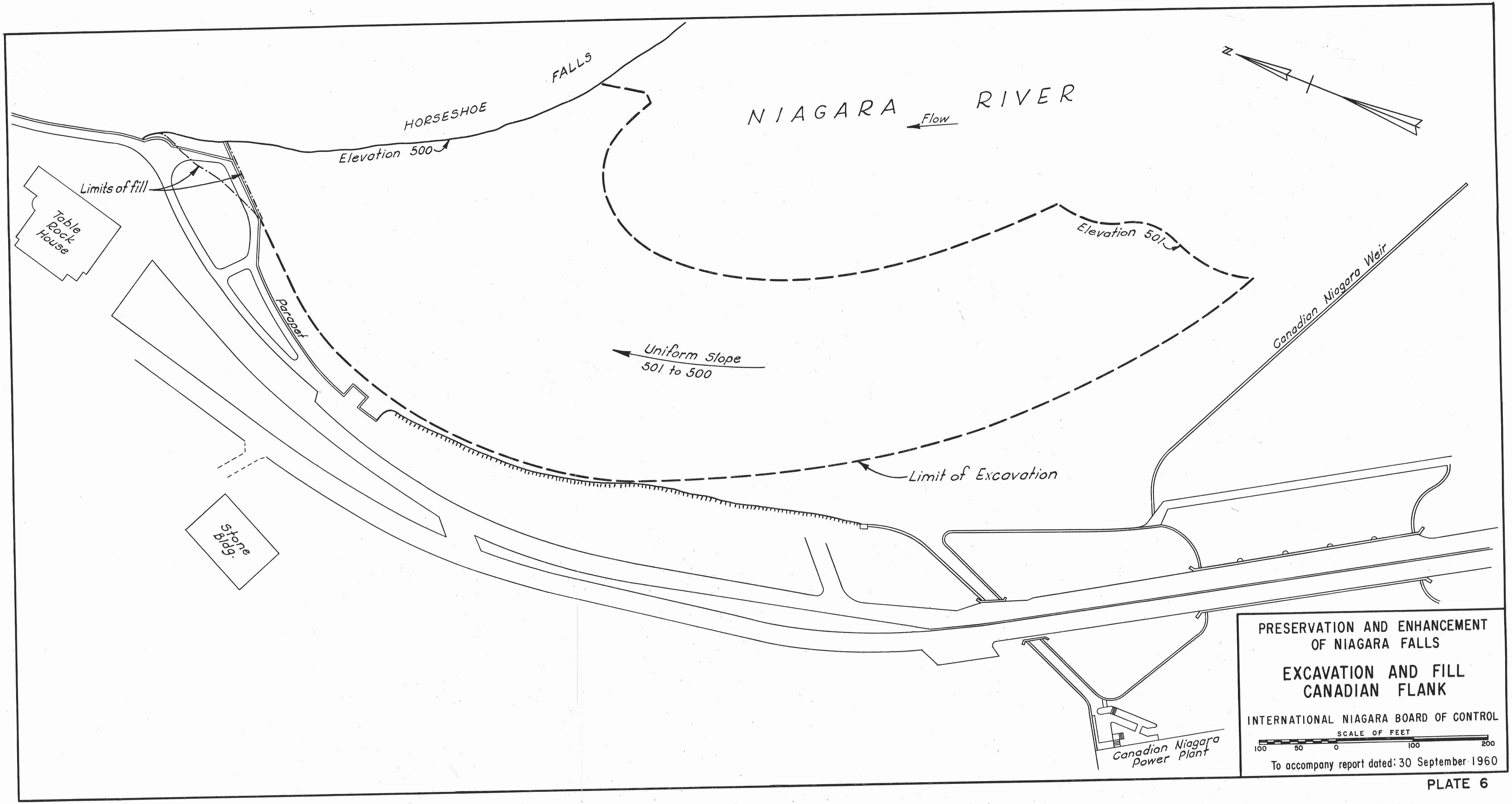


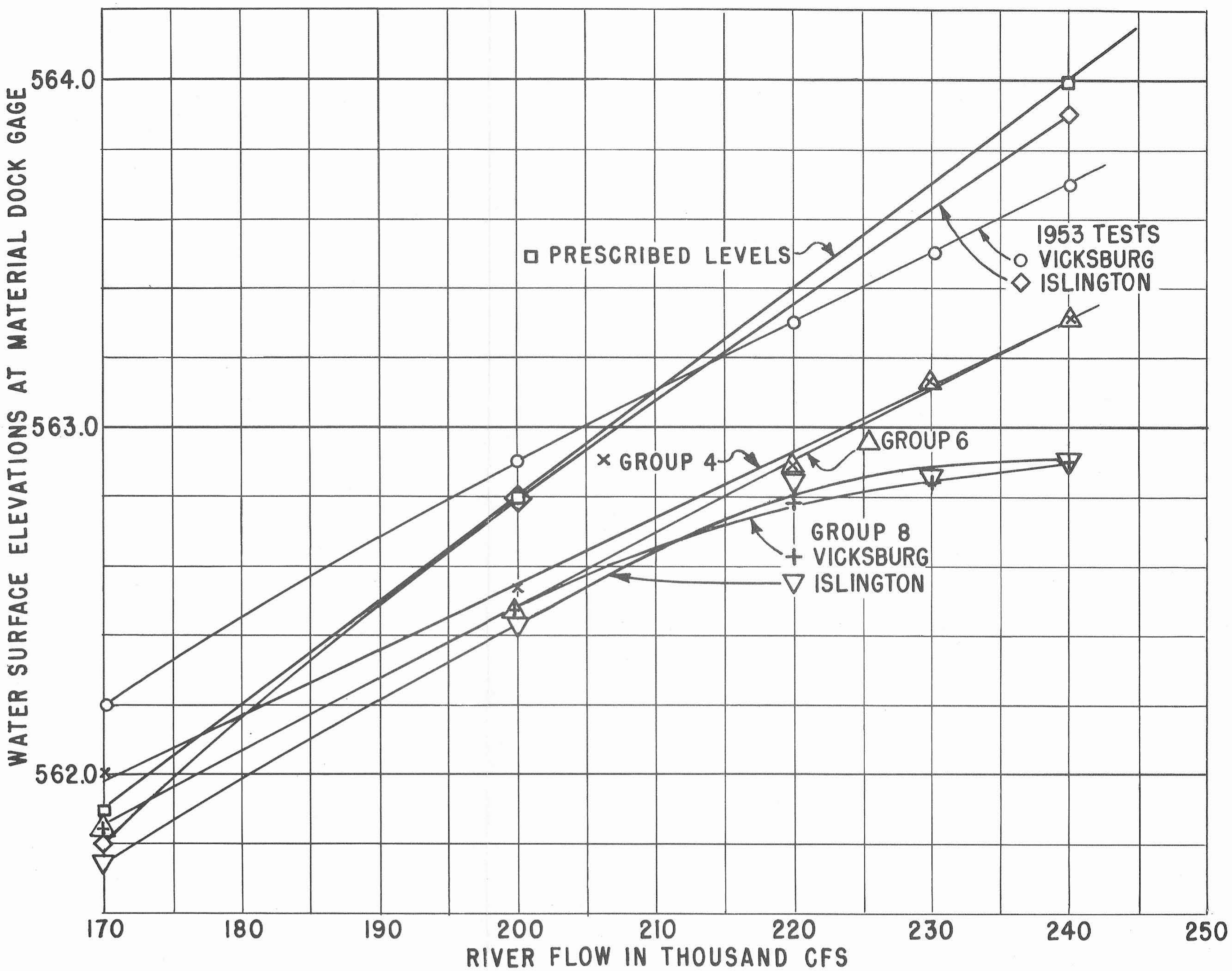
PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS

PLAN OF FILL GOAT ISLAND FLANK

INTERNATIONAL NIAGARA BOARD OF CONTROL

To accompany report dated: 30 September 1960


HORSESHOE FALLS
NIAGARA RIVER
Flow
Elevation 500
Limits of fill
Table Rock House
Parapet
Elevation 501
Canadian Niagara Weir
Uniform Slope 501 to 500
Limit of Excavation
Stone Bldg.
Canadian Niagara Power Plant
PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS
EXCAVATION AND FILL CANADIAN FLANK
INTERNATIONAL NIAGARA BOARD OF CONTROL
SCALE OF FEET
100 50 0 100 200
To accompany report dated: 30 September 1960



NOTE
Curves show stage-discharge relationships at Material Dock gage with all gates closed in 1,550-foot control structure.

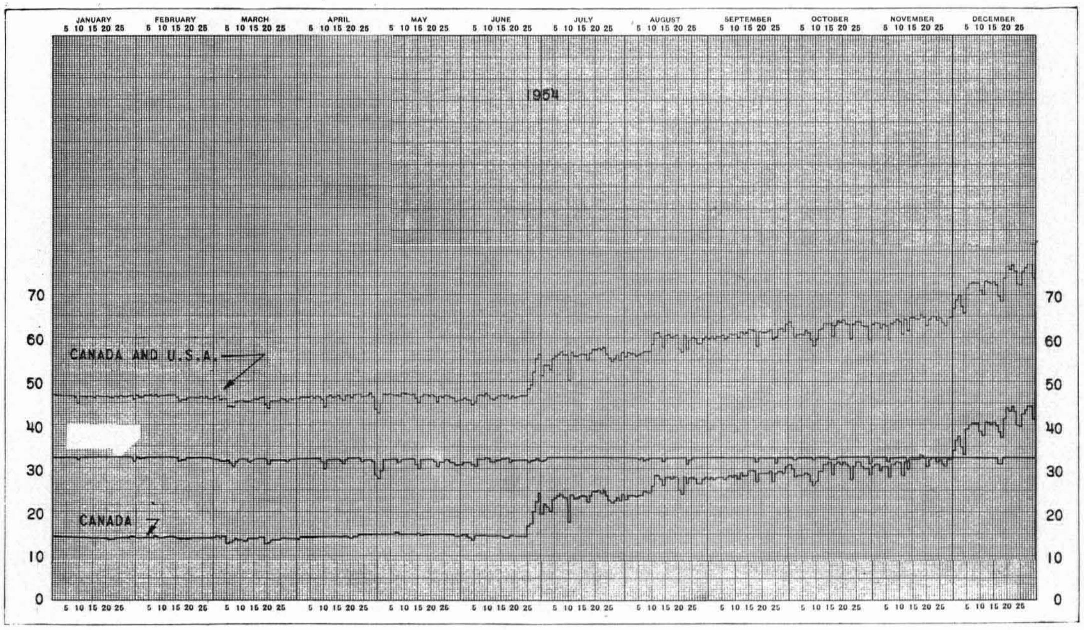
PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS

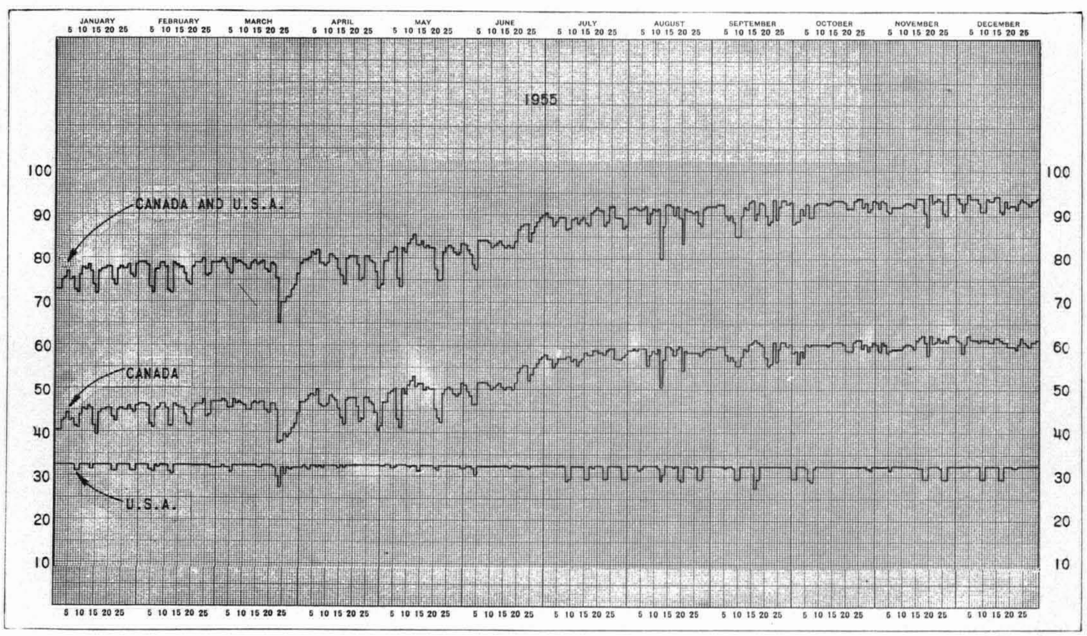
RESULTS OF MODEL TESTS

INTERNATIONAL NIAGARA BOARD OF CONTROL

To accompany report dated: 30 September 1960

PLATE 7





NOTE:

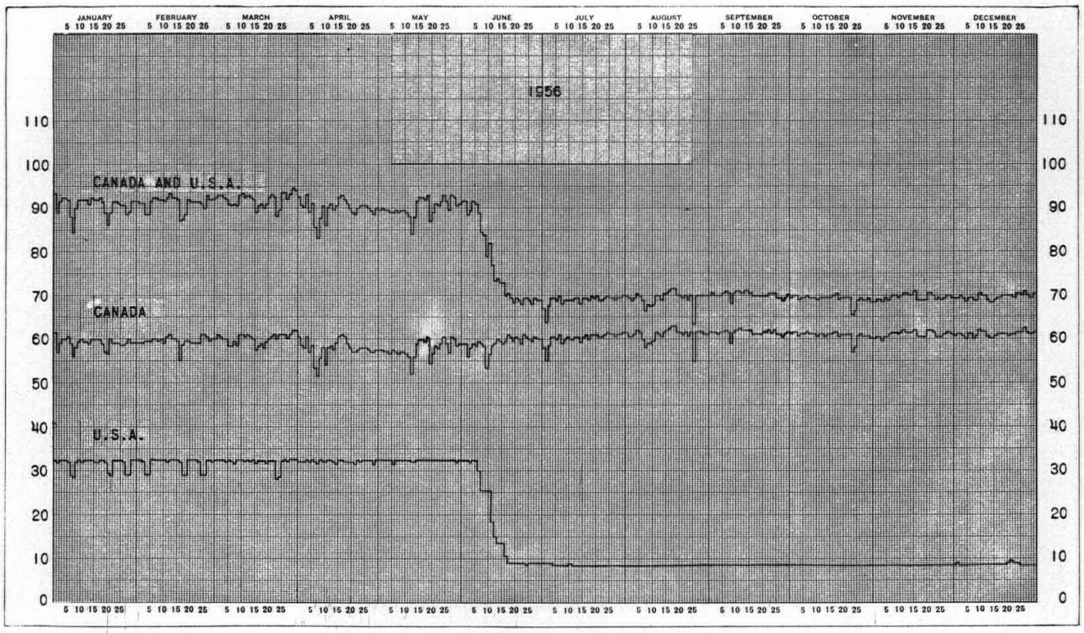
Diversions shown in thousands of cubic feet per second.

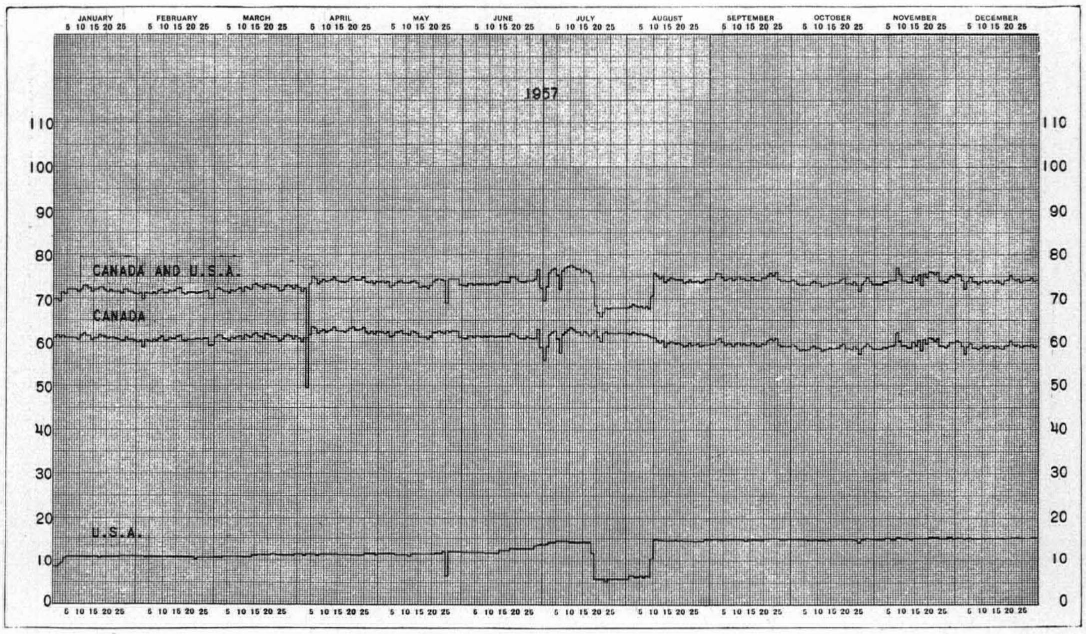
PRESERVATION AND ENHANCEMENT
OF NIAGARA FALLS

DIVERSIONS FROM CHIPPAWA - GRASS ISLAND POOL

INTERNATIONAL NIAGARA BOARD OF CONTROL

To accompany report dated: 30 September 1960





NOTE:

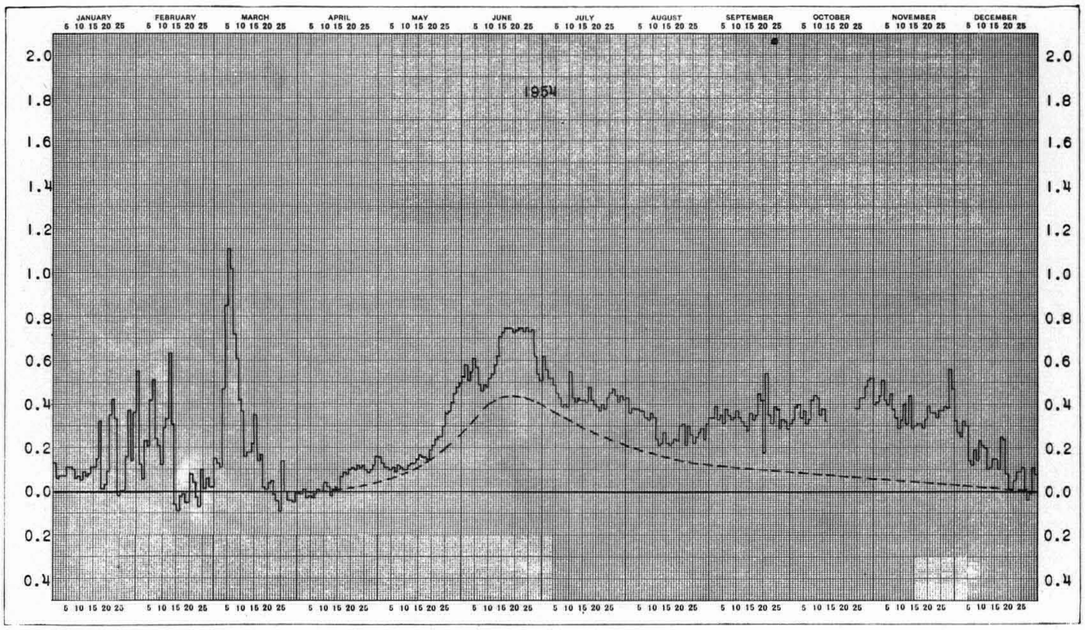
Diversions shown in thousands of cubic feet per second.

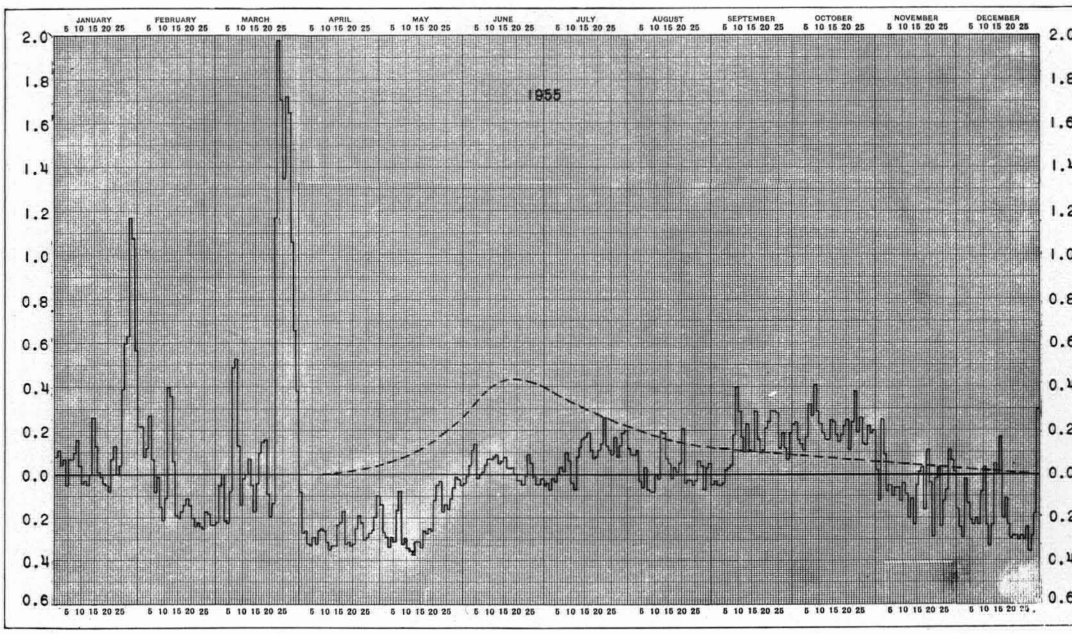
PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS

DIVERSIONS FROM CHIPPAWA - GRASS ISLAND POOL

INTERNATIONAL NIAGARA BOARD OF CONTROL

To accompany report dated: 30 September 1960





NOTES:

Difference in mean daily stages shown in feet

Computed stage = 560.49 + 0.301 (Q-160,000)/10,000

----Normal conditions

——Actual conditions

PRESERVATION AND ENHANCEMENT

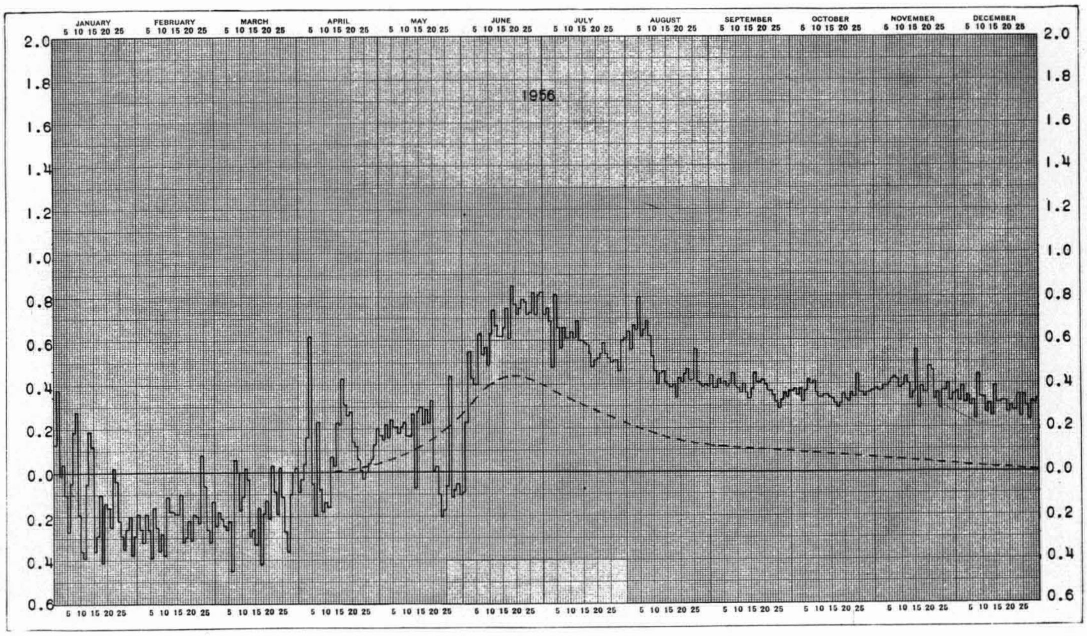
OF NIAGARA FALLS

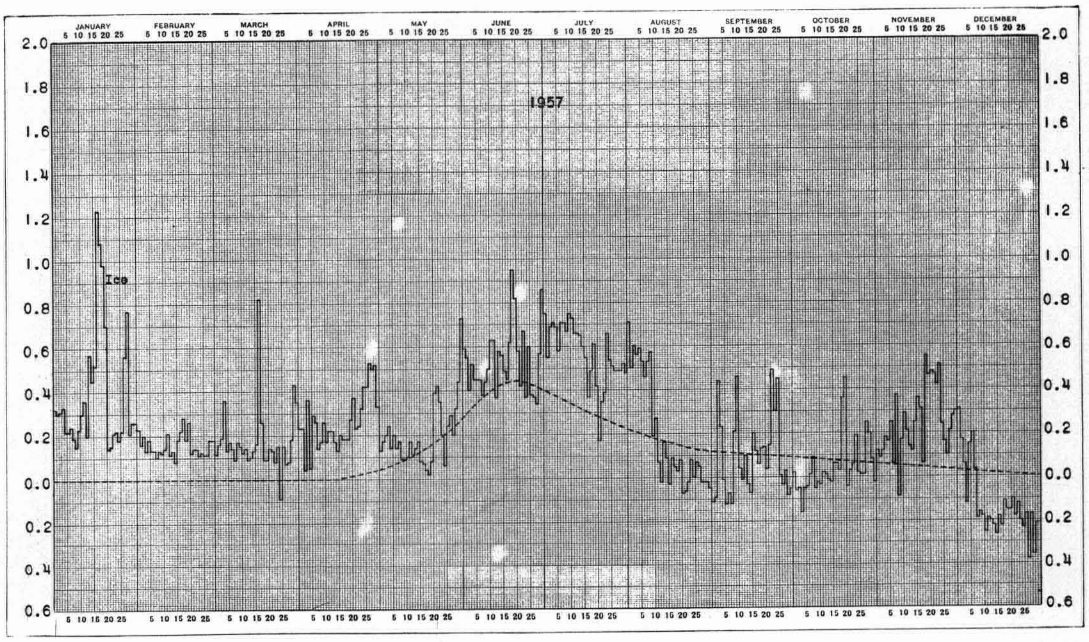
OBSERVED STAGE MINUS COMPUTED STAGE AT SLATERS POINT

INTERNATIONAL NIAGARA BOARD OF CONTROL

To accompany report dated: 30 September 1960

PLATE 10





NOTES:

Difference in mean daily stages shown in feet.

Computed stage = 560.49 + 0.301 (Q-160,000)/10,000

---- Normal conditions

—— Actual conditions

PRESERVATION AND ENHANCEMENT OF NIAGARA FALLS

OBSERVED STAGE MINUS COMPUTED STAGE AT SLATERS POINT

INTERNATIONAL NIAGARA BOARD OF CONTROL

To accompany report dated: 30 September 1960

REPORT OF CONSTRUCTION

of

NIAGARA RIVER REMEDIAL WORKS

APPENDIX A

REPORT OF CONSTRUCTION OF NIAGARA RIVER REMEDIAL WORKS

APPENDIX A

OPERATING INSTRUCTIONS

SECTION I

ORIGINAL INSTRUCTIONS – LETTER DATED 30 JUNE 1955

Niagara Mohawk Power Corporation,
Electric Building,
Buffalo, New York,
and
Hydro-Electric Power Commission of Ontario,
620 University Avenue,
Toronto 2, Ontario.

1. The International Niagara Board of Control, hereinafter called the Board, has been charged by the International Joint Commission with the responsibility for maintaining normal elevations in the Chippawa-Grass Island Pool, hereinafter called the Pool. Beginning on the 16th day of July 1955 and until modified by a later directive, the Board hereby directs that the water diversions from the Pool shall be controlled and the gates of the Control Structure now under construction by the Hydro-Electric Power Commission of Ontario, as they come into use, shall be operated in accordance with the following objectives:

2. Without regard to minor variations from hour to hour, the elevation of the Pool, as recorded by the Material Dock gauge, shall be maintained each day by regulating the diversions of water from the Pool and by operating the available gates in the Control Structure, within the tolerances specified in paragraphs 3 and 4 below, according to the elevation indicated for that particular day by the attached Fig. 1 for the mean daily flow of the river on that day as given by the mean for the day at the foot of Column 14 in the "Daily Report of Power Diversions from Niagara River and Welland Ship Canal." If for any reason the Material Dock gauge is inoperative, the Slaters Point or Grass Island gauge and the attached Fig. 2 or 3, respectively, shall be substituted for the Material Dock gauge and Fig. 1.

3. The Board hereby establishes the following tolerances which shall apply during the construction period or until revoked by the Board:

(a) In general, a tolerance of plus or minus 0.5 foot in the daily mean elevation of the pool as determined accordingly to paragraph 2 above.

(b) In general, a tolerance of plus or minus 0.3 foot in the monthly mean elevation of the pool as determined in a manner similar to that described in paragraph 2 above for the daily mean, except that from 16 July 1955 to 31 October 1955, a tolerance of minus 0.5 foot will be allowed.

(c) If necessary, the Board will allow an extra plus tolerance of a reasonable amount when all available gates are wide open.

(d) When the flow of the river as indicated in Column 14 of the daily report mentioned above exceeds 270,000 cubic feet per second, the tolerance shall be changed from the amount mentioned in sub-section (a) above and shall be merely minus 0.5 foot.

(e) When the flow of the river as indicated in Column 14 of the daily report becomes less than 150,000 cubic feet per second, the tolerance shall be changed from that mentioned in sub-section (a) above and shall be plus 0.5 foot.

4. The method of regulation specified in paragraph 2 may be suspended temporarily on days when there are ice runs or storms. Under such circumstances, the operating superintendents are expected to use their best judgment. After such a case has occurred, the power entity concerned shall report in writing to the Board, explaining the action taken and the reasons therefor. In this way, usual occurrences will be placed on record so that they may be taken into account when revision of this directive is under consideration.

5. Nothing in this directive shall be construed as obviating the 1950 Treaty requirement that no diversions shall be made for power purposes which will reduce the flow over Niagara Falls to less than the amounts specified in Article IV of the Treaty.

6. The responsibility for operation of the control structure will be in the hands of the Hydro-Electric Power Commission of Ontario during the construction period, and Niagara-Mohawk Power Corporation is expected to maintain regular contact with that Commission to assure close co-ordination of power diversions between the two operating entities.

7. Records shall be maintained in the operating superintendent's office and a report submitted in duplicate to Mr. C. G. Cline and to the District Engineer of the Buffalo District of the Corps showing for each day: (a) a detailed log of the operation of the gates; (b) the actual mean elevation of the pool; (c) the elevation indicated for that day by Fig. 1; (d) the difference between items (b) and (c) indicating by a minus sign when item (b) is less than item (c); (e) the cumulative difference from and including the first day of the month.

Members for Canada:

T. M. PATTERSON —
Director, Engineering and Water Resources Branch,
Department of Northern Affairs and
National Resources,

G. H. THURBER —

Superintending Engineer,
Department of Public Works,
Ottawa, Ontario.

Members for the United States:

P. D. BERRIGAN —
Colonel, Corps of Engineers,
Division Engineer, North Central Division,
Chicago, Illinois.

FRANCIS L. ADAMS —

Chief, Bureau of Power,
Federal Power Commission,
Washington, D.C.

SECTION II

REPORT OF CONSTRUCTION OF NIAGARA RIVER REMEDIAL WORKS

REVISED INSTRUCTIONS – LETTER DATED 2 OCTOBER 1956

Niagara Mohawk Power Corporation,
Electric Building,
Buffalo, New York,
and
Hydro-Electric Power Commission of Ontario.
620 University Avenue,
Toronto 2, Ontario.

1. Reference is made to letter dated 30 June 1955 from the International Niagara Board of Control to the Hydro-Electric Power Commission of Ontario and Niagara Mohawk Power Corporation.

2. Paragraph 3(c) of above letter states, "If necessary the Board will allow an extra plus tolerance of a reasonable amount when all available gates are wide open."

3. In view of the recent rock slide at the Schoellkopf Station which resulted in a drop in diversion of 24,000 cfs from the Chippawa-Grass Island Pool, operation within the tolerances as set down by the Board has become quite difficult. Until the last 4 gates in the control structure come into operation next summer, there may not be enough gate capacity to pass the necessary flow to regulate the pool level within the limits set down in the operating instructions.

4. In view of the above the instructions of the Board in letter of 30 June 1955 are hereby modified to establish plus tolerances for the monthly and daily means to be 0.5 foot and 0.7 foot, respectively, during periods when all available gates are wide open.

5. The modified plus tolerances established herein will be in effect from this day until modified by a letter directive from the Board.

Members for the United States:

P. D. BERRIGAN —
Brig. General, Corps of Engineers,
Division Engineer, North Central Division,
Chicago, Illinois.

FRANCIS L. ADAMS —
Chief, Bureau of Power,
Federal Power Commission,
Washington, D.C.

Members for Canada:

T. M. PATTERSON —
Director, Engineering and Water Resources Branch,
Department of Northern Affairs and
National Resources,
Ottawa, Ontario.

G. H. THURBER —
Chief, Marine Excavation Division,
Department of Public Works,
Ottawa, Ontario.