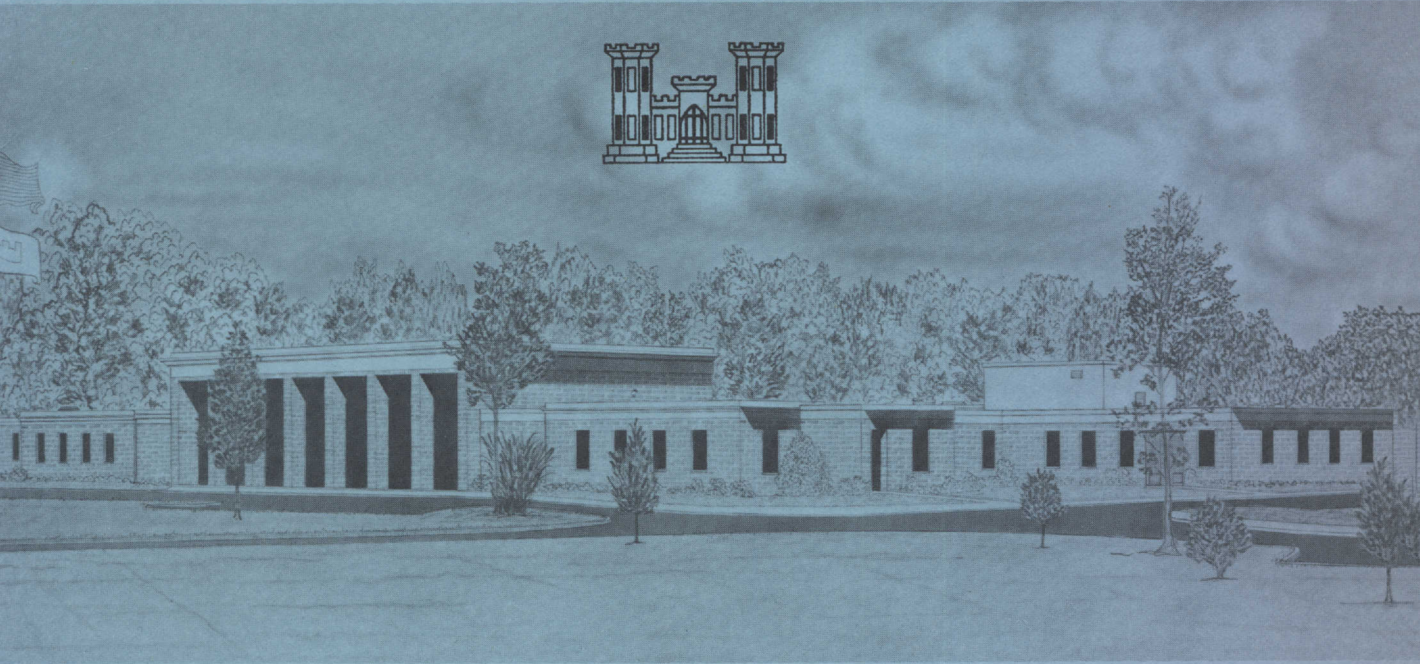
TECHNICAL REPORT H-70-3

CONSIDERED LAKE ERIE-LAKE ONTARIO WATERWAY

Hydraulic Model Investigation

by

T. E. Murphy



April 1970

Sponsored by U. S. Army Engineer District, Buffalo

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

Model investigations of a proposed Lake Erie-Lake Ontario Waterway were authorized by the Office, Chief of Engineers, in an eighth indorsement, dated 23 October 1964, at the request of the U. S. Army Engineer District, Buffalo, through the U. S. Army Engineer Division, North Central.

The model study was conducted in the Hydraulics Division of the U. S. Army Engineer Waterways Experiment Station during the periods January to November 1965 and September to December 1966 under the general supervision of Mr. E. P. Fortson, Jr., Chief of the Hydraulics Division, and Mr. T. E. Murphy, Chief of the Structures Branch. Engineers actively concerned with some phase of the investigations were Messrs. M. B. Boyd, J. H. Ables, Jr., N. R. Oswalt, and E. C. McNair. This report was prepared by Mr. Murphy.

Visitors to the Waterways Experiment Station actively concerned with the investigations were: Mr. J. P. Davis of the Office, Chief of Engineers; Messrs. C. F. MacNish and R. T. Snider of the North Central Division; and Messrs R. H. Gallinger, D. M. Liddell, R. B. McKee, R. S. Goodno, and COL R. W. Neff of the Buffalo District.

Directors of the Waterways Experiment Station during the testing program and the preparation and publication of this report were COL John R. Oswalt, Jr., CE, and COL Levi A. Brown, CE. Technical Directors were Messrs. J. B. Tiffany and F. R. Brown.

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
miles (U. S. statute)	1.609344	kilometers
feet per second	0.3048	meters per second
cubic feet per second	0.02831685	cubic meters per second

SUMMARY

The investigation reported herein was conducted to assist the U. S. Army Engineer District, Buffalo, in determination of the economic justification of a water route connecting Lake Erie and Lake Ontario. Specifically, the studies involved determination of the most functional and economical location for a lock in the vicinity of Buffalo, N. Y., and evaluation of navigation conditions at the entrance to an overland canal joining the American channel of the Niagara River northwest of North Tonawanda, N. Y.

An existing model of the Niagara River with a horizontal scale of 1:360 and a vertical scale of 1:60 and a new undistorted model of the canal entrance with a 1:120 scale were used in the investigation.

Tests demonstrated the desirability of placing the new lock in the vicinity of Buffalo as far downstream as is feasible without rendering the existing Black Rock Lock and Canal inoperable during the construction period. Navigation problems at the canal entrance were not as severe as had been contemplated and a small amount of overexcavation resulted in satisfactory conditions.

CONSIDERED LAKE ERIE-LAKE ONTARIO WATERWAY

Hydraulic Model Investigation

PART I: INTRODUCTION

LAKE ERIE-LAKE ONTARIO PROJECT

1. In 1958 the Public Works Committee of the U. S. Senate and House of Representatives passed a resolution requesting the Chief of Engineers to review previous reports and conduct a study on the Great Lakes and connecting waters, including the Niagara River. The U. S. Army Engineer District, Buffalo, was assigned the responsibility of compiling and evaluating all information necessary to determine the economic justification of a water route connecting Lake Erie with Lake Ontario.

2. By the end of 1964 a general plan for the Lake Erie-Lake Ontario Waterway Project (LEO) had been developed. This plan provided a new lock in the vicinity of Buffalo, N. Y.; a navigation channel in the Niagara River from Buffalo to the entrance of an overland canal northwest of North Tonawanda, N. Y.; and an overland canal, with three to five navigation locks, extending from the Niagara River northwest of North Tonawanda to Lake Ontario. The navigation locks were to be 110 ft* wide and 1200 ft long and the improved channels were to have a depth of 30 ft and minimum bottom width of 600 ft.

THE PROBLEM

3. Feasibility studies by the U. S. Army Engineer District, Buffalo, required solution by model studies of two major problems. The first involved determination of the most functional and economical location for the lock in the vicinity of Buffalo and development of navigation channel features, including compensating excavations or structures, in the reach from Lake Erie to the start of the overland canal. The second major problem concerned the entrance to the overland portion of the canal and required determination of the location and size of structures and excavations needed to reduce velocities across the navigation channel to acceptable values. At this stage of the studies neither of these problems required development of design details; instead it was necessary only to verify the functional adequacy of the plans and determine needs for incident constructions and excavations so that reasonable cost estimates could be developed.

THE MODELS

4. Two models were used in the investigations: an existing distorted-scale model of the Niagara River and a new undistorted-scale model of the canal entrance.

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* A table of factors for converting British units of measurement to metric units is presented on page vii.

PART II: NIAGARA RIVER MODEL

DESCRIPTION

5. The Niagara River fixed-bed model,* constructed in 1950-1951, was designed for study of the preservation and enhancement of Niagara Falls. Specifically, the model was used to determine the effects on Niagara River and the Falls of proposed diversions of water for power, and the extent and nature of remedial works required for maintenance of adequate flow conditions in the river and at the Falls, and for preservation of the scenic beauty of the Falls. Reproduced in the model (fig. 1) were a portion of Lake Erie and the Niagara River, including Chippawa and Tonawanda Channels (referred to herein as Canadian and American channels, respectively) around Grand Island, to a section downstream of Niagara Falls.

SCALE RELATIONS

6. The model was constructed to linear scale ratios, model to prototype, of 1:360 horizontally and 1:60 vertically with a geometrically resultant slope scale of 6 to 1. Scale ratios, model to prototype, in accordance with the Froudian relation are presented in the following tabulation:

Dimension	Scale Relation
Length	1:360
Depth	1:60
Velocity	1:7.74
Discharge	1:167,328
Time	1:46.48

PURPOSE OF TESTS

7. Tests in this model were directed toward solution of the first major problem listed in paragraph 3. Specifically the model provided a means for:

a. Selection of a satisfactory location and alignment for the lock and navigation approaches to the lock in the vicinity of Buffalo.

b. Determination of the approximate amount of excavation required to compensate for encroachment of the lock or navigation channel into the rapids section and thus maintain the existing Lake Erie stage-Niagara River discharge relation.

c. Resolution of the need for any overexcavation of the navigation channel in order to obtain acceptable velocities.

d. Determination of the effects of the navigation works on flow distribution around Grand Island and, if needed, development of compensating structures.

MODEL LIMITATIONS

8. The existing model with its distorted scale was not an ideal tool for study of the items

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* U. S. Army Engineer Waterways Experiment Station, CE, "Preservation and Enhancement of Niagara Falls; Hydraulic Model Investigation," Technical Memorandum No. 2-411, July 1955, Vicksburg, Miss.

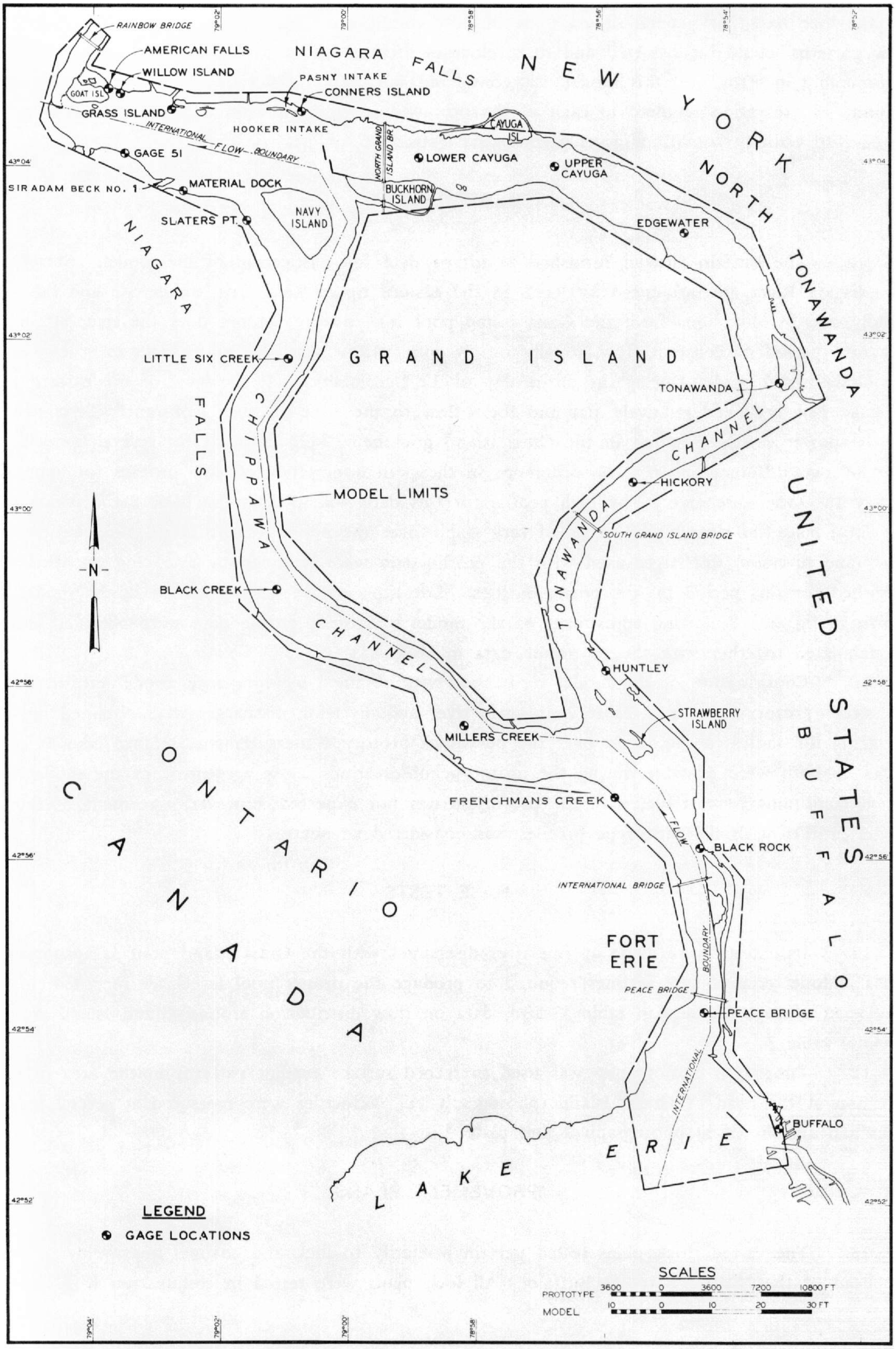


Fig. 1. Model layout and location of model gages

listed above. However, it was considered adequate to furnish an indication of the best location for the lock based on general observations of flow conditions. Also, while it was realized that flow patterns would be distorted and that velocities measured at a particular location might be considerably in error, still this model was considered suitable for determination of the approximate amount of excavation required in each of the proposed schemes to maintain existing stages and to develop velocity conditions acceptable for navigation.

VERIFICATION

9. The Buffalo District furnished prototype data for verification of the model. Stages in the Niagara River are influenced by levels in the eastern tip of Lake Erie which rise and fall rapidly and by diversions from the Grass Island pool for power. Seldom does the river attain a sustained period of constant flow, usually inflow and outflow vary due to changes in storage in the Grass Island pool. During the entire day of 12 December 1964, the level of the eastern tip of Lake Erie remained relatively flat and the inflow to the river relatively constant. Tests made by the power entities resulted in the Grass Island pool being held constant for several hours at each of two different levels. The difference in the pool level produced two profiles for approximately the same discharge. The high profile for this date was used as the basic verification profile since lake and river stages remained very stable over the period of prototype measurements. River and diversion discharges used with the profile data were obtained by averaging the discharges furnished for this period by the power entities. Locations of the gages installed in the model are shown in fig. 1. Following adjustment of the model roughness, profile data were obtained and are tabulated together with the prototype data in table 1.

10. Confirmation of the model verification was obtained by comparing model profiles with five other prototype profiles (table 2). Again river and diversion discharges were obtained by averaging the indicated discharges over the period of prototype measurements. Since lake or river stages or both were unstable during the prototype observations, close agreement of the model, in which conditions were stable, with the prototype was not expected; however, agreement of the model profiles with the prototype profiles was considered adequate.

BASE TESTS

11. Base tests were made at five river discharges with the Grass Island pool at appropriate levels. Model control gate settings required to produce the proper pool levels are recorded in the tabulation of gage readings in table 3; also, data on flow distribution around Grand Island are given in table 3.

12. Time-lapse photography was used to record surface current patterns in the area of flow diversion at the head of Grand Island (photograph 1). Velocities were measured at several locations and are shown in photograph 1 and plate 1.

IMPROVEMENT PLANS

13. The various lock plans tested pertain primarily to lock and channel improvements near the head of the Niagara River at Buffalo. All lock plans were tested in conjunction with an

improved channel in the river from the vicinity of Squaw Island to the junction with the overland section. This channel was generally 700 ft wide, widened more at bends, and narrowed through the South Grand Island bridges.

Lock Plan 1

14. Lock plan 1 was essentially an improvement of the existing Black Rock Canal. A long section of the Bird Island pier was relocated riverward of the existing structure in order to permit a widened channel. The new lock was located on Squaw Island westerly of the present lock. Below the lock the channel entered the river and joined the improved river channel.

15. Water-surface elevation and flow distribution data obtained with lock plan 1 and the improved channel are given in table 4. Water-surface elevations at the downstream river gages were in close agreement with base tests but elevations at the head of Grand Island were somewhat lower and Lake Erie levels were considerably higher. The increase in Lake Erie levels varied from about 0.9 ft at a river discharge of 113,350 cfs to about 2.5 ft at a discharge of 254,000 cfs. Flow distribution around Grand Island essentially was the same as observed in the base tests. Velocities (see data in photograph 2 and plate 2) were considerably higher at several ranges upstream from Grand Island but in the navigation channel were of the same order of magnitude as those measured in the base tests.

16. An additional flow distribution test was made with the lower guide wall of the lock removed to determine if the deflection of flow by this wall into the Canadian channel compensated for any effect of the excavation in the American channel. Flow distribution data for this and previous tests are listed below:

	Niagara River Discharge, 145,500 cfs		Niagara River Discharge, 254,000 cfs	
	American Channel Discharge cfs	Canadian Channel Discharge cfs	American Channel Discharge cfs	Canadian Channel Discharge cfs
Base test	58,750	86,750	101,000	153,000
Lock plan 1	59,450	86,050	101,350	152,650
Lock plan 1, lower guide wall removed	60,750	84,750	104,000	150,000

With the guide wall removed there was a slight increase in flow into the American channel. However, these data indicate that relatively major changes at the head of Grand Island produce only minor variations in distribution of flow around Grand Island. This is attributed to the predominant influence of hydraulic losses in the two long channels around the island and the slight increase in flow in the American channel is attributed to the excavation in this channel.

17. Two plans for excavation through the reach at Peace Bridge were tested in an attempt to restore the Lake Erie stage-Niagara River discharge relation. Information obtained in a previous study* was used to estimate the elevation to which the river channel should be excavated.

* E. B. Lipscomb, "Plans for Regulation of Levels of Lake Erie; Hydraulic Model Investigation," Technical Report No. 2-456, June 1957, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Excavation plan 1 provided a channel bottom elevation of 543.2* extending from a fan-shaped entrance about 6500 ft upstream from Peace Bridge to approximately 3500 ft downstream from this bridge. Excavation plan 2 was similar except the channel bottom was at el 549.2 and extended only about 1500 ft downstream from Peace Bridge. Calibration data are listed below.

Niagara River Inflow at Buffalo, cfs	Lake Erie Elevation, IGLD			
		Lock Plan 1		
	Natural Conditions	Existing Topography	Excavation Plan 1	Excavation Plan 2
113,350	566.64	567.54	563.64	564.30
144,500	568.20	569.58	565.33	566.22
202,170	570.60	572.70	568.26	569.22

Results of these tests indicate that only a relatively small amount of channel excavation would be required to approximately restore the normal Lake Erie stage-Niagara River discharge relation.

Lock Plan 2

18. In lock plan 2 the Black Rock Canal was followed only to the sharp turn just above the Peace Bridge, where the new route diverged to reach the proposed lock upstream of the bridge and westerly of the Bird Island pier. Below the lock, the channel entered the river along the westerly side of Squaw Island and then into the river channel as in lock plan 1. A control structure at the head of the river would be needed in this plan. The approximate location of the proposed control structure is indicated in plate 3. Also shown in plate 3, immediately downstream from the control structure, are control gages 1 and 2; water-surface elevations at these gages must not exceed certain maximums in order for the control structure to perform its primary task of regulation of the levels in Lake Erie.

19. Initial tests of lock plan 2 were made with excavation plan 1A which was the same as excavation plan 1 (paragraph 17) except that it also included a 700-ft-wide navigation channel along Squaw Island excavated to el 533.8.

20. Flow patterns at the head of Grand Island, and water-surface profiles and distribution of flow around Grand Island were very similar to those observed with the lower guide wall removed in lock plan 1. Data are shown in table 5 and photograph 3. However, velocities excessively high for navigation together with severe crosscurrents were observed in the channel between the lower guide wall of the proposed lock and the International Bridge. Also, for a discharge of 254,000 cfs, water-surface elevations at control gages 1 and 2 were about 1.5 ft higher than the maximums permissible for satisfactory performance of the control structure.

21. Tests were conducted with lock plan 2 and three additional excavation plans (plans 3, 4, and 5). Observations indicated that excavation similar to that used in plan 5 (1500-ft-wide channel at el 518.2) would be necessary to reduce velocities in the navigation channel to less than 4 fps. A sketch of excavation plan 5 and velocities in the channel are given in plate 3. However, even with this extensive excavation high velocities obtained along the lock guide wall and crosscurrents just downstream from the wall were quite severe. It is considered that additional local corrective measures in this area would be required to eliminate the undesirable crosscurrents.

* All elevations (el) cited herein are in feet referred to International Great Lakes Datum (IGLD).

Water-surface elevations at control gages 1 and 2 were 3 to 4 ft below the required maximums. Also, profiles and flow distribution around Grand Island were unchanged from those with excavation plan 1A shown in table 5.

Lock Plan 3

22. Lock plan 3 followed an entirely new route, leaving the Buffalo Harbor North Entrance Channel about one mile lakeward of the west breakwater, and proceeding directly to a new lock at the head of the river. Below the lock the channel in the river was similar to lock plan 2. This scheme not only would require a control structure across the river but also a new breakwater in the lake to protect the lock approach.

23. Profile, flow distribution, and velocity data obtained with lock plan 3 essentially were the same as those obtained with lock plan 2. Again excavation plan 5 was required to obtain velocities less than 4 fps in the navigation channel (plate 4). Also crosscurrents in the lower approach to the proposed lock were quite severe and again local corrective measures in this area would be required.

24. An additional test was made with the channel bottom raised 6 ft to el 524.2 (excavation plan 6) but this resulted in velocities considered excessive for navigation.

Lock Plan 4

25. Lock plan 4 followed the same route as lock plan 2 as far as the sharp bend upstream of the Peace Bridge; from there the channel shifted riverward to a new lock on the west side of Squaw Island. A new pier connected the lock with the existing Bird Island pier. Downstream from the lock the navigation channel was in the river.

26. Lock plan 4 was tested with several excavation plans and excavation plan 8A shown in plate 5 proved the most feasible. However, crosscurrents in the downstream lock approach were severe and again local corrective measures are indicated. Profiles and distribution of flow around Grand Island essentially were the same as with other lock plans tested. Water-surface elevations at control gages 1 and 2 were low enough to permit adequate functioning of a control structure. However, this plan probably could be used without a control structure by modification of the excavation in the vicinity of the Peace Bridge in order to raise the stage in Lake Erie about 3.5 ft for a river discharge of 254,000 cfs.

Lock Plan 1B (Recommended)

27. At this stage of the test program a conference was held at the U. S. Army Engineer Waterways Experiment Station during which results of tests on lock plans 1-4 were reviewed for engineers of the Buffalo District, the U. S. Army Engineer Division, North Central, and the Office, Chief of Engineers. Engineers of the Waterways Experiment Station considered lock plan 1 the most feasible in that:

- *a.* Problems in the navigation approaches to the lock, particularly the lower approach, were much less severe than in the other plans.
- *b.* A control structure at the origin of the river was not required. In plans 2 and 3 a control structure was imperative, and in plan 4 indications were that a control structure probably would be required.
- *c.* The excavation required to compensate for encroachment into the rapids section

and thus maintain the existing Lake Erie stage-Niagara River discharge relation was minimum.

d. No overexcavation in the rapids section in order to obtain acceptable navigation velocities was indicated while large amounts of excavation for this purpose would be required with the other plans.

28. In accord with these recommendations design engineers developed lock plan 1B which differed from lock plan 1 primarily in that it provided a straight channel, 600 ft wide, from the Peace Bridge to the proposed lock. Also, the proposed locations of the lock and the channel in the Niagara River to about sta 400+00 were changed slightly.

29. With lock plan 1B installed in the model, excavation in the vicinity of Peace Bridge (section 14 to section 22) to about el 554 (excavation plan 9) was required to maintain the natural relation between Lake Erie water-surface elevation and a river discharge of 254,000 cfs. At lesser lake levels, indications were that the capacity of the excavated channel would be greater than the capacity of the present channel.

30. Only minor changes in water-surface elevations throughout the model were produced by installation of lock plan 1B. Data are presented in table 6. Also, distribution of flow around Grand Island was not materially changed in that the increase in discharge in the American channel was only about 1 percent. Flow patterns and velocity data are presented in photograph 4 and plate 6. Of all plans tested this one resulted in the most favorable flow conditions for ships entering and leaving the lock. However, a crosscurrent at the head of Strawberry Island (photograph 4) might require corrective works.

PART III: CANAL ENTRANCE MODEL

DESCRIPTION

31. The canal entrance model was of the fixed-bed type and reproduced a 25,000-ft-long reach of the American channel extending from a section about 7000 ft upstream from Tonawanda Island to a section about 7000 ft downstream from the proposed entrance to the overland canal. A layout of this model is shown in plate 7. An important feature of this model was a scaled reproduction of a Great Lakes 730-ft-long bulk carrier, with a 75.5-ft beam and a draft of 26.5 ft when fully loaded (fig. 2). This model ship was equipped with a gyroscopic control device and

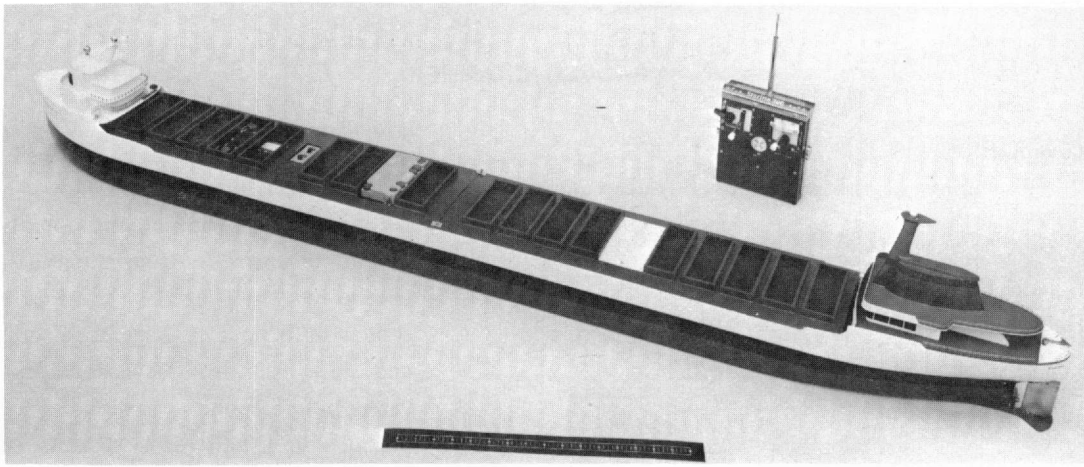


Fig. 2. Model of 730-ft-long bulk carrier

instrumentation for recording rudder position and heading. Also, remote radio-operated controls permitted power regulation and rudder manipulation.

SCALE RELATIONS

32. The model was constructed to a linear scale of 1:120. Scale ratios, model to prototype, in accordance with the Froudian relation are presented in the following tabulation.

Dimension	Scale Relation
Length	1:120
Velocity	1:10.95
Discharge	1:157,545
Time	1:10.95
Roughness (Manning's n)	1:2.221

PURPOSE OF TESTS

33. This model was concerned with the second major problem, i.e. current conditions at the entrance to the overland canal (see paragraph 3). Specifically, the model provided means for determining the influence that the channel excavation would have on the magnitude and direction of

currents in this reach of the river and evaluating the effects of these currents on ships entering and leaving the canal. If test results indicated that supplementary excavations and/or structures were needed, then the model would be used as a tool to develop designs which would result in acceptable navigation conditions.

BASE TEST

34. Base tests were conducted to verify water-surface profiles in the model and to obtain basic data on velocities and current patterns. Water-surface elevations agree closely with corresponding elevations observed in the Niagara River model (table 7). Current patterns are shown in photograph 5 and velocity data are plotted in plate 8.

IMPROVED CHANNEL

Original Design

35. Limits of the proposed 30-ft-deep improved channel are shown in plate 9. This channel was 700 ft wide at and for about 10,000 ft upstream from the canal entrance. Water-surface elevations are shown in table 8. Current patterns and velocities with this channel excavated in the model are shown in photograph 6 and plate 10. As expected, the excavated channel resulted in a decrease in average velocity but also resulted in a greater decrease than anticipated in velocities along the right bank of the river downstream from Tonawanda Island. Flow tended to move longitudinally down the excavated channel and slide out of the left side of this channel over a considerable reach. The crosscurrent at the canal entrance, shown in fig. 3, was not as severe as expected.

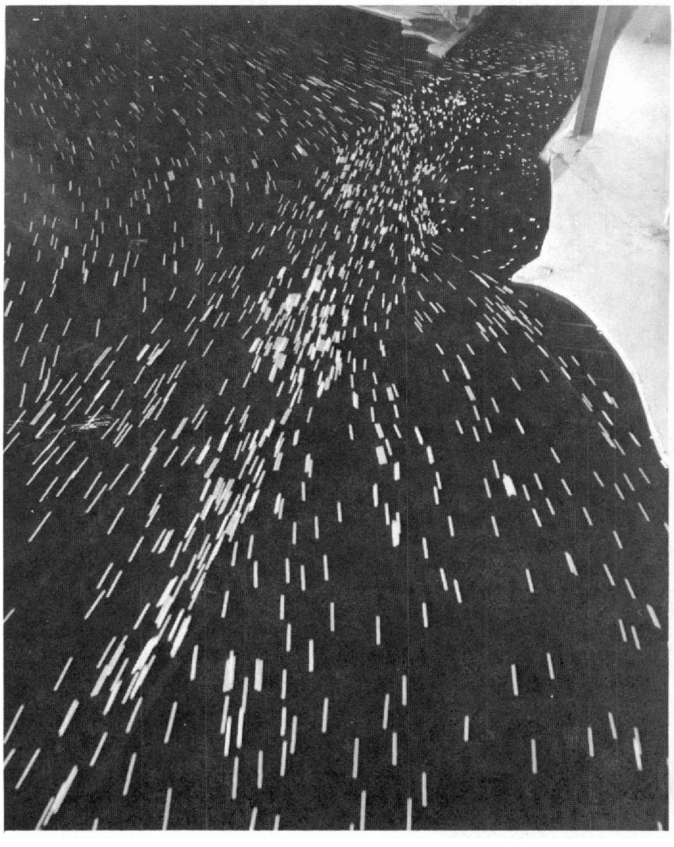


Fig. 3. Crosscurrents at canal entrance; discharge 101,000 cfs

36. Sequence views of the model bulk carrier moving into and out of the canal are shown in photographs 7 and 8. A light on the bow of the ship produced the white line in each photograph, which indicates the path of the bow throughout the test. The power setting required for a particular slack water speed was determined in water about 40 ft deep. In the 30-ft-deep channel with the carrier at a draft of 26.5 ft, the power

setting for a slack water speed of 8 knots resulted in ground speeds of about 7 knots downbound and 5 knots upbound. No difficulty was experienced, even when operating at slow speeds, in maneuvering the vessel into or out of the canal. The crosscurrent extended over a reach of about 2000 ft and resulted in only a gradual downriver drift of the ship but no sudden swinging of the heading as the ship entered or left the area of crosscurrent (ship trial stations 6000 to 8000, see plate 9). In maneuvering the ship near the sides of the channel the downriver drift was increased greatly when the ship was within about 50 ft of the downriver edge of the navigation channel.

Structures

37. Preliminary observations were made with dikes at various positions and alignments, both upriver and downriver from the canal entrance, but in every case the structure aggravated navigation conditions.

Supplementary Excavations

38. Several supplementary excavations on the downriver side of the navigation channel between ship trial stations 3000 and 10,000 were tested. These excavations varied between el 540 and 532 (ship channel elevation) and in extent to as much as 1000 ft downriver from the navigation channel. All of these supplementary excavations reduced velocities along the right bank of the river in the vicinity of river station 50,000. This would suggest a decrease in currents crossing the navigation channel immediately upstream from the canal entrance. However, no differences in ship handling could be detected among any of the excavation plans except that all plans reduced the drift of the ship when it was within 50 ft of the downriver edge of the original improved channel. This latter benefit was fully realized with supplementary excavation between ship trial stations 3000 and 10,000 to el 532 extending 100 ft downriver from the edge of the original design channel, and this amount of supplementary excavation is recommended.

Two Ship Trials

39. Final tests were made with two ships operating simultaneously in the model: the scaled model of a bulk carrier constructed for this project and a model of the same bulk carrier but twice as large, which had been constructed for another project (fig. 4). The larger model represented a vessel of 1460-ft length, 151-ft beam, and 26-ft draft. Tests were conducted with

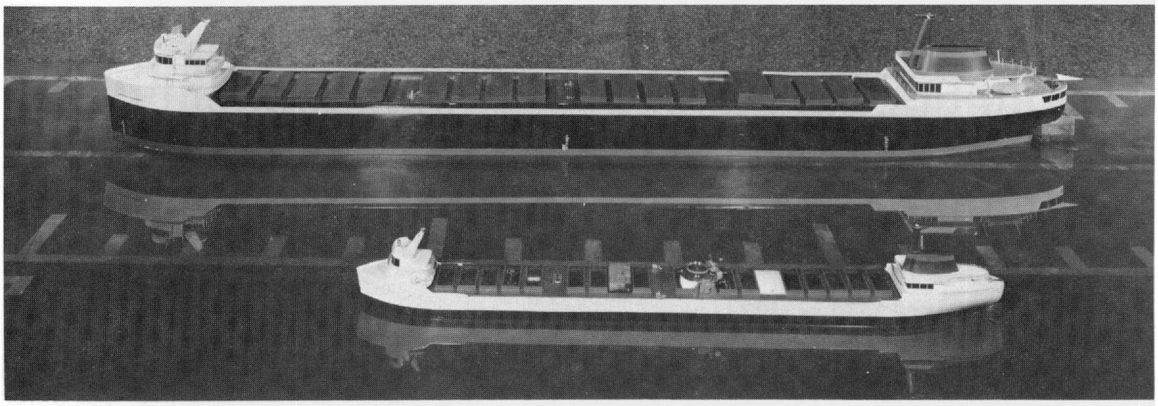


Fig. 4. Scaled model ship in foreground; double size vessel in background

the supplementary excavation recommended in paragraph 38 and with an American channel discharge of 101,000 cfs.

40. No difference in performance of the two model ships could be detected as each required about the same amount of rudder adjustment to compensate for the river currents. When operated under the power required for a still-water speed of only 4 knots, no difficulty was experienced in steering either of the two ship models into or out of the canal or in having the ships pass at any location within the channel.

PART IV: DISCUSSION

41. The model tests reported herein satisfactorily resolved major problems involving the location of the lock in the vicinity of Buffalo and navigation conditions at the entrance to the overland canal.

42. It was demonstrated that a location as far downstream as is feasible is the most suitable for the proposed lock in the vicinity of Buffalo. Limitation on the downstream position of this lock is imposed by the requirement that the Black Rock Lock and Canal be maintained in operation during the construction period. Lock plan 1B, plate 6, was the most desirable of the plans tested.

43. The widened canal upstream from the lock will constrict the channel of the Niagara River and thus will require compensating excavation to maintain the existing Lake Erie stage-Niagara River discharge relation. The model indicated that excavation to about el 554 over a distance of about 6000 ft would be required. However, this model, constructed to scales of 1:60 vertically and 1:360 horizontally resulting in a slope scale of 6:1, model to prototype, was not considered a suitable tool for study of details, involving either amount or position, of excavation.

44. To overcome the effect of slope distortion and greater channel efficiency caused by the variation in width-depth ratio, it was necessary to add a large amount of roughness to the model surface in the form of stucco and expanded wire mesh in order to reproduce prototype stages. The reach of the model in the vicinity of the Peace and International Bridges was adjusted to reproduce prototype differentials between the Black Rock and Buffalo gages. No attempt was made to accurately reproduce a prototype flow line at intermediate points between these gages, and it is possible that there were considerable local discrepancies in water-surface elevations between model and prototype. Further, the added roughness in this relatively shallow reach may have resulted in a significant reduction in cross-sectional area at certain sections.

45. Installation in the prototype of LEO conditions will result in a narrower and deeper channel. For instance, at section 18 the channel will have a width of only about 1220 ft instead of 1600 ft but will have a corresponding increase in average depth and thus hydraulic radius. If in the Manning equation the roughness factor and slope are considered equal before and after the excavation then the increase in hydraulic radius in the excavated channel would result in about a 19 percent increase in velocity. Thus, in the more efficient excavated channel it will be necessary to accept some increase in average velocity, but it will not be necessary to fully compensate by excavation for the loss of cross section due to the lateral constriction.

46. Prototype measurements indicate relatively constant velocities from a section about 1000 ft upstream from the Peace Bridge to a section at least 2000 ft downstream from this bridge. When LEO conditions are installed the excavation must be accomplished in such a manner as to maintain relatively constant velocities over as long a reach as is feasible. If this is not done then the existing Lake Erie stage-Niagara River discharge relation probably would not be maintained over a reasonable range of Lake Erie stages.

47. Tests indicated no severe navigation conditions in the downstream approach to the lock and that overexcavation of the navigation channel in order to obtain acceptable velocities would not be necessary. However, here again the distorted model was not an ideal tool for this study. The eddy that was produced by the lock training wall extended a greater distance downstream in the model than it would in the prototype, and this, no doubt, resulted in unnatural distribution

of flow around the small islands immediately upstream from Grand Island.

48. Thus while adoption of lock plan 1B for the feasibility studies appears reasonable, if the project enters the design stage it is strongly recommended that an undistorted-scale model be used for study of excavation plans and navigation conditions in the reach from Lake Erie to the upstream portion of the American channel around Grand Island.

49. Tests in the distorted model showed that installation of the navigation works would result in an increase in flow in the American channel of about 1 percent of the total Niagara River flow. Relatively major changes in the model at the head of Grand Island produced only minor variations in distribution of flow around this island. Therefore it was concluded that hydraulic losses in the channels, and not flow patterns at the head of the island, predominantly influence the distribution of flow around Grand Island. Thus a mathematical model should be reliable for predicting flow distribution for any proposed improved channel dimensions. If restoration of the natural distribution of flow around Grand Island is considered necessary, then consideration should be given to accomplishing this by constriction of the American channel downstream from the canal entrance, possibly with spoil from the improved channel excavations. Again a mathematical model should be adequate for determination of the required degree and extent of channel constriction.

50. Tests in the undistorted model of the overland canal entrance clearly demonstrated that ships should have no difficulty entering or leaving the canal. Overexcavation extending 100 ft on the downriver side of the 700-ft-wide channel approaching the canal entrance was found desirable. This overexcavation should extend over a channel distance of about 7000 ft.

Table 1

Basic Verification

Gage	Water-Surface Elevations, ft IGLD Prototype	Model
American channel		
Buffalo	568.37	568.15
Peace Bridge	565.43	565.38
Black Rock	563.80	563.70
Huntley	563.29	563.22
Hickory	562.90	562.92
Tonawanda Island	562.88	562.86
Edgewater	562.18	562.26
Upper Cayuga	562.00	562.02
Lower Cayuga	561.82	561.84
Hooker	561.60	561.54
Canadian channel		
Frenchmans Creek	563.35	563.40
Millers Creek	562.98	562.98
Black Creek	562.65	562.56
Little Six Creek	561.96	561.90
Slaters Point	561.51	561.48
Material Dock	561.30	561.30

Note: High profile for 12 December 1964.

Niagara River inflow at Buffalo:	145,500 cfs
Power intake diversions	
PASNY	47,650 cfs
Sir Adam Beck No. 1	45,350 cfs
Flow passing Falls	52,500 cfs

Table 2

Verification Confirmation

Location	Flows and Diversions, cfs				
	Profile for 4 December 1964	Lower Profile for 12 December 1964	Higher Profile for 23 November 1964	Lower Profile for 23 November 1964	Lower Profile for 21 November 1964
Niagara River inflow at Buffalo	113,350	159,940	169,870*	173,500*	202,170
Power intake diversions					
PASNY	28,750	53,100	60,920	61,740	89,770
Sir Adam Beck No. 1	33,710	53,350	57,830	60,320	60,640
Flow passing Falls	50,890	53,490	51,120	51,440	51,760

Gage	Water-Surface Elevations, ft IGLD									
	Prototype	Model	Prototype	Model	Prototype	Model	Prototype	Model	Prototype	Model
American channel										
Buffalo	565.65	566.65	568.37	568.80	569.85	569.24	569.13	569.40	570.55	570.61
Black Rock	561.25	561.42	563.47	563.58	564.35	564.06	564.18	564.06	565.57	564.96
Huntley	560.69	560.94	562.90	563.04	563.52	563.46	563.33	563.40	564.48	564.36
Hickory	560.50	560.76	562.56	562.74	563.22	563.16	563.03	563.04		
Tonawanda Island	560.45	560.64	562.50	562.62	563.00	562.98	562.82	562.92	563.78	563.76
Edgewater	559.77	559.92	561.65	561.84	562.22	562.26	562.12	562.14		
Upper Cayuga	559.37	559.56	561.27	561.42	561.85	561.90	561.68	561.72		
Lower Cayuga	559.16	559.20	561.00	561.12	561.51	561.54	561.34	561.36		
Hooker	559.00	558.84	560.75	560.64	561.14	561.12	560.98	560.88		
Canadian channel										
Frenchmans Creek	560.80	561.36	562.98	563.28	563.74	563.70	563.58	563.70	564.58	564.66
Millers Creek	560.65	560.58	562.56	562.68	563.25	563.10	563.10	563.10		
Black Creek	559.94	560.16	562.10	562.20	562.65	562.62	562.45	562.50		
Little Six Creek	559.20	559.32	561.28	561.30	561.73	561.72	561.55	561.54		
Slaters Point	558.74	558.78	560.64	560.64	561.07	561.06	560.87	560.88		
Material Dock	558.50	558.48	560.40	560.40	560.80	560.82	560.50	560.52	561.10	561.18

* See paragraph 9.

Table 3

Water-Surface Elevations, Base Test

Location	Flows and Diversions, cfs					
Niagara River inflow at Buffalo	113,350	145,500	202,170	202,170	254,000	300,000
American channel	45,700	58,750	86,950	83,900	101,000	--
Canadian channel	67,650	86,750	115,220	118,270	153,000	--
Power intake diversions						
PASNY	33,000	50,000	87,000	52,000	89,000	101,000
Sir Adam Beck No. 1	30,350	45,500	65,170	50,170	65,000	64,700
Flow passing Falls	50,000	50,000	50,000	100,000	100,000	134,300
Control gates open	1-10	1-7	1	1-8	1-4	1-5

Gage	Water-Surface Elevations, ft IGLD					
American channel						
Buffalo	566.6	568.2	570.6	570.6	572.7	574.3
Black Rock	561.4	562.8	564.9	564.9	566.6	568.2
Huntley	560.7	562.0	564.0	564.1	565.8	567.2
Hickory	560.5	561.7	563.6	563.6	565.2	566.5
Tonawanda Island	560.4	561.6	563.4	563.5	565.0	566.3
Edgewater	559.7	560.8	562.6	562.6	564.1	565.4
Upper Cayuga	559.3	560.3	562.0	562.1	563.6	564.9
Lower Cayuga	558.9	559.9	561.6	561.7	563.2	564.4
Hooker	558.7	559.6	561.2	561.4	562.7	564.0
Canadian channel						
Frenchmans Creek	561.0	562.3	564.3	564.4	566.0	567.5
Millers Creek	560.4	561.6	563.6	563.7	565.3	566.8
Black Creek	560.0	561.1	563.0	563.2	564.8	566.2
Little Six Creek	559.1	560.2	562.0	562.0	563.5	564.8
Slaters Point	558.6	559.6	561.2	561.3	562.7	564.0
Material Dock	558.4	559.4	561.1	561.1	562.6	563.8

Table 4

Water-Surface Elevations, Lock Plan 1

Location	Flows and Diversions, cfs							
Niagara River inflow at Buffalo	113,350		145,500		202,170		254,000	
American channel	45,700	44,900	58,750	59,450	83,900	84,400	101,000	101,350
Canadian channel	67,650	68,450	86,750	86,050	118,270	117,770	153,000	152,650
Power intake diversions								
PASNY	33,000		50,000		52,000		89,000	
Sir Adam Beck No. 1	30,350		45,500		50,170		65,000	
Flow passing Falls	50,000		50,000		100,000		100,000	
Control gates open	1-10		1-7		1-8		1-4	

Gage	Water-Surface Elevations, ft IGLD							
	Base Test	Plan 1	Base Test	Plan 1	Base Test	Plan 1	Base Test	Plan 1
American channel								
Buffalo	566.6	567.5	568.2	569.6	570.6	572.7	572.7	575.2
Black Rock	561.4	560.5	562.8	561.9	564.9	564.0	566.6	565.6
Huntley	560.7	560.5	562.0	561.8	564.1	563.8	565.8	565.3
Hickory	560.5	*	561.7	*	563.6	*	565.2	*
Tonawanda Island	560.4	560.3	561.6	561.5	563.5	563.4	565.0	564.7
Edgewater	559.7	559.9	560.8	561.0	562.6	562.9	564.1	564.1
Upper Cayuga	559.3	559.3	560.3	560.5	562.1	562.3	563.6	563.7
Lower Cayuga	558.9	559.0	559.9	560.1	561.7	562.0	563.2	563.3
Hooker	558.7	558.5	559.6	559.6	561.4	561.4	562.7	562.8
Canadian channel								
Frenchmans Creek	561.0	560.5	562.3	562.0	564.4	564.1	566.0	565.7
Millers Creek	560.4	560.1	561.6	561.5	563.7	563.6	565.4	565.3
Black Creek	560.0	559.7	561.1	561.0	563.2	563.1	564.8	564.7
Little Six Creek	559.1	559.0	560.2	560.2	562.0	562.1	563.5	563.6
Slaters Point	558.6	558.6	559.6	559.7	561.3	561.5	562.7	562.8
Material Dock	558.4	558.4	559.4	559.5	561.1	561.3	562.6	562.7

* Out of service.

Table 5

Water-Surface Elevations, Lock Plan 2 with Excavation Plan 1A

Location	Flows and Diversions, cfs			
Niagara River inflow at Buffalo	145,500		254,000	
American channel	58,750	60,200	101,000	103,900
Canadian channel	86,750	85,300	153,000	150,100
Power intake diversions				
PASNY	50,000		89,000	
Sir Adam Beck No. 1	45,500		65,000	
Flow passing Falls	50,000		100,000	
Control gates open	1-7		1-4	

Gage	Water-Surface Elevations, ft IGLD			
	Base Test	Plan 2	Base Test	Plan 2
American channel				
Buffalo	568.2	565.3	572.7	571.4
Black Rock	562.8	562.0	566.6	566.0
Huntley	562.0	561.8	565.8	565.6
Hickory	561.7	*	565.2	*
Tonawanda Island	561.6	561.4	565.0	565.0
Edgewater	560.8	560.9	564.1	564.3
Upper Cayuga	560.3	560.3	563.6	563.8
Lower Cayuga	559.9	559.9	563.2	563.4
Hooker	559.6	559.5	562.7	563.0
Canadian channel				
Frenchmans Creek	562.3	561.8	566.0	565.7
Millers Creek	561.6	561.2	565.4	565.0
Black Creek	561.1	560.8	564.8	564.5
Little Six Creek	560.2	550.0	563.5	563.5
Slaters Point	559.6	559.5	562.7	563.0
Material Dock	559.4	559.3	562.6	562.7

* Out of service.

Table 6

Water-Surface Elevations, Lock Plan 1B with Excavation Plan 9

Location	Flows and Diversions, cfs					
Niagara River inflow at Buffalo	113,350	145,500		202,170	254,000	
American channel		58,750	60,200		101,000	103,200
Canadian channel		86,750	85,300		153,000	150,800
Power intake diversions						
PASNY	33,000	47,650		52,000	89,000	
Sir Adam Beck No. 1	30,350	45,350		50,170	65,000	
Flow passing Falls	50,000	52,500		100,000	100,000	
Control gates open	1-10	1-7		1-8	1-4	

Gage	Water-Surface Elevations, ft IGLD							
	Base Test	Plan 1B	Base Test	Plan 1B	Base Test	Plan 1B	Base Test	Plan 1B
American channel								
Buffalo	566.6	565.0	568.2	566.8	570.6	569.8	572.7	572.5
Black Rock	561.4	560.1	562.8	561.4	564.9	563.4	566.6	565.2
Huntley	560.7	560.0	562.0	561.3	564.1	563.3	565.8	565.0
Hickory	560.5	*	561.7	*	563.6	*	565.2	*
Tonawanda Island	560.4	559.9	561.6	561.1	563.5	562.9	565.0	564.6
Edgewater	559.7	559.6	560.8	560.8	562.6	562.6	564.1	564.2
Upper Cayuga	559.3	559.1	560.3	560.2	562.1	562.1	563.6	563.7
Lower Cayuga	559.0	558.9	559.9	560.0	561.7	561.8	563.2	563.4
Hooker	558.7	558.5	559.6	559.6	561.4	561.4	562.7	562.9
Canadian channel								
Frenchmans Creek	561.0	560.1	562.3	561.4	564.4	563.4	566.0	565.2
Millers Creek	560.4	559.6	561.6	560.9	563.7	563.0	565.4	564.8
Black Creek	560.0	559.3	561.1	560.5	563.2	562.5	564.8	564.2
Little Six Creek	559.1	558.9	560.2	560.0	562.0	561.8	563.5	563.5
Slaters Point	558.6	558.6	559.6	559.6	561.3	561.4	562.7	563.0
Material Dock	558.4	558.5	559.4	559.5	561.1	561.2	562.6	562.8

* Out of service.

Table 7

Canal Entrance Model, Base Test

Location	Flows and Diversions, cfs					
Niagara River inflow at Buffalo	113,350	145,500	202,170	202,170	254,000	300,000
Power intake diversions						
PASNY	33,000	50,000	52,000	87,000	89,000	101,000
Sir Adam Beck No. 1	30,350	45,500	50,170	65,170	65,000	64,700
Flow passing Falls	50,000	50,000	100,000	50,000	100,000	134,300

Gage	Water-Surface Elevations, ft IGLD											
	American Channel Discharge 45,700 cfs		American Channel Discharge 58,750 cfs		American Channel Discharge 83,900 cfs		American Channel Discharge 86,950 cfs		American Channel Discharge 101,000 cfs		American Channel Discharge 120,000 cfs (Est)	
	Canal Entrance Model	Niagara River Model	Canal Entrance Model	Niagara River Model	Canal Entrance Model	Niagara River Model	Canal Entrance Model	Niagara River Model	Canal Entrance Model	Niagara River Model	Canal Entrance Model	Niagara River Model
1	560.5	560.5	561.7	561.7	563.6	563.5	563.6	563.5	565.1	565.0	566.3	566.2
2	560.5		561.7		563.5		563.6		565.1		566.3	
3	560.5	560.4	561.6	561.5	563.5	563.3	563.5	563.3	565.0	564.8	566.1	566.1
4	560.5		561.6		563.5		563.5		565.1		566.2	
5 Tonawanda Island	560.4	560.4	561.6	561.6	563.5	563.5	563.5	563.4	565.0	565.0	566.2	566.3
6	560.3		561.5		563.3		563.4		564.9		566.0	
7	560.3	560.3	561.4	561.3	563.3	563.1	563.3	563.0	564.8	564.6	565.9	565.8
8	560.2		561.2		563.2		563.2		564.7		565.8	
9	560.0		561.1		563.0		563.0		564.5		565.6	
10	559.9	560.0	561.0	561.0	562.9	562.8	562.9	562.6	564.4	564.2	565.5	565.6
11 Edgewater	559.7	559.7	560.8	560.8	562.6	562.6	562.6	562.6	564.1	564.1	565.4	565.4
12	559.0	559.3	560.2	560.3	562.0	562.2	561.8	562.1	563.6	563.6	564.8	564.8

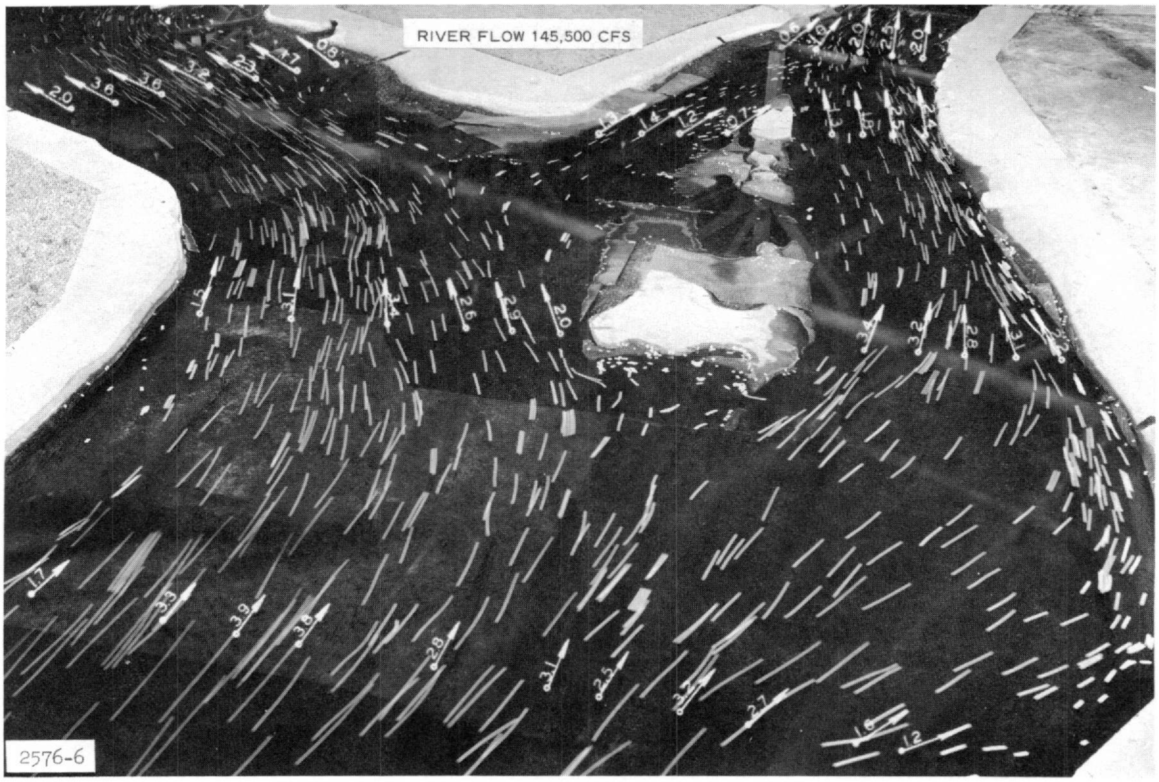
Table 8

Canal Entrance Model Improved Channel, Original Design

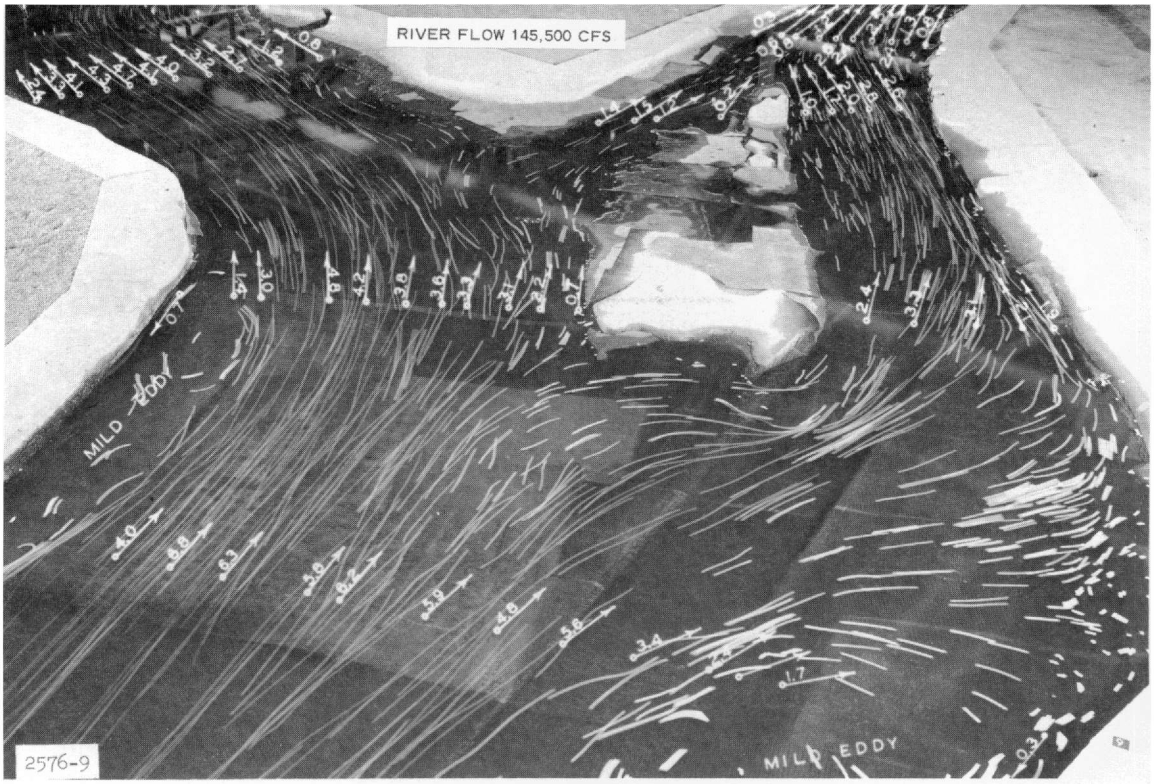
Location	Flows and Diversions, cfs	
Niagara River inflow at Buffalo	145,500	254,000
Power intake diversions		
PASNY	50,000	89,000
Sir Adam Beck No. 1	45,500	65,000
Flow passing Falls	50,000	100,000

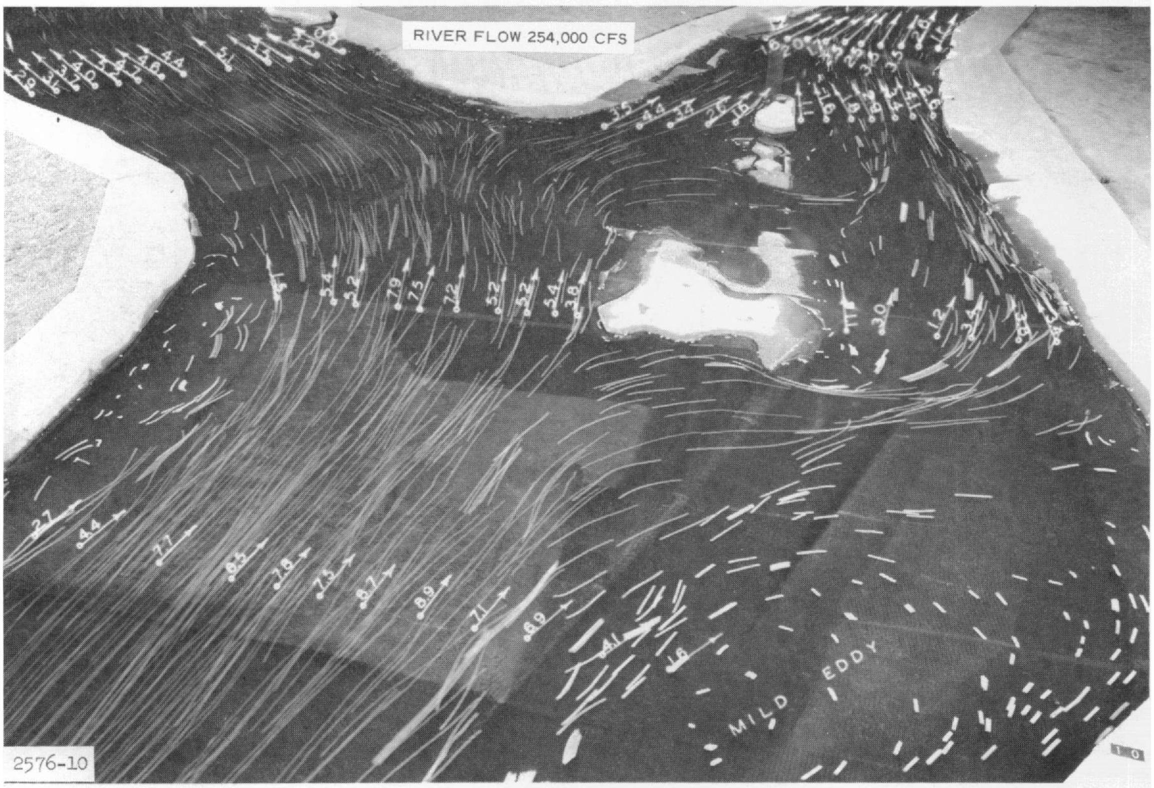
	Water-Surface Elevations, ft IGLD			
	American Channel Discharge 58,750 cfs		American Channel Discharge 101,000 cfs	
Gage	Base Test	Improved Channel	Base Test	Improved Channel
1	561.7	561.1	565.1	564.7
2	561.7	561.1	565.1	564.7
3	561.6	561.1	565.0	564.7
4	561.6	561.1	565.1	564.7
5 Tonawanda Island	561.6	561.1	565.0	564.7
6	561.5	561.0	564.9	564.7
7	561.4	561.1	564.8	564.6
8	561.2	561.0	564.7	564.6
9	561.1	561.0	564.5	564.5
10	561.0	560.9	564.4	564.5
11 Edgewater	560.7	560.8	564.1	564.1
12	560.2	560.3	563.6	563.6

PHOTOGRAPHS

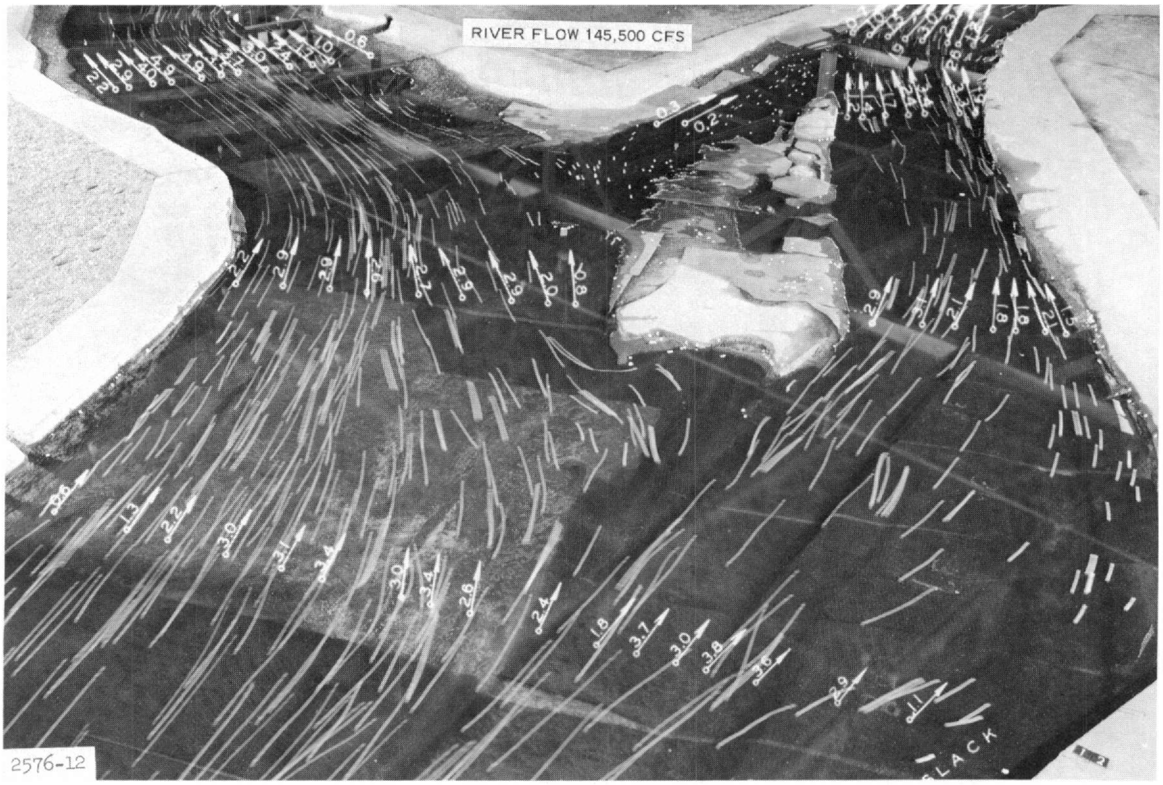


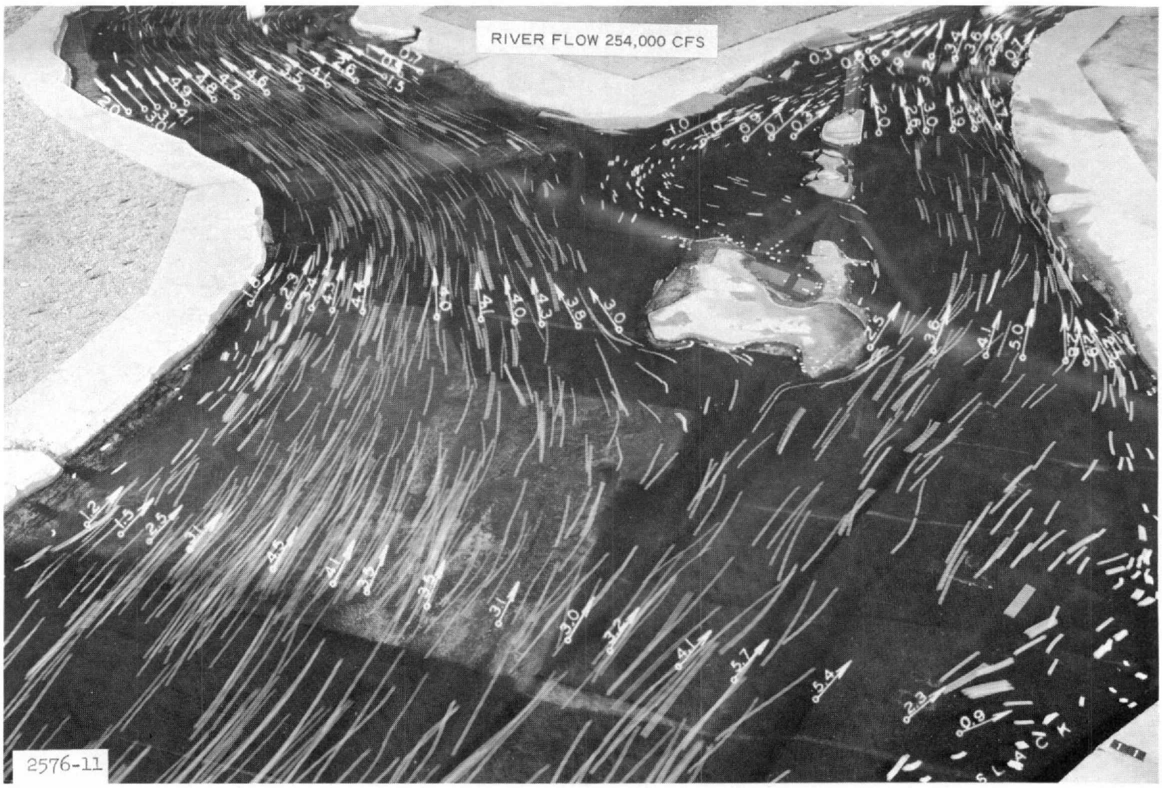
Photograph 1. Base test, flow at head of Grand Island



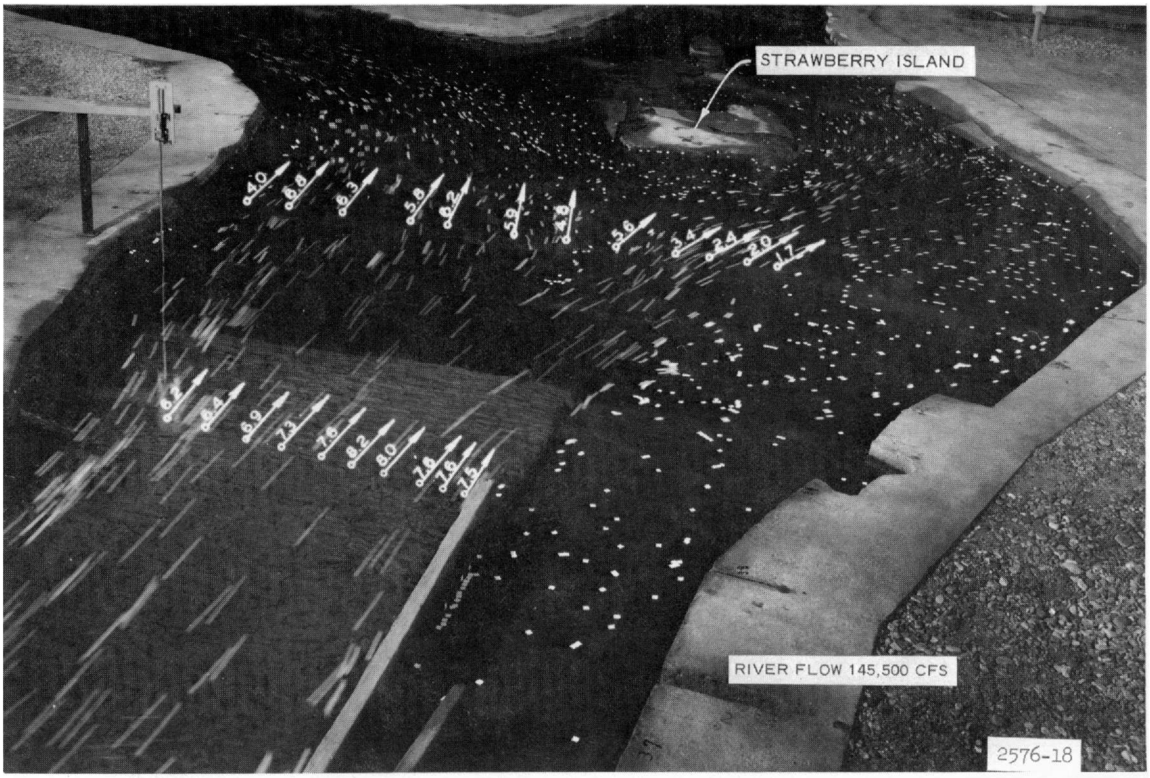


Photograph 2. Lock plan 1, flow at head of Grand Island

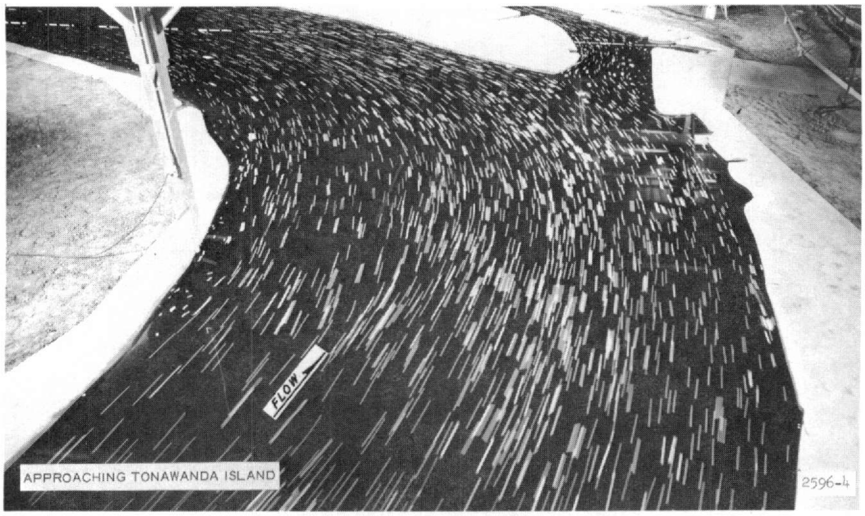


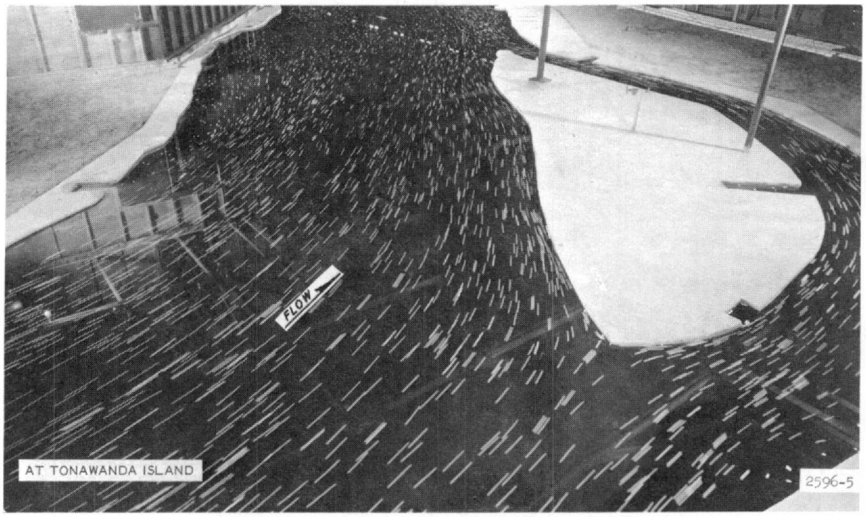


Photograph 3. Lock plan 2, excavation plan 1A, flow at head of Grand Island



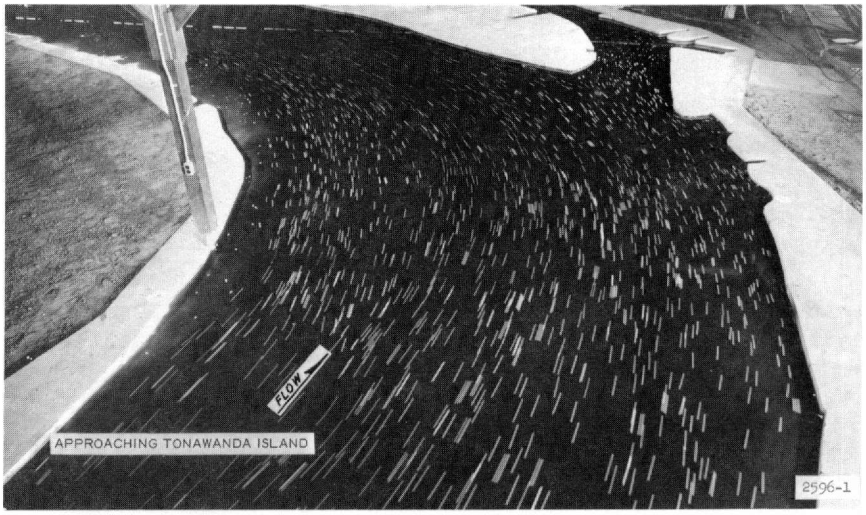
Photograph 4. Lock plan 1B, excavation plan 9, flow at head of Grand Island

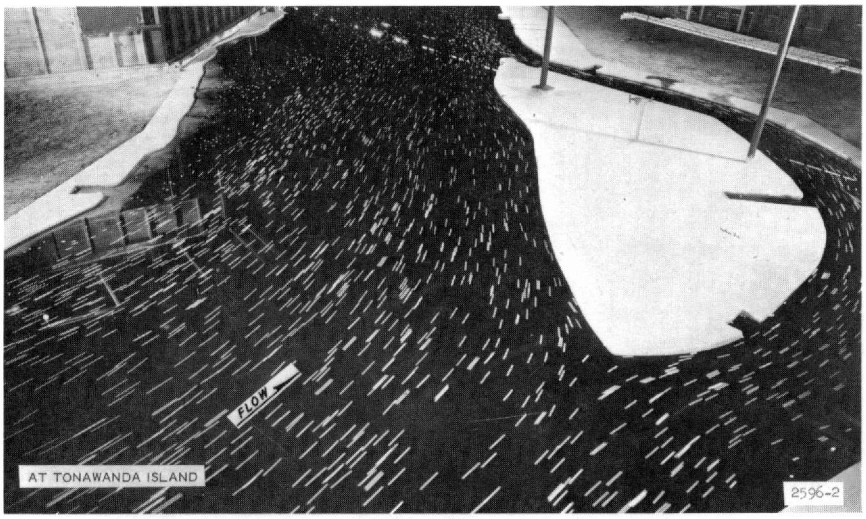


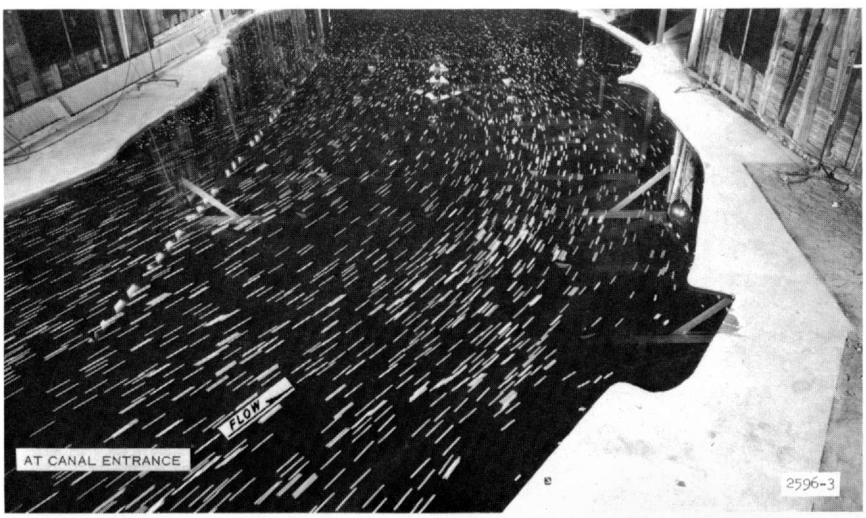


a. Discharge 101,000 cfs

Photograph 5. American channel, base test flow patterns (sheet 1 of 2)

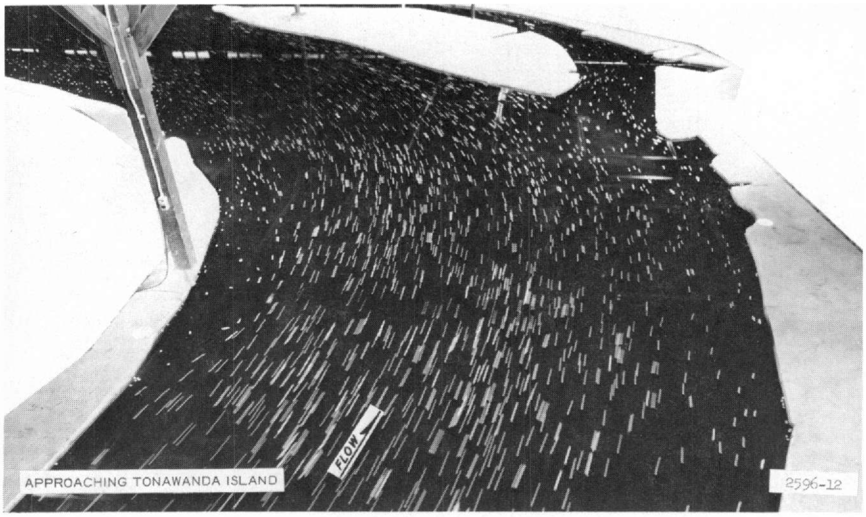


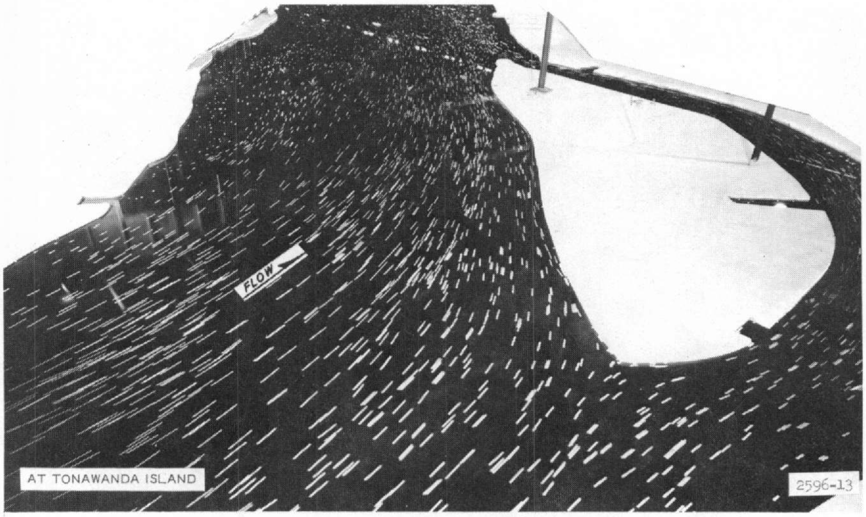


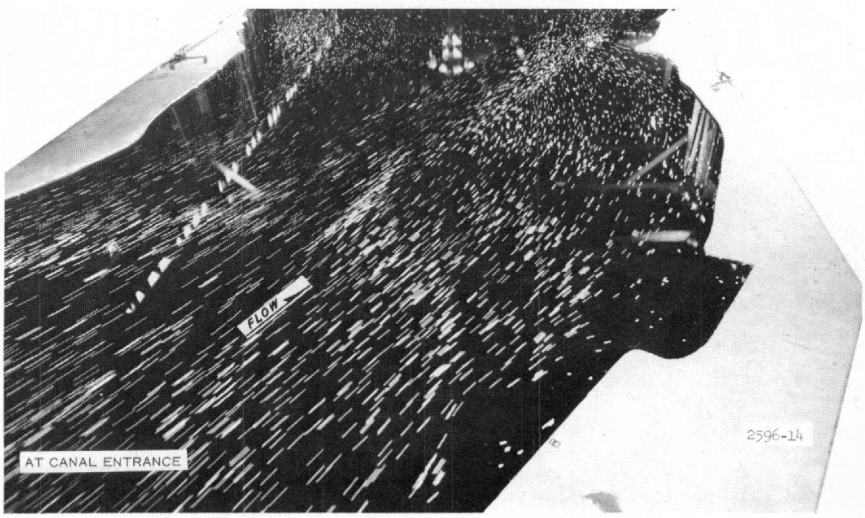


b. Discharge 58,750 cfs

Photograph 5. (sheet 2 of 2)

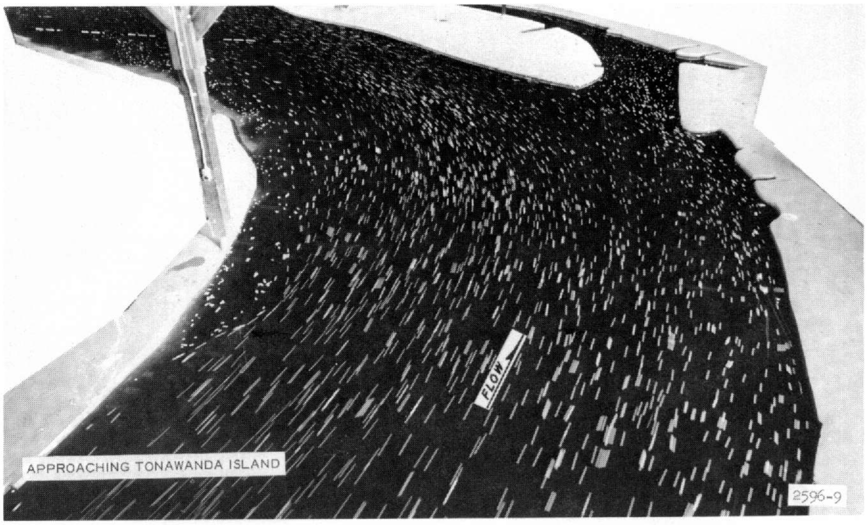


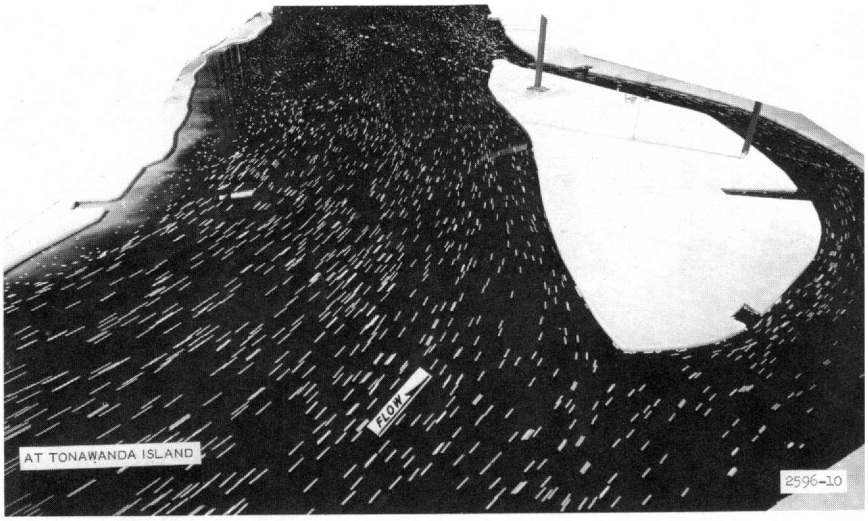


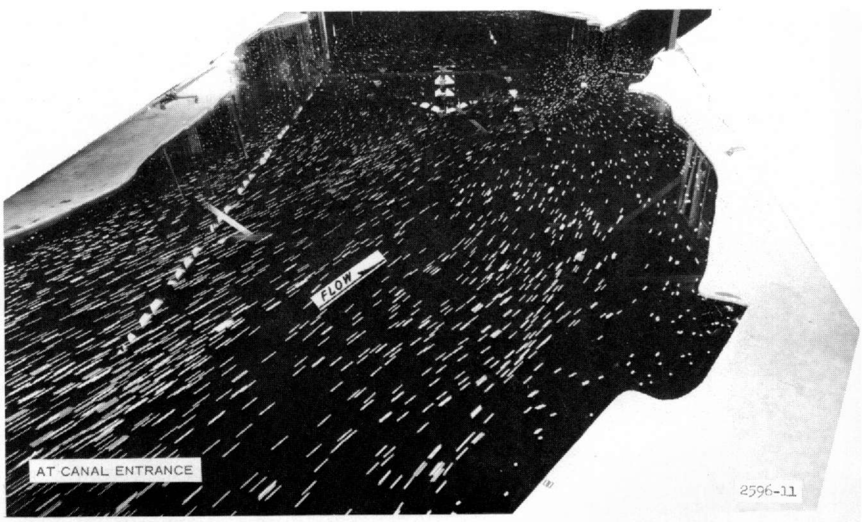


a. Discharge 101,000 cfs

Photograph 6. American channel, improved channel (original design) flow patterns (sheet 1 of 2)

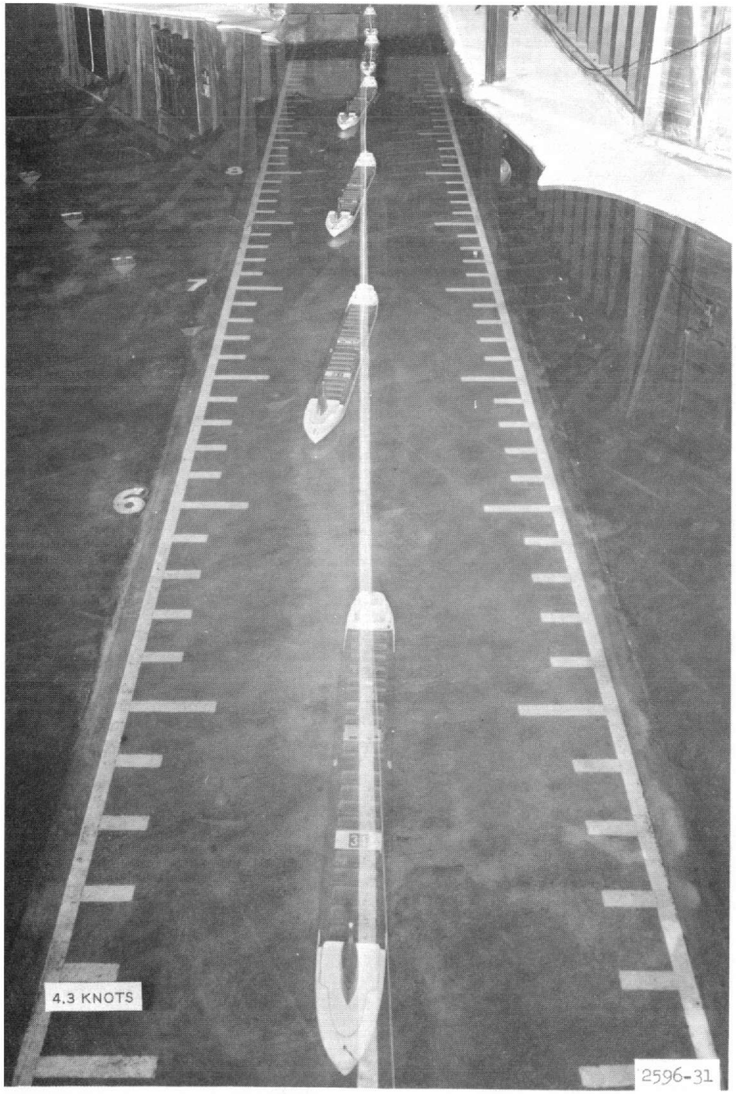


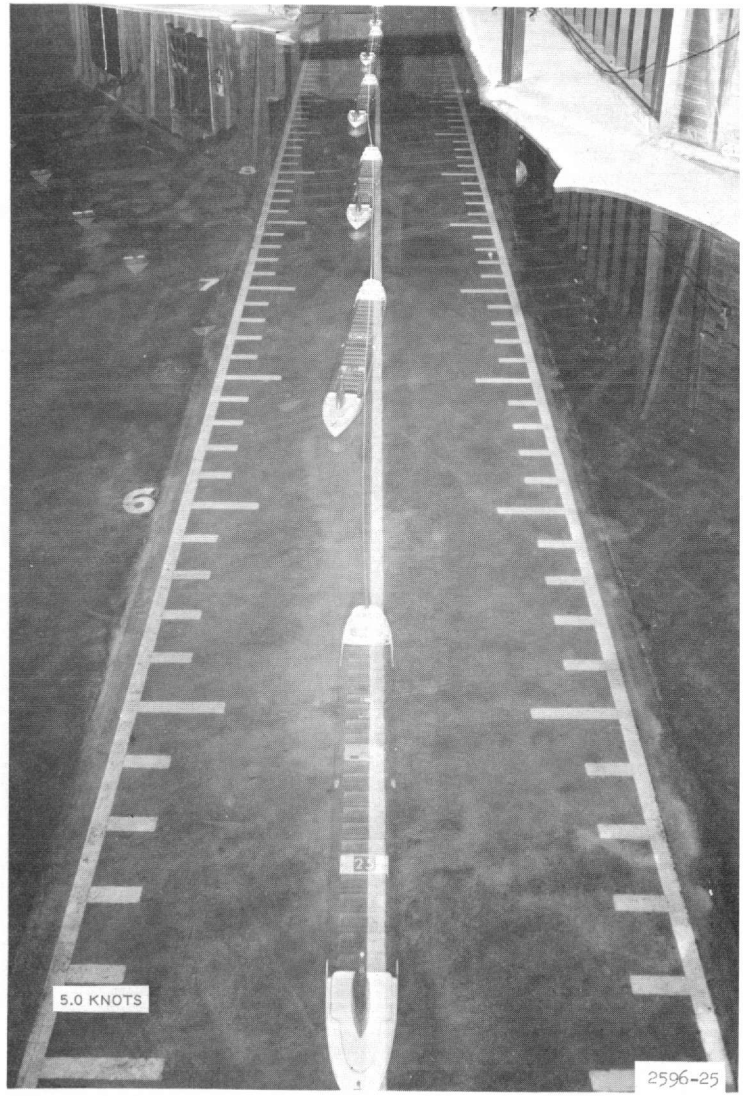




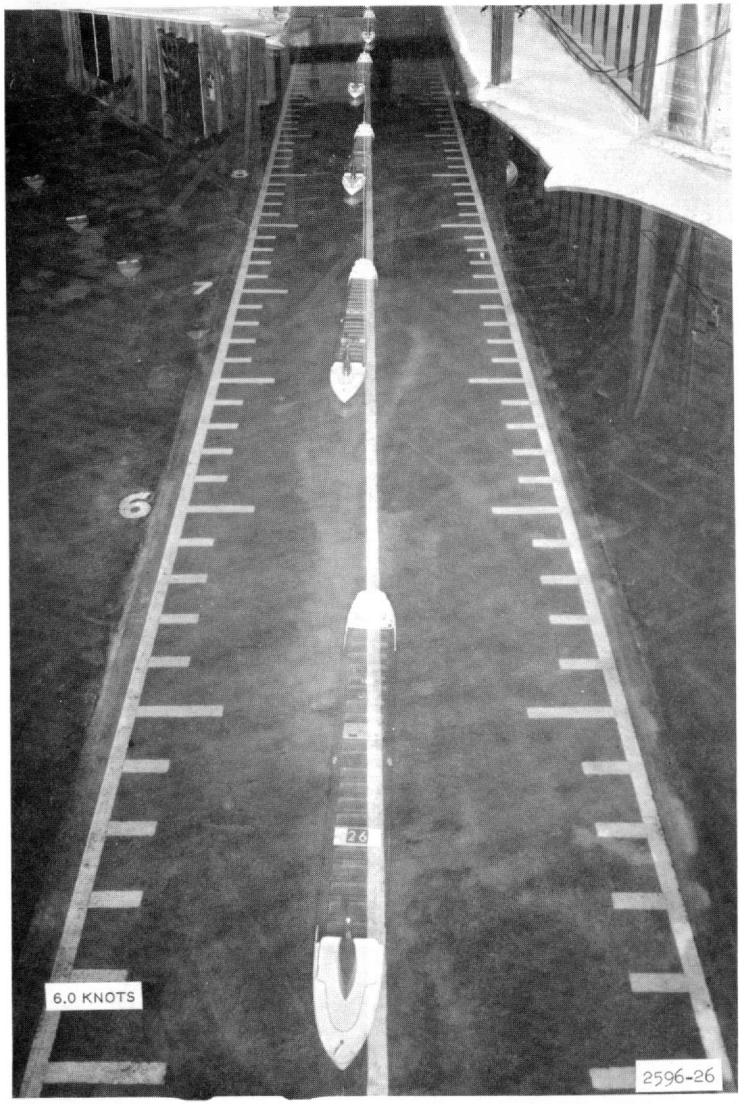
b. Discharge 58,750 cfs

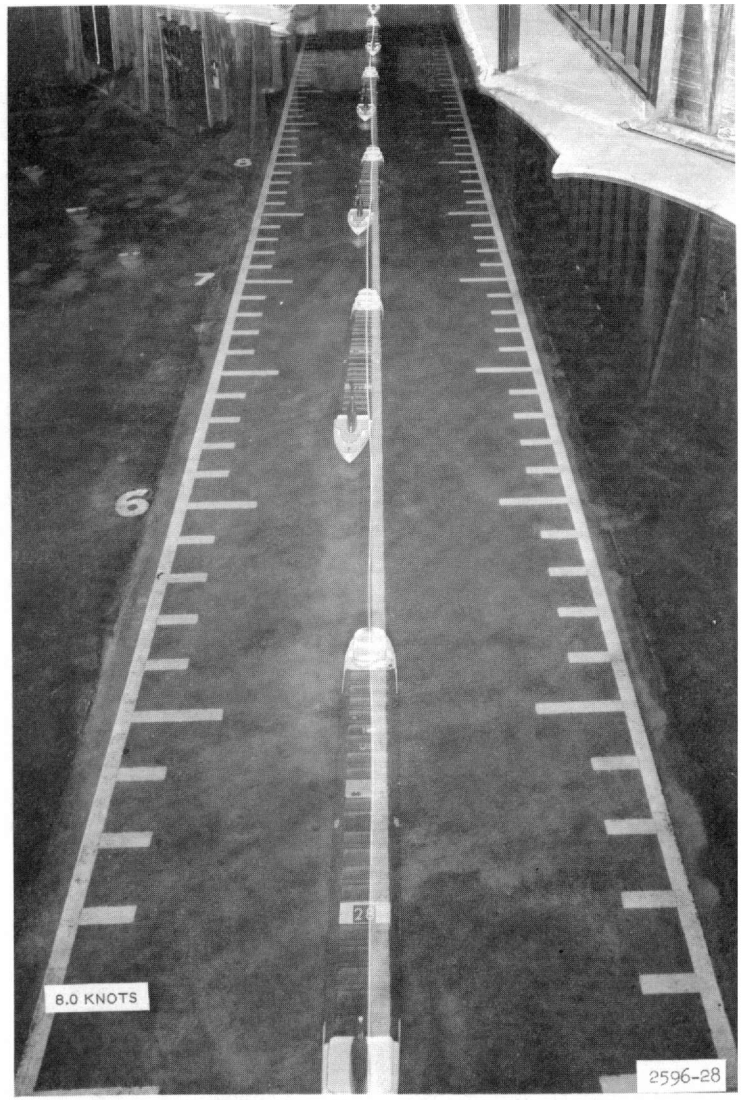
Photograph 6. (sheet 2 of 2)



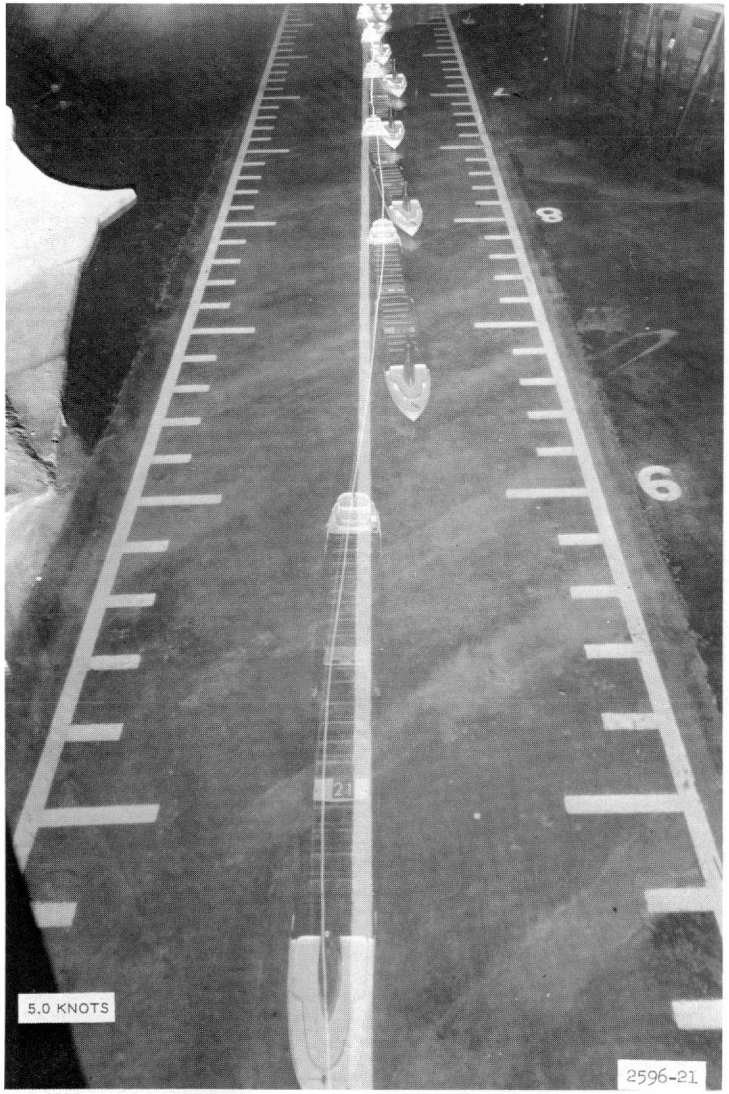


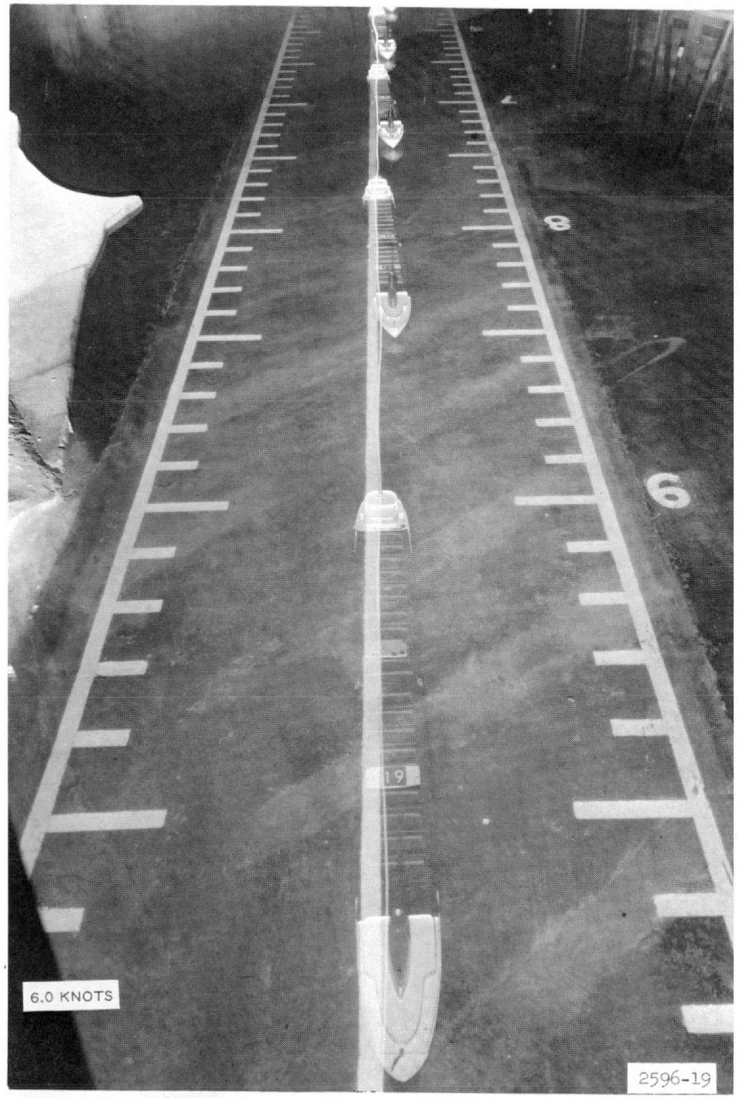
Photograph 7. Downbound bulk carrier at various slack water speeds; American channel discharge 101,000 cfs (sheet 1 of 2)



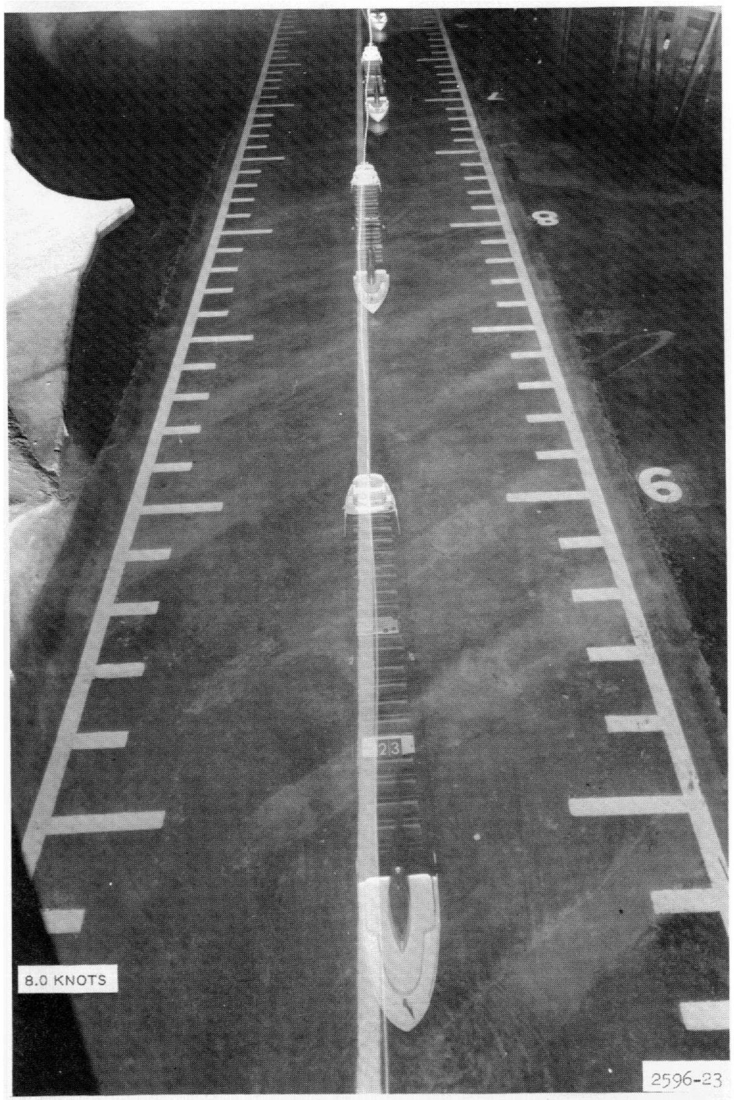


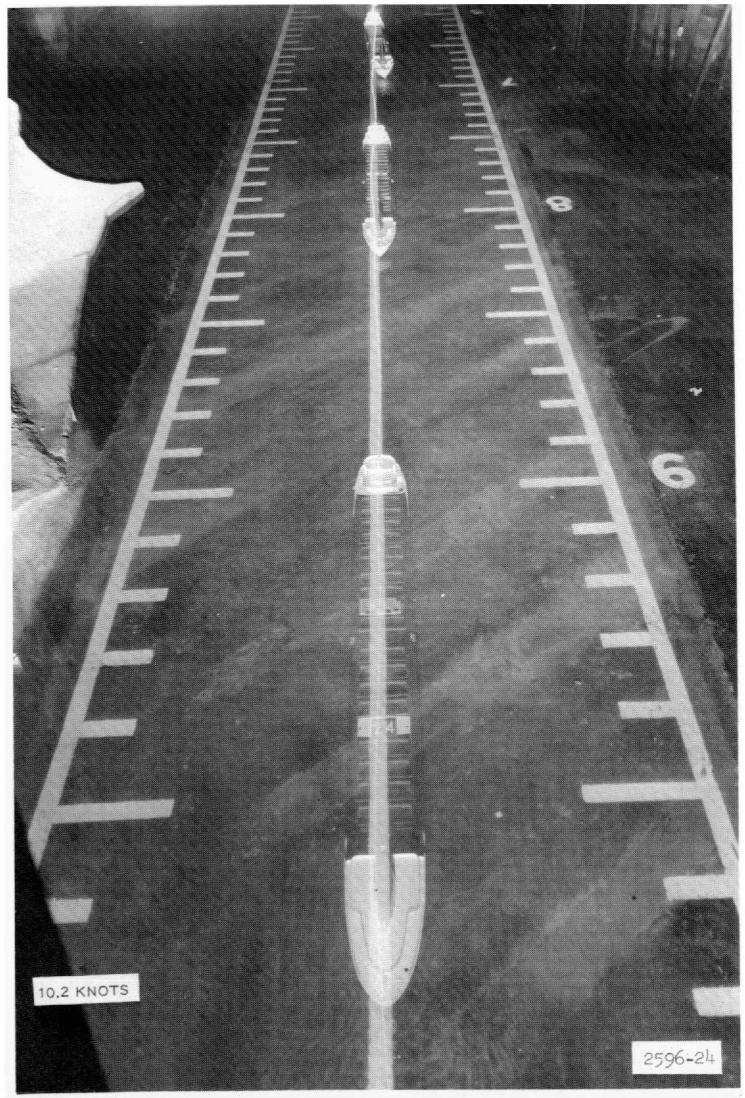
Photograph 7. (sheet 2 of 2)





Photograph 8. Upbound bulk carrier at various slack water speeds; American channel discharge 101,000 cfs (sheet 1 of 2)





Photograph 8. (sheet 2 of 2)

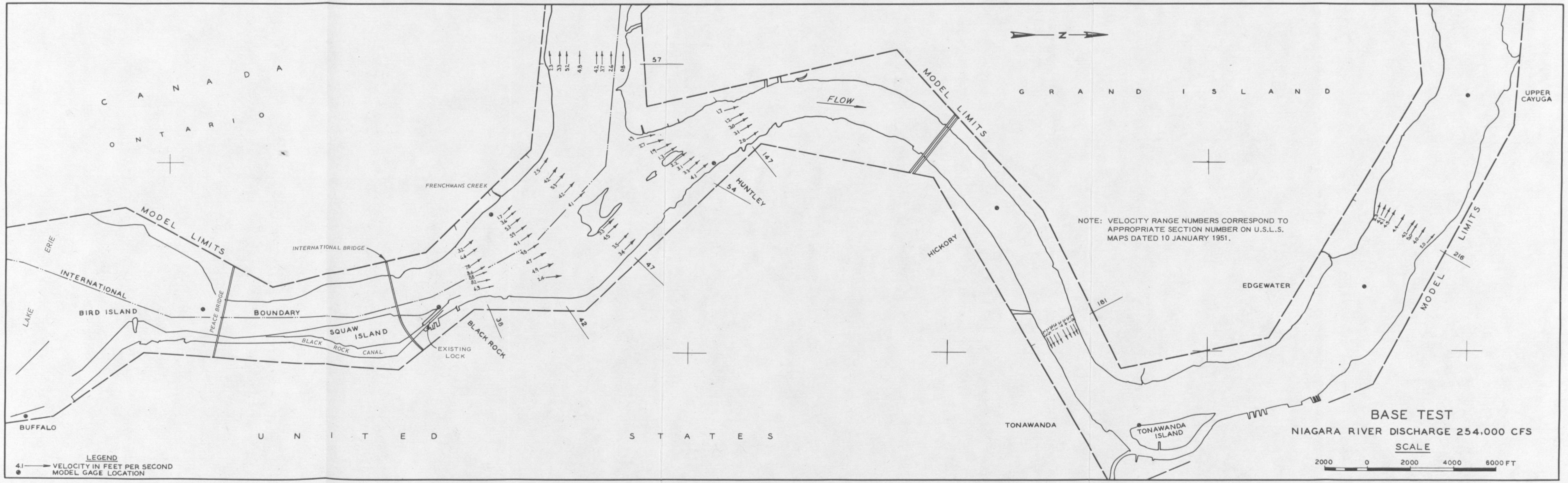
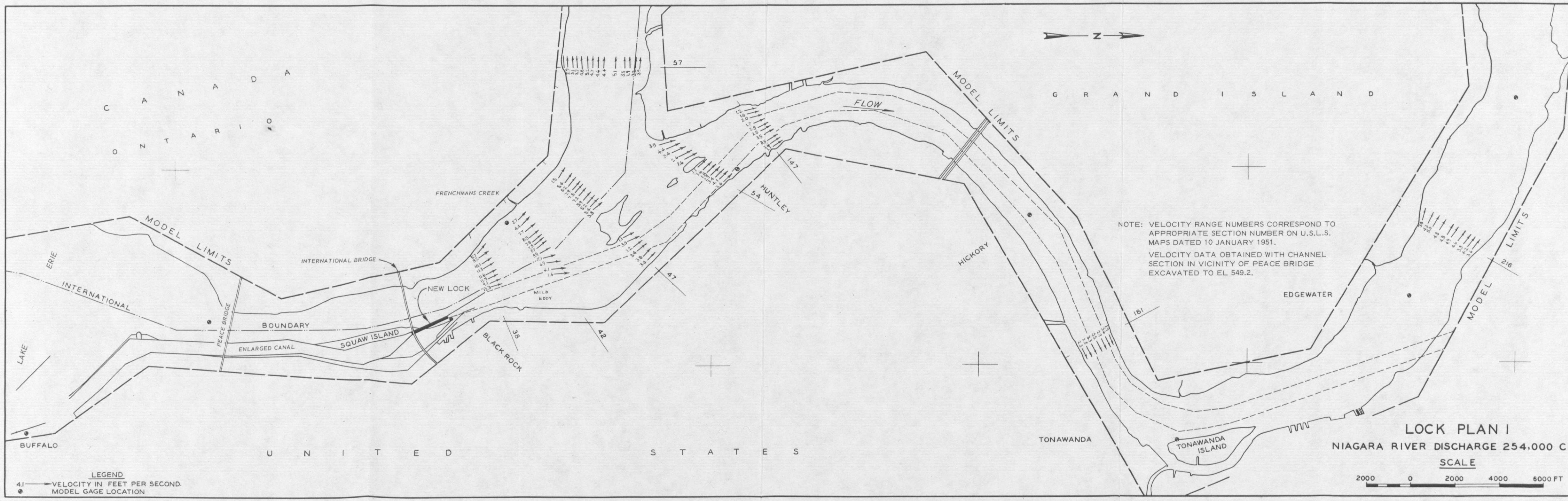
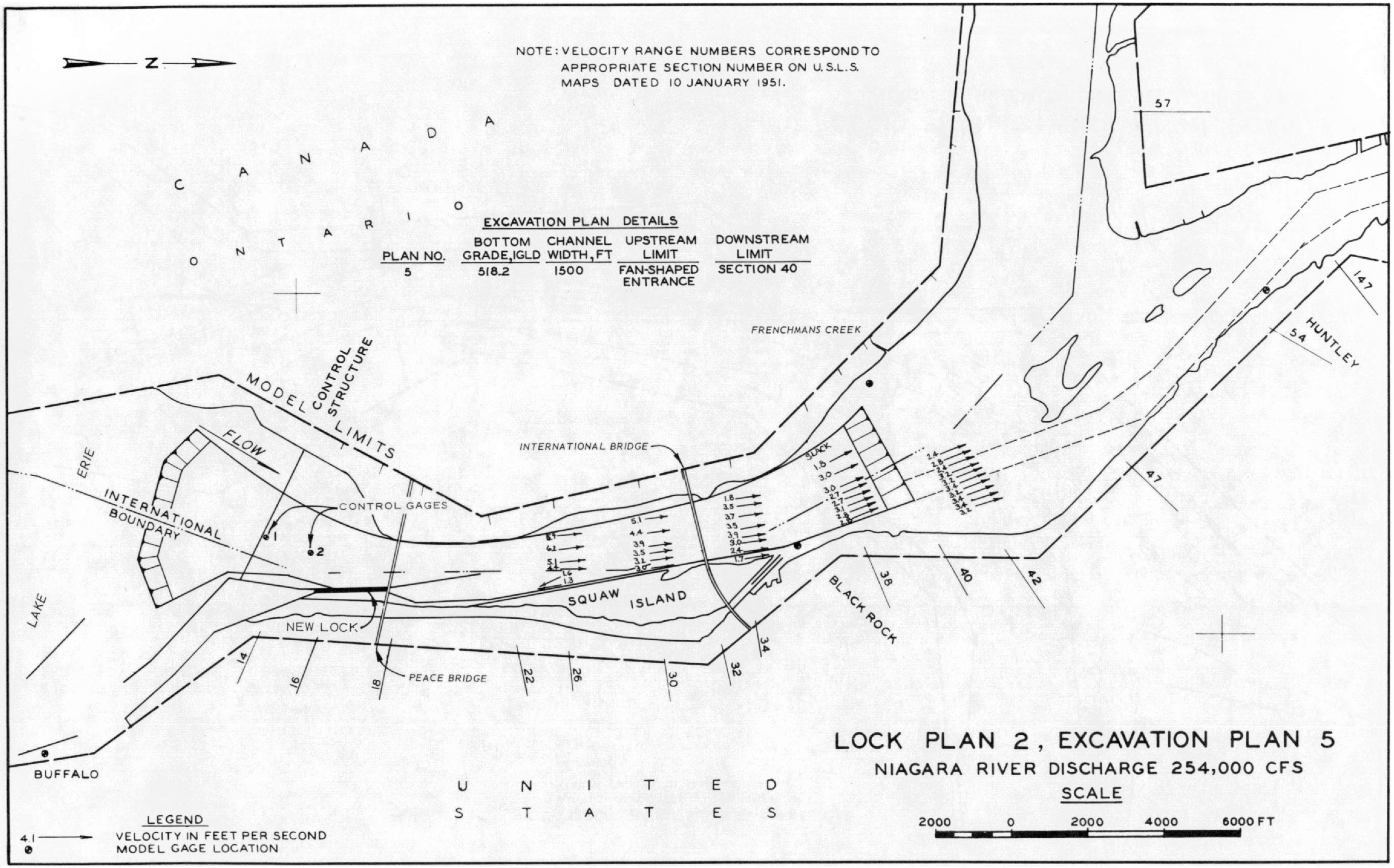

CANADA
ONTARIO
GRAND ISLAND
UNITED STATES
MODEL LIMITS
MODEL LIMITS
MODEL LIMITS
FLOW
LAKE ERIE
INTERNATIONAL BOUNDARY
BIRD ISLAND
PEACE BRIDGE
SQUAW ISLAND
BLACK ROCK CANAL
INTERNATIONAL BRIDGE
EXISTING LOCK
BLACK ROCK
FRENCHMANS CREEK
HUNTLEY
HICKORY
TONAWANDA
TONAWANDA ISLAND
EDGEWATER
UPPER CAYUGA
BUFFALO
57
147
54
47
38
42
181
216
NOTE: VELOCITY RANGE NUMBERS CORRESPOND TO APPROPRIATE SECTION NUMBER ON U.S.L.S. MAPS DATED 10 JANUARY 1951.
LEGEND
4.1 VELOCITY IN FEET PER SECOND
MODEL GAGE LOCATION
BASE TEST
NIAGARA RIVER DISCHARGE 254,000 CFS
SCALE
2000 0 2000 4000 6000 FT

PLATE 1



LOCK PLAN I
NIAGARA RIVER DISCHARGE 254,000 CFS

PLATE 2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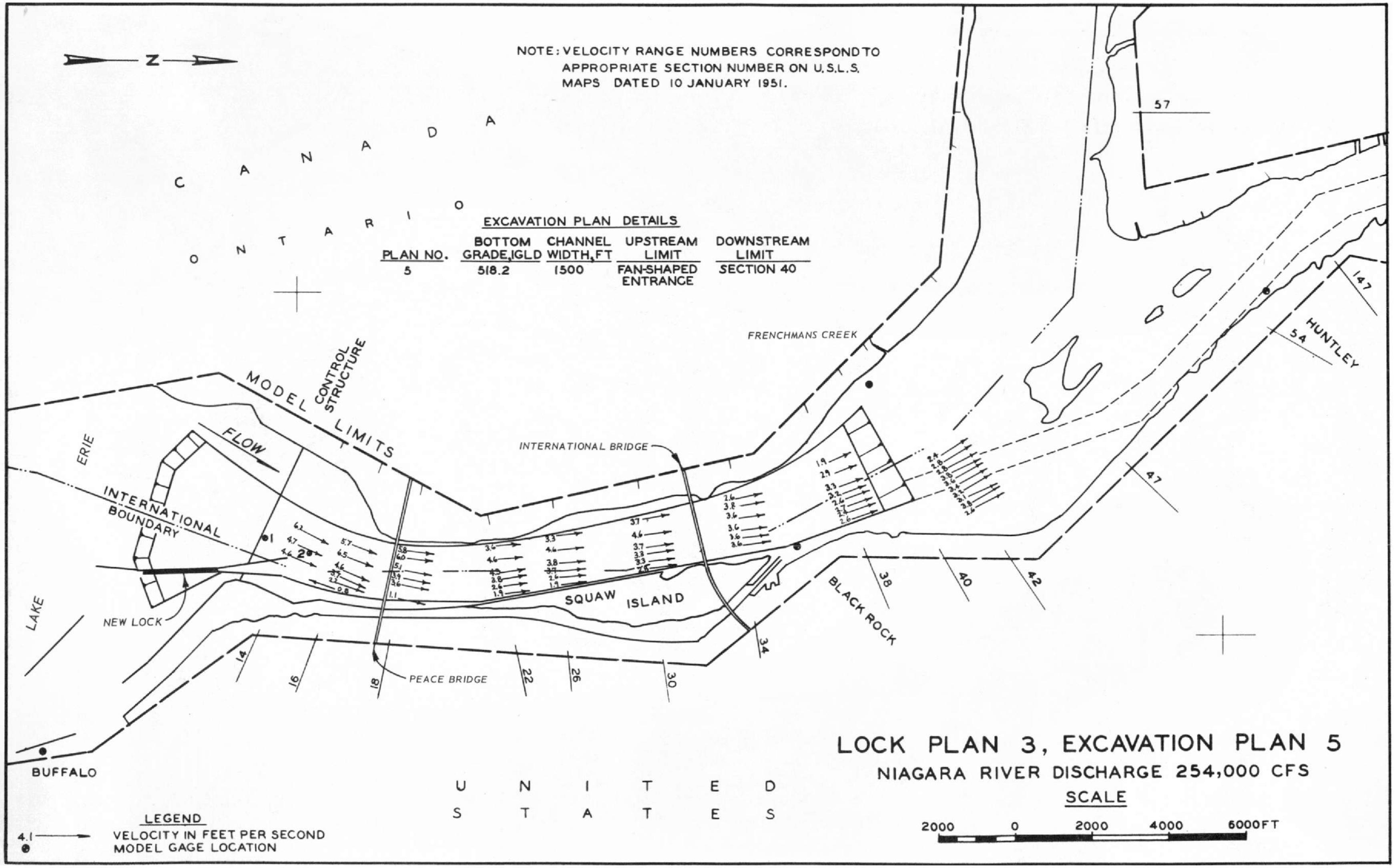
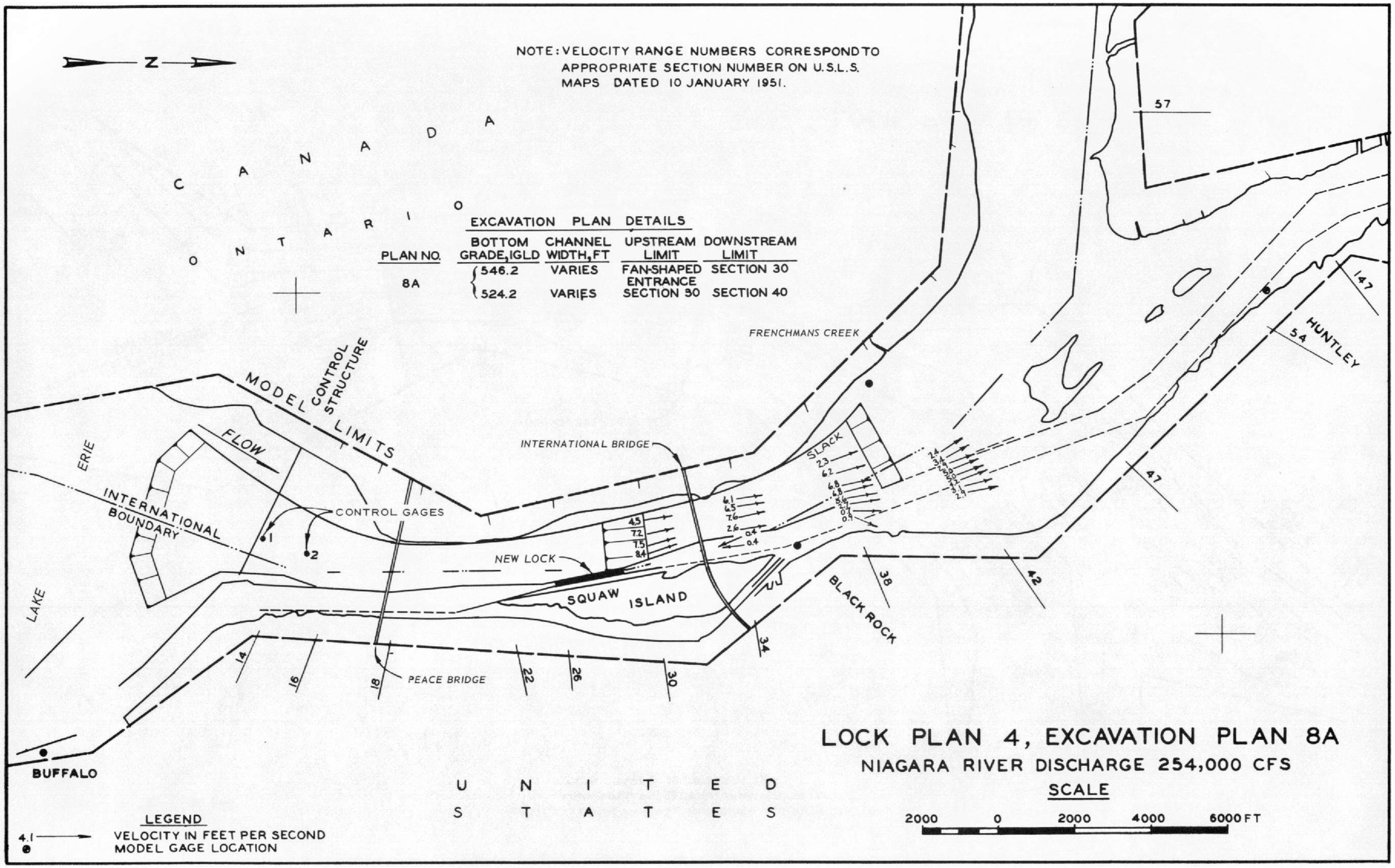
C A N A D A
O N T A R I O
EXCAVATION PLAN DETAILS
PLAN NO. 5
BOTTOM GRADE, IGLD 518.2
CHANNEL WIDTH, FT 1500
UPSTREAM LIMIT FAN-SHAPED ENTRANCE
DOWNSTREAM LIMIT SECTION 40
FRENCHMANS CREEK
HUNTLEY
CONTROL STRUCTURE
MODEL LIMITS
FLOW
ERIE
LAKE
INTERNATIONAL BOUNDARY
CONTROL GAGES
INTERNATIONAL BRIDGE
SQUAW ISLAND
NEW LOCK
PEACE BRIDGE
BLACK ROCK
BUFFALO
SLACK
57
147
54
47
42
40
38
34
32
30
26
22
18
16
14
U N I T E D
S T A T E S
LOCK PLAN 2, EXCAVATION PLAN 5
NIAGARA RIVER DISCHARGE 254,000 CFS
SCALE
2000 0 2000 4000 6000 FT
LEGEND
4.1 VELOCITY IN FEET PER SECOND
MODEL GAGE LOCATION

PLATE 3

PLATE 4



NOTE: VELOCITY RANGE NUMBERS CORRESPOND TO APPROPRIATE SECTION NUMBER ON U.S.L.S. MAPS DATED 10 JANUARY 1951.
N
C A N A D A
O N T A R I O
EXCAVATION PLAN DETAILS
PLAN NO. | BOTTOM GRADE, IGLD | CHANNEL WIDTH, FT | UPSTREAM LIMIT | DOWNSTREAM LIMIT
5 | 518.2 | 1500 | FAN-SHAPED ENTRANCE | SECTION 40
FRENCHMANS CREEK
MODEL LIMITS
CONTROL STRUCTURE
FLOW
ERIE
LAKE
INTERNATIONAL BOUNDARY
INTERNATIONAL BRIDGE
NEW LOCK
SQUAW ISLAND
PEACE BRIDGE
BLACK ROCK
HUNTLEY
BUFFALO
57
147
54
47
42
40
38
34
30
26
22
18
16
14
U N I T E D S T A T E S
LEGEND
4.1 VELOCITY IN FEET PER SECOND
MODEL GAGE LOCATION
LOCK PLAN 3, EXCAVATION PLAN 5
NIAGARA RIVER DISCHARGE 254,000 CFS
SCALE
2000 0 2000 4000 6000 FT



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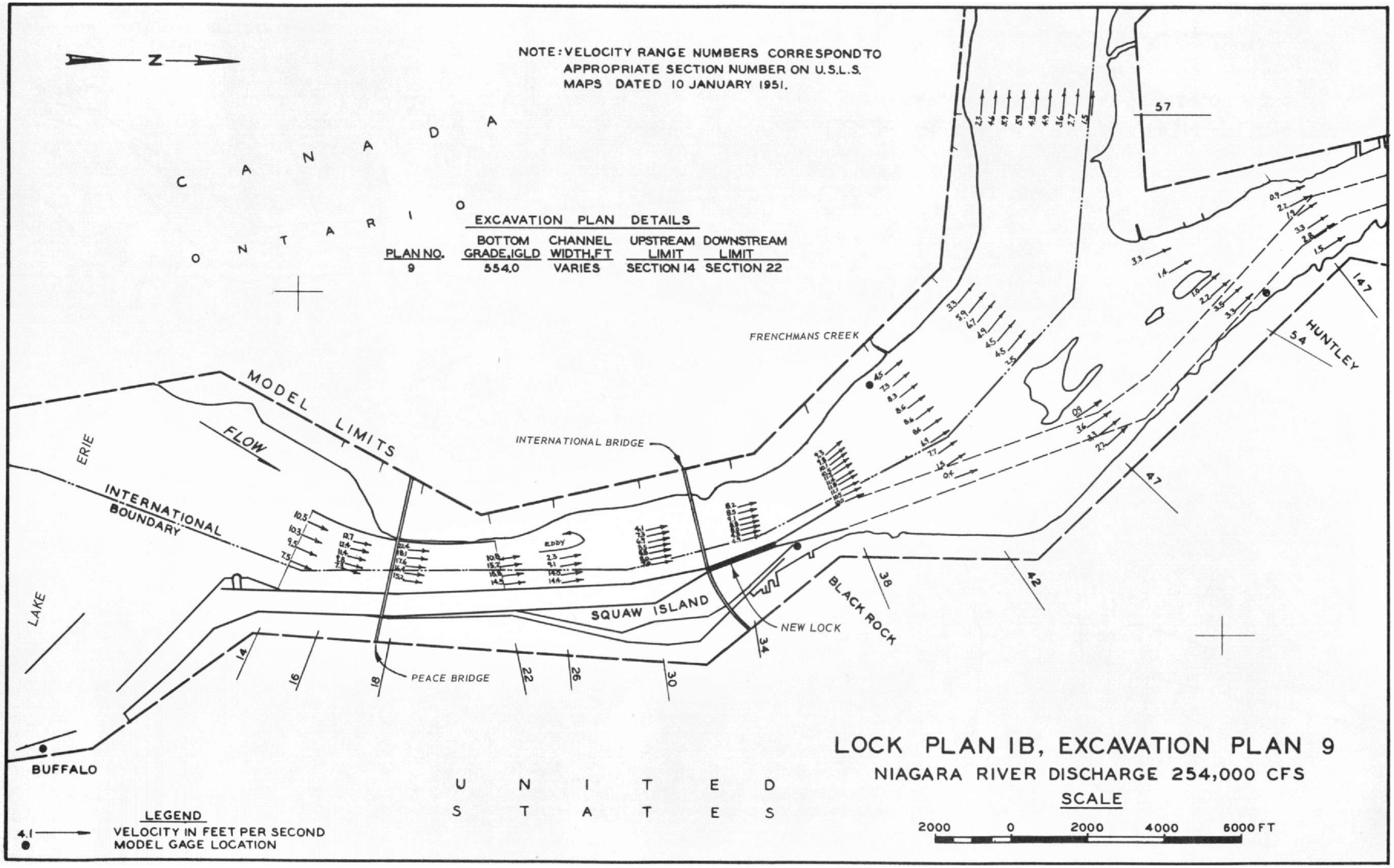
NOTE: VELOCITY RANGE NUMBERS CORRESPOND TO APPROPRIATE SECTION NUMBER ON U.S.L.S. MAPS DATED 10 JANUARY 1951.
CANADA
ONTARIO
EXCAVATION PLAN DETAILS
PLAN NO. | BOTTOM GRADE, IGLD | CHANNEL WIDTH, FT | UPSTREAM LIMIT | DOWNSTREAM LIMIT
8A | 546.2 | VARIES | FAN-SHAPED ENTRANCE | SECTION 30
524.2 | VARIES | SECTION 30 | SECTION 40
FRENCHMANS CREEK
57
147
54
HUNTLEY
MODEL LIMITS
CONTROL STRUCTURE
FLOW
LAKE ERIE
INTERNATIONAL BOUNDARY
CONTROL GAGES
1
2
INTERNATIONAL BRIDGE
SLACK
NEW LOCK
SQUAW ISLAND
BLACK ROCK
47
42
38
34
30
26
22
18
16
14
PEACE BRIDGE
BUFFALO
UNITED STATES
LOCK PLAN 4, EXCAVATION PLAN 8A
NIAGARA RIVER DISCHARGE 254,000 CFS
SCALE
2000 0 2000 4000 6000 FT
LEGEND
4.1 VELOCITY IN FEET PER SECOND
MODEL GAGE LOCATION

PLATE 5

PLATE 6



LOCK PLAN IB, EXCAVATION PLAN 9
NIAGARA RIVER DISCHARGE 254,000 CFS

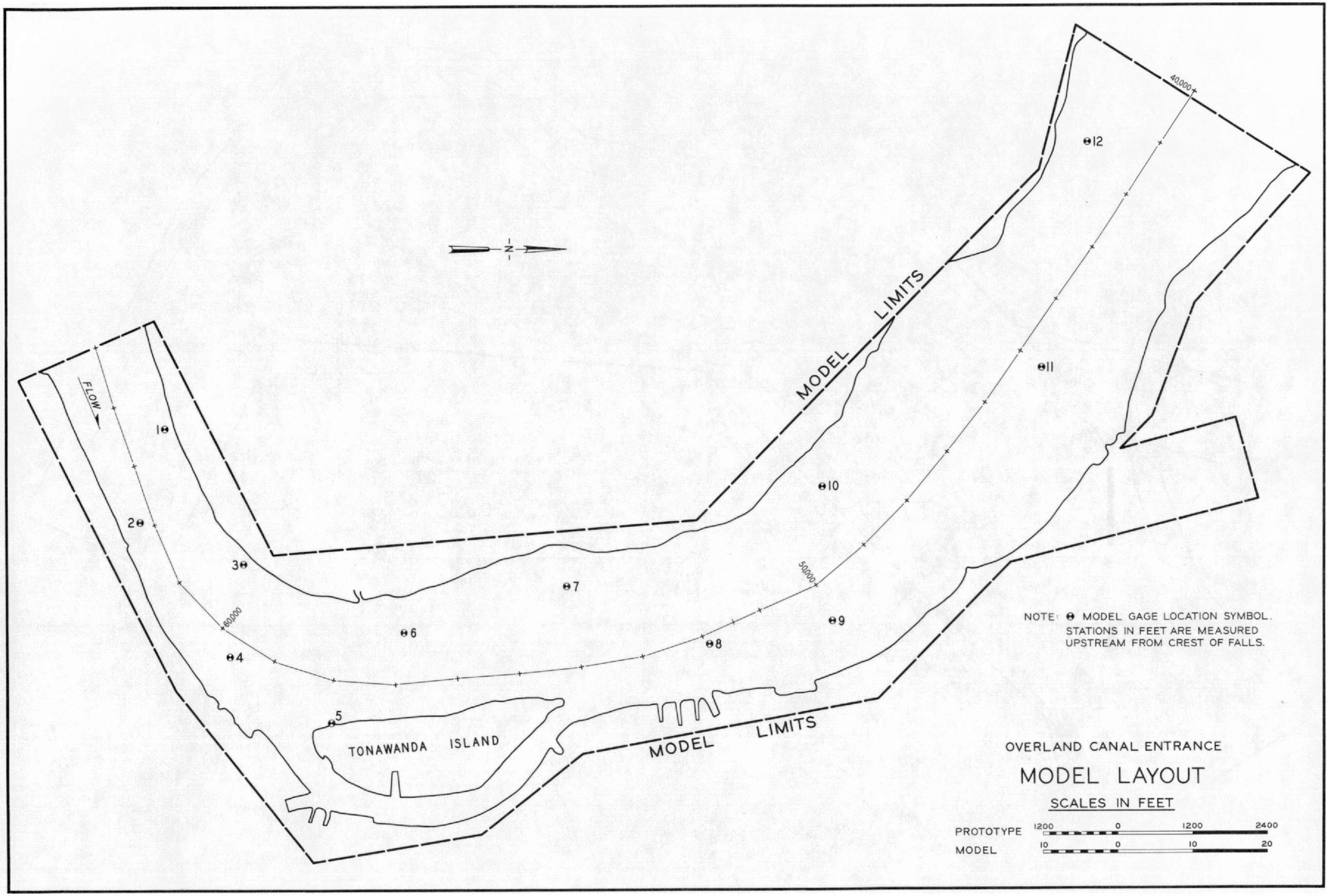
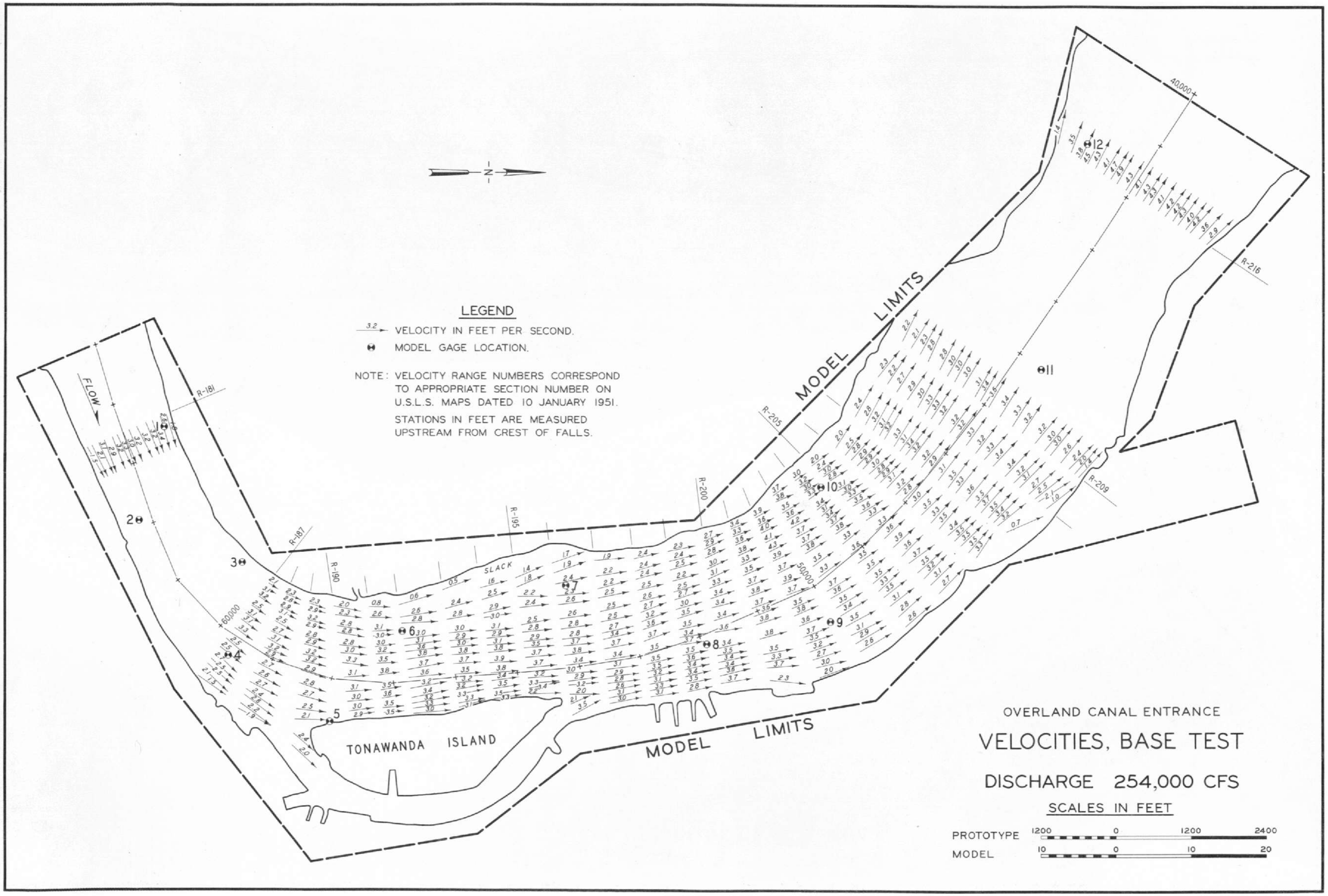
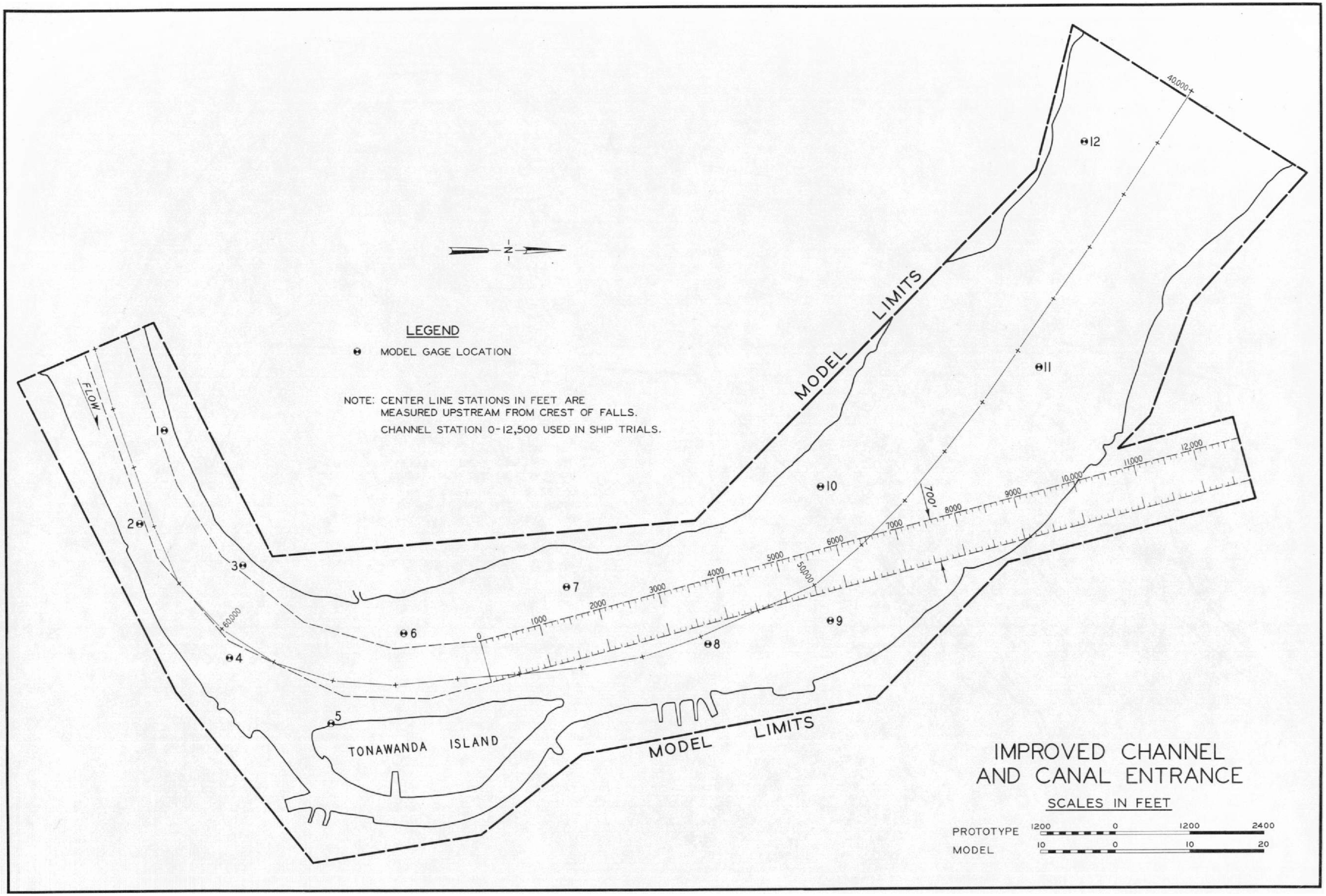

N
FLOW
1
2
3
4
5
6
7
8
9
10
11
12
60,000
50,000
40,000
TONAWANDA ISLAND
MODEL LIMITS
MODEL LIMITS
NOTE: MODEL GAGE LOCATION SYMBOL.
STATIONS IN FEET ARE MEASURED UPSTREAM FROM CREST OF FALLS.
OVERLAND CANAL ENTRANCE
MODEL LAYOUT
SCALES IN FEET
PROTOTYPE 1200 0 1200 2400
MODEL 10 0 10 20

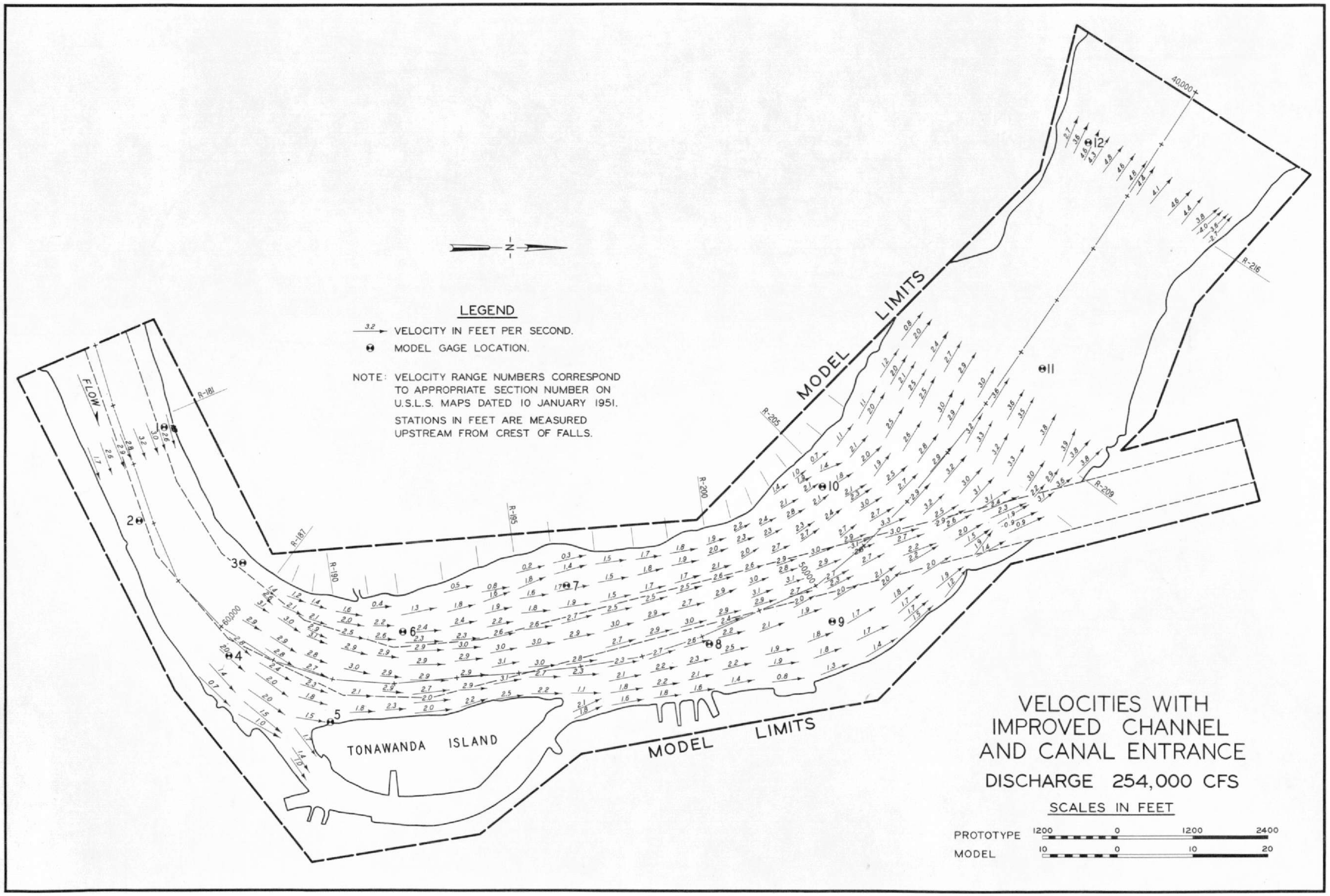
PLATE 7


LEGEND
3.2 VELOCITY IN FEET PER SECOND.
MODEL GAGE LOCATION.
NOTE: VELOCITY RANGE NUMBERS CORRESPOND TO APPROPRIATE SECTION NUMBER ON U.S.L.S. MAPS DATED 10 JANUARY 1951.
STATIONS IN FEET ARE MEASURED UPSTREAM FROM CREST OF FALLS.
N
FLOW
MODEL LIMITS
MODEL LIMITS
TONAWANDA ISLAND
SLACK
R-181
R-187
R-190
R-195
R-200
R-205
R-209
R-216
40,000
50,000
60,000
OVERLAND CANAL ENTRANCE
VELOCITIES, BASE TEST
DISCHARGE 254,000 CFS
SCALES IN FEET
PROTOTYPE 1200 0 1200 2400
MODEL 10 0 10 20



IMPROVED CHANNEL AND CANAL ENTRANCE

PLATE 9



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13. ABSTRACT

The investigation reported herein was conducted to assist the U. S. Army Engineer District, Buffalo, in determination of the economic justification of a water route connecting Lake Erie and Lake Ontario. Specifically, the studies involved determination of the most functional and economical location for a lock in the vicinity of Buffalo, N. Y., and evaluation of navigation conditions at the entrance to an overland canal joining the American channel of the Niagara River northwest of North Tonawanda, N. Y. An existing model of the Niagara River with a horizontal scale of 1:360 and a vertical scale of 1:60 and a new undistorted model of the canal entrance with a 1:120 scale were used in the investigation. Tests demonstrated the desirability of placing the new lock in the vicinity of Buffalo as far downstream as is feasible without rendering the existing Black Rock Lock and Canal inoperable during the construction period. Navigation problems at the canal entrance were not as severe as had been contemplated and a small amount of overexcavation resulted in satisfactory conditions.

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Great Lakes						
Hydraulic models						
Inland waterways						
Lake Erie						
Lake Ontario						
Locks (waterways)						
Navigation conditions						
Niagara River						
Waterways						

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