B. L. Chance
4 April 1961

REPORT OF THE INTERNATIONAL JOINT COMMISSION
UNITED STATES AND CANADA

ON THE

INTERNATIONAL PASSAMAQUODDY TIDAL POWER PROJECT

April 1961

Washington — Ottawa

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TIDAL POWER PROJECT

WASHINGTON

OTTAWA

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REFERENCE TO THE INTERNATIONAL JOINT COMMISSION

The Governments of the United States and Canada forwarded on August 2, 1956, to the International Joint Commission identical letters requesting the Commission to conduct investigations and to submit a report on the proposed international Passamaquoddy Tidal Power Project. This request was made in accordance with the Boundary Waters Treaty of 1909 and with United States Public Law 401, 84th Congress, 2d Session, approved January 31, 1956. The full text of the Reference of the two Governments is quoted below:

> "In accordance with the provisions of Article IX of the Boundary Waters Treaty of January 11, 1909, the Governments of Canada and the United States have agreed to refer and do hereby refer to the International Joint Commission the following matters for joint examination and advisory report, including conclusions and recommendations:
>
> a) It is desired that the Commission determine the estimated cost of developing the international tidal power potential of Passamaquoddy Bay in the State of Maine and the Province of New Brunswick, and determine whether such cost would allow hydroelectric power to be produced at a price which is economically feasible;
>
> b) The Commission is requested to determine the effects, beneficial or otherwise, which such a power project might have on the local and national economies in the United States and Canada, and to this end, to study specifically the effects which the construction, maintenance and operation of the tidal power structures

might have upon the fisheries in the area.

In the discharge of its responsibilities under this reference, the Commission is requested to review and, insofar as is practicable, make advantageous use of existing reports and plans such as the Report of March 15, 1950, submitted by the International Passamaquoddy Engineering Board to the Commission and the supplemental report of May 1952 prepared by the United States Army Corps of Engineers on the details of estimate of cost of a comprehensive investigation of the Passamaquoddy tidal power project. Having regard to the foregoing, the Commission should determine the most desirable general project design from the viewpoint of the public interest in United States and Canada respectively -- such design to include plans for structure and appurtenant works in sufficient detail to form the basis of dependable cost estimates and considerations of economic feasibility.

In the conduct of its investigations, and otherwise in the performance of its duties under this reference, the Commission may utilize the services of specially qualified engineers and other experts of the technical agencies of the United States and Canada and will, so far as possible, make use of any pertinent data that may be available in such agencies or which may become available during the course of the investigations, thus avoiding duplication of effort and unnecessary expense.

The United States Government is willing, subject to the availability of funds, to incur cost in connection with this survey up to $3,000,000 and the Canadian Government is willing to incur costs up to $300,000. Each Government has the right to participate at its own expense in all aspects of the survey to an extent appropriate with its interest. In making administrative arrangements for the necessary surveys and studies, the Commission should give suitable effect to these responsibilities.

The costs incurred by the Governments of the United States and Canada respectively under this Reference will be credited against the costs to be borne by each of the Governments in the event that the project should be constructed as a joint undertaking by the two Governments. The decision of the two Governments to refer this study to the Commission does not imply any commitment regarding the eventual construction of the project.

It is the desire of both Governments that the Commission endeavour to complete its various surveys, investigations, studies and other activities under the Reference within a three-year period. Upon completion, it is requested that the Commission prepare and submit to the Governments of the United States and Canada a comprehensive report covering the subject matter of this Reference. The Commission's report should include the details of the specific design, cost estimates, and an estimate of the benefits to be derived or the losses to result from this project."

BACKGROUND OF THE PROJECT

Power from the Tides

The ocean tides have long been envisioned as a source of power. "Tide mills" were constructed in Europe as early as the 11th century and in America as early as 1617. Such small tidal hydro-mechanical power developments were practical for grinding corn or spices as the work could be adjusted to the periodic and varying power from the tides. Electrification and the rapid industrial and economic growth of the 20th century, however, have established a heavy growth in demand for electric power, and today the economic utilization of power requires its availability on a controlled schedule. Therefore, a tidal power project must be capable of sustaining dependable power production from the tides or be interconnected with other power sources and so operated that the coordinated capability would conform to the needs of the power load.

Utilization of the tides to generate a substantial quantity of power requires provision for the storage of large quantities of water so that discharges may be made

from a higher to a lower elevation through hydraulic turbines. A large single pool may be built to entrap or exclude water from the ocean, but generation of power is limited to those times in the tidal cycle when the differential in elevation between the ocean and the pool is sufficient for operation of the turbines. A combination of two storage pools for simultaneous entrapment and exclusion of water from the ocean can, however, provide for some generation at all times. Also, either single or two pool projects may be arranged to accommodate reversible units capable of pumping or generating from flow in either direction, thus further increasing the power potential and providing greater flexibility for coordinated operation with other power sources. As compared to most river hydro-electric projects the potential average hydraulic head of tidal projects is quite small; but the very large quantities of water available for power production are accurately predictable for many years in the future.

Passamaquoddy Bay located near the mouth of the Bay of Fundy experiences smaller tidal ranges than those occurring in the head of that bay in Canada. The site, by reason of adjacent Cobscook Bay and the narrow passages among islands with inter-spaced shoal areas offers many alternatives for one or two pool schemes. The large area of Passamaquoddy Bay with the substantial additional area of Cobscook Bay is favorable for a two pool plan.

Prior Surveys of the Passamaquoddy Project

From 1924 to 1934 Dexter P. Cooper, Inc. prepared plans originally for an international tidal power project at Passamaquoddy and Cobscook Bays, but later for a project located wholly in the United States. The United States' Federal Power Commission in its review of the Dexter P. Cooper, Inc. loan application to the Federal Emergency Administration of Public Works reported adversely on the project in January 1934 and the loan was not approved. The project as finally revised would have had an initial installation of 235,000 kilowatts with provision for an additional 100,000 kilowatts.

In 1927 Murray and Flood, Engineers, of New York, N. Y. reported on the international project proposed by Cooper. They estimated that an installed capacity of 400,000 kilowatts with a firm capacity of 122,000 kw could

deliver 1,594 million kilowatt hours annually to Woburn, Massachusetts, at an average cost of 8.09 mills per kilowatt-hour. The total estimated cost of the project at 1926-27 price levels, was $125 million.

In 1935 the Passamaquoddy Bay Tidal Project Commission of the United States' Federal Emergency Administration of Public Works recommended construction of an initial Cobscook Bay project, all within the State of Maine, at an estimated cost of $30 million. An ultimate project was contemplated to embrace the Passamaquoddy Bay. The recommended initial project was approved by the United States Government and $10 million (later reduced to $7 million) was allotted to the U. S. Army, Corps of Engineers to start construction.

The Corps of Engineers estimated that the initial project with a modified design would cost $61,500,000. A review board raised this estimate to $68,158,000. Work progressed until August 1936 with an expenditure of about $7 million, and was discontinued due to lack of further appropriations by the Congress.

In 1941, the Federal Power Commission in a report prepared pursuant to Senate Resolution 62, 76th Congress, 1st Session, concluded that Passamaquoddy tidal power (development of U. S. waters only) could not compete successfully at that time with river hydroelectric power potentially available in the State of Maine, or with power from modern, efficient steam-electric plants. The Commission stated, however, that this conclusion should not preclude thorough exploration of the possibilities of a large international tidal power project at Passamaquoddy by the Governments of the United States and Canada.

Prior Activities of I.J.C. Relative to the Passamaquoddy Project

The Governments of the United States and Canada by a formal reference dated November 9, 1948, requested the International Joint Commission to review the then existing plans for the construction of tidal power plants at Passamaquoddy and Cobscook Bays and report on the scope and cost of a survey necessary to determine whether

the plans then proposed or any other plans for using these waters for generation of electric power would be practicable and desirable.

The Commission appointed an International Passamaquoddy Engineering Board to advise it on the technical phases of the study. In its report to the two Governments dated October 20, 1950, the International Joint Commission concluded that the economic feasibility of an international tidal power project at Passamaquoddy Bay could be determined only after careful and detailed investigations had been made. The cost of the necessary survey was estimated to be about $3,900,000, including $300,000 for investigation of the fisheries problem.

Subsequent to completion of the Commission's 1950 report on the Passamaquoddy project, the Corps of Engineers and the United States Geological Survey concluded from experiments with modern techniques in underwater foundation exploration that the over-all survey cost could be reduced. Accordingly, the Corps submitted in May 1952 to the International Joint Commission a revised cost estimate of $3,000,000, including $300,000 for fisheries investigations.

Objectives of the Current Survey

The objectives of the current survey are to determine the cost of developing an international tidal power project in Passamaquoddy and Cobscook Bays and whether such a project would be economically feasible. More specifically: to determine the most desirable general project design in sufficient detail for preparation of dependable cost estimates; to determine the effects which such a project might have on the local and national economies in the United States and Canada; to determine the present and future electric power requirements in Maine and New Brunswick and the ability of the tidal project to supply these requirements; to determine the value of the tidal power in the market area, as compared to the cost of its development; and to study the effects which the construction, maintenance and operation of the tidal power structures might have upon the fisheries in the area.

INVESTIGATION PROCEDURE

International Passamaquoddy Engineering Board and International Passamaquoddy Fisheries Board

To assist in the investigation, the Commission established two separate boards, the International Passamaquoddy Engineering Board and the International Passamaquoddy Fisheries Board. Membership on the Boards included two representatives each from Canada and the United States. On October 3, 1956, the International Joint Commission issued the following directive to the two Boards:

> "(a) The Engineering Board will carry out all the engineering investigations and studies necessary to enable the Commission to prepare and submit to the Governments of the United States and Canada a comprehensive report on the proposed Passamaquoddy Tidal Power Project, as requested by the two Governments in a Reference to the Commission dated 2 August, 1956.
>
> (b) The Fisheries Board will study specifically the effects which the construction, maintenance and operation of the tidal power structures, proposed, might have upon the fisheries in the area.
>
> (c) In order to enable the Fisheries Board to commence its studies and investigations without delay, the Engineering Board is requested to forward to the Commission as soon as possible, for transmittal to the Fisheries Board, an outline of the various project plans which the Engineering Board proposes to investigate. Pending the submission of this information it is suggested that the Fisheries Board proceed with its studies on the basis of the general plans outlined in the March 15, 1950 Report of the previous International Passamaquoddy Engineering Board.
>
> (d) In order that each of the Boards may be fully aware at all times of the progress being made in the investigations and studies carried

out by the other Board, each Board is requested to keep the Commission currently informed regarding the investigations and studies it is conducting. The Commission will undertake responsibility for promptly transmitting the information thus received to the other Board, together with such suggestions or instructions as may appear to be appropriate.

(e) In accordance with the desire of the two Governments as evidenced by the terms of the Reference the Engineering Board is requested to review and to utilize, insofar as is practicable, existing reports and plans such as the Report of 15 March 1950, submitted to the Commission by the previous International Passamaquoddy Engineering Board, and the supplemental report of May, 1952 prepared by the Corps of Engineers, United States Department of the Army.

(f) Each Board is authorized to establish such committees and working groups as may be required to effectively discharge the Board's responsibilities.

(g) In accordance with the desire expressed by the two Governments, the Commission will endeavour to complete its various investigations and studies under the Reference within a three year period and submit a comprehensive report covering the subject matter of the Reference as soon as possible thereafter. In order that this may be done, the Commission would appreciate receiving the final reports of both Boards prior to 1 October, 1959.

(h) Each Board will prepare and submit semi-annual progress reports to the Commission on or about 31 March and 30 September of each year and such other reports from time to time as the Commission may direct or as the Board may consider desirable."

The Engineering Board established an Engineering Committee to supervise the detailed engineering studies of the tidal power project. These studies were carried out primarily by the U. S. Army Engineer Division,

New England, Corps of Engineers, and the Regional Office of the United States Federal Power Commission, New York. Canadian aspects of the engineering studies were conducted by the Department of Public Works, the Department of Northern Affairs and National Resources, and other agencies of the Governments of Canada and New Brunswick. The Fisheries Board appointed a Research Committee of Canadian and United States Scientists to develop plans and to conduct the necessary research on the fisheries of the Passamaquoddy region.

A Joint Engineering and Fisheries Committee of the Engineering and Fisheries Boards was set up in accordance with directions from the International Joint Commission dated October 4, 1957. That Committee established an appropriate and practicable line of demarcation between the work of the two Boards and outlined the methods of measuring benefits and damages in matters of common interest to the fisheries and engineering investigations.

Referral of Reports of the Engineering Board and Fisheries Board to Interested Parties for Review and Comment

On November 13, 1959, the International Joint Commission issued a public notice stating that the comprehensive technical investigations and studies necessary for the preparation of the Commission's report were completed, and that the final reports of the two Boards had been formally presented to the Commission. In order to obtain the views of interested parties prior to formulation of the Commission's report and recommendations to the two Governments, the Commission made the reports of the Boards available for examination at convenient places in both countries. In addition copies of the report were sent to the Maine delegation in the United States Congress; the New Brunswick members of the Canadian Parliament; interested agencies of each Government; State, Provincial, and local governments and officials concerned; and others.

In response to the Commission's public notice inviting comments on the reports of the Boards numerous communications were received. Most of these communications favoured the tidal power project in principle but dealt only in very general terms with the details of the Board's reports.

Commission Hearing on Findings of Engineering and Fisheries Boards Reports

On April 22, 1960, the International Joint Commission conducted a public hearing in the Calais Memorial High School, Calais, Maine, for the purpose of receiving testimony and evidence bearing on the findings and conclusions set forth in the reports of the International Passamaquoddy Engineering Board and the International Passamaquoddy Fisheries Board.

The Calais hearing was attended by a total of about 200 persons from the United States and Canada, including a representative of the United States Congress, the Governor of the State of Maine, representatives of Federal, State, Provincial, County, and Municipal agencies, local civic groups, and other interested individuals. Twenty-nine persons presented briefs or oral testimony at the hearing. About two-thirds of these were favourably inclined toward the tidal power project. In addition to the testimony presented at the hearing, several communications commenting on the tidal power project were received by the Commission and included in the record of the hearing. These communications, for the most part, were favorable to the tidal power project. The views expressed at the hearing are covered more fully in the section dealing with the public hearing.

REPORT OF THE ENGINEERING BOARD

Scope of the Survey

The report of the International Passamaquoddy Engineering Board sets forth the results of a comprehensive survey to determine the engineering and economic feasibility of developing the international tidal power potential of Passamaquoddy Bay in Maine and New Brunswick and the effects which such a project might have on the local and national economies in the United States and Canada. It includes within its scope the results of investigations of the following subjects: the engineering and economic aspects of the tidal project by itself; the engineering and economic aspects of the tidal project combined with an auxiliary source of power supply to supplement the varying output of the tidal power plant;

RECOMMENDATIONS

In view of the finding that the Passamaquoddy tidal power project is not economically feasible under present conditions, the Commission recommends that development of the project be viewed as a long-range possibility having better prospects of realization when other less costly energy resources available to the area are exhausted. In making this recommendation the Commission wishes to point out that the economic feasibility of the project may be affected by future changes in the costs and benefits considered in the present evaluation of the project. The two Governments may wish to give consideration to the desirability of crediting the tidal project with certain public benefits that have not been included in the economic feasibility determination presented in this report.

The Commission recommends, further, that this report with the accompanying reports of the Engineering and Fisheries Boards be made available to all interested parties as a valuable source of relevant engineering and economic data for use in any future study of the possibilities for development of the international tidal power potential of Passamaquoddy Bay.

Signed at Washington this 4th day of April 1961.

Edward A. Bacon

A. G. L. McNaughton

Eugene W. Weber

J. Lucien Dansereau

Francis L. Adams

D. M. Stephens

the market for and value of the power from the tidal power project with and without an auxiliary; and the possible beneficial and damaging effects that construction of the tidal project may have on the regional and national economies.

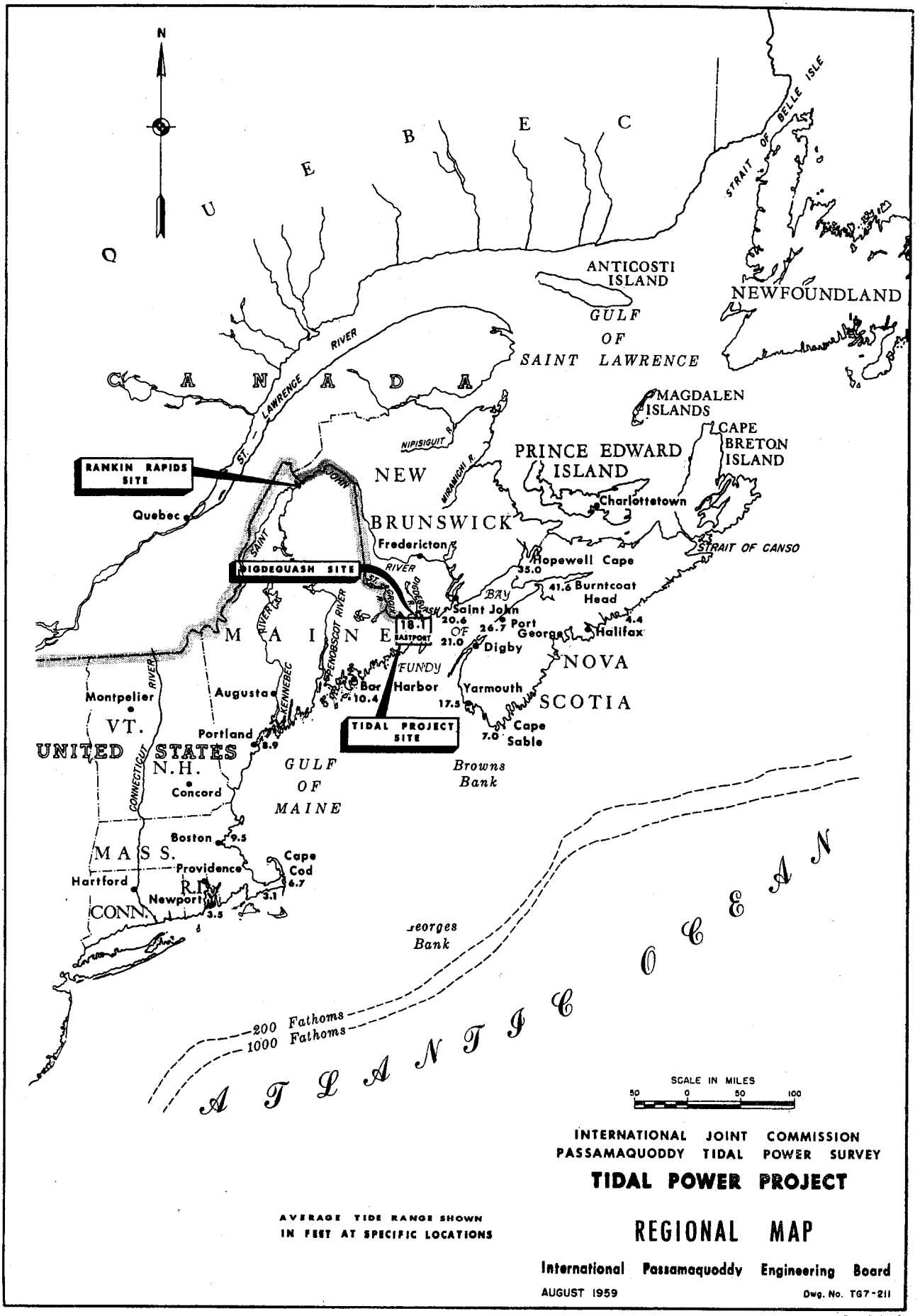
Field Investigations

In order to formulate the best plan of development for the tidal power project it was necessary for the Engineering Board to conduct a series of field investigations and studies of site conditions in the Passamaquoddy-Cobscook Bay area. These investigations included aerial mapping, deep and shallow water drilling, land drilling, underwater mapping, analysis of soils, and tide gauging. Core drilling in great water depths and high tidal velocities and underwater mapping by newly developed sonic equipment constituted two of the most costly and difficult undertakings of the survey. Highly specialized sonic equipment was utilized to chart the bottoms of the bays and determine depths of overburden.

The Selected Tidal Power Project

In order to determine the most efficient arrangement of works for the tidal power project, estimates were made by the Engineering Board to determine the average annual energy available and the construction cost of a considerable number of alternative arrangements. Since the time required for manual computation of the annual energy output of each of the numerous possible project arrangements was prohibitive, these computations were performed electronically by digital computer. In this way annual energy generation could be determined for any project arrangement, once its pool areas, number of generating units, and number of filling and emptying gates were established. The project arrangement that revealed the best relationship of power output to cost was selected for detailed design.

The project arrangement thus selected for design includes the 101 square miles of Passamaquoddy Bay as the high pool and the 41 square miles of Cobscook Bay as the low pool, with a powerhouse located at Carryingplace Cove. The location of the tidal power project is shown on Plate 1 and the general arrangement of the selected plan of development is shown on Plate 2.



AVERAGE TIDE RANGE SHOWN IN FEET AT SPECIFIC LOCATIONS

INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY

TIDAL POWER PROJECT

REGIONAL MAP

International Passamaquoddy Engineering Board

AUGUST 1959 Dwg. No. TG7-211

PLATE 1

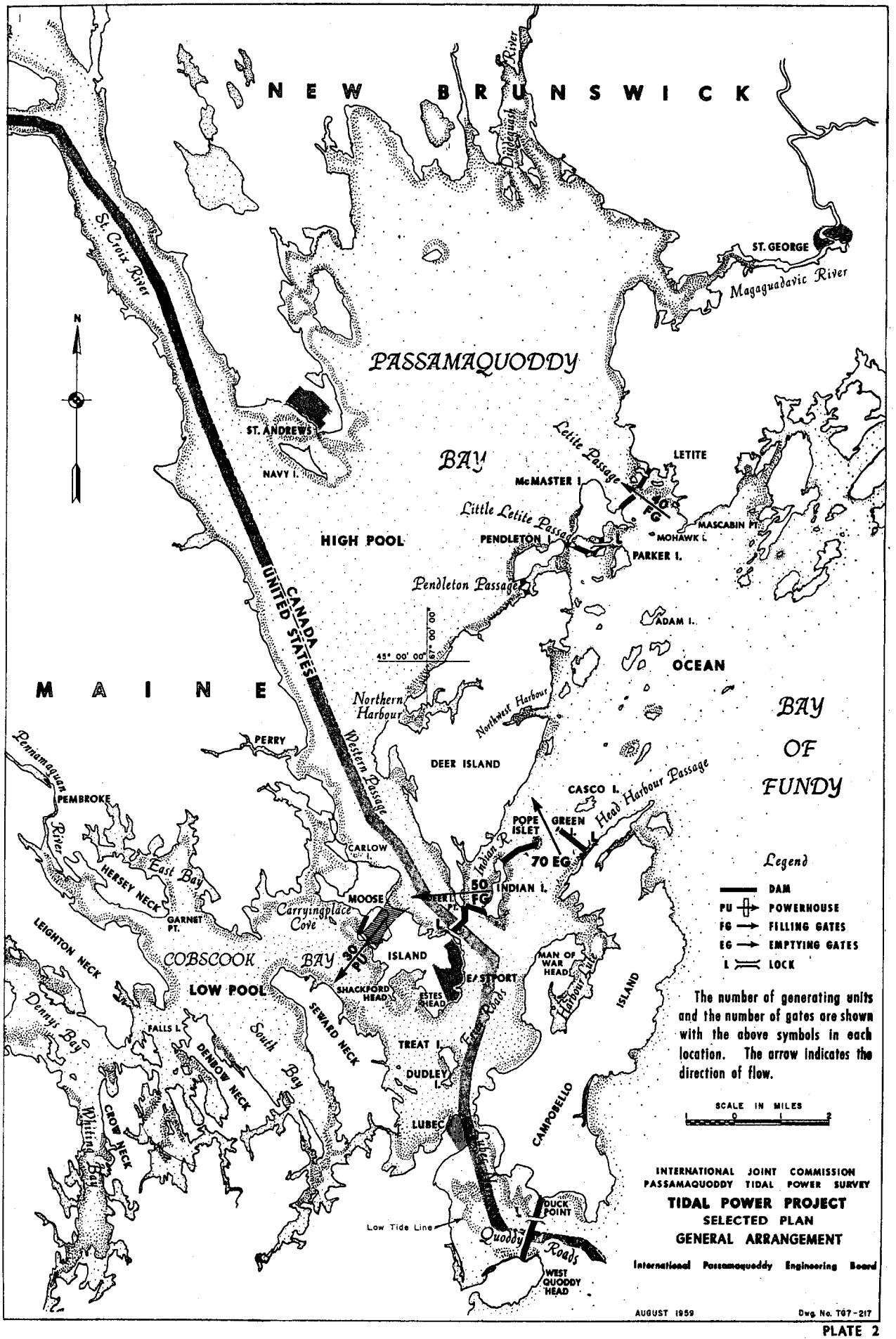

NEW BRUNSWICK
MAINE
CANADA
UNITED STATES
St. Croix River
Digdeguash River
Magaguadavic River
ST. GEORGE
PASSAMAQUODDY
BAY
ST. ANDREWS
NAVY I.
HIGH POOL
Letite Passage
LETITE
McMASTER I.
Little Letite Passage
PENDLETON I.
MOHAWK I.
MASCABIN PT.
PARKER I.
Pendleton Passage
ADAM I.
OCEAN
45° 00' 00"
67° 00' 00"
Northern Harbour
Northwest Harbour
BAY OF FUNDY
PERRY
DEER ISLAND
Western Passage
Pennamaquan River
PEMBROKE
CASCO I.
Head Harbour Passage
POPE ISLET
GREEN I.
CARLOW I.
Indian R.
70 EG
HERSEY NECK
East Bay
50 FG
INDIAN I.
MOOSE
Carryingplace Cove
GARNET PT.
LEIGHTON NECK
COBSCOOK BAY
50 PU
ISLAND
EASTPORT
MAN OF WAR HEAD
Harbour Line
LOW POOL
SHACKFORD HEAD
ESTES HEAD
Dennys Bay
FALLS I.
SEWARD NECK
South Bay
TREAT I.
Eastern Roads
DUDLEY I.
DENBOW NECK
CROW NECK
Whiting Bay
LUBEC
CAMPOBELLO ISLAND
DUCK POINT
Low Tide Line
Quoddy Roads
WEST QUODDY HEAD
N
Legend
DAM
PU POWERHOUSE
FG FILLING GATES
EG EMPTYING GATES
L LOCK
The number of generating units and the number of gates are shown with the above symbols in each location. The arrow indicates the direction of flow.
SCALE IN MILES
0 1 2
INTERNATIONAL JOINT COMMISSION
PASSAMAQUODDY TIDAL POWER SURVEY
TIDAL POWER PROJECT
SELECTED PLAN
GENERAL ARRANGEMENT
International Passamaquoddy Engineering Board
AUGUST 1959
Dwg. No. T67-217

PLATE 2

The selected plan would provide an installed generating capacity of 300,000 kilowatts, a dependable capacity of 95,000 kilowatts, and an average annual generation of about 1,843 million kilowatt-hours.

Components of the Project Selected for Detailed Design

With the major aspects of the project layout determined, design studies were undertaken by the Engineering Board of each component of the selected plan - tidal dams and cofferdams, filling and emptying gates, navigation locks, powerhouse, turbines, and generators - in sufficient detail to permit reliable cost estimates.

The 35,700 linear feet of tidal dams are located as far as practicable on foundations of bedrock or granular material to avoid clay overburden. The tidal dams, composed of clay core supported by flanking dumped-rock fills, are designed to permit greatest possible use of materials excavated for the gate structures, navigation locks and the powerhouse.

Cofferdams of several different types, depending on the depths to be unwatered, would be used to excavate for the foundations of the powerhouse, filling and emptying gates, and navigation locks. Cofferdam designs include embankments, log cribs with timber sheathing, and steel sheet piling of both circular and cloverleaf design.

The selected plan calls for 90 filling gates, 40 in Letite Passage and 50 between Western Passage and Indian River. In the reach between Pope and Green Islets 70 emptying gates, similar to the filling gates but set at a lower elevation, would empty the lower pool. Comprehensive study of all types of gates led to selection of a 30' x 30' vertical lift gate set in a venturi throat. The venturi throat permits maximum discharge for a given gate area.

Four navigation locks are planned for the selected tidal project. Two locks, one at Little Letite Passage and one at Quoddy Roads, would have clear dimensions of 95' x 25' x 12' to pass fishing vessels. Two locks, one at Head Harbour Passage immediately east of the emptying gates and one at Western Passage north of Eastport, would have clear dimensions of 415' x 60' x 21' to pass vessels somewhat larger than the present traffic.

The powerhouse would be of the outdoor type and would contain 30 generating units of 10,000 kilowatts rated capacity each with an overload of 15 percent. The turbines selected for the project are the fixed-blade propellor type with a maximum diameter of 320 inches and a speed of 40 revolutions per minute. The generators would be connected in banks of 7 and 8 to four 90,000 kilovolt-ampere transformers located on the upstream side of the powerhouse and connected to the switchyard by oil-filled high voltage cables. Two transformers would operate at 230 kilovolts for supply to the United States and two at 138 kilovolts for Canada.

A comparison of the performance of fixed-blade and Kaplan turbines indicated that the greater efficiency of the Kaplan turbine over a wide range of heads was offset by its greater cost. A new type of horizontal-axis, bulb-type turbine-generator unit recently developed in Europe and adopted for use in the single-pool tidal project in LaRance Estuary on the northwest coast of France was also studied by the Engineering Board for possible use in the Passamaquoddy project. This unit can be used as a turbine, pump, or sluiceway, with flow in either direction. Studies by the Board showed that the bulb-type turbine-generator develops approximately as much power as the Kaplan, and structural studies indicated that the powerhouse structure would cost about $300,000 less per unit than with conventional units. This saving, however, was off-set by the greater cost of the bulb-type turbine-generator set and the need to compensate for low rotative inertia. For these reasons, and because of unresolved maintenance problems, the Board adopted the conventional fixed-blade type unit for cost estimates of the Passamaquoddy project.

Auxiliary Power Sources Considered

In order to supplement the varying output of the tidal power project, the Engineering Board considered several different types of auxiliary power sources to determine the type best suited for meeting the power loads of the region. These studies included river hydroelectric plants, pumped-storage plants, and steam-electric auxiliaries.

Among a number of river hydroelectric sites examined, Rankin Rapids on the upper Saint John River in Maine, was selected by the Board as the best source of auxiliary power. The Rankin Rapids project would provide 2.8 million acre-feet of usable storage capacity. Operated in conjunction with the tidal plant, the combined project would provide 555,000 kilowatts of dependable capacity and 3,063 million kilowatt-hours of average annual generation.

As a possible alternative plan of development, Rankin Rapids could be constructed, initially, to carry part of the load in Maine, with provision for later installation of additional generating capacity which could be used as an auxiliary power supply for the tidal project. Energy thus borrowed from the Rankin Rapids project when using the "incremental capacity" would be repaid when tidal output is greater than the load. This combination would provide 355,000 kilowatts of dependable capacity and 1,843 million kilowatt-hours of average annual generation without a serious effect on the basic Rankin Rapids project (200,000 KW and 1,220 million KWHrs).

Tidal power also could be supplemented by means of a pumped-storage plant. Using power from the tidal plant at times when it is not required to meet load demands, water could be pumped to a higher storage basin and released through turbines as required to meet the load. Since the output of the tidal plant alone would vary from 95,000 to 345,000 kilowatts, a pumped-storage plant with 260,000 kilowatts of installed capacity would provide a dependable capacity of 323,000 kilowatts from the combined project. The average annual generation would be 1,759 million kilowatt-hours. A pumped-storage site on the Digdeguash River near its outlet into Passamaquoddy Bay east of St. Andrews was adopted by the Engineering Board for detailed study.

A steam-electric plant also could be used to firm the potential power output of the tidal plant up to its rated capacity of 300,000 kilowatts. Since the tidal plant would have a dependable capacity of 95,000 kilowatts, a steam-electric plant would need to supply a maximum of 205,000 kilowatts. This combination would provide about 2,143 million kilowatt-hours of electric energy annually. Since

a steam-electric plant was found to be economically the least favorable type of auxiliary for the tidal power project, this combination was not considered further by the Engineering Board.

In summary, four project combinations were selected by the Engineering Board for evaluation of costs and benefits. These are: (1) the Passamaquoddy tidal project alone; (2) the tidal project operated in combination with all the Rankin Rapids project; (3) the tidal project supplemented by incremental capacity only at Rankin Rapids; and (4) the tidal project supplemented by the Digdeguash pumped-storage auxiliary. Pertinent data for these four project combinations, as determined by the Board, are summarized as follows:

Project Combination	Installed Capacity (1000 kw)	Dependable Capacity (1000 kw)	Average Annual Generation (Billion kwh)	Capital Investment (At Site) (Millions of dollars)	Capital Investment (Including Transmission to Market) (Millions of dollars)
(1) Tidal Project alone	300	95	1.843	532.1	546.8
(2) Tidal Project and all of Rankin Rapids	700	555	3.063	687.7	732.1
(3) Tidal Project and incremental capacity only at Rankin Rapids	526	355	1.843	565.7	600.0
(4) Tidal Project and Digdeguash pumped-storage storage project	560	323	1.759	568.9	586.4

The Board concluded that the second of the above combinations, the tidal project and all of Rankin Rapids, would provide the most favorable project.

Conclusions of the Engineering Board

On the basis of its comprehensive studies the International Passamaquoddy Engineering Board reached the following conclusions:

(1) A tidal power project using the waters of Passamaquoddy and Cobscook Bays can be built and operated. The two-pool type of project is best suited for the site conditions in the area and the power markets it would serve. The tidal project arrangement selected makes best use of the site conditions.

(2) The first cost (construction cost) of the tidal power project by itself would be $484 million. With interest during construction, the investment would be $532.1 million. The tidal power project would have an installed capacity of 300,000 kilowatts and a dependable capacity of 95,000 kilowatts. Average annual energy would be 1,843 million kilowatt-hours. However, for maximum power benefits, the tidal power project would have to be combined with an auxiliary power source.

(3) The most favorable project combination is the tidal power project operated in conjunction with a river hydroelectric auxiliary built at the Rankin Rapids site on the upper Saint John River in Maine. The combined cost of the tidal project and the Rankin Rapids auxiliary is $630 million. With interest during construction, the investment would be $687.7 million. The dependable capacity of this combination would be 555,000 kilowatts, and average annual generation would be 3,063 million kilowatt-hours.

(4) Construction of the tidal project - Rankin Rapids combination would increase low flows in the lower Saint John River by a considerable amount, thus increasing substantially the usefulness of the river for downstream generation of power. Downstream benefits accruing to existing power plants were included in the economic evaluation.

(5) The combination of the tidal power project and the installation and use of 260,000 kilowatts of capacity only at Rankin Rapids for firming up the output of the tidal power project would cost $515.5 million. With interest during construction, the investment would be $565.7 million. This combination would provide a total dependable capacity of 355,000 kilowatts and an average annual generation of 1,843 million kilowatt-hours.

(6) The tidal power project and the Digdeguash pumped-storage auxiliary would cost $518.5 million. With interest during construction, the investment would be $568.9 million. The dependable capacity would be 323,000 kilowatts, and average annual generation would be 1,759 million kilowatt-hours.

(7) The total output from the tidal power project and Rankin Rapids hydroelectric plant can be absorbed readily by the growing utility markets of Maine and New Brunswick.

(8) Because of differences in interest rates prevailing in the two countries, and because of different values of alternative power, it was necessary to compute separate benefit-cost ratios for United States and Canada. Economic evaluations, assuming 50-year and 75-year amortization periods, and assuming that power output and project first cost would be equally divided between the United States and Canada, are tabulated below:

	50-YEAR AMORTIZATION		75-YEAR AMORTIZATION	
	BENEFIT COST RATIO	COST PER KW.-HR., (MILLS)	BENEFIT COST RATIO	COST PER KW-HR., (MILLS)
TIDAL PROJECT ALONE				
UNITED STATES	0.60	10.8	0.70	9.3
CANADA	0.34	14.9	0.37	13.7
TIDAL PROJECT AND ALL OF RANKIN RAPIDS				
UNITED STATES	1.31	8.4	1.53	7.2
CANADA	0.58	11.5	0.63	10.6
TIDAL PROJECT AND INCREMENTAL CAPACITY ONLY AT RANKIN RAPIDS				
UNITED STATES	0.93	11.5	1.08	9.9
CANADA	0.42	15.8	0.45	14.5
TIDAL PROJECT AND DIGDEGUASH PUMPED-STORAGE AUXILIARY				
UNITED STATES	0.91	12.2	1.06	10.5
CANADA	0.42	16.8	0.46	15.4

(9) The inclusion of taxes foregonewith project costs is not the practice in the economic justification of public projects in Canada, and due to the international nature of the project, such taxes have not been applied to United States' costs. However, if they were included in United States' costs, the benefit to cost ratio of the most favorable project combination would be reduced to 1.10 for the 50-year amortization period and to 1.25 for the 75-year period.

(10) By including appropriate remedial measures in the design of the tidal power structures, the construction, maintenance and operation of the tidal power project would have only a minor residual effect on the fisheries of the region.

(11) Considerable annual recreation benefits would grow out of the construction and operation of the tidal power project. However, the monetary value of these benefits was not included in the economic evaluation.

(12) Assuming an equal division of power output and of first costs between United States and Canada, construction of the tidal power project with all of Rankin Rapids as auxiliary is not an economically justified project for Canada.

(13) The Passamaquoddy tidal project and Rankin Rapids combination, if built entirely by the United States at an interest rate of 2-1/2 percent, is economically justified.

REPORT OF THE FISHERIES BOARD

Scope of the Fisheries Investigation

The investigations of the Fisheries Board were directed primarily toward determination of the effect the tidal power project might have on the fisheries of the area. Consideration was given not only to the sardine industry which accounts for most of the landings in the area but also to the fisheries for cod, haddock, flounder, redfish, hake, pollock, salmon, alewives, clam, smelt, scallops, and lobsters. The Board's report presents results of: studies of the present oceanographic, biologic, and economic features of the area; investigations pertaining to temperature, salinity, tides and tidal currents in the Bays, in the approaches, and outside the Bays; and biological studies of fish populations, breeding grounds, nursery areas, food and feeding habits and inter-relationship of fish and their environment.

Conclusions of the Fisheries Board

On the basis of its studies, the Fisheries Board reached the following conclusions:

1. The construction of dams in the tidal passages will change the oceanographic features of the Quoddy Region. Major changes are anticipated inside Passamaquoddy and Cobscook Bays and immediately outside the dams. Effects outside the Head Harbour-Bliss Island line will likely be insignificant.

2. The mean water level of Passamaquoddy Bay will be raised about 6 feet while the mean level of Cobscook Bay will be lowered about 5 feet. The mean "tidal" range in the high pool and low pool will be reduced to approximately 4 feet and 8 feet respectively. The tidal range of the Bay of Fundy may increase approximately one percent with a maximum increase at the head of this Bay of less than one foot.

3. Current patterns in Passamaquoddy and Cobscook Bays and in the approaches will be altered markedly since the emptying and filling gates will be closed for about 9 and 9½ hours respectively during each tidal cycle of 12½ hours. When the gates are open, velocities in most areas should be only slightly lower than at present. The residual counter-clockwise circulation in Passamaquoddy Bay will likely be more pronounced. Tidal streams in the outer Quoddy Region will probably be altered by not more than 20 percent. No change in non-tidal circulation is anticipated for the Bay of Fundy.

4. Reduced velocities in Passamaquoddy and Cobscook Bays will result in decreased vertical mixing, giving rise to increased stratification and hence to greater seasonal variations in surface water temperature. The summer maximum is likely to be in the vicinity of 68 degrees Fahrenheit while in winter an ice cover is expected over part of the Bays. Outside, little change is expected adjacent to the emptying and filling gates where there will be a slightly greater seasonal variation.

5. Mean surface salinities for both pools will be lowered but bottom salinities are likely to be altered only slightly. It is doubtful if fresh water will penetrate below 30 to 50 feet. Flushing time is expected to increase substantially. Outside, no significant change is expected except near the emptying gates where there will be a slight reduction in salinity.

6. Oxygen concentrations of the deep water inside the dams may be lowered somewhat, especially during periods of maximum fresh water discharge. However, it is unlikely to fall below 50 percent saturation.

7. The herring population is produced outside the Quoddy Region, probably off southwest Nova Scotia. The general abundance of herring in the Bay of Fundy and the Gulf of Maine is unlikely to be affected.

8. Echo-sounder records show that a large proportion of herring are in the open waters of Passamaquoddy Bay where no fishing takes place. Tagging experiments show that herring move freely throughout the Quoddy Region during the fishing season.

9. Since there are unlikely to be any significant changes in oceanographic conditions outside the dams, herring should arrive in this area as before. Little change is expected in current velocities in the approaches to the filling gates when open. Since velocities are well above the maximum sustained swimming speed of herring, the fish will be carried through the filling gates. Since the filling gates are open for about 6 hours each day, movement of herring into Passamaquoddy Bay is expected to be delayed. This is also true for Cobscook Bay where entry will be chiefly through turbines. Although the rate at which herring accumulate will be slower, there should be no reduction in over-all abundance inside the Bays.

10. Predicted changes in temperatures and salinities are expected to make the areas inside the dams no less favourable for herring except in isolated areas where high temperatures and low salinities may cause some mortality. Predicted pressures and rates of pressure change between the turbine intakes and exits are within limits which herring can withstand.

11. No relationship between herring landings and various meteorological and oceanographic conditions including surface drift, river discharge, wind speed and direction, zooplankton, temperatures, and salinities is apparent.

12. Long-term statistics of herring landings show year-to-year variations in individual weir catches and in total catches in various parts of the Quoddy Region. These are of far greater magnitude than the changes that can be forecast as resulting from the dams.

13. No measurable change in groundfish landings in the Quoddy Region is anticipated, but a change in species composition of the fraction of the catch taken inside the dams is expected. Inside the dams, winter flounder fisheries may increase while haddock and pollock fisheries will be greatly reduced. Clam fisheries will be greatly reduced for a period of ten years and then may become re-established at a lower level of production. Scallop stocks should increase substantially. Inside the dams, a modest increase in production of lobsters is anticipated. Conditions for anadromous species such as Atlantic salmon and alewives may be improved. Smelt, shad, and sea-run trout stocks should increase. Striped bass and tom cod thrive in areas where conditions of temperature and salinity are similar to those predicted for Passamaquoddy and Cobscook Bays. Some reduction is expected in the availability of marine worms and rockweed.

14. Six existing herring weir sites will be eliminated by the construction of dams. Other weirs must be relocated or altered to suit the new oceanographic

environment. Weir stakes and nets will have to be increased in size to suit new water levels. The resultant fixed costs are estimated at $129,000. Wood borer activity is expected to increase. Ice will cause some damage to weir materials during the winter. The annual cost of weir operations will rise approximately $10,000. It is conceivable that weir owners may discontinue their investments in weirs inside the dams. A shift to alternative methods of fishing could be expected to maintain the fishery, at least at its present level.

15. Lobster fishermen are not expected to be adversely affected, but physical damages due to relocation of lobsters pounds, refrigeration of water, or extension of intake pipes are expected to cost $450,000. Changes in the clam fishery may result in a loss of capital investment in plants valued at $100,000 and an annual loss in primary production of $104,000 for 10 years. The disappearance of some groundfish from inside the dams will result in an annual loss of approximately $3,000.

16. Fish passage facilities for anadromous species were estimated by fisheries engineers to cost $3.0 million.

On completion of the preliminary engineering design, which complied with the criteria set down by the Fisheries Board, the Engineering Board determined that incorporation of the fish passage facilities in the initial design and construction would increase the project costs by only $919,100.

PUBLIC HEARING

Public Hearing at Calais, Maine

On April 22, 1960, the International Joint Commission conducted a public hearing in Calais, Maine, for the purpose of obtaining the views of all parties concerned with the international Passamaquoddy tidal power project.

Many of the witnesses at the hearing urged construction of the Passamaquoddy tidal power project with the Rankin Rapids project as an auxiliary. They stressed that this combination project could be expected to have a favorable impact upon the efforts of Maine and New Brunswick to expand industrially, and that construction and operation of the project would greatly enhance the economy of the region. They asserted that the Rankin Rapids project is the logical source of power for firming the power output of the tidal plant, and that construction of the project would not destroy the Allagash wilderness area in Maine as some alleged. Some proponents expressed the view that recreational patronage accorded the Allagash area in recent years was slim and unprofitable, and that over-all recreational use of the area could be expected to increase with construction of the Rankin Rapids project. Members of the State of Maine's Delegation in the Congress, the Governor of Maine, the Maine Governor's Committee on Passamaquoddy Bay, and representatives of local governments in the region went on record in support of the combination Passamaquoddy-Rankin Rapids project presented in the report of the Passamaquoddy Engineering Board.

On the other hand, several witnesses raised objections to the tidal power project alone and to the tidal project combined with the Rankin Rapids project. A spokesman for privately-owned electric utility companies in New England argued that neither the tidal plant alone nor the tidal plant with an auxiliary is economically feasible. A similar view was expressed by a representative of a Special Committee of Maine Engineers. This Committee included representatives of the Maine section of the American Society of Civil Engineers, the Maine Section of the American Institute of Electrical Engineers* and the

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* - The Acting Secretary-Treasurer of the Maine Section of the American Institute of Electrical Engineers informed the Commission by letter dated May 16, 1960, that the findings of the Special Committee of Maine Engineers do not necessarily represent the opinions of all members of that Section.

Maine Association of Engineers. A spokesman for the New Brunswick Electric Power Commission expressed the view that the tidal power project with or without an auxiliary was not economically justified insofar as Canada is concerned.

Several witnesses from Canada urged further consideration of the Cumberland Basin-Shepody Bay tidal power scheme and of potential developments in the Saint John and Hamilton Rivers with the suggestion that these possibilities should be considered in evaluating future sources of power supply for the region.

Conservationists raised objections to the Rankin Rapids project because of inundation of the Allagash wilderness area. They advocated the alternative Big Rapids-Lincoln School development if this reach of the Saint John River is to be utilized as a source of firming power for the tidal project. This alternative was favored by the Maine Department of Inland Fisheries, the United States Bureau of Sports Fisheries of the Department of the Interior, and numerous organizations interested in conservation.

Representatives of fishery interests in the Passamaquoddy Bay region expressed concern that their sources of sardine supply might be damaged by construction of the tidal project. They asserted that the risk to the fishery inherent in the development of the tidal power project is so great as to outweigh any indicated benefits to the region. They expressed the hope that the fishing industry would be compensated for any damages that might result from construction of the tidal power project.

PROBLEMS OF PROJECT FORMULATION AND ECONOMIC EVALUATION

The Problem of Tidal Power Production

As indicated previously, tidal power can be produced by passing water from a higher to a lower elevation through hydraulic turbines. Unaffected by droughts, floods, or ice jams, the tides provide a dependable source of power and can be predicted with accuracy. One of the principal disadvantages of tidal power production is that four times a day the tides reverse direction, thus causing

variations in available power. Development of a workable method of producing continuous power from such a varying flow constitutes one of the principal problems of formulation of a tidal power project.

The generation of large amounts of tidal power requires one or more storage pools. A single pool has the serious disadvantage of producing varying and intermittent power, because no power can be generated when there is insufficient difference between the level of the storage pool and the level of the ocean. Thus no generation is possible until the ocean has receded sufficiently to obtain this difference in water levels, or the power head; nor is generation possible on the rising tide after the level of the ocean becomes too high to provide this necessary minimum head. This disadvantage is reduced in the two-pool plan adopted by the Engineering Board, which generates varying power but a certain minimum amount of continuous power.

Need for an Auxiliary Source of Power to Supplement the Variable Output of the Tidal Project

Another disadvantage of the tides as a source of power is that the tides, following the gravitational pull of the moon as it passes overhead every 24 hours and 50 minutes, are out of phase with the 24-hour solar day. This 50-minute daily lag is fundamental to the economics of tidal power for, since power output varies with the tides, tidal power is out of step with the normal pattern of power demands. Therefore, unless the tidal plant is supplemented by an auxiliary power plant, such varying power would be of limited value. The different types of auxiliary power sources studied by the Engineering Board to determine the type best suited for making the combined power output of the tidal project and its auxiliary match the characteristic load pattern are discussed in Section III of this report.

The Rankin Rapids-Allagash Problem

The Rankin Rapids site is located in Maine downstream from the junction of the Allagash River and the main stem of the Saint John River. Development of this site would flood a series of rapids in the lower reaches of the Allagash River. These rapids are esteemed by many sportsmen

for the trout fishing and the white water canoeing they afford although the number of visitors has not been great in recent years. Their flooding by construction of the Rankin Rapids reservoir is strongly opposed by associations and agencies concerned with preservation of recreation and wildlife resources.

An alternative to the Rankin Rapids project was considered by the Engineering Board in order to determine the best means of comprehensive development of the upper St. John River with due consideration to all the uses of the water resources. The alternative would consist of a two-dam project, with a high dam at the Big Rapids site, upstream from the mouth of the Allagash River, and a low dam at the Lincoln School site, a short distance downstream from the Rankin Rapids site. The two-dam plan would greatly reduce the extent of inundation of the lower Allagash River and also mitigate possible losses to fish and wildlife.

The Engineering Board estimated that the Rankin Rapids project would produce 68,000 kilowatts of capacity and 215 million kilowatt-hours a year more than the Big Rapids-Lincoln School project. The Board also estimated that the unit cost of power would be 20 percent more at the Big Rapids-Lincoln School project than at Rankin Rapids. Because of the greater drainage area, usable storage capacity, and regulated outflow, Rankin Rapids would improve conditions for further power development on the downstream Saint John River to a greater extent than the alternative Big Rapids-Lincoln School project. Moreover, the larger installed generating capacity at Rankin Rapids permits greater utilization of the tidal power potential. In view of these findings, the Engineering Board selected the Rankin Rapids project as the river hydro auxiliary for the tidal power project.

Because of the opposition of certain groups in the United States to the development of the Rankin Rapids site, the Engineering Board undertook to secure the views of the Bureau of Sports Fisheries and Wildlife, Fish and Wildlife Service of the United States Department of the Interior. The Bureau stated that the Rankin Rapids project would injure the fish and wildlife assets of the area more than the Big Rapids-Lincoln School combination. It

recommended a series of measures for the protection of the fish and wildlife resources of the area regardless of the auxiliary project selected. The measures recommended by the Bureau are as follows:

(1) Establishment of a framework for management of fish and wildlife resources.

(2) Provision of public access.

(3) Purchase of additional lands for wildlife management purposes.

(4) Modification of land clearing plans.

(5) Construction of barrier dams.

(6) Provision for minimum flows as required to benefit downstream fisheries.

(7) Provision for a fish hatchery and rearing facilities.

(8) Management of tributary streams.

(9) Sub-impoundments for waterfowl within reservoir maximum flow line.

(10) Control of reservoir pool elevations and provisions for spawning beds.

(11) Control of release temperatures.

Consideration should be given to all the measures listed above if construction of either the Rankin Rapids or Big Rapids-Lincoln School auxiliary is undertaken.

Disparity of Interest Rates and Other Economic Factors Between the United States and Canada

For the purpose of selecting the most favorable tidal project plan, the Engineering Board compared the ratios of construction cost to average annual generation for the various possible plans considered. Estimates of the capital costs of the tidal project combinations made by the Engineering Board were based on United States currency and January 1958 price levels.

In computing the annual costs of project plans, it was found that there are differences between the two countries in interest rates and other economic factors. In the United States, projects such as this are assumed to be financed by the federal government. Thus, the Engineering Board computed interest during construction and annual power costs for the United States portion of development using interest at 2½ percent, since that was the rate recommended, at the time of the survey, by the United States Bureau of the Budget for use by federal agencies in evaluating water resource development projects.1/ For the Canadian share of development, which was assumed to be financed by an agency of the Province of New Brunswick, an interest rate of 4-1/8 percent was used, because that was the rate used in January 1958 by the federal government of Canada on loans to crown corporations and provincial governments. No amount for taxes was included in the annual project costs applicable to either country.

The annual power benefits of the tidal project combinations were measured by the Engineering Board on the basis of the cost of power from modern steam-electric plants in Maine and New Brunswick. In view of the present ownership and predominant type of generating plants of the respective electric power systems, it was deemed appropriate to assume that the most likely alternative power supply, in the absence of the tidal project, would be privately-financed steam-electric plants in Maine and publicly-financed plants in New Brunswick. In computing the annual costs of the steam-electric plants in Maine, the Engineering Board used 6.00 percent as the cost of money and included an amount for taxes equal to 4.44 percent of the capital investment. Annual costs of steam-electric plants in New Brunswick were based on an interest rate of 4-1/8 percent and on including no amount for taxes since the public power agency of the Province does not pay taxes.

1/ On July 26, 1960, the Bureau of the Budget recommended that this rate be increased to 2-5/8 percent.

In view of these disparities in practices, the Engineering Board prepared separate economic analyses showing ratios of benefits-to-costs applicable to each country's share of the development. These analyses assumed that the capital costs and project power would be divided equally between the two countries. In addition to comparing the United States' share of project costs, using interest at $2\frac{1}{2}$ percent and excluding taxes, with the cost of providing equivalent power by steam-electric plants, using cost of money at 6.00 percent and including taxes, the Engineering Board showed benefit-cost ratios for the United States' share with an item of "taxes foregone," amounting to about $9 per kilowatt of dependable capacity, included as an economic cost of the project.

Economic Impact of the Tidal Power Project on the Region

An evaluation was made by the Engineering Board of all possible beneficial and damaging effects that construction of the tidal project, with and without an auxiliary source of power, may have on the regional and national economies. The Board concluded from these studies that the tidal project and its auxiliary would have a favorable impact on all segments of the economy of Maine; and that the effect on the general economy of New Brunswick would be the same as that of any other block of power of equal size and cost developed to satisfy the growing power demand. Power market studies by the Engineering Board indicate that the anticipated load growth in the region will be sufficient to absorb a block of power equal to the output of the tidal plant and its auxiliary by 1980 or earlier.

Construction of the tidal power project would produce an important short-term economic impact on the economy of Maine and New Brunswick. Estimates by the Engineering Board indicate that during the six-year construction period of the tidal project alone, total investment outlays in Maine and New Brunswick would amount to about $200 million. The spending of this money would probably stimulate an additional $200 million expenditure which would have a beneficial effect on the region's wholesale and retail trade.

The Passamaquoddy tidal power project would attract a great many visitors. The Engineering Board estimates that had the tidal project been in existence in 1957, about 800,000 visitors from the United States and Canada would have been attracted to the area. In accordance with a practice that has been followed in some cases by the United States Army Corps of Engineers water resources projects might be credited with recreational benefits ranging from $0.50 to $1.50 per visitor day. Using a median value of $1.00 per day, and assuming that each visitor spends one day at the project, the recreation benefits would be at least $800,000 per year. In addition to recreation benefits, other benefits undoubtedly would result from the increased local economic activities due to a greater number of visitors.

The Passamaquoddy tidal project would require no fuel. On the basis of estimates by the Engineering Board, the tidal project in combination with the Rankin Rapids hydroelectric plant would produce power equivalent to that from 1,280,000 tons of coal, or approximately 5,700,000 barrels of oil a year.

Construction of the dams, locks, and gates would provide foundations on which 7 miles of public highways could be built to connect the Canadian coastal highway in New Brunswick with the United States coastal highway in Maine. Although the desirability of such a new link in the highway systems of the two countries is evident, the monetary benefits have not been estimated. Other benefits stemming from construction of the highway would be the increased recreational use of Campobello and Deer Islands that should follow the provision of a ready access to these attractive areas.

The Passamaquoddy tidal project, the Rankin Rapids project, and the Digdeguash pumped-storage project each would affect the fisheries in the waters they would control. The Fisheries Board studied the effects that the tidal project would have on the fisheries in the Bay of Fundy and within the tidal project in Passamaquoddy and Cobscook Bays. The Board found that the tidal project would have very little effect on the important sardine industry in the region, and only a minor effect on other fisheries. It should be noted that the estimated cost of the tidal project includes approximately $450,000 for modifications in or relocation of the lobster pounds at St. Andrews.

The Rankin Rapids project would flood substantial reaches of the Allagash and Saint John Rivers in Maine which now support an important trout fishery, particularly on the Allagash River. Changing portions of the Saint John or Allagash Rivers from fast-water streams to deep hydro-electric project reservoirs would change the type of fish and fishing which would prevail. Other wildlife habitat would also be affected. As indicated previously, the Bureau of Fisheries and Wildlife of the United States Department of the Interior considered the problem and recommended that remedial measures be taken if the project is built. The Digdeguash River now supports a small run of Atlantic salmon which would be destroyed by construction of the pumped-storage auxiliary. Methods of restoring this run were not determined.

The Arthur D. Little Corporation of Cambridge, Massachusetts, was engaged by the Engineering Board to make an economic survey of Maine to determine all possible potential uses for the power from the Passamaquoddy project. One of the principal aims of this survey was to identify industries that might be attracted to the area by the availability of a new source of dependable power at a price they would be willing to pay. These studies indicated that the economic impact of the availability of the project's power would not be significant unless power were made available to industry at a cost considerably less than the current estimate of the cost of power from the project. The Arthur D. Little Corporation concluded that the course of economic development in the State of Maine as a whole would not be significantly affected by construction of the tidal project.

A similar economic survey of New Brunswick was made by Professor Eugene Grasberg and Professor H. J. Whalen of the Department of Economics of the University of New Brunswick. This survey indicated that the mere availability of electric power from the Passamaquoddy project cannot be expected to spark and propel economic growth in New Brunswick.

FEASIBILITY OF THE PASSAMAQUODDY TIDAL POWER PROJECT AS VIEWED BY THE COMMISSION

The Commission has carefully reviewed the conclusions of the Engineering Board with respect to the engineering

and economic feasibility of developing the international tidal power potential of Passamaquoddy Bay and the findings on which these conclusions are based. The Commission is in general agreement with the engineering findings of the Engineering Board. However as regards the economic analysis, the Commission considers it appropriate to modify certain of the Board's assumptions in considering the tidal project alone and in conjunction with auxiliary power sources in the area.

The feasibility of the Passamaquoddy tidal power project as viewed by the Commission in the light of the findings of the Engineering Board will be discussed in this section, first from the standpoint of its engineering feasibility and secondly its economic feasibility. The economic analysis of the tidal power project alone and of each of the project combinations studied by the Board will be discussed separately with particular attention given to points on which the Commission differs from the Board in the determination of benefit-cost ratios. The unit cost of power also will be developed to show the relative cost of Passamaquoddy power either alone or with an auxiliary source compared with the cost of power from alternative steam-electric plants that are likely to be constructed in the absence of the project.

To assist the two Governments in appraising certain public values of the tidal project beyond those normally considered in determination of benefit-cost ratios for proposed hydroelectric developments, the Commission will, in concluding its feasibility analysis, discuss the effect that consideration of these values might have on the economics of the project.

Engineering Feasibility

The tidal project plan selected by the Engineering Board poses difficult engineering problems which, although challenging, are not insurmountable. Small portions of the tidal dams are in water depths ranging from 125 to 300 feet. The difficulties of closing these dams in the face of restricted and greatly increased velocity heads pose engineering and design problems without precedent. In view of these problems, several outstanding experts in the fields of hydraulic engineering and soil mechanics were consulted by the Engineering Board and model studies were made of deep tidal dams to determine the best and

most economical design and methods of construction. The Board concluded from these studies that tidal dams could be built in the deep water passages by use of a granular core placed by special bottom-dump buckets, and that all other tidal dams could be built with conventional land and marine equipment. To overcome the increased tidal velocities during construction, the progress of work on the dams could be scheduled so that the filling and emptying gates would handle part of the tidal ebb and flood.

The cofferdams required for construction of the filling and emptying gates, as well as for navigation locks and the powerhouse, would be subjected to heads as high as 60 feet, whereas the heads on the completed structures would not exceed 26 feet. Construction of cofferdams of this magnitude constitutes one of the major engineering and construction tasks of the Passamaquoddy tidal power project. While they will be expensive there appear to be no grounds for apprehension that these cofferdams cannot be built.

Based on its review of the studies by its Engineering Board, the Commission is of the opinion that a tidal power project using the waters of Passamaquoddy and Cobscook Bays could be built and operated.

Economic Analysis

Determination of the economic feasibility of a proposed hydroelectric development, whether in a conventional river project or a tidal project, involves a comparison of the value of the power, or power benefits, with the power costs. Normally, a proposed power development is not considered to be economically feasible if the benefit-cost ratio is less than 1.0.

Power benefits are usually measured by or limited in value by the cost of power from the most likely alternative source in the market area, giving due consideration to any differences in transmission costs and losses and in operating characteristics between the alternative plant and the proposed hydroelectric project. In the Maine and New Brunswick area, as well as in many other areas of the United States and Canada, the alternative power source is considered to be a modern steam-electric plant. It is considered also that such an alternative plant in Maine would be privately financed, and in New Brunswick publicly financed, consistent with the present and expected future practice in these two areas.

In analyzing the economic feasibility of the several tidal project combinations considered by the Engineering Board, the Commission has assumed that the capital costs and the project power would be divided equally between the two countries.

The annual cost of power assigned to the United States is determined on the basis of federal financing, assuming an interest rate of 2½ percent and an amortization period of 50 years. "Taxes foregone," defined as the amount of taxes which would not be collected as a result of a federal power development rather than the most likely alternative development, are included in the hydroelectric power costs in an amount approximately equal to the taxes included in the estimated steam-electric power costs used in deriving power benefits. Such inclusion places the United States costs of the tidal project combinations and of alternative steam-electric plants on a comparable basis for purposes of economic analysis. The above criteria are in accord with those used by federal agencies in the United States concerned with water resource development.

The annual cost of power assigned to Canada is determined on the basis of non-federal public financing, assuming an interest rate of 4-1/8 percent and an amortization period of 50 years. No tax item is included in the hydroelectric power costs since none would be paid on alternative steam-electric plants. These criteria are in accord with the practice in New Brunswick.

As indicated in the foregoing, there are differences between United States and Canadian practices in deriving both the annual power values and annual power costs. For this reason it is necessary to compute separate benefit-cost ratios for the two countries, each applicable to that country's share of the project power. The over-all economic feasibility of the tidal project combinations, United States and Canada, may be determined by comparing the total benefits and costs of the combinations.

Under the conditions and criteria discussed above and on the basis of information in the Engineering Board's report, the Commission has considered the economic feasibility of the tidal project alone and in combination

with the several sources of firming power studied by the Board. The results of this economic analysis are discussed in the following paragraphs and summarized in Table 1.

Tidal Project Alone -- This project would have an installed capacity of 300,000 kilowatts, of which 95,000 kilowatts would be dependable. Average annual generation would amount to 1,843 million kilowatt-hours. The project investment, including transmission, would be $546,800,000.

For the United States the annual power benefits would amount to $5,977,000 and the annual power costs $10,343,000, resulting in a benefit-cost ratio of 0.58. For Canada the annual power benefits would be $4,663,000, the annual power costs $13,665,000, and the benefit-cost ratio 0.34. For the entire project, United States and Canada, the benefit cost ratio would be 0.44.

Studies by the Engineering Board, based on somewhat different economic assumptions, also failed to provide a ratio of unity.

It is evident that construction of the tidal power project by itself is economically infeasible by a wide margin.

Tidal Project combined with Steam-Electric Capacity -- Under this plan, the 300,000 kilowatts installed capacity at the tidal project is assumed to be combined with 220,000 kilowatts of steam-electric capacity to provide a total dependable capacity of 300,000 kilowatts. The average annual generation would amount to about 2,143 million kilowatt-hours. The project investment would be $595,100,000.

For the United States the annual benefits would amount to $10,365,000, the annual costs $13,615,000, and the benefit-cost ratio 0.76. For Canada the annual benefits and costs would amount to $6,900,000 and $16,014,000 respectively, and the benefit-cost ratio 0.42. For the entire project, United States and Canada, the benefit-cost ratio would be 0.58. None of the studies using less rigorous criteria resulted in a ratio as high as unity.

TABLE 1

POWER AND ECONOMIC DATA
AS DERIVED BY
THE INTERNATIONAL JOINT COMMISSION

		Tidal Project Alone	Tidal Project and Steam-Electric Plant	Tidal Project and Digdeguash Pumped-Storage	Tidal Project and Incremental Capacity only at Rankin Rapids	Tidal Project and all of Rankin Rapids
Power Data (Entire Project)						
Installed Capacity						
Tidal Project	1,000 kw	300	300	300	300	300
Auxiliary	1,000 kw	---	220	260	226	400
Dependable Capacity,	1,000 kw	95	300	323	355	555
Avg. Annual Generation,	Million Kwh	1,843	2,143	1,759	1,843	3,063
Economic Data (United States Half of Project)						
Capital Investment	Million Dollars	271.6	297.5	292.6	300.5	367.6
Annual Power Benefits	" "	5.977	10.365	9.719	9.779	16.782
Annual Power Costs	" "	10.343	13.615	12.134	12.154	15.302
Benefit-Cost Ratio		0.58	0.76	0.80	0.80	1.10
Economic Data (Canadian Half of Project)						
Capital Investment	Million Dollars	275.2	297.6	293.8	299.5	364.5
Annual Power Benefits	" "	4.663	6.900	6.177	6.043	10.235
Annual Power Costs	" "	13.665	16.014	14.669	14.527	17.610
Benefit-Cost Ratio		0.34	0.42	0.42	0.42	0.58
Economic Data (Entire Project)						
Capital Investment	Million Dollars	546.8	595.1	586.4	600.0	732.1
Annual Power Benefits	" "	10.640	17.265	15.896	15.822	27.017
Annual Power Costs	" "	24.008	29.629	26.803	26.681	32.912
Benefit-Cost Ratio		0.44	0.58	0.59	0.59	0.82

NOTES: CAPITAL INVESTMENT INCLUDES COST OF TRANSMISSION LINES.
BENEFIT-COST RATIOS ARE DETERMINED AT THE PROJECT SITES, WITH APPROPRIATE ALLOWANCE FOR TRANSMISSION COSTS.

Tidal Project Combined with Digdeguash Pumped-Storage Project -- The installed capacity of this combination project would be 560,000 kilowatts, of which 323,000 kilowatts would be dependable. Average annual generation would amount to 1,759 million kilowatt-hours. The total project investment, including transmission, would be $586,400,000.

For the United States the annual power benefits would total $9,719,000 and the annual power costs $12,134,000, giving a benefit-cost ratio of 0.80. For Canada the annual power benefits and costs would amount to $6,177,000 and $14,669,000, respectively, and the benefit-cost ratio 0.42. For the entire project, United States and Canada, the benefit-cost ratio would be 0.59.

The only favorable benefit-cost ratio (1.06) derived in the Engineering Board's studies in this combination was for the United States share of the power, assuming a 75-year amortization period and excluding taxes foregone from project costs.

The Commission is of the opinion that the Digdeguash pumped-storage project could be used as a realistic auxiliary to the tidal power project, and that the combination of the two in a single economic analysis is sound in principle. Combined with the tidal project, the Digdeguash pumped-storage project could utilize off-peak power from the tidal plant to pump water from Passamaquoddy Bay to the reservoir. However, power from the tidal project combined with the Digdeguash pumped-storage project would be more costly than power from available alternative sources.

Tidal Project Combined with Incremental Capacity at Rankin Rapids -- The concept of using incremental capacity only at Rankin Rapids as an auxiliary to the tidal project assumes that the Rankin Rapids site would be developed first with 200,000 kilowatts of dependable capacity to serve loads wholly in the State of Maine. An additional 260,000 kilowatts of dependable capacity (226,000 kilowatts installed) would be provided at this site specifically for firming the tidal project output. The combined dependable capacity of this combination (the tidal project plus 260,000-kilowatt incremental capacity at Rankin Rapids) would be 355,000 kilowatts, capable of

generating 1,843 million kilowatt-hours of electric energy annually. Under this combination when the tidal plant output drops below the load to be carried, the energy deficiency would be borrowed from the basic Rankin Rapids project, using the 260,000-kilowatt incremental dependable capacity provided for this purpose, and repaid when tidal energy exceeds load. Thus there would be no net energy withdrawal from the basic Rankin Rapids project (200,000 kilowatts and 1,220 million kilowatt-hours). In this way, Rankin Rapids and the tidal project could provide 355,000 kilowatts of dependable power for the load at a 60 percent annual load factor. Accordingly, the Commission believes that "incremental capacity" at Rankin Rapids constitutes a realistic auxiliary to the tidal project, and that the treatment of the combination in a single economic analysis is valid. The project investment, including transmission, would be $600,000,000. Only the incremental cost of the additional (260,000 kilowatts) capacity installation at Rankin Rapids is charged against the combination project.

For the United States the annual power benefits would amount to $9,779,000, the annual power costs $12,154,000, and the benefit-cost ratio 0.80. For Canada the annual power benefits would be $6,043,000, the annual power costs $14,527,000, and the benefit-cost ratio 0.42. For the entire project, United States and Canada, the benefit-cost ratio would be 0.59.

As in the case of the combination with the Digdeguash pumped-storage project, the only favorable benefit-cost ratio for this combination (1.08) in the Engineering Board's studies was that for the United States' share of the power assuming a 75-year amortization period and excluding taxes foregone from project costs.

Tidal Project combined with all of Rankin Rapids -- In this plan, as proposed by the Engineering Board, 300,000 kilowatts installed capacity at the tidal project would be combined with all of the capacity and energy available at Rankin Rapids (400,000 kilowatts installed, 460,000 kilowatts dependable and 1.22 billion kilowatt-hours) to provide a total dependable capacity of 555,000 kilowatts and an average annual generation of 3,063 million kilowatt-hours. The project investment would be $732,100,000.

For the United States the annual power benefits would be $16,782,000, the annual power costs $15,302,000, and the benefit-cost ratio 1.10. For Canada the annual benefits would be $10,235,000, the annual costs $17,610,000, and the benefit-cost ratio 0.58. For the entire project, United States and Canada, the benefit-cost ratio would be 0.82. Downstream benefits estimated to be $953,000 annually were assumed in deriving these ratios.

Although the criteria used in certain studies by the Engineering Board resulted in a higher benefit-cost ratio for the United States' share of the power from this combination, no studies made by the Board gave a favorable benefit-cost ratio for the Canadian share.

The Engineering Board found that, with a 50-year amortization period, the benefit-cost ratio for the tidal project combined with all of Rankin Rapids would be greater than unity (1.31), and concluded that this combination, if built entirely by the United States at an interest rate of 2½ percent, would be economically justified. However, the Commission believes there is an economic fallacy in the concept of such a combination project.

The facts presented in the Engineering Board's report and in this report show that, when considered alone, the tidal project is clearly uneconomic. Its benefit-cost ratio with a 50-year amortization period is considerably less than unity both for the United States and Canadian shares of the project power. On the other hand, the Rankin Rapids project with 200,000 kilowatts installed when considered alone has a benefit-cost ratio somewhat in excess of unity; i.e., 2.0 for United States federal development. In the Board's economic analysis the costs and benefits of the uneconomic tidal project are added to those of the economically feasible Rankin Rapids project to determine the benefit-cost ratio of this possible combination project. The Commission is of the opinion that a benefit-cost ratio determined on this basis is not a valid representation of the economic worth of the tidal project, and the ratio of 1.31 determined by the Engineering Board for the combination project cannot be construed as indicating economic feasibility for the tidal power project. Hence, the findings of the Commission do not include consideration of this combination project.

Unit Cost of Power

While the benefit-cost ratios summarized in Table 1 for the Tidal project alone and the proposed project combinations provide a ready comparison of their relative economic value, they do not reveal the relative unit costs of power. Energy cost per kilowatt-hour furnishes a more direct basis for comparison of the cost of tidal power with other sources of power in the area. Unit costs of energy from tidal project combinations are summarized below. The cost of energy from alternative steam-electric plants is shown for comparison since such plants are the most likely alternative source of a comparable block of power for Maine and New Brunswick in the absence of the tidal project. In accordance with present practice, alternative steam-electric plants in Maine are assumed to be privately financed and in New Brunswick, publicly financed.

COMPARISON OF UNIT COST OF POWER FROM TIDAL PROJECT AND FROM ALTERNATIVE STEAM-ELECTRIC PLANTS

	Power Source	Unit Cost of Energy - Mills per Kwh			
		At-Site		At-Market 1/	
		United States	Canada	United States	Canada
1.	Tidal project alone	26.2	42.8	28.9	43.8
2.	Tidal project and steam-electric capacity	13.5	18.6	15.0	19.6
3.	Tidal project and Digdeguash pumped storage project	12.2	16.8	13.5	17.4
4.	Tidal project and incremental capacity at Rankin Rapids	11.5	15.8	13.4	17.3
5.	Alternative steam-electric plants	10.6	7.3	11.6	7.4

1/ Includes cost of transmission of power from project site to the market.

United States' costs it should be noted that the Tidal project and the project combinations are assumed to be federally financed, while the alternative steam-electric plants are assumed to be privately financed, as previously pointed out.

In the discussion of the combination of the Tidal project with all of Rankin Rapids as proposed by the Engineering Board, the Commission points out that, if constructed alone to serve power loads in the State of Maine, the Rankin Rapids project could provide 200,000 kilowatts of dependable capacity and 1,220 million kilowatt-hours average annual energy. If this project were constructed with private financing, power could be produced at a unit cost of about 11.0 mills per kilowatt-hour at the dam-site and 13.0 mills per kilowatt-hours delivered to the market. On the basis of federal financing at the 2½ percent interest rate used in this report and 50-year amortization of the investment the unit cost would be about 3.8 mills at site and 5.3 mills at market. In addition to supplying a large block of relatively low cost power for the State of Maine the Rankin Rapids project would provide substantial benefits to downstream hydroelectric plants in New Brunswick.

Economic Feasibility

On the basis of the foregoing economic analyses, the Commission finds that the tidal project alone is not economically feasible and could not provide firm power at a unit cost as low as the cost of power from new alternative steam-electric plants that could be built in the area to meet its future power requirements. None of the proposed combination projects considered by the Commission to be valid would provide an economic development for either the United States or Canada if they are evaluated on the basis of the usual practices followed in the two countries in determining the economic feasibility of proposed hydroelectric projects.

The Commission notes, however, that the tidal project could provide certain public benefits in addition to those which have been evaluated in monetary terms in determining benefit-cost ratios as previously described. Important among such benefits would be the recreation value of the project. It is believed that the uniqueness of the tidal project would make a substantial contribution to the large recreation industry of the area by attracting many

For the purpose of this comparison "taxes foregone" are not included in the United States' share of the Tidal project costs (as was done in the economic analyses summarized in Table 1) because rates for the sale of power from federally-financed projects are customarily established on the basis of returning only the power costs actually incurred. Unit energy costs for both the Tidal project and the alternative steam-electric plants are calculated on the basis of about 60 percent load factor, to present them on a uniform basis. This is the approximate present annual load factor of the utility systems in the area.

It will be noted that the unit costs of energy for the Tidal project alone are considerably higher than the 10.8 mills and 14.9 mills shown in the Engineering Board's report for the United States and Canadian shares of the power. Since the Board's figures were determined without regard to the 60 percent load factor limitation placed on the combination projects they do not provide a proper basis for comparison of unit costs. The Commission has, therefore, adjusted the Board's figures to a 60 percent load factor basis, and credited to the project costs (at a steam-energy replacement value of 5.0 mills per kilowatt-hour in the United States and 4.4 mills in Canada as derived by the Engineering Board) all energy that could be produced in excess of a 60 percent load factor. This adjustment results in unit at-site costs of 26.2 mills for the United States' share and 42.8 mills for the Canadian share of the Tidal project power. It may be expected, however, that in actual operation the dependable capacity (95,000 kilowatts) of the Tidal project would be used at about 100 percent load factor. Under such operation the unit cost of energy would be 18.2 and 27.5 mills in Maine and New Brunswick, respectively.

It will be observed from the preceding tabulation that alternative steam-electric plants in Maine and New Brunswick, financed in accordance with present practices, could produce power at a lower cost than either the Tidal project alone or any of the project combinations. It may be noted that this tabulation does not include the combination of the Tidal project and all of Rankin Rapids for the reasons indicated on page 41. In comparing the

visitors. The Engineering Board points out that on the basis of evaluation procedures currently used by the Corps of Engineers, the potential recreation benefits of the project would be at least $800,000 per year. Inclusion of these benefits in the foregoing analyses would improve slightly the benefit-cost ratio but would not alter the indicated conclusions as to economic feasibility of the project.

Other potential project benefits not evaluated in the benefit-cost analyses include those to navigation and to the highway systems of Maine and New Brunswick. The cost estimates prepared by the Engineering Board include navigation locks adequate for the volume of current traffic and for a moderate increase in vessel size. While the Board made no attempt to determine the future ship traffic in the project area, the Commission recognizes that the availability of an upper pool having considerably less range in its levels than now occurs with normal ebb and flood of the tides might stimulate greater traffic to shipping points on Passamaquoddy Bay. These possibilities may justify further study of navigation values in the future.

A highway system built on the approximately 7 miles of tidal dams could replace the present ferries serving the Passamaquoddy Bay area and provide a connecting link between United States and Canadian coastal highways that would shorten the highway distance between Whiting, Maine, and St. George, New Brunswick by about 40 miles. Ready access would also be provided to Campobello and Deer Islands thereby increasing their recreational value. Neither the Engineering Board nor the Commission has attempted to estimate in monetary terms the potential highway value of the tidal dams.

Other factors, largely subject to policy determination, that could have an effect on the economics of the tidal project are: possible changes in interest rates, allowance of a longer amortization period, and exclusion of taxes foregone from the United States costs. In addition it may be noted that any increase in fuel costs in the project area would have a favorable affect on the benefit-cost ratio by increasing the value of the tidal project power.

TABLE 2

EFFECT ON BENEFIT-COST RATIO OF
ASSUMED VARIATIONS FROM THE PROJECT BENEFITS
AND COSTS DETERMINED BY THE INTERNATIONAL JOINT COMMISSION

ASSUMPTIONS FOR DETERMINATION OF BENEFIT-COST RATIOS	TIDAL PROJECT ALONE			TIDAL PROJECT AND INCREMENTAL CAPACITY ONLY AT RANKIN RAPIDS (1)		
	UNITED STATES	CANADA	UNITED STATES AND CANADA	UNITED STATES	CANADA	UNITED STATES AND CANADA
BASIC ANALYSIS USING CONVENTIONAL EVALUATION PRACTICES IN UNITED STATES AND CANADA. (FROM TABLE 1)	0.58	0.34	0.44	0.80	0.42	0.59
CUMULATIVE EFFECT OF SUCCESSIVE VARIATIONS FROM BASIC ANALYSIS:						
1. ANNUAL COSTS BASED ON UNIFORM INTEREST RATE OF 3% FOR BOTH COUNTRIES.	0.52	0.42	0.47	0.72	0.52	0.63
2. AMORTIZATION OF CAPITAL INVESTMENT IN 75 YEARS.	0.60	0.49	0.54	0.83	0.59	0.72
3. ALLOWANCE OF $800,000 ANNUAL RECREATION BENEFITS. ($400,000 TO EACH COUNTRY)	0.64	0.53	0.58	0.86	0.63	0.75
4. WITH TAXES FOREGONE ELIMINATED FROM UNITED STATES COSTS.	0.66	0.53	0.60	0.99	0.63	0.81

(1) THIS COMBINATION PROJECT IS SHOWN IN THE TABLE FOR ILLUSTRATIVE PURPOSES. THE COMBINATION WITH DIGDEGUASH PUMPED-STORAGE WOULD GIVE APPROXIMATELY THE SAME RESULTS.

Table 2 illustrates the cumulative effect on the project's benefit-cost ratios of assumed variations from the project benefits and costs determined by the International Joint Commission. The cumulative effects are shown in relation to the Commission's basic analyses presented in Table 1 using conventional evaluation practices in the United States and Canada. The assumed variations from the basic assumptions are as follows: (1) a uniform interest rate of 3 percent for both the United States and Canada; (2) amortization of the project investment in 75 years instead of 50 years; (3) allowance of $800,000 for annual recreational benefits (one-half to each country); and (4) taxes foregone eliminated from United States costs.

It may be seen from Table 2 that none of the assumed variations from the basic evaluation made by the Commission would result in a benefit-cost ratio of unity for the tidal project alone or in combination with either incremental capacity at Rankin Rapids or the Digdeguash pumped-storage project. An increase as great as 25 percent in fuel costs would still not provide a benefit-cost ratio of unity for the Canadian share or for the entire project.

As to other possible effects of future trends on the economics of the project, the Commission notes that improvements in equipment design and construction methods may result in some saving in project costs. It is possible, for example, that further experience with bulb-type generating units may lead to savings through their adoption and use in the tidal project.

The Commission recognizes the existence of other tidal power potentials in the area and that their construction might provide sufficient diversity of power production to enhance the marketability of power from the International project considered for Passamaquoddy Bay.

The Commission also recognizes that factors other than strict economic feasibility based on tangible benefits and costs, and which were not taken into account by the Commission, may be of importance to the two Governments in arriving at decisions to undertake resource development projects such as this. Such factors might include the development of new and unique sources of power, the conservation of fossil fuel resources, and the provision of employment opportunities in economically depressed areas.

FINDINGS OF THE INTERNATIONAL JOINT COMMISSION ON SPECIFIC POINTS OF THE REFERENCE

The reference to the International Joint Commission by the Governments of Canada and the United States requested findings on certain specific points with respect to development of the international tidal power potential of Passamaquoddy Bay in the State of Maine and the Province of New Brunswick. These findings follow:

(a) The estimated cost of developing the international tidal power potential of Passamaquoddy Bay

On the basis of the detailed studies of the Engineering Board, the Commission finds the estimated costs, using United States currency and January 1958 price levels, of the tidal project alone and in combination with several possible sources of firming power to be as follows:

	Project	Generating Capacity (100 kw) Installed	Generating Capacity (100 kw) Dependable	Avg. Ann. Energy (Million Kwh)	Capital Investments, Including Transmission To Market (Million Dollars)
1.	Tidal project alone	300	95	1,843	546.8
2.	Tidal project and steam-electric capacity	520	300	2,143	595.1
3.	Tidal project and Digdeguash pumped-storage	560	323	1,759	586.4
4.	Tidal project and incremental capacity at Rankin Rapids	526	355	1,843	600.0

The at-site unit costs per kilowatt hour of producing electric energy from the Tidal project alone is estimated to be 26.2 mills for the United States' share of the power and 42.8 mills for Canada's share based on a 60 percent annual load factor. Based on a 100 percent load factor the unit costs would be 18.2 mills and 27.5 mills for the United States and Canada, respectively.

The unit costs per kilowatt hour of energy of power from a combination of the tidal project with either incremental generating capacity at the Rankin Rapids reservoir site in Maine or the Digdeguash pumped-storage site in New Brunswick would be approximately 12 mills for the United States' share of the power and 16 mills for Canada's share. The Rankin Rapids and Digdeguash sites are considered the lowest cost means available of supplying auxiliary power for the tidal project.

(b) Whether such costs will allow hydroelectric power to be produced at a price which is economically feasible

The Commission finds that the tidal project either alone or in combination with auxiliary power sources is not economically feasible if it is evaluated in accordance with the conventional methods of economic analysis of hydroelectric projects in the United States and Canada. On the basis of such evaluation standards, the benefit-cost ratios for the tidal project alone would be 0.58 for the United States and 0.34 for Canada. For the project as a whole the benefit-cost ratio would be about 0.44. Using either the Digdeguash pumped-storage auxiliary in Canada or incremental generating capacity at the Rankin Rapids project in the United States, the benefit-cost ratio for each combination project would be 0.80 for the United States and 0.42 for Canada. The over-all benefit-cost ratio for each of these combinations would be about 0.59.

If, as a matter of policy applicable to this international project, the Governments of the United States and Canada wish to adopt criteria different from the conventional concepts of economic analysis with respect to such factors as interest rates, amortization period, taxes foregone, and allowance of recreation benefits, the benefit-cost ratios for the combination project (Tidal project and Digdeguash or Tidal project and incremental capacity at Rankin Rapids) would, as shown in Table 2, become 0.99 for the United States, 0.63 for Canada, and 0.81 for the two countries combined.

Construction of the Rankin Rapids dam and reservoir on the Upper Saint John River in the State of Maine would be prerequisite to its use to supply incremental firming capacity for the tidal project. The Rankin Rapids project could be constructed initially with an installed generating capacity of 200,000 kilowatts to supply economic hydroelectric power to the State of Maine and downstream benefits to hydroelectric plants on the Saint John River in New Brunswick. Such a plan of development would not preclude later use of Rankin Rapids as a source of firming power by construction of 260,000 kilowatts of additional dependable capacity at the site to be operated in coordination with and as an auxiliary to the tidal project. The Commission is of the opinion, however, that it would not be consistent with sound practices of economic analysis of hydroelectric projects to combine the basic Rankin Rapids project (200,000 kilowatts and 1,220 million kilowatt-hours) with the tidal project to determine the economic worth of the tidal project.

In short, the Commission finds that the tidal project, either alone or in combination with auxiliary power sources will not permit power to be produced at a price which is competitive with the price of power from alternative available sources.

(c) The effects, beneficial or otherwise, which such a power project might have on the local and national economies in the United States and Canada

Because of the relatively high cost of development of the tidal power potential, the Commission finds that construction of the tidal project would not appreciably affect industrial development in the project area.

Construction of the project would have a substantial although short-term beneficial effect on the economies of Maine and New Brunswick during the six-year construction period resulting from expenditures of over $200,000,000 for goods and services.

The uniqueness of the tidal project and the creation of two large salt water lakes in an area where recreation is already an important industry would result in the provision of additional recreation benefits.

Since the tidal project would raise the level of the Passamaquoddy Bay high pool and decrease the tidal range, navigation conditions would be improved in the Saint Croix River estuary and at Saint Andrews and other ports on Passamaquoddy Bay. In the low pool, on the other hand, the beneficial effects of decreasing the tidal range would be partially offset by lowering the maximum level of Cobscook Bay to a point below the level of normal high tide. Navigation conditions in the lower pool in the Falls Island and Lubec area, where rapid tidal currents now occur, would be improved during a considerable portion of the tidal cycle. In general, tidal velocities in the project area would be reduced, except in areas immediately adjacent to the gates when open.

Construction of the tidal dams, locks and gates would provide foundations on which an international highway could be built connecting the present coastal highways in Maine and New Brunswick, reducing the travel distance from Whiting, Maine to St. George, New Brunswick by about 40 miles. Ready access to the recreational advantages of the large islands in Passamaquoddy Bay also would be provided by this highway.

(d) Specifically, the effects which the construction, maintenance, and operation of the tidal power project might have upon the fisheries in the area

On the basis of the extensive studies of the Fisheries Board, the Commission finds that by providing for relocation and modification of existing fisheries facilities and by including appropriate remedial measures in the design of the tidal power structures, construction and operation of the tidal power project would have very little effect on the important sardine industry in the region and only a minor effect on other fisheries.

The Rankin Rapids project would flood substantial reaches of the Allagash and Saint John Rivers in Maine which now support an important trout fishery. Construction of this project would change the type of fishing which now prevails. Other wildlife habitat would also be affected.

The Digdeguash River now supports a small run of Atlantic salmon which would be destroyed by construction of the pumped-storage auxiliary. Methods of restoring this run were not determined.