ANNUAL REPORT
to the
GOVERNMENTS
of
THE UNITED STATES and CANADA

COLUMBIA RIVER TREATY
PERMANENT ENGINEERING BOARD

Washington, D.C. Ottawa, Ontario

30 SEPTEMBER 1977

COLUMBIA RIVER TREATY PERMANENT ENGINEERING BOARD

CANADA · UNITED STATES

CANADIAN SECTION
G.M. MacNABB, Chairman
B.E. Marr, Member

UNITED STATES SECTION
H.B. WILLIS, Chairman
Raymond A. Peck Jr., Member

31 December 1977

The Honorable Cyrus Vance
The Secretary of State
Washington, D.C.

The Honourable A. Gillespie
Minister of Energy, Mines and
Resources
Ottawa, Ontario

Gentlemen:

Reference is made to the Treaty between the United States of America and Canada, relating to co-operative development of the water resources of the Columbia River basin, signed at Washington, D.C., on 17 January 1961.

In accordance with the provisions of Article XV paragraph 2(e), there is submitted herewith the thirteenth Annual Report, dated 30 September 1977, of the Permanent Engineering Board.

The report sets forth results achieved and benefits produced under the Treaty for the period from 1 October 1976 to 30 September 1977.

Respectfully submitted:

For the United States

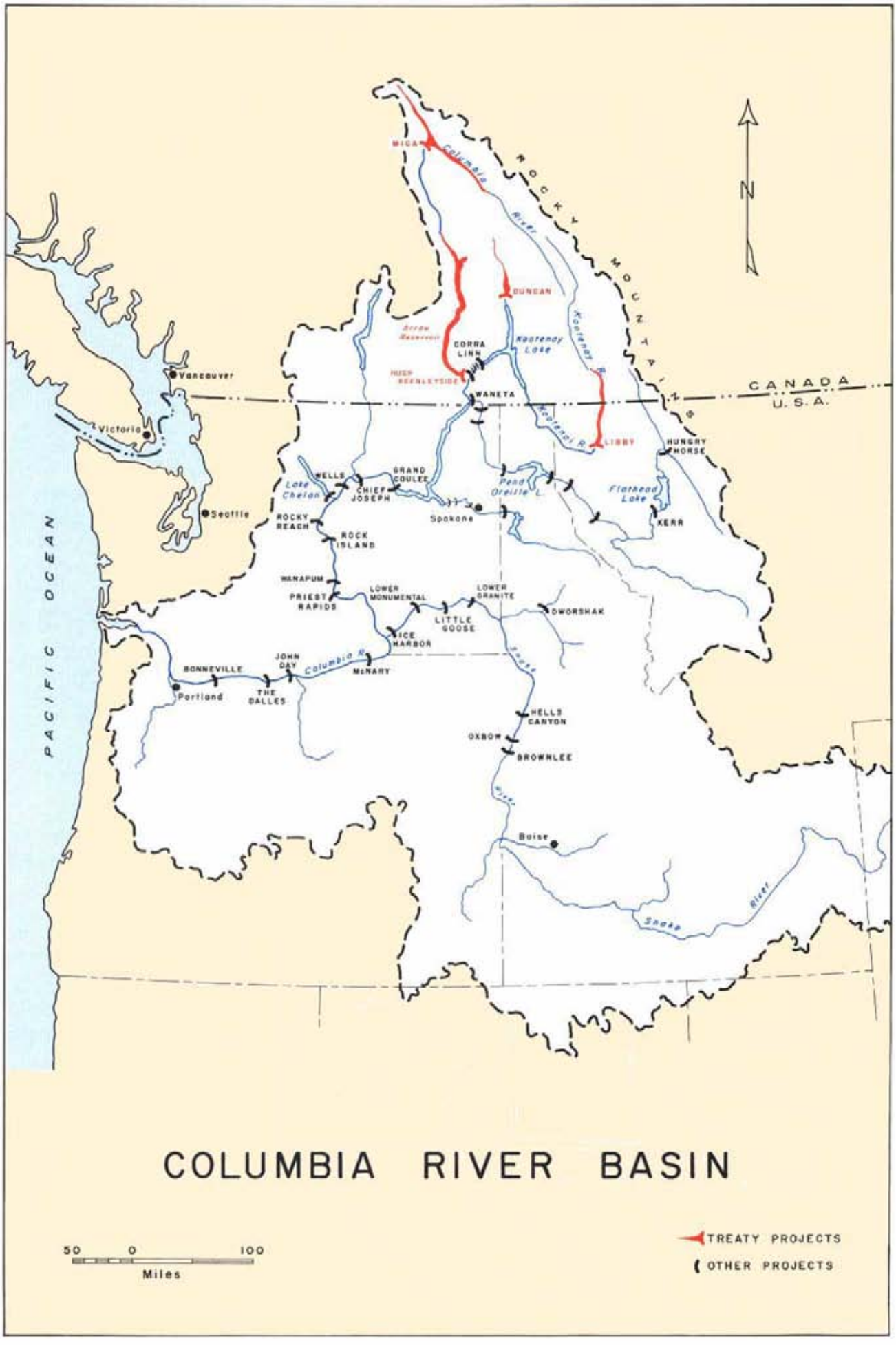
Homer B. Willis, Chairman

J. Emerson Harper

For Canada

G.M. MacNabb, Chairman

B.E. Marr


ROCKY MOUNTAINS
CANADA
U.S.A.
PACIFIC OCEAN
MICA
Columbia River
DUNCAN
Arrow Reservoir
CORRA LINN
Kootenay Lake
Kootenay R.
HUGH KEENLEYSIDE
WANETA
LIBBY
HUNGRY HORSE
Vancouver
Victoria
Seattle
WELLS
Lake Chelan
GRAND COULEE
CHIEF JOSEPH
Pend Oreille L.
Flathead Lake
KERR
Spokane
ROCKY REACH
ROCK ISLAND
WANAPUM
PRIEST RAPIDS
LOWER MONUMENTAL
LOWER GRANITE
DWORSHAK
LITTLE GOOSE
ICE HARBOR
JOHN DAY
Columbia R.
McNARY
BONNEVILLE
Portland
THE DALLES
Snake
HELLS CANYON
OXBOW
BROWNLEE
Boise
Snake River
N
COLUMBIA RIVER BASIN
50 0 100
Miles
TREATY PROJECTS
OTHER PROJECTS

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Photographs supplied by the British Columbia Hydro and Power Authority, the Government of British Columbia, and the Corps of Engineers, U.S. Army.

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SUMMARY

The thirteenth Annual Report of the Permanent Engineering Board is submitted to the Governments of the United States and Canada in compliance with Article XV of the Columbia River Treaty of 17 January 1961. The status of projects, progress of Entity studies, operation of the Duncan, Arrow, Mica and Libby reservoirs, and the resulting benefits are described.

Two Board meetings and one meeting of the Board with the Entities were held during the 12-month period ending 30 September 1977.

The Duncan, Arrow, Mica and Libby storage projects were operated throughout the year in accordance with the objectives of the Treaty and the terms of operating plans developed by the Entities. Reservoir operations were not required for flood control purposes in Canada or the United States because of extremely low runoff levels during the flood season.

Studies pertaining to development of the hydrometeorological network and power operating plans are being continued by the Entities to ensure operation of the projects in accordance with the terms of the Treaty.

The Board concludes that the objectives of the Treaty are being met.

INTRODUCTION

The Columbia River Treaty, which provides for co-operative development of the water resources of the Columbia River basin, was signed in Washington, D.C. on 17 January 1961 by representatives of the United States and Canada. Article XV of the Treaty established a Permanent Engineering Board and specified that one of its duties would be to "make reports to Canada and the United States of America at least once a year of the results being achieved under the Treaty . . ."

This Annual Report, which covers the period 1 October 1976 to 30 September 1977, describes activities of the Board, progress being achieved by both countries under the terms of the Treaty, operation of the Treaty projects, and the resulting benefits. The report also states that, in the opinion of the Board, the objectives of the Treaty are being met. Summaries of the essential features of the Treaty and of the responsibilities of the Board and of the Entities are included.

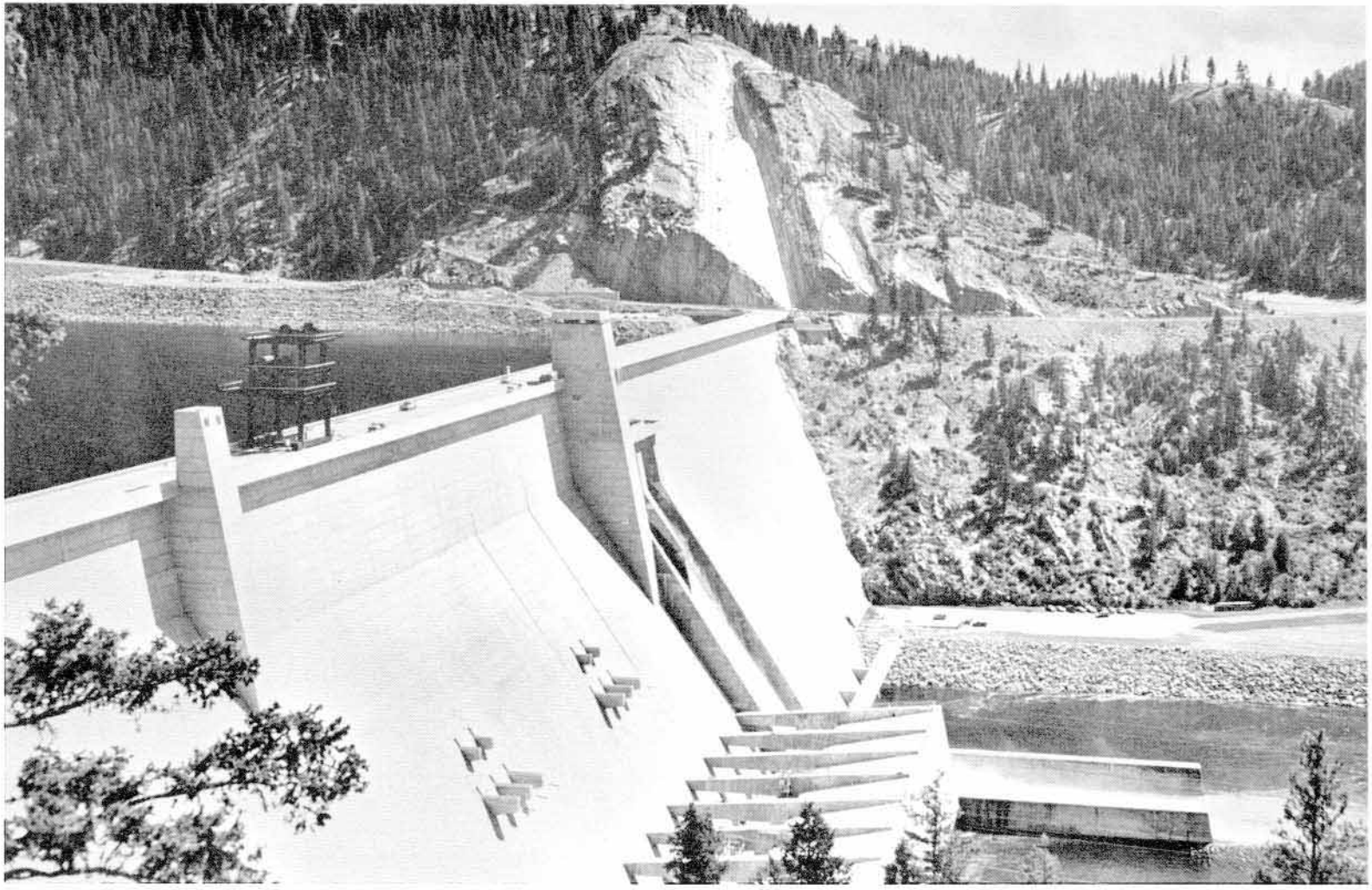
THE COLUMBIA RIVER TREATY

General

The Columbia River Treaty was signed in Washington, D.C. on 17 January 1961 and was ratified by the United States Senate in March of that year. In Canada ratification was delayed. Further negotiations between the two countries resulted in formal agreement by an exchange of notes on 22 January 1964 to a Protocol to the Treaty and to an Attachment Relating to Terms of Sale. The Treaty and related documents were approved by the Canadian Parliament in June 1964.

The Canadian Entitlement Purchase Agreement was signed on 13 August 1964. Under the terms of this agreement Canada's share of downstream power benefits resulting from the first thirty years of scheduled operation of each of the storage projects was sold to a group of electric utilities in the United States known as the Columbia Storage Power Exchange.

On 16 September 1964 the Treaty and Protocol were formally ratified by an exchange of notes between the two governments. The sum of $253.9 million (U.S. funds) was delivered to the Canadian representatives as payment in advance for the Canadian entitlement to downstream power benefits during the period of the Purchase Agreement. On the same date at a ceremony at the Peace Arch Park on the International Boundary the Treaty and its Protocol were proclaimed by President Johnson, Prime Minister Pearson, and Premier Bennett of British Columbia.



LIBBY DAM
The dam, powerhouse and spillway.

Kootenai River, Montana

Features of the Treaty and Related Documents

The essential undertakings of the Treaty are as follows:

(a) Canada will provide 15.5 million acre-feet of usable storage by constructing dams near Mica Creek, the outlet of Arrow Lakes and Duncan Lake, in British Columbia.

(b) The United States will maintain and operate hydroelectric power facilities included in the base system and any new main-stem projects to make the most effective use of improved stream flow resulting from operation of the Canadian storage. Canada will operate the storage in accordance with procedures and operating plans specified in the Treaty.

(c) The United States and Canada will share equally the additional power generated in the United States as a result of river regulation by upstream storage in Canada.

(d) On commencement of the respective storage operations the United States will make payments to Canada totalling $64.4 million (U.S. funds) for flood control provided by Canada.

(e) The United States has the option of constructing a dam on the Kootenai River near Libby, Montana. The Libby reservoir would extend some 42 miles into Canada and Canada would make the necessary Canadian land available for flooding.

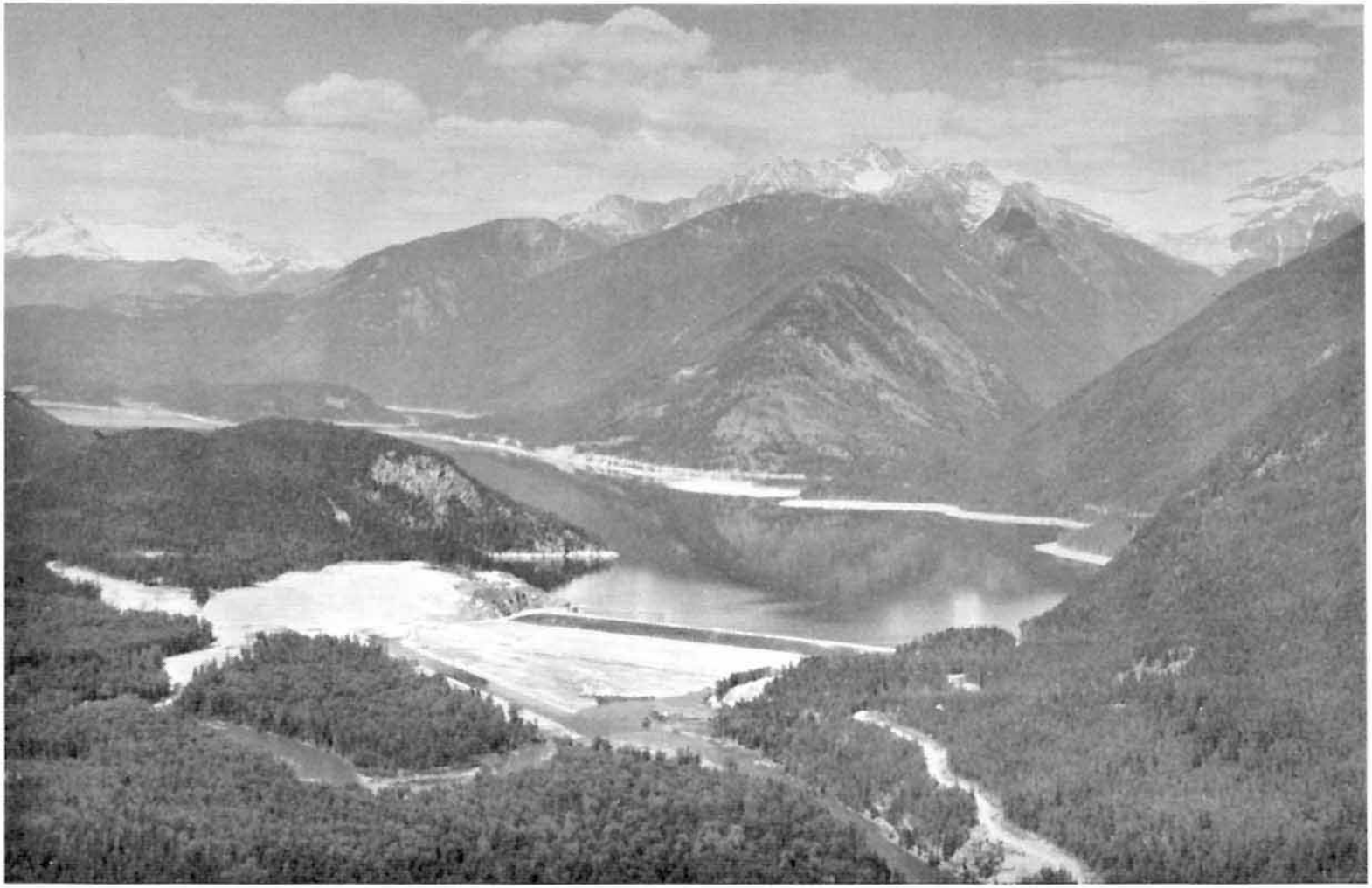
(f) Both Canada and the United States have the right to make diversions of water for consumptive uses and, in addition, after September 1984 Canada has the option of making for power purposes specific diversions of the Kootenay River into the headwaters of the Columbia River.

(g) Differences arising under the Treaty which cannot be resolved by the two countries may be referred by either to the International Joint Commission or to arbitration by an appropriate tribunal as specified by the Treaty.

(h) The Treaty shall remain in force for at least 60 years from its date of ratification, 16 September 1964.

The Protocol of January 1964 amplified and clarified certain terms of the Columbia River Treaty. The Attachment Relating to Terms of Sale signed on the same date established agreement that under certain terms Canada would sell in the United States its entitlement to downstream power benefits for a 30-year period. The Canadian Entitlement Purchase Agreement of 13 August 1964 provided that the Treaty storages would be operative for power purposes on the following dates:

Duncan storage	1 April 1968
Arrow storage	1 April 1969
Mica storage	1 April 1973



DUNCAN DAM
The dam and Duncan Lake.

Duncan River, British Columbia

PERMANENT ENGINEERING BOARD

General

Article IV of the Columbia River Treaty established a Permanent Engineering Board consisting of two members to be appointed by Canada and two members by the United States. Appointments to the Board were to be made within three months of the date of ratification. The duties and responsibilities of the Board were also stipulated in the Treaty and related documents.

Establishment of the Board

Pursuant to Executive Order No. 11177 dated 16 September 1964 the Secretary of the Army and the Secretary of the Interior on 7 December 1964 appointed two members and two alternate members to form the United States Section of the Permanent Engineering Board. The members of the Canadian Section of the Board were appointed by Order in Council P.C. 1964-1671 dated 29 October 1964. Each member was authorized to appoint an alternate member. On 11 December 1964 the two governments announced the composition of the Board.

The names of the Board members, alternate members and secretaries are shown in Appendix A. It is noted that Board member Mr. Raymond A. Peck Jr. left government service on 24 January 1977, and his replacement had not been appointed as of the end of this reporting year.

DEDICATION CEREMONY for Mica Dam and powerhouse, 13 October 1977.

Duties and Responsibilities of the Board

The general duties and responsibilities of the Board to the governments, as set forth in the Treaty and related documents, include:

(a) assembling records of the flows of the Columbia River and the Kootenay River at the Canada-United States of America boundary;

(b) reporting to Canada and the United States of America whenever there is substantial deviation from the hydroelectric and flood control operating plans and if appropriate including in the report recommendations for remedial action and compensatory adjustments;

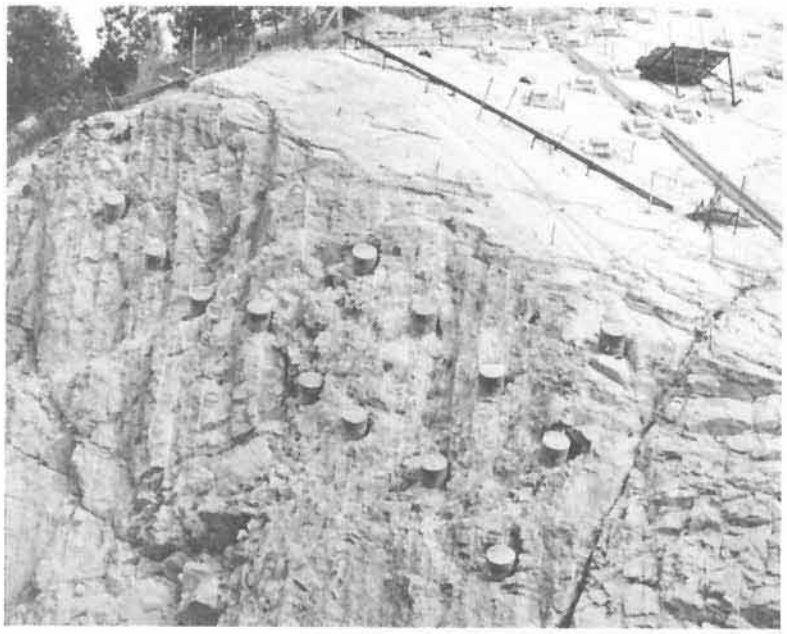
(c) assisting in reconciling differences concerning technical or operational matters that may arise between the entities;

(d) making periodic inspections and requiring reports as necessary from the entities with a view to ensuring that the objectives of the Treaty are being met;

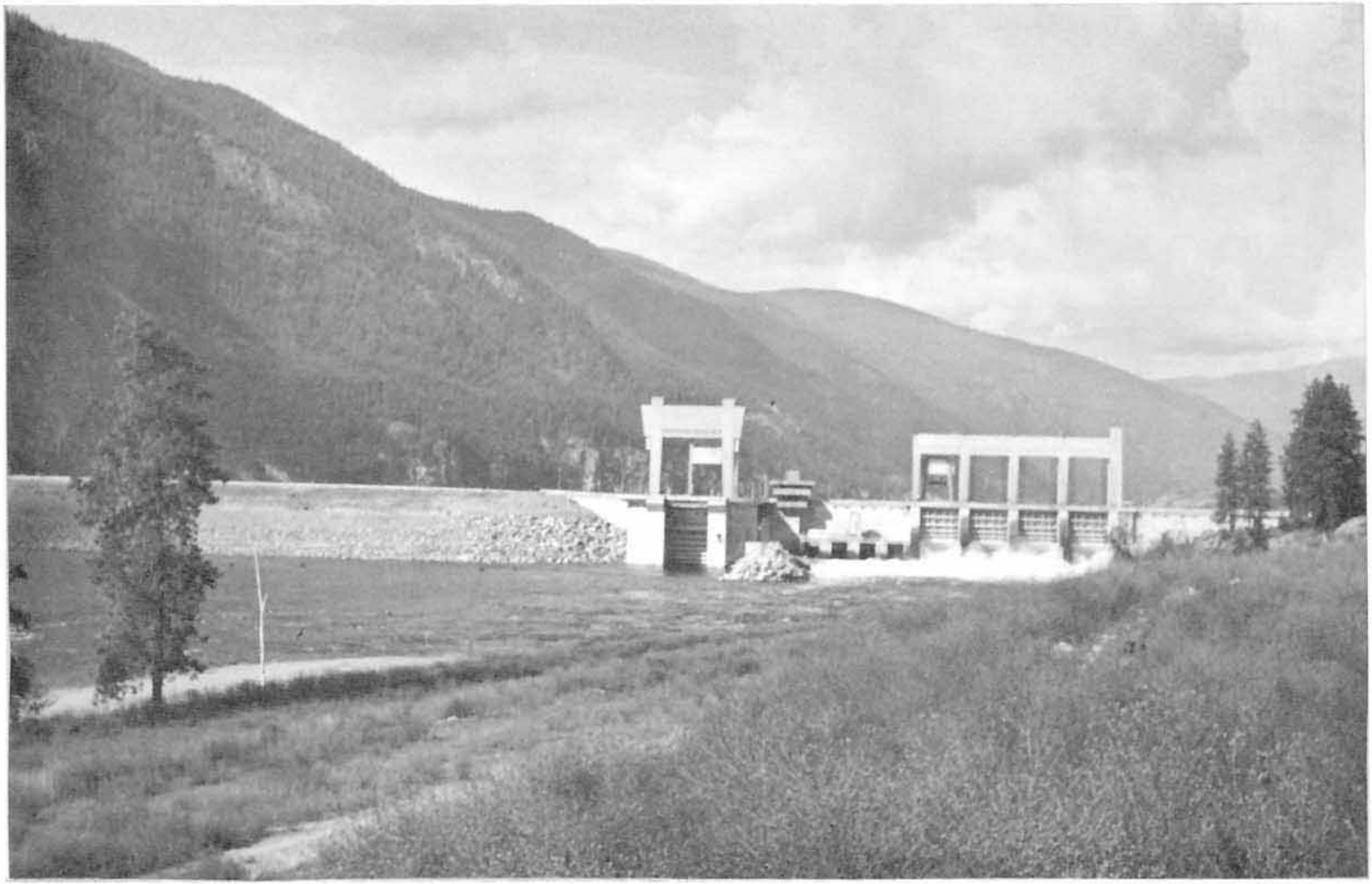
(e) making reports to Canada and the United States of America at least once a year of the results being achieved under the Treaty and making special reports concerning any matter which it considered should be brought to their attention;

(f) investigating and reporting with respect to any other matter coming within the scope of the Treaty at the request of either Canada or the United States of America;

(g) consulting with the entities in the establishment and operation of a hydrometeorolgical system as required by Annex A of the Treaty.



ROCK STABILIZING
capped steel tendons
eliminate slide danger
at left abutment
of Libby Dam.



HUGH KEENLEYSIDE DAM — Columbia River, British Columbia

Earth dam, navigation lock and spillway at the outlet of Arrow Lakes reservoir.

ENTITIES

General

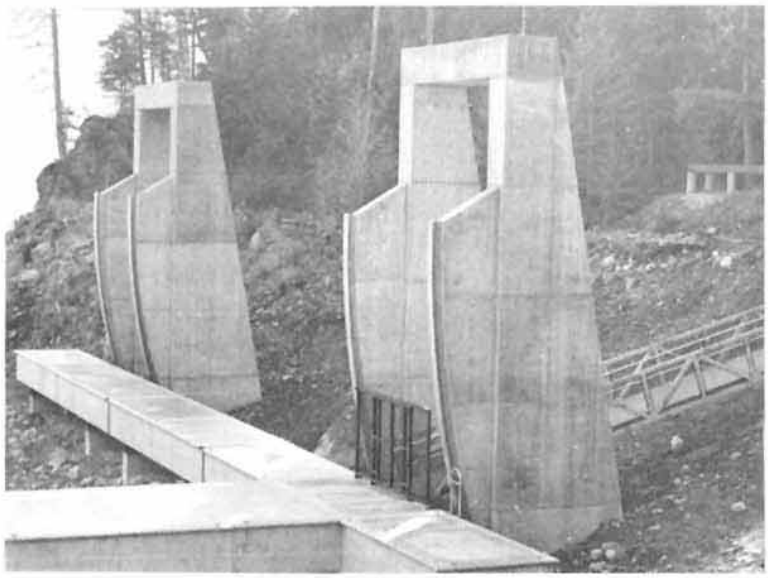
Article XIV(1) of the Treaty provides for the designation by Canada and the United States of entities which are empowered and charged with the duty of formulating and executing the operating arrangements necessary to implement the Treaty. Provision is made for either government to designate one or more entities. The powers and duties of the entities are specified in the Treaty and related documents.

Establishment of the Entities

Executive Order No. 11177, previously referred to, designated the Administrator of the Bonneville Power Administration, Department of the Interior, and the Division Engineer, North Pacific Division, Corps of Engineers, Department of the Army, as the United States Entity with the Administrator to serve as Chairman. Order in Council P.C. 1964-1407 dated 4 September 1964 designated the British Columbia Hydro and Power Authority as the Canadian Entity for the purposes of the Treaty.

The names of the members of the two entities are shown in Appendix B.

SMALL BOAT MOORAGE
at Souse Gulch
on Lake Koocanusa
designed to move with
changing reservoir level.



Powers and Duties of the Entities

In addition to the powers and duties specified elsewhere in the Treaty and related documents the Treaty requires that the entities be responsible for:

(a) co-ordination of plans and exchange of information relating to facilities to be used in producing and obtaining the benefits contemplated by the Treaty,

(b) calculation of and arrangements for delivery of hydroelectric power to which Canada is entitled for providing flood control,

(c) calculation of the amounts payable to the United States of America for standby transmission services,

(d) consultation on requests for variations made pursuant to Articles XII(5) and XIII(6),

(e) the establishment and operation of a hydrometeorological system as required by Annex A,

(f) assisting and co-operating with the Permanent Engineering Board in the discharge of its functions,

(g) periodic calculation of accounts,

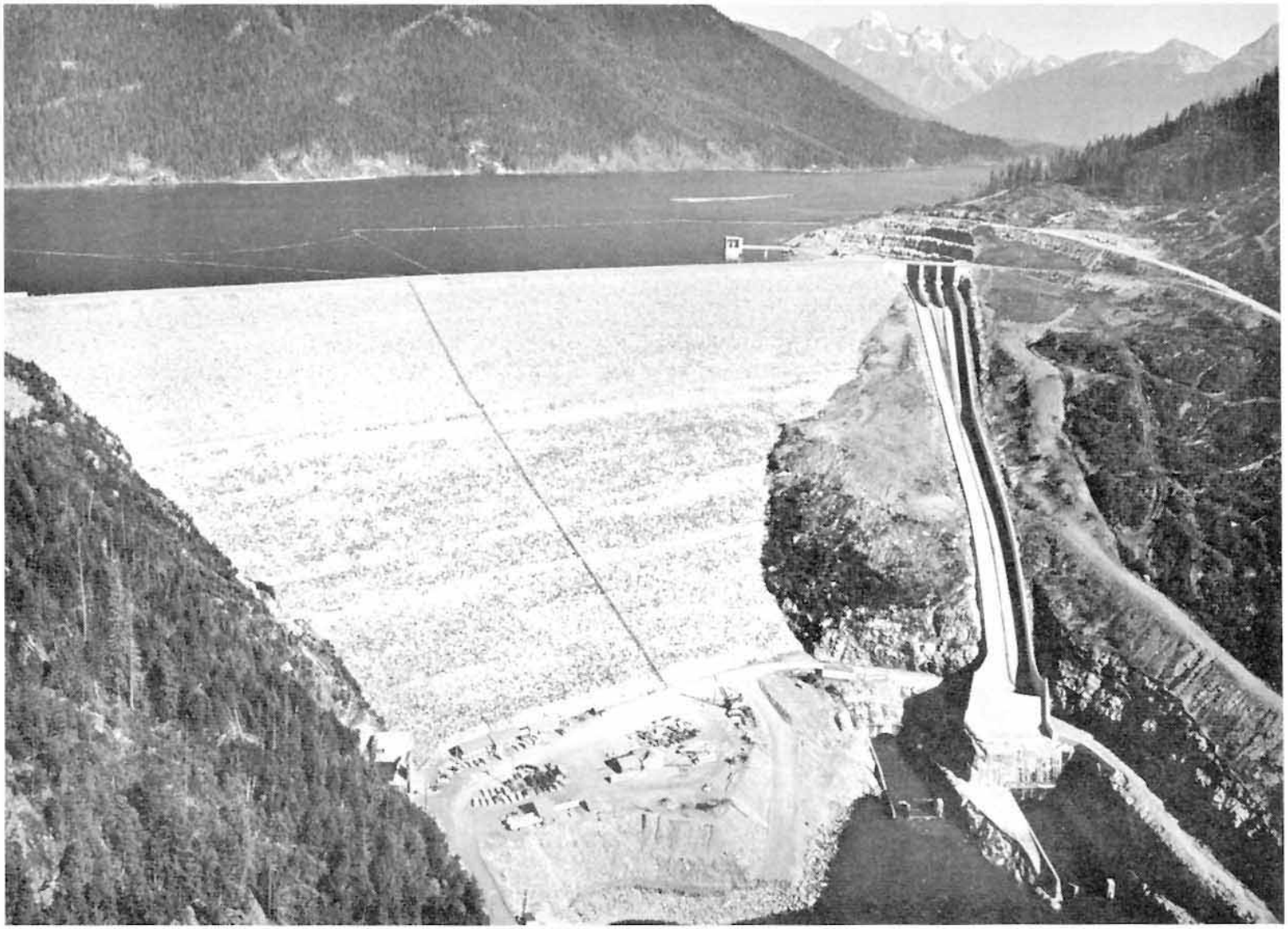
(h) preparation of the hydroelectric operating plans and the flood control operating plans for the Canadian storage together with determination of the downstream power benefits to which Canada is entitled,

(i) preparation of proposals to implement Article VIII and carrying out any disposal authorized or exchange provided for therein,

(j) making appropriate arrangements for delivery to Canada of the downstream power benefits to which Canada is entitled including such matters as load factors for delivery, times and points of delivery, and calculation of transmission loss,

(k) preparation and implementation of detailed operating plans that may produce results more advantageous to both countries than those that would arise from operation under the plans referred to in Annexes A and B.

Article XIV(4) of the Treaty provides that the two governments may, by an exchange of notes, empower or charge the entities with any other matter coming within the scope of the Treaty.



MICA DAM
The dam with McNaughton Lake full.

Columbia River, British Columbia

ACTIVITIES OF THE BOARD

Meetings

The first meeting of the Board during the report year was held in Portland, Oregon on 16 November 1976 to review progress under the Treaty and to discuss preparation of the Board's Annual Report. The Board met with the Entities on the same day to discuss Entity studies and general progress. The second meeting of the Board was held in Castlegar, B.C. on 27 September 1977. On 27, 28 and 29 September the Board made its biennial inspection of the Mica, Hugh Keenleyside, Duncan and Libby dams. The Board also toured the third powerhouse at Grand Coulee Dam where new generators and turbines are being installed.

Reports Received

Throughout the report year the Canadian Entity provided the Board with weekly reports on operation of the Canadian storage reservoirs and with daily flow forecasts during the freshet season for the northern part of the Columbia River basin. The United States Entity provided monthly reports on the operation of the Libby storage reservoir. The Entities also provided copies of computer printouts of studies for the Assured Operating Plan and downstream power benefit calculations, and the following documents and reports:

— Report of Columbia River Treaty Canadian and United States Entities for the period 1 October 1975 to 30 September 1976

— Columbia River Treaty Hydroelectric Operating Plan — Assured Operating Plan for Operating Year 1981-82, plus a copy of the Entities' agreement on this document

— Detailed Operating Plan for Columbia River Treaty Storage 1 August 1976 through 31 July 1977, plus a copy of the Entities' agreement on this document

— Determination of Downstream Power Benefits Resulting from Canadian Storage for Operating Year 1981-82, plus a copy of the Entities' agreement on this document

— Columbia River Treaty Hydrometeorological System Plan for Exchange of Operational Hydromet Data, 30 September 1976, plus a copy of the Entities' agreement on this document

— Agreement between the Canadian and United States Entities for an Emergency Draft Arrangement, February 1977

— Special Agreement between British Columbia Hydro and Power Authority and Bonneville Power Administration on operating storage in Arrow Lakes reservoir during the period 1 July 1977 through 31 March 1978.

Subsequent to the end of the this report year the Board received the following documents and reports from the Entities:

— Detailed Operating Plan for Columbia River Treaty Storage 1 August 1977 through 31 July 1978, plus a copy of the Entities' agreement on this document

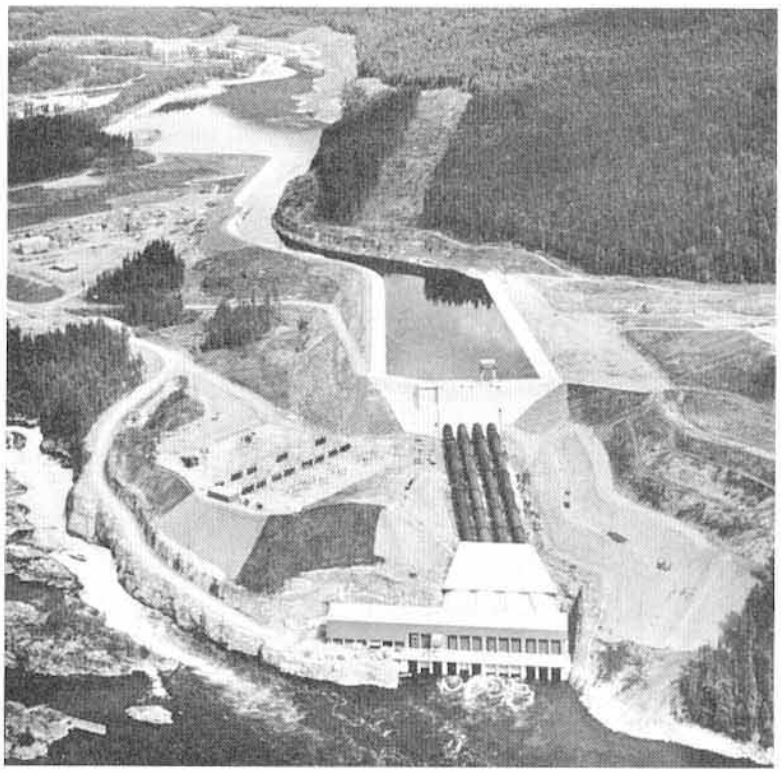
— Columbia River Treaty Hydroelectric Operating Plan — Assured Operating Plan for Operating Year 1982-83, plus a copy of the Entities' agreement on this document

— Determination of Downstream Power Benefits Resulting from Canadian Storage for Operating Year 1982-83, plus a copy of the Entities' agreement on this document

— Report of Columbia River Treaty Canadian and United States Entities for the period 1 October 1976 to 30 September 1977.

Report to Governments

The twelfth Annual Report of the Board was submitted to the two governments on 31 December 1976.



CANAL PLANT on Kootenay River in British Columbia became feasible with the Treaty.

PROGRESS

General

The results achieved under the terms of the Treaty include construction of the Treaty projects, progress in developing the hydrometeorological network, power and flood control operating plans, and the annual calculation of downstream power benefits. The three Treaty storage projects in British Columbia, the Duncan, Arrow and Mica projects, are now in operation and supply power benefits and flood control benefits in both Canada and the United States. The Libby storage project in Montana is in operation and provides power and flood control benefits in both countries. Completion of the Canal Plant on the Kootenay River in 1976 and installation of generators at Mica Dam during the report year have caused the power benefits in Canada to increase substantially. Completion of the Revelstoke project, now under construction, will result in a further substantial increase in power benefits in Canada. By 1985 some 4000 megawatts of generation in Canada that would otherwise not have been installed will be benefiting from the operation of Treaty storage.

The locations of the above projects are shown in Plate 1 in Appendix D.

Status of the Treaty Projects

Duncan Project

Duncan Dam, the smallest Treaty project, was scheduled by the Sales Agreement for operation by 1 April 1968 and was the first of the Treaty projects to be completed. It became fully operational on 31 July 1967, well in advance of Treaty requirements.

The earthfill dam, about 130 feet high, is located on the Duncan River a few miles north of Kootenay Lake. The reservoir behind the dam extends for about 27 miles and provides 1,400,000 acre-feet of usable storage which is all committed under the Treaty.

There are no power facilities included in this project which is shown in the picture on page 6.

Characteristics of the project are shown in Table 1 of Appendix D.

NAVIGATION LOCK
passing logs at
Hugh Keenleyside Dam.

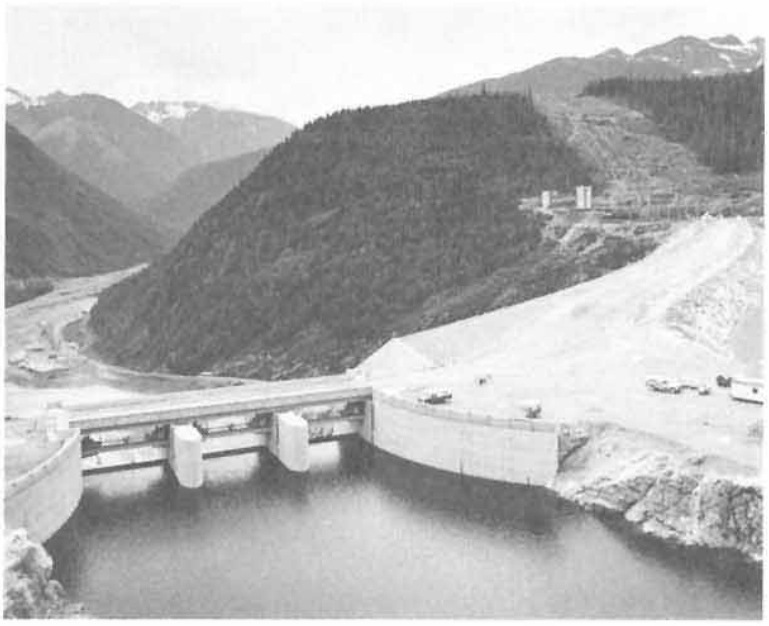
Arrow Project

The Hugh Keenleyside Dam, at the outlet of the Arrow Lakes, was the second Treaty project to be completed. It became operational on 10 October 1968 well ahead of the date of 1 April 1969 scheduled by the Sales Agreement. The project has no associated power facilities.

The dam consists of two main components: a concrete gravity structure which includes the spillway, low level outlets and navigation lock and an earthfill section which rises 170 feet above the riverbed. The reservoir, about 145 miles long, includes both the Upper and Lower Arrow Lakes, and provides 7,100,000 acre-feet of Treaty storage.

The project is shown in the picture on page 10 and project data are shown in Table 2 of Appendix D.

SPILLWAY CONTROL structure and crest of Mica Dam.



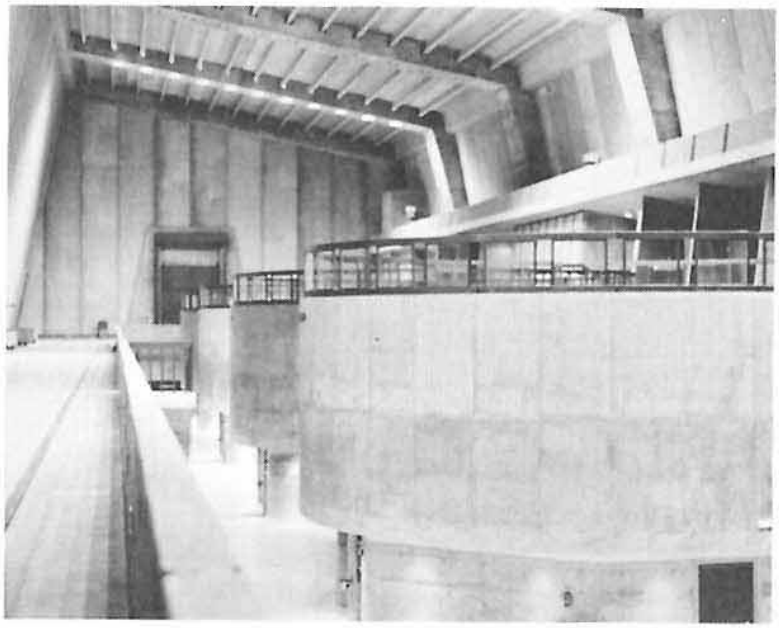
Mica Project

Mica Dam, the largest of the Treaty projects, was scheduled by the Sales Agreement for initial operation on 1 April 1973. The project was declared operational and commenced storing on 29 March 1973.

Mica Dam is located on the Columbia River about 85 miles north of Revelstoke, British Columbia. The earthfill dam rises more than 800 feet above its foundation and creates a reservoir 135 miles long, McNaughton Lake, with a storage capacity of 20,000,000 acre-feet. The project utilizes 12,000,000 acre-feet of live storage of which 7,000,000 acre-feet are committed under the Treaty. The reservoir filled for the first time during the summer of 1976.

The underground powerhouse will have space for a total of six 435,000 kw units with a total capacity of 2,610,000 kw. Three of the initial four generators were placed in service during the report year and the fourth unit will commence operation in October 1977.

The dam is shown in the picture on page 14 and project data are shown in Table 3 of Appendix D.



GENERATORS
in Libby powerhouse.

Libby Project in the United States

Libby Dam is located on the Kootenai River 17 miles northeast of the town of Libby, Montana. Construction began in the spring of 1966, storage has been operational since 17 April 1973, and commercial generation of power began on 24 August 1975, coincident with formal dedication of the project. The concrete gravity dam rises 370 feet above the river bed and creates Lake Koocanusa which is 90 miles long and extends 42 miles into Canada. Lake Koocanusa has a gross storage of 5,809,000 acre-feet, of which 4,934,000 acre-feet are usable for flood control and power purposes.

A relatively small amount of work was undertaken during the report year. This included repair of the stilling basin, miscellaneous work on recreation facilities and some improvement of portions of the state highway and forest development roads in the vicinity.

STILLING BASIN
for spillway at Libby Dam
undergoing concrete repairs.

The work on the stilling basin, less than 50 percent complete at the end of September, is scheduled to be finished by February 1978.

It is anticipated that contracts will be let in 1978 for completion of Libby Dam units 5 through 8, and for initial access and relocation activities in preparation for construction of Libby reregulating dam. Additional recreation and beautification projects are also scheduled during the year.

The Libby project is shown in the picture on page 3 and project data are shown in Table 4 of Appendix D.

Libby Project in Canada

Canada has fulfilled its obligation to prepare the land required for the 42-mile portion of Lake Koocanusa in Canada. The Water Resources Service of British Columbia, now a component of the Ministry of the Environment, was responsible for co-ordinating the program. The Provincial Forest Service has completed a program of piling and burning debris collected on the shores of the reservoir.

Fishery and wildlife studies of the area are expected to continue for several years. The Kikomun Park facility toward the north end of the reservoir has received heavy summer use and the Provincial Parks Branch is studying ten other sites that have recreational potential. The photograph on page 24 shows one of these potential sites.

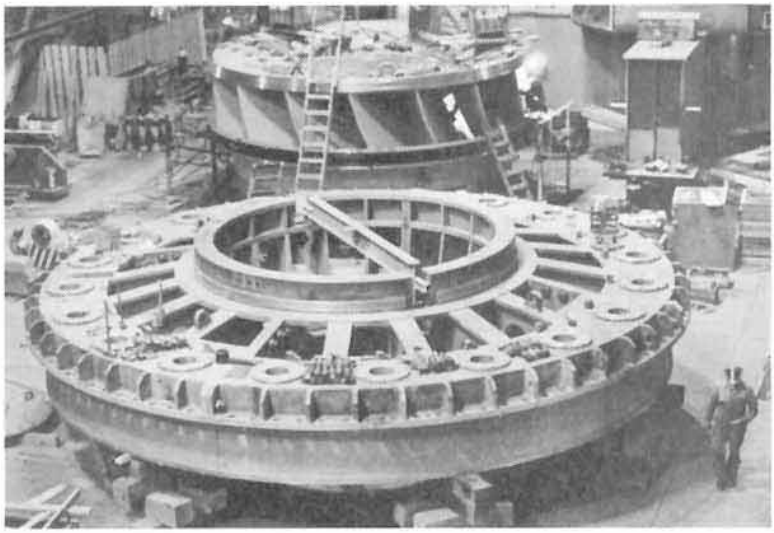
POTENTIAL RECREATION AREA
at Lake Koocanusa
in British Columbia.

Hydrometeorological Network

One of the responsibilities assigned to the Entities by the Treaty is the establishment and operation, in consultation with the Permanent Engineering Board, of a hydrometeorological system to obtain data for detailed programming of flood control and power operation. This system includes snow courses, meteorological stations and streamflow gauges.

In developing the hydrometeorological network the Entities, with the concurrence of the Board, adopted a document which defines the Columbia River Treaty Hydrometeorological System Network and sets forth a method of classifying facilities into those required as part of the Treaty System and those of value as Supporting Facilities. The Columbia River Treaty Hydrometeorological Committee, formed by the Entities, makes recommendations on establishing the Treaty Hydrometeorological System.

During this report year the Entities, with the concurrence of the Board, adopted a revised plan for exchange of operational hydrometeorological data.



HEADCOVER
for No. 4 turbine at
Mica powerhouse.

Power Operating Plans

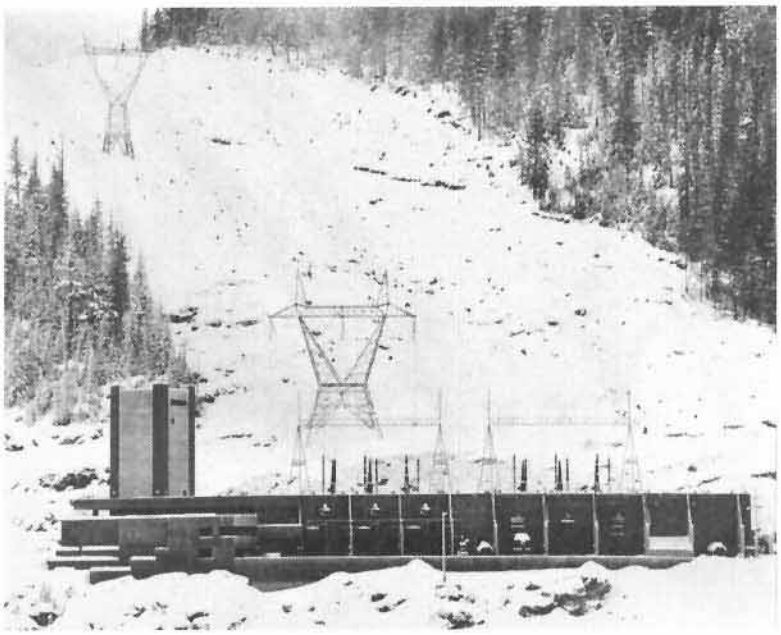
The Treaty and related documents provide that the Entities are to agree annually on operating plans and on the resulting downstream power benefits for the sixth succeeding year of operation. These operating plans prepared five years in advance are called assured operating plans and provide the Entities with a basis for system planning. At the beginning of each operating year a detailed operating plan is prepared on the basis of current resources and loads to obtain results that may be more advantageous to both countries than those which would be obtained by operating in accordance with the assured operating plan.

The assured operating plan for operating year 1981-82, received by the Board early in the report year, includes generation at the Mica project and is based on the operation of the system for optimum generation in both countries. The Board has reviewed this plan and

concludes that it is consistent with the terms of the Treaty and does not depart substantially from previous plans. The assured operating plan for 1982-83 was provided to the Board after the end of the report year.

Early in this report year the Entities provided the Board with a detailed operating plan for Canadian storage for the operating year ending 31 July 1977. A detailed operating plan for the operating year ending 31 July 1978 was forwarded to the Board after the end of the report year. These plans contain criteria for operating the Arrow, Duncan, Mica and Libby reservoirs.

TOURIST BUILDING
with adjacent switchgear
at right abutment
of Mica Dam.



Annual Calculation of Downstream Benefits

The general requirements for determination of assured operating plans and downstream power benefits are summarized in the first paragraph of the preceding section.

In this report year the Entities provided the Board with a copy of their agreed document outlining downstream power benefits resulting from Canadian storage for the operating year 1981-82. The Board has completed its review of this document and concludes that it meets the requirements of the Treaty. Copies of the three computer studies used in the final calculations for the determination of downstream benefits and which also provide the basis of the hydroelectric operating plan were forwarded to the Board by the Entities. This material facilitated review of the documents by the Board. A report on determination of downstream power benefits for the operating year 1982-83 was received from the Entities after the end of the report year.

Flood Control Operating Plans

The Treaty provides that Canadian storage reservoirs will be operated by the Canadian Entity in accordance with operating plans designed to minimize flood damage in the United States and Canada.

The "Columbia River Treaty Flood Control Operating Plan" defines flood control operation of the Duncan, Arrow, Mica and Libby reservoirs. This plan was received from the Entities and reviewed by the Board in the 1972-73 report year.

Flow Records

Article XV(2)(a) of the Treaty specified that the Permanent Engineering Board shall assemble records of flows of the Columbia and Kootenay Rivers at the Canada-United States of America boundary. Actual recorded flows for the Kootenai River at Porthill, Idaho, and for the Columbia River at Birchbank, British Columbia, Plate 1, are tabulated in Appendix C for this report year.

OPERATION

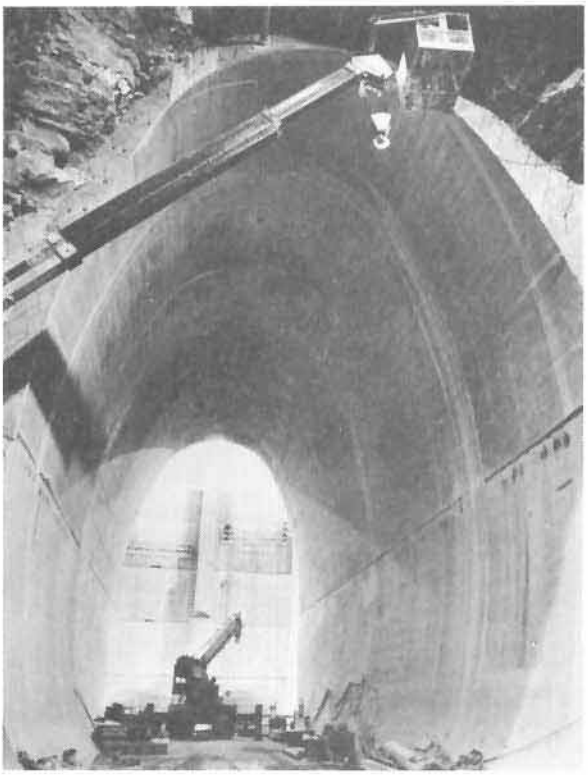
General

The Columbia River Treaty Operating Committee was established by the Entities to develop operating plans for the Treaty storages and to direct operation of these storages in accordance with the terms of the Entity agreements.

During the report year the Treaty storage in Canada was operated by the Canadian Entity in accordance with:

- Columbia River Treaty Flood Control Operating Plan
- Detailed Operating Plan for Columbia River Treaty Storage 1 August 1976 through 31 July 1977
- Detailed Operating Plan for Columbia River Treaty Storage 1 August 1977 through 31 July 1978
- Columbia River Treaty Hydroelectric Operating Plan, Assured Operating Plan for Operating Year 1976-77
- Columbia River Treaty Hydroelectric Operating Plan, Assured Operating Plan for Operating Year 1977-78.

In addition, three special agreements were in effect in this period: an agreement to provide an additional two feet of storage in Arrow Lakes reservoir to make use of surplus water from the 1976 freshet; an Emergency Draft Arrangement for Canadian storage to permit additional energy generation in the United States system early in 1977; and an agreement to permit British Columbia Hydro and Power Authority to deliver energy in lieu of releases from Arrow Lakes reservoir to obtain improvement in reservoir levels for recreation and navigation purposes.



DRAFT TUBE
and gate chamber
under construction
at Mica powerhouse.

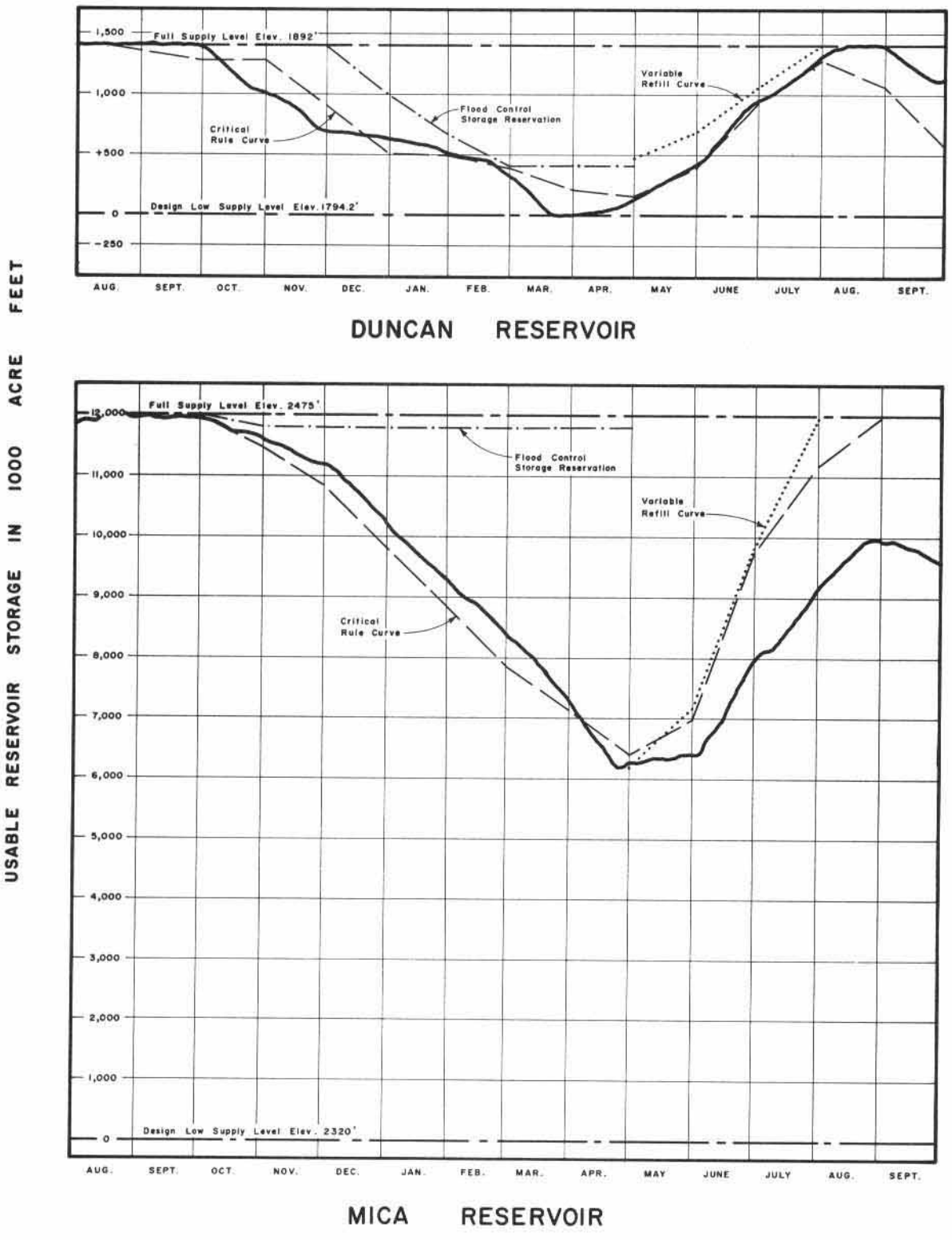
Power Operation

The three Canadian Treaty reservoirs, Duncan, Arrow, and Mica, and the Libby reservoir in the United States were in full operation throughout this report year. After the above-average freshet in 1976, followed by a wet July and August, all storages in Canada committed under the Treaty and most other reservoirs in the Pacific Northwest were full. However, a period of very light precipitation began in September 1976 and continued through the winter resulting in very low natural streamflows during the storage withdrawal season and in much below normal snow accumulation throughout the basin. The freshet produced by the melting of this deficient snowpack was the smallest in volume in fifty years of record as measured at The Dalles, Oregon. Flood control therefore was not a problem in 1977 and operation throughout the year was based on power and reservoir refill requirements.

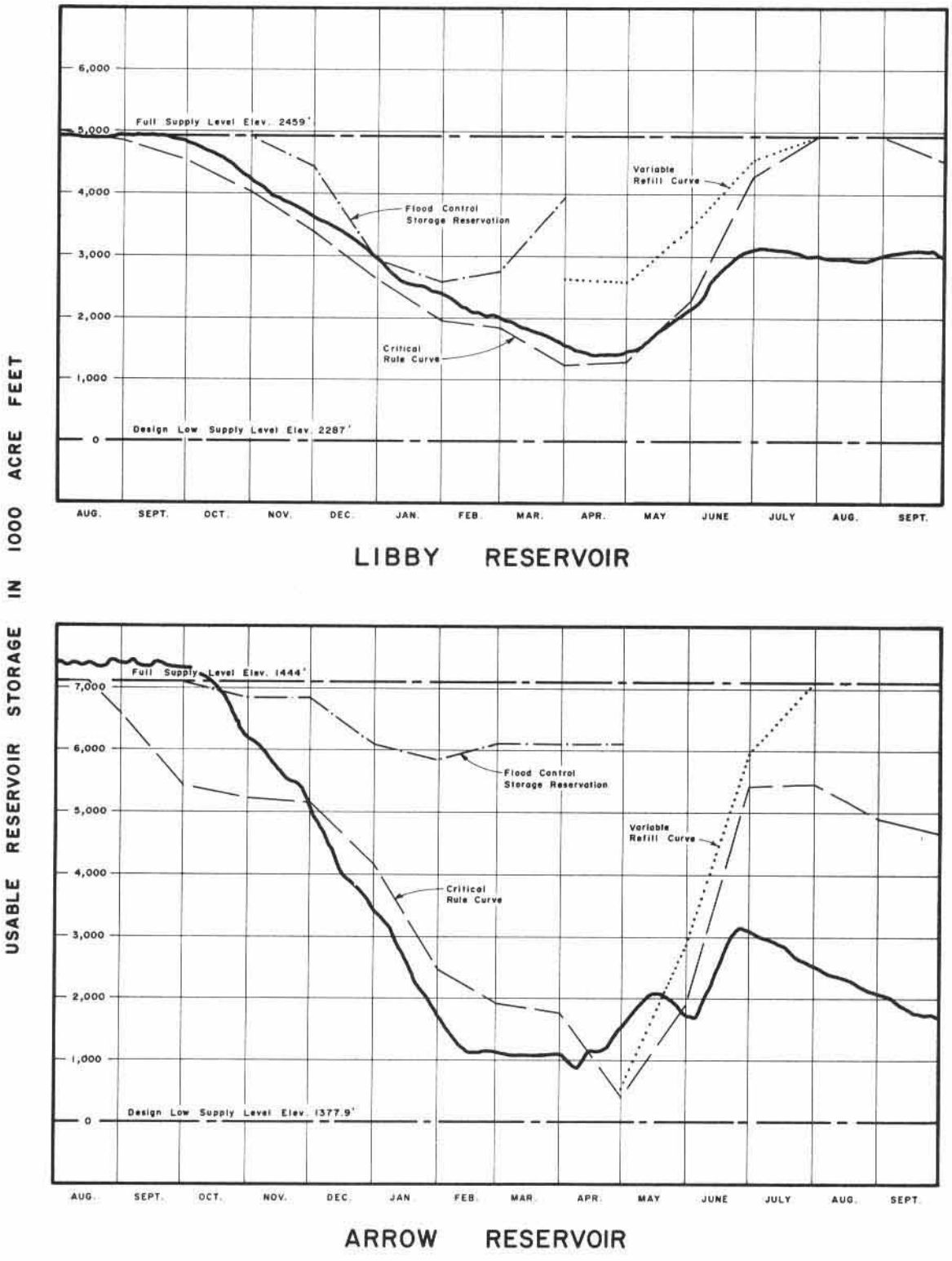
The Entities agreed in February 1977 on an Emergency Draft Arrangement for Canadian storage to provide for release of Treaty storage in addition to that required under the agreed operating plans. The additional storage, drafted from Arrow and Duncan reservoirs, made it possible to generate 600 million kilowatt hours of emergency energy at United States federal projects on the Columbia River. Water released from McNaughton Lake during May and June restored the levels of the Arrow and Duncan reservoirs to the levels they would have reached under normal operating rules. The agreement provides for compensation to the Canadian Entity for use of the additional storage and for any associated power losses in Canada. It also provides for the restoration of McNaughton Lake storage by 31 July 1979.

Operation of the reservoirs is illustrated on pages 31 and 32 by hydrographs which show actual reservoir levels and some of the more important rule curves which govern operation of the Treaty storages. The Flood Control Storage Reservation curve specifies maximum month-end reservoir levels which will permit evacuation of the reservoir to control the forecasted freshet. The Critical Rule Curve shows minimum month-end reservoir levels which should be maintained to enable the anticipated power demands to be met under adverse water supply conditions. The Assured Refill Curve shows reservoir elevations necessary to ensure refilling the reservoir by the end of July with a reasonable degree of confidence. Similar rule curves which apply to operation of the combined Canadian Treaty storages have also been provided to the Board.

At the beginning of the report year Duncan reservoir was at elevation 1891.5 feet. Drafting of storage began on 2 October 1976 and continued throughout the season at rates up to 10,000 cfs. Storage releases were co-ordinated with releases from Libby, with the Emergency Draft Arrangement, and with the operation of Kootenay Lake storage to ensure



HYDROGRAPHS—Duncan and Mica reservoir levels for the 14-month period ending 30 September 1977.



HYDROGRAPHS—Libby and Arrow reservoir levels for the 14-month period ending 30 September 1977.

compliance with the International Joint Commission's Control Order for Kootenay Lake levels. Commencing 30 March 1977 discharges were held to 100 cfs until the reservoir filled to normal full pool elevation, 1892 feet, on 14 August. Drafting commenced shortly after and on 30 September the reservoir elevation was 1875.3 feet.

The Arrow reservoir was at elevation 1445.4 feet at the beginning of the report year. Downstream power needs required storage drafts commencing 16 October and by the end of January 1977 the reservoir was five feet below the Critical Rule Curve. Drafting continued under the Emergency Draft Arrangement until the minimum elevation, 1387.8 feet, was reached on 9 April. Because basin snowmelt runoff was extremely low this reservoir did not refill. The peak elevation during the summer of 1977 was 1410.9 feet and was reached on 27 June. On 30 September 1977 Arrow reservoir was at elevation 1397.3 feet.

NARROWS
between Upper and
Lower Arrow Lakes with
reservoir bottom dry,
September 1977.

At the beginning of the report year extra storage was available in the Arrow reservoir above normal full pool elevation, 1444 feet, as a result of the agreement to fill the additional two feet of storage at the end of the 1976 freshet. In the period June through September 1977 some improvement in water levels for recreation and navigation purposes was obtained under the agreement which provided for the supply of electrical energy to the United States in lieu of requested storage drafts.

McNaughton Lake was essentially full at the beginning of the report year at elevation 2474.5 feet. Discharges in October and November were in accordance with the Detailed Operating Plan. After generating units 1 and 2 at Mica Dam became operational in mid-December discharges were made through the powerhouse at a rate of about 20,000 cfs. The third unit began commercial operation in late March 1977 and discharges ranged from 17,000 to 30,000 cfs throughout the remainder of the report year. Discharges were reduced to minimum for two days at the end of April to facilitate the removal of the cofferdam at tailrace tunnel No. 2. During May and June discharges exceeded reservoir refill criteria in order to restore the Arrow and Duncan reservoir levels in accordance with the Emergency Draft Arrangement.

Minimum reservoir elevation for the year was 2414.6 feet on 29 April 1977 and the maximum refill elevation was 2455.5 feet on 27 August 1977. At the end of the report year McNaughton Lake was at elevation 2451.6 feet.

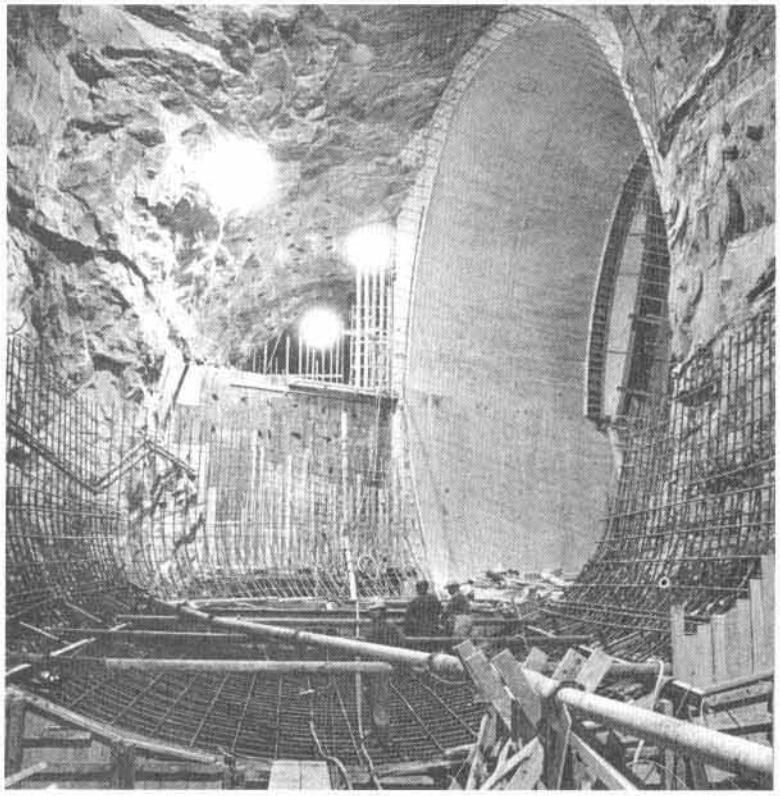
On 30 September 1976 Lake Koocanusa, at elevation 2457 feet, was two feet below full pool elevation. Drafting for power requirements, which also satisfied flood control rules, continued until 26 April 1977 when the reservoir reached its lowest elevation for the year, 2358.5 feet. In May and early June extra water was released to provide higher flows to assist downstream migration of juvenile salmonids in the United States. Operation

thereafter was in accordance with power requirements and because runoff was low the reservoir did not fill. The maximum elevation of Lake Koocanusa in 1977 of 2415 feet, 44 feet below full pool, was reached on 6 July. At the end of September the reservoir was at elevation 2411 feet.

Flood Control Operation

Operation for flood control was not a factor during the 1977 freshet. Storage space provided prior to the freshet under operation for power purposes at the Duncan, Arrow, Mica and Libby projects exceeded the requirements of the Columbia River Treaty Flood Control Operating Plan.

TAILRACE MANIFOLD No. 2
and draft tube
for Unit No. 6 at
Mica powerhouse.



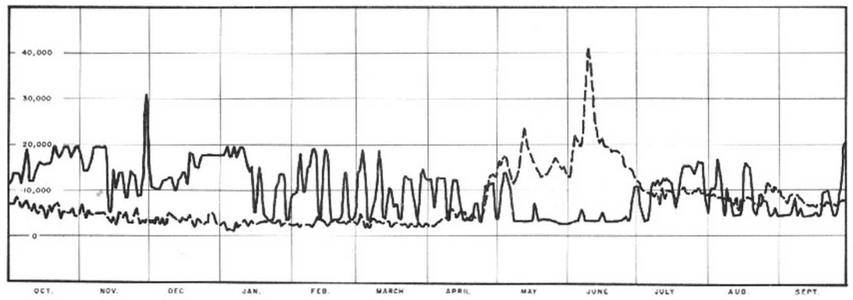
BENEFITS

Flood Control Provided

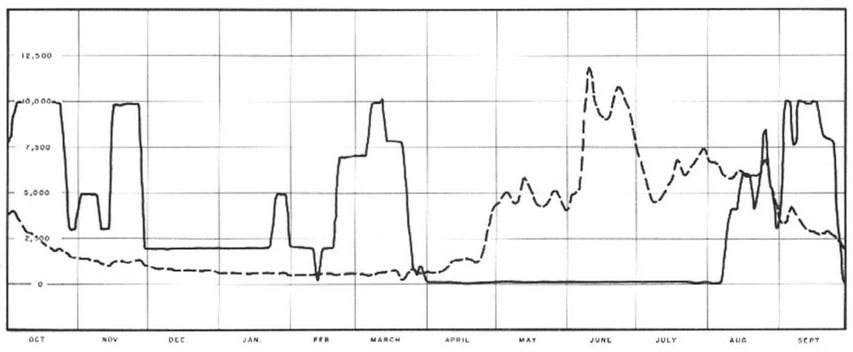
The 1977 unregulated freshet would have resulted in a record low peak discharge at The Dalles, Oregon, and would not have caused flood damage. Regulation by upstream storage was therefore not required for flood control in the United States. In Canada, without the four storage projects constructed as a result of the Treaty, the peak discharge of the Columbia River at Trail would not have reached damaging levels.

It is estimated that the Duncan and Libby projects reduced the peak stage on Kootenay Lake by about three feet and that the Duncan, Arrow, Mica and Libby projects reduced the peak stage of the Columbia River at Trail, British Columbia by about six feet. The effect of storage in the Duncan, Arrow, Mica and Libby reservoirs on flows at the sites and on flows of the Columbia River at Birchbank is illustrated on page 37 by hydrographs which show both the actual discharges and the pre-project flows that would have occurred if the dams had not been built. It is noted that the pre-project hydrograph for Birchbank has been computed on the assumption that the effects of Duncan, Arrow, Mica and Libby regulation and of the regulation provided by the Corra Linn development on Kootenay Lake have been removed.

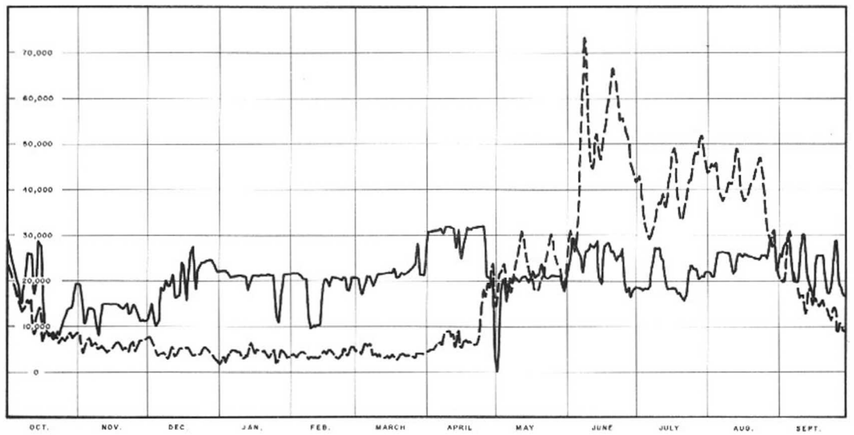
The operation of Columbia Basin reservoirs for the system as a whole reduced the natural annual peak discharge of the Columbia River near The Dalles, Oregon from about 276,000 cfs to 184,000 cfs. Regulation by the Treaty storage projects during the 1977 freshet period did not contribute flood control benefits in Canada or the United States.



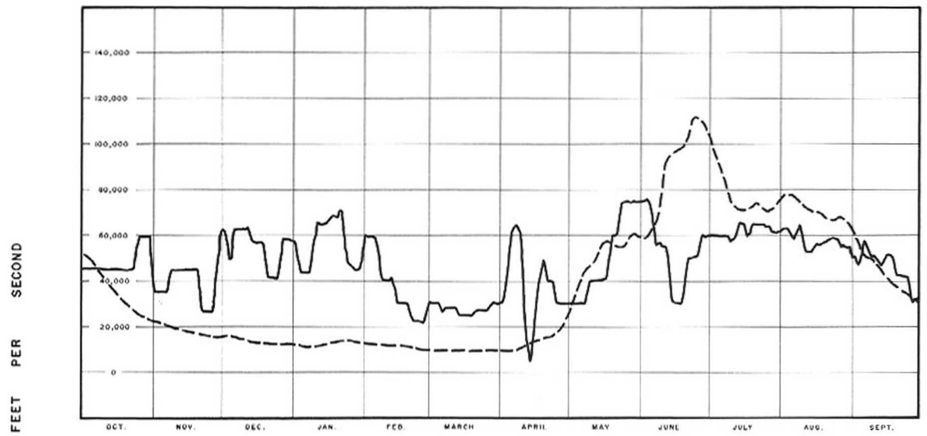
KOOTENAI RIVER AT LIBBY DAM



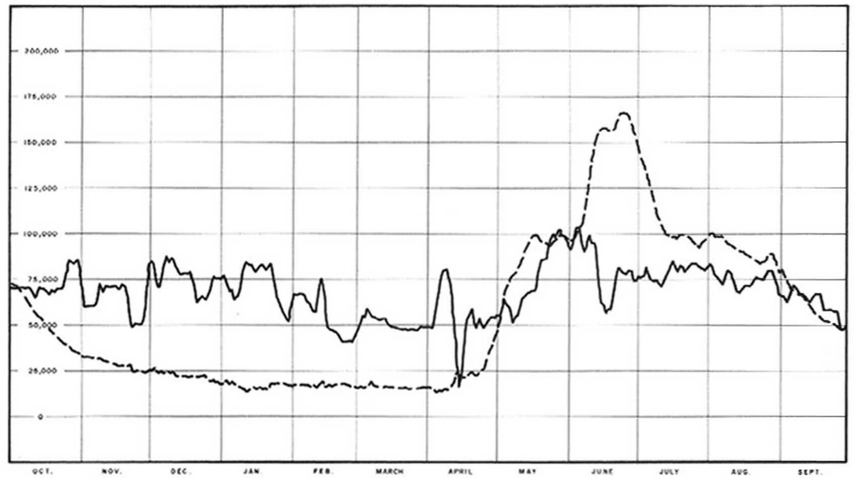
DUNCAN RIVER AT DUNCAN DAM



COLUMBIA RIVER AT MICA DAM



COLUMBIA RIVER AT HUGH KEENLEYSIDE DAM



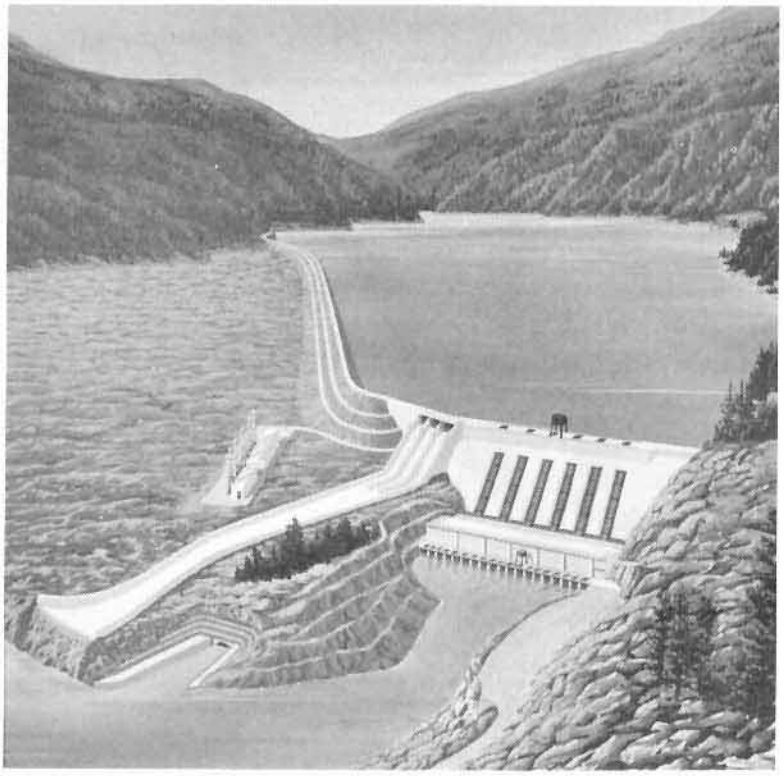
COLUMBIA RIVER AT BIRCHBANK

LEGEND

——— Observed Flows

– – – – Pre-Project Flows

HYDROGRAPHS—Observed and pre-project flows for year ending 30 September 1977.



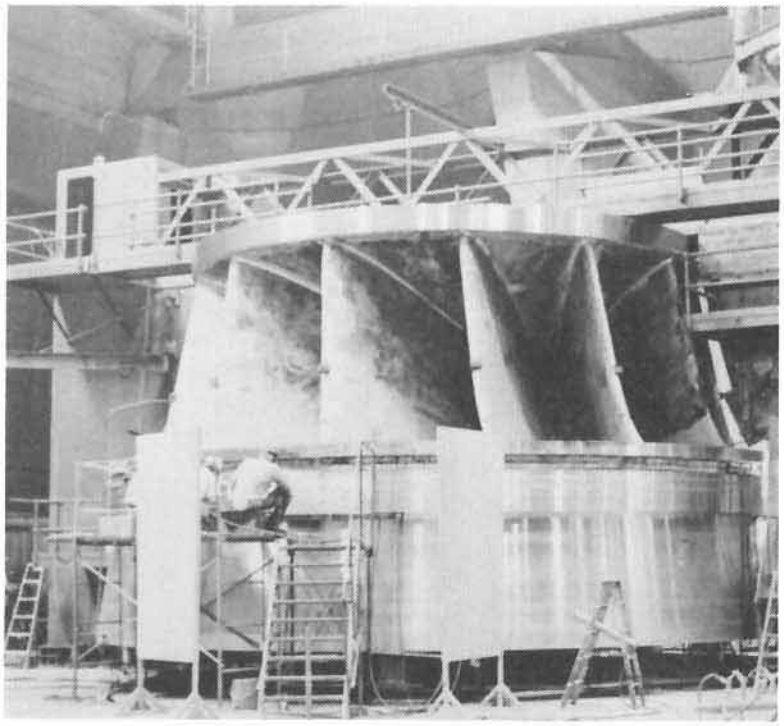
REVELSTOKE PROJECT
upstream from
Arrow Lakes reservoir,
an artist's concept.

All payments required by Article VI(1) as compensation for flood control provided by the Canadian Treaty storage projects have been made by the United States to Canada; the final payment was made on 29 March 1973 when the Mica project was declared operational.

Power Benefits

Downstream power benefits in the United States which arise from operation of the Canadian Treaty Storage were pre-determined and the Canadian one-half share was sold in the United States under the terms of the Canadian Entitlement Purchase Agreement for a 30-year period. No additional downstream power benefits were realized during the year from the operation of Treaty dams other than the added generation made possible on the Kootenay River in Canada and additional generation in the United States system resulting

from regulation provided by Libby. The Kootenay River benefits in Canada, under Article XII of the Treaty, and generation at the Mica project are retained wholly within Canada while the benefits from Libby in the United States are not shareable under the Treaty.



TURBINE RUNNER being machined at Grand Coulee project will produce about one million horsepower.

Other Benefits

The three special agreements in effect at various times during the report year, as noted on page 28, produced additional benefits. Each agreement defined a complete transaction extra to Treaty requirements and also defined procedures, assignment of benefits and compensation to be made. The agreement to provide an additional two feet of storage in Arrow Lakes from the above average 1976 freshet provided 183,000 acre-feet of water at the beginning of the report year. This water was used to generate extra power in

the United States during the 1976-77 winter season. Early in 1977 the Emergency Draft Agreement, which was developed as a result of low water supply conditions, added 600 million kilowatt hours of emergency energy to generation by United States Federal projects. The agreement to permit the delivery of electrical energy in lieu of releases from Arrow Lakes conserved 0.76 million acre-feet of water. In late summer this water raised reservoir levels by about six feet to improve conditions for recreation and navigation.

MICA PROJECT, overview of dam and reservoir.

CONCLUSIONS

1. The Duncan, Arrow, Mica and Libby projects have been operated in conformity with the provisions of the Treaty, the detailed operating plans developed by the Entities, and the flood control operating plan for Treaty reservoirs. Special operating agreements pursued as a result of unusual streamflow conditions were consistent with the intent of the Treaty.

2. Entity evaluations pertaining to development of the hydrometeorological network, power operating plans, and the annual calculation of downstream power benefits are proceeding satisfactorily.

3. Regulation by the Treaty storage projects during the 1977 freshet period was not required for flood control purposes in Canada or the United States because of extremely low runoff conditions.

4. Finally, the Board concludes that the objectives of the Treaty are being met.

COLUMBIA RIVER TREATY PERMANENT ENGINEERING BOARD

United States	Canada
Members	
Mr. Homer B. Willis, Chairman Chief, Engineering Division, Civil Works Directorate, Office, Chief of Engineers, U.S. Army, Washington, D.C.	Mr. G.M. MacNabb, Chairman Deputy Minister, Department of Energy, Mines and Resources, Ottawa, Ontario
Vacant 1)	Mr. B.E. Marr Deputy Minister, Ministry of the Environment, Victoria, B.C.
Alternates	
Mr. Alex Shwaiko Acting Chief, Planning Division, Civil Works Directorate, Office, Chief of Engineers, U.S. Army, Washington, D.C.	Mr. E.M. Clark Regional Director, Pacific and Yukon Region, Inland Waters Directorate, Department of the Environment, Vancouver, B.C.
Mr. J. Emerson Harper Assistant and Power Engineering Advisor, Office of the Assistant Secretary for Energy and Minerals, Department of the Interior, Washington, D.C.	Mr. H.M. Hunt Chief, Power and Special Projects Division, Ministry of the Environment, Victoria, B.C.
Secretaries	
Mr. Walter W. Duncan Assistant Chief, Hydrologic Engineering Branch, Civil Works Directorate, Office, Chief of Engineers, U.S. Army, Washington, D.C.	Mr. E.M. Clark Regional Director, Pacific and Yukon Region, Inland Waters Directorate, Department of the Environment, Vancouver, B.C.

1) Mr. Raymond A. Peck, Jr. left government service as of 24 January 1977.

APPENDIX B

COLUMBIA RIVER TREATY ENTITIES

United States

Mr. Donald P. Hodel, Chairman

Administrator, Bonneville
Power Administration,
Department of the Interior,
Portland, Oregon

Major General Wesley E. Peel

Division Engineer, North
Pacific Division,
Corps of Engineers,
U.S. Army,
Portland, Oregon

Canada

Mr. R.W. Bonner, Chairman

Chairman, British Columbia
Hydro and Power Authority,
Vancouver, B.C.

APPENDIX C

RECORD OF FLOWS

AT THE

INTERNATIONAL BOUNDARY

Day	Oct.	Nov.	Dec.	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	70,200	59,700	84,400	77,600	66,800	48,900	49,000	54,900	90,700	76,100	81,600	65,600
2	70,300	59,500	80,800	71,800	66,700	55,600	48,600	60,000	94,600	76,400	76,500	63,900
3	70,800	59,800	70,900	68,100	67,500	54,000	53,600	64,000	104,000	82,100	76,200	62,300
4	70,800	59,600	70,600	69,200	67,000	58,900	67,000	61,500	104,000	79,200	74,300	67,000
5	70,600	60,400	75,900	63,800	66,600	58,800	76,700	60,100	100,000	76,100	71,900	72,300
6	70,400	60,500	85,300	64,900	62,900	56,700	79,500	57,800	92,100	74,400	72,000	71,300
7	70,100	66,600	87,700	65,800	62,400	54,200	80,300	50,800	90,600	74,300	76,900	69,400
8	70,900	72,800	83,400	69,900	57,300	54,000	79,900	54,800	96,800	74,700	80,000	66,500
9	70,500	67,400	86,400	79,000	57,200	53,000	75,400	54,700	98,800	71,900	78,200	66,500
10	66,900	71,600	83,700	84,900	57,900	53,100	62,600	60,500	94,500	71,100	70,700	66,400
11	64,900	70,800	81,100	84,000	68,400	53,700	47,600	64,900	94,900	72,700	68,200	64,400
12	67,900	70,900	78,700	83,500	76,600	53,900	30,900	65,300	85,500	74,900	67,700	62,400
13	70,400	71,000	77,300	83,500	62,500	52,100	15,600	67,500	74,200	78,900	67,600	62,600
14	70,000	71,100	78,300	80,500	46,900	49,600	18,200	68,300	62,000	81,600	69,100	64,400
15	70,200	71,700	78,400	79,400	47,900	48,900	34,300	68,600	61,500	84,200	71,500	67,200
16	68,600	69,200	77,700	81,200	47,200	49,200	47,000	68,600	56,300	81,900	71,700	67,100
17	66,600	72,500	79,600	83,000	47,500	48,300	54,300	72,100	58,800	78,500	71,600	67,200
18	68,900	72,000	76,000	82,300	47,100	47,900	55,100	81,300	57,700	82,600	71,400	63,100
19	67,900	71,300	69,200	80,200	45,100	47,600	59,600	86,000	61,200	82,200	74,300	57,500
20	69,400	67,700	62,000	80,600	44,500	47,700	54,100	86,000	73,300	78,400	76,200	57,800
21	69,700	56,500	64,200	84,400	41,200	48,300	48,600	86,100	81,400	80,900	76,600	58,200
22	70,300	48,200	65,700	78,600	40,600	47,300	54,100	93,500	81,000	82,200	75,700	58,000
23	70,100	50,400	65,200	68,200	40,700	48,100	52,500	96,300	78,500	83,700	75,000	57,900
24	77,400	50,300	63,300	62,700	41,100	47,600	47,900	99,400	78,500	83,600	75,000	57,700
25	85,300	50,000	66,500	60,800	41,900	47,000	49,600	98,000	77,000	83,200	79,600	52,900
26	85,400	50,100	72,700	58,100	40,700	46,900	52,600	102,000	80,300	82,100	80,100	47,100
27	85,100	53,200	77,300	56,500	43,900	48,100	54,300	102,000	80,300	82,100	79,500	47,200
28	84,000	67,800	75,900	52,700	47,800	49,400	54,600	98,700	75,600	80,900	74,800	48,600
29	85,600	82,800	75,900	52,200		48,600	53,700	98,500	74,600	79,500	72,000	48,900
30	85,700	84,400	75,100	59,000		48,900	55,900	95,300	76,500	81,600	66,300	49,100
31	70,900		76,200	67,100		49,000		92,000		83,800	65,100	
Mean	72,800	64,700	75,700	72,000	53,700	50,800	53,800	76,400	81,200	79,200	73,800	61,000

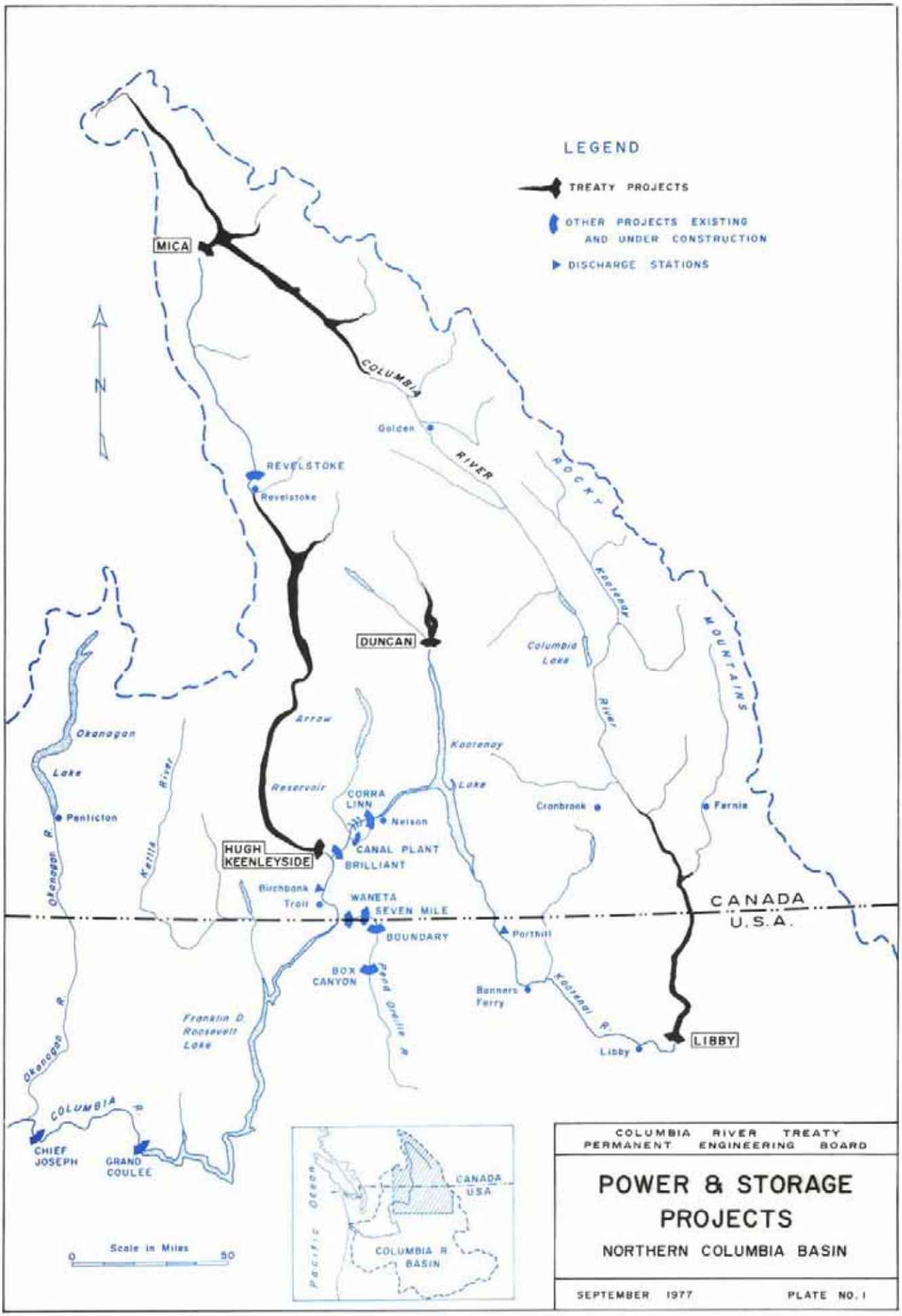
COLUMBIA RIVER AT BIRCHBANK, B.C.—Daily discharges for the year ending 30 September 1977 in cubic feet per second.

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	10,600	21,400	16,800	19,000	9,670	6,270	14,000	13,800	6,910	11,100	4,940	4,710
2	11,900	16,800	12,200	18,900	10,200	15,200	13,900	14,500	7,180	10,700	9,360	4,640
3	14,300	16,200	11,500	20,700	10,300	19,600	14,100	22,400	7,090	5,830	9,750	4,630
4	14,300	16,000	11,200	21,400	14,900	20,400	7,220	24,400	7,340	4,320	9,190	4,880
5	14,300	15,900	11,100	19,400	16,500	12,400	12,900	23,900	7,830	4,330	15,100	5,200
6	12,700	18,700	11,800	19,600	11,100	4,920	13,900	21,600	7,700	4,140	14,900	4,950
7	11,800	21,400	13,300	20,600	11,500	4,450	14,600	18,700	9,600	8,410	10,700	5,840
8	17,000	21,400	13,600	19,100	15,800	7,980	15,300	11,100	9,040	11,400	4,800	8,000
9	16,700	21,700	13,400	21,200	19,900	9,030	15,900	10,500	8,560	10,600	9,480	4,540
10	12,800	21,700	13,900	21,300	21,400	15,100	7,670	11,100	7,570	11,700	6,940	5,960
11	11,800	21,700	13,600	20,800	22,000	20,300	6,900	11,900	7,110	11,300	7,190	4,680
12	12,100	21,700	11,200	18,500	16,600	17,800	14,600	11,300	6,810	12,100	4,470	4,610
13	14,900	16,400	10,900	12,800	5,160	5,610	15,600	10,300	6,650	11,800	4,470	4,620
14	16,200	5,900	13,100	15,700	5,740	5,200	15,900	9,850	6,560	12,200	4,640	4,370
15	16,200	6,570	13,800	15,400	20,000	11,900	10,500	9,550	6,400	11,900	4,550	4,840
16	16,100	17,400	14,700	6,340	22,200	12,100	8,740	9,160	7,840	11,600	7,690	4,950
17	15,900	9,550	14,400	7,050	18,000	7,960	6,290	9,060	6,010	10,000	13,900	5,430
18	16,000	15,400	15,400	16,000	5,460	8,140	6,060	12,700	5,780	5,920	14,000	4,950
19	16,200	15,700	19,700	11,000	4,890	7,590	5,880	8,720	5,550	9,390	13,200	4,960
20	18,800	15,300	18,100	6,450	4,770	4,550	5,730	8,290	5,420	13,100	10,800	8,900
21	20,000	9,440	17,100	5,040	4,760	4,760	5,560	8,260	5,420	14,300	4,120	9,310
22	18,100	9,740	16,600	4,260	4,390	13,900	9,020	8,440	5,020	14,400	4,580	9,260
23	17,700	17,400	16,200	4,230	6,370	14,200	9,920	8,390	4,990	14,500	7,360	9,220
24	19,600	15,500	19,000	5,080	15,900	14,300	7,660	8,430	4,870	14,400	8,520	5,820
25	20,500	13,500	19,200	9,700	16,500	14,400	9,960	8,050	4,750	13,500	7,550	4,980
26	20,500	10,500	19,500	12,000	5,350	10,000	20,000	7,740	5,270	12,900	7,440	4,980
27	18,600	9,920	19,500	14,400	4,810	7,530	20,900	7,600	4,870	15,600	6,730	8,680
28	18,100	9,990	19,600	14,700	4,570	4,940	21,100	7,220	4,570	15,500	4,460	12,000
29	20,300	21,300	19,000	14,500		17,300	21,300	7,020	8,090	15,300	5,180	19,700
30	20,900	30,800	18,900	4,040		13,300	21,200	6,810	10,700	15,100	6,000	20,800
31	21,300		18,900	3,940		14,000		6,790		7,960	4,720	
Mean	16,300	16,200	15,400	13,700	11,700	11,100	12,400	11,500	6,720	11,100	7,960	7,010

KOOTENAI RIVER AT PORTHILL, IDAHO—Daily discharges for the year ending 30 September 1977 in cubic feet per second.

APPENDIX D

PROJECT INFORMATION



COLUMBIA RIVER TREATY
PERMANENT ENGINEERING BOARD

POWER & STORAGE PROJECTS

NORTHERN COLUMBIA BASIN

SEPTEMBER 1977 PLATE NO. 1

TABLE 1

DUNCAN PROJECT

Duncan Dam and Duncan Lake

Storage Project	
Construction began	17 September 1964
Storage became fully operational	31 July 1967
Reservoir	
Normal Full Pool Elevation	1,892 feet
Normal Minimum Pool Elevation	1,794.2 feet
Surface Area at Full Pool	18,432 acres
Total Storage Capacity	1,432,500 ac-ft
Usable Storage Capacity	1,400,000 ac-ft
Treaty Storage Commitment	1,400,000 ac-ft
Dam, Earthfill	
Crest Elevation	1,907 feet
Length	2,600 feet
Approximate height above riverbed	130 feet
Spillway—Maximum Capacity	47,700 cfs
Discharge Tunnels—Maximum Capacity	20,000 cfs
Power Facilities	
None	

TABLE 2

ARROW PROJECT

Hugh Keenleyside Dam and Arrow Lakes

Storage Project	
Construction began	March 1965
Storage became fully operational	10 October 1968
Reservoir	
Normal Full Pool Elevation	1,444 feet
Normal Minimum Pool Elevation	1,377.9 feet
Surface Area at Full Pool	128,000 acres
Total Storage Capacity	8,337,000 ac-ft
Usable Storage Capacity	7,100,000 ac-ft
Treaty Storage Commitment	7,100,000 ac-ft
Dam, Concrete Gravity and Earthfill	
Crest Elevation	1,459 feet
Length	2,850 feet
Approximate height above riverbed	170 feet
Spillway—Maximum Capacity	240,000 cfs
Low Level Outlets—Maximum Capacity	132,000 cfs
Power Facilities	
None	

TABLE 3

MICA PROJECT

Mica Dam and McNaughton Lake

Storage	
Construction began	September 1965
Storage became fully operational	29 March 1973
Reservoir	
Normal Full Pool Elevation	2,475 feet
Normal Minimum Pool Elevation	2,320 feet
Surface Area at Full Pool	105,600 acres
Total Storage Capacity	20,000,000 ac-ft
Usable Storage Capacity	
Total	12,000,000 ac-ft
Commitment to Treaty	7,000,000 ac-ft
Dam, Earthfill	
Crest Elevation	2,500 feet
Length	2,600 feet
Approximate height above foundation	800 feet
Spillway—Maximum Capacity	150,000 cfs
Outlet Works—Maximum Capacity	37,400 cfs
Power Facilities	
Designed ultimate installation	
6 units at 435 mw	2,610 mw
Power commercially available	December 1976
Present undertaking	
4 units at 435 mw	1,740 mw
Head at full pool	600 feet
Maximum Turbine Discharge	
of 4 units at full pool	40,000 cfs

TABLE 4

LIBBY PROJECT

Libby Dam and Lake Koocanusa

Storage Project	
Construction began	1966
Storage became fully operational	17 April 1973
Reservoir	
Normal Full Pool Elevation	2,459 feet
Normal Minimum Pool Elevation	2,287 feet
Surface Area at Full Pool	46,500 acres
Total Storage Capacity	5,809,000 ac-ft
Usable Storage Capacity	4,934,000 ac-ft
Dam, Concrete Gravity	
Deck Elevation	2,472 feet
Length	3,055 feet
Approximate height above riverbed	370 feet
Spillway—Maximum Capacity	145,000 cfs
Low Level Outlets—Maximum Capacity	61,000 cfs
Power Facilities	
Designed ultimate installation	
8 units at 105 mw	840 mw
Power commercially available	24 August 1975
Present undertaking	
4 units at 105 mw	420 mw
Head at full pool	352 feet
Maximum Turbine Discharge of 4 units at full pool	19,625 cfs