Report of the International Joint Commission
Canada and United States

on the

COOPERATIVE DEVELOPMENT
of the

PEMBINA RIVER BASIN

OCTOBER 1967
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The Canada-United States boundary from the Atlantic to the Pacific Ocean is almost 4,000 miles long. Many water problems inevitably arise along the common frontier. This report is concerned with one of the problems in the mid-west where precipitation is low and irregular and where reservoirs on transboundary streams could store water or control floods.

Projects could be undertaken unilaterally by each country or on a cooperative basis by the two countries. In the latter case apportionment of water and sharing of costs would become important matters to be agreed upon by the two Governments.

In 1948, the Governments of Canada and the United States requested the International Joint Commission to investigate and report upon the existing and future uses of the waters of common interest to Canada and the United States in the Souris and Red Rivers Basins, and if considered advisable, to recommend an apportionment of such waters. The Pembina River, being a tributary of the Red River, was included in the area investigated.

Studies of the Pembina River Basin were undertaken unilaterally in each country in the decade prior to 1960. Such studies disclosed that potential multi-purpose developments for flood control, water supply or irrigation in either country would not be justifiable economically on the basis of benefits in one country alone.

The International Joint Commission in the course of its studies under the Souris-Red Rivers Reference of 1948 instructed its International Souris-Red Rivers Engineering Board to prepare a preliminary report on the feasibility of a cooperative undertaking by both countries to develop the water resources of the Pembina River. The Commission, on the basis of the resulting report, recommended to the Governments of Canada and the United States, in a letter dated April 12, 1961, that they consider transmitting to the Commission a reference specifically pertaining to the waters of the Pembina River Basin.

On April 3, 1962, the Governments of Canada and the United States requested the International Joint Commission to investigate and report on measures to develop the water resources of the Pembina River Basin in
Manitoba and North Dakota and determine what plan or plans of cooperative development would be practical, economically feasible and to the mutual advantage of both countries, having in mind domestic water supply and sanitation, control of floods, irrigation and other beneficial uses.

The Commission was asked specifically to recommend what plan or plans would best meet the above purposes and requirements, to estimate the costs, benefits and any adverse effects of carrying out such plan or plans, to recommend how the available water should be apportioned in order to achieve the above benefits, and to recommend how the cost of carrying out such plan or plans might be apportioned between Canada and the United States.

The text of the Reference from the two Governments is quoted in full in the Appendix.
SECTION II

CONDUCT OF THE INQUIRY

In accordance with its usual procedure in such investigations, the Commission appointed three senior officials from appropriate agencies in each of the two countries to its International Pembina River Engineering Board. They were experienced engineers from the Canadian Departments of Agriculture, and of Energy, Mines and Resources and the United States Departments of the Interior and of the Army. A list of the members of the Board, its Committee and participating agencies is set out in the Appendix.

The Board was directed to carry out, through appropriate agencies in the two countries, the necessary technical investigations and studies, and, to avoid duplication of effort and unnecessary expense, make use of the information and technical data acquired by the International Souris-Red Rivers Engineering Board and technical agencies in both countries.

Over the course of the next three years, as its work progressed the Board submitted five semi-annual progress reports. At the conclusion of its study the Board presented a report dated December 1964 supported by twelve comprehensive appendices. In October 1965 the Commission, after reviewing the report, asked the Board to re-examine two of the proposed plans, which called for construction of a dam in each country, and to indicate the extent to which the construction schedule might be varied in order to meet the immediate needs of each country; and to ascertain the advantages and disadvantages to each country of implementing construction in stages. The Board indicated in March 1966 that construction in stages would not be advantageous as compared to construction in three consecutive years.

The Commission inspected the Pembina River Basin, the proposed dam sites, the irrigable areas and communities that would benefit on August 12, 1962.

The Commission made the Board's report available to the public and then held public hearings at Manitou, Manitoba and Walhalla, North Dakota on June 9 and 10, 1965.

After deliberating on the Board's report and representations made at public hearings, the Commission undertook additional studies to determine the modifications required in the proposed plans in order to best meet the
purposes and requirements set forth in the Reference from the two Governments. Throughout these studies the Commission's major objectives were to:

Formulate a plan for cooperative development that would achieve a high degree of optimization of net benefits for the entire Pembina River Basin, considering all potentials for the management of its water resources;

Devise arrangements under which participation in the cooperative development would provide a net advantage to each country as compared with the advantages of any alternative courses of action available to it and under which the net advantages to each country would be reasonably equivalent; and

Determine what apportionment of water would be equitable in the light of all pertinent considerations and at the same time practicable for the accomplishment of the cooperative development.
SECTION III

THE RIVER AND ITS BASIN

The Pembina River Basin is approximately 80 miles southwest of Winnipeg, Manitoba and 160 miles north of Bismarck, North Dakota. It lies astride the international boundary between the Red River (known in the United States as Red River of the North) and the eastern edge of the Souris River Basin. See Figure 1.

Physical Features

The Pembina River Basin is approximately 130 miles long and varies in width from 18 to 52 miles. The area of the watershed west of Walhalla is 3330 square miles of which 1990 are in Canada and 1340 in the United States.

Between the Red River and the Pembina Escarpment, a distance of 35 miles, is an unusually smooth plain with regular slopes gently varying from nearly flat to 10 feet per mile. In this reach the Pembina River has cut a meandering channel 10 to 30 feet below the featureless plain which was once the bed of an ancient glacial lake.

Immediately west of Walhalla the Pembina Escarpment abruptly rises 500 feet to a drift prairie plateau interspersed with irregular hills, undulating plain, flat areas, poorly drained depressions, and the Pembina Valley.

For about 130 miles below Pelican Lake the Pembina Valley is terraced, approximately 200 feet deep and 2 miles wide. In this reach alluvial and sedimentary deposits from deep coulees have formed natural dams creating a series of shallow lakes. For the next 40 miles to Walhalla, the “V” shaped valley is characterized by slump blocks and soil creep and is about a mile wide and 400 feet deep. East of Walhalla the valley rapidly decreases in size and within 15 miles disappears. Further downstream, the river banks are at the same or slightly above the elevation of the adjacent broad flat plain.

The main stem of the Pembina River rises in Canada, flows in an easterly direction in a deeply incised glacial valley for 200 miles through southern Manitoba before crossing into North Dakota. It then winds gently to the east for a further 110 miles to its mouth on the Red River, two miles south of the
international boundary. It drops from elevation 2000 feet at its source to elevation 750 feet at its mouth.

Above Walhalla, the principal tributaries of the Pembina River are Badger Creek, Long River and the Little Pembina River. Below Walhalla, the Tongue River joins the Pembina a few miles above its confluence with the Red.

Climate

The climate in the Basin is characterized by wide variations in temperature and rainfall. Average monthly temperatures vary from 67°F in July to 2°F in January. Extreme temperatures of 112°F and —54°F have been recorded. The mean effective growing season is about 155 days. The average frost free period is 124 days.

The average annual precipitation is about 18 inches. Average monthly precipitation ranges from 3.2 inches in June to 0.6 inches in February. Rainfall during the growing season is rarely more than 13 inches. Severe drought conditions were experienced during the 1930’s and more recently in
Low flow conditions on the Pembina River, August 15, 1967

1961. Snowfall, averaging 38 inches annually, is approximately 21 per cent of the total precipitation. The estimated gross evaporation in the Pembina Basin is 28.5 inches.

Runoff

The maximum stream flow of the year usually occurs in the latter part of March or in April, following the spring snow melt. Occasionally these high flows are increased and prolonged by accompanying rains. Following the spring runoff the flow rapidly decreases and usually remains low during the summer and fall months. Winter flows are very low or negligible.

During the period from 1921 to 1957 when hydrometric records were maintained, the average annual runoff of the Pembina River near Manitou was 73,000 acre feet. It has varied from approximately 1,000 to 245,000 acre feet. Similarly, during the period from 1921 to 1962 the average annual runoff at Walhalla was approximately 112,000 acre feet. Recorded extremes ranged from approximately 2,000 to 461,000 acre feet.

Economy

In considering the economic factors related to the development of the Pembina it is necessary to take into account not only the Basin itself but also the adjacent areas which might be affected. For this reason the area immedi-
ately north of the Basin bounded by the escarpment, an east-west line through Morden, and the Red River is included in the economic appraisal.

The population of this total area is approximately 63,000 with 38,000 residing in Manitoba and 25,000 in North Dakota. Except for relatively high population densities in the urban communities, the population is less than 10 persons per square mile. The principal towns in North Dakota are Langdon, Walhalla, and Cavalier; and in Manitoba are Morden, Winkler, Altona, Killarney, and Boissevain.

The most important resource of the Basin is fertile soil. The area between the escarpment and the Red River is regarded as one of the best agricultural areas in either country. Climatic conditions and intensive use of land, particularly in the area south of Winkler, permit the growing of specialty crops. In addition to wheat, major crops include oats, barley, hay, flax, rye, sunflower seed, potatoes, sugar beets and vegetables. In recent years there has been a noticeable shift from cash grains to livestock.

The area is well supplied with rail transportation. A network of primary and secondary all-weather highways is adequate for commercial trucking in the area.
Industry is limited largely to food processing such as vegetable oil, vegetable canning, poultry eviscerating, food packaging, bakeries, potato chips and cat food. Employment throughout the region is principally in agriculture, related industries and service enterprises.
Flood damage occurs on the broad flat plain east of the Pembina Escarpment. Flood flows from the Pembina River have escaped overland, some to the Tongue River Basin in the United States and some to the Plum River.
Pembina, North Dakota during the spring flood of 1950

Watershed in Canada. Although the Pembina floods do not usually coincide with flood peaks on the Red River, they do contribute to the magnitude and duration of major floods on the Red. It has been estimated that a flood equal to the magnitude of that of 1950 would, on the basis of 1963 prices, cause $2,730,000 damage along the Pembina River in the United States and $1,558,000 in the Gretna-Altona area in Canada; and when combined with the Red River flood peak of 1950 would cause $2,290,000 in the area near the mouth of the Pembina River and $11,278,000 between Emerson and Winnipeg.

Water Supply

Industries dependent on agricultural products have been reluctant to locate in the area because water supplies from the Pembina are not reliable. Ground water supplies are very limited and contain iron, sulphates and dissolved solids in quantities which exceed accepted drinking water standards. It has been estimated that the municipal and industrial water needs from the Pembina River in the year 2010 will be 0.6 million US gallons per day in the United States and 3.4 million US gallons per day in Canada. Supplies to meet these needs cannot be assured under existing conditions.
**Water Quality**

Water quality in the Pembina River below Walhalla during low flow conditions is extremely poor. At times, the dissolved oxygen content has been zero and the biochemical oxygen demand as high as 15 parts per million. A supplemental flow is needed to dilute waste effluents and compensate for channel losses in this reach of the river.

Assuming that the wastes from each of the communities and industries concerned will receive adequate treatment prior to being discharged to the River, it is estimated that the supplemental flow required will increase from 2 cfs at present to 3 cfs by the year 2010. This supplemental flow for quality control cannot be assured under existing conditions.

**Moisture Deficiency**

Agricultural risks associated with marginal and variable rainfall have strongly influenced the selection of crops, farm practices, and the economy of the area. The success of agriculture and its related industries is primarily dependent on the adequacy and timely occurrence of rainfall during the growing season. Moisture required for full crop production is approximately 20 inches a year, if ideally distributed. Precipitation during the growing season seldom exceeds 13 inches. During the past 42 years the annual moisture requirements to supplement rainfall have varied from 6 to 14 inches, and during six years of drought exceeded 12 inches a year.

The soils near the base of the Escarpment between Walhalla and Winkler are generally deep and fertile. They are free from harmful concentrations of salts and sodium and have adequate water holding capacity. The topography is excellent. The barrier to ground water movement is the dense lake clays, found from 6 to more than 30 feet below the ground surface in the arable lands. The relatively shallow depth to the underlying clay barrier in the southern portion imposes a drainage problem.

The economy of the area, which is almost entirely maintained by agriculture, suffers from the inadequacy of moisture supplies during the growing season.

**Recreation**

Adequate water related recreational facilities such as boating, water skiing, fishing, picnic and camping areas are lacking in much of the Pembina River Basin. Recreational use has been confined to Rock and Pelican Lakes. They are shallow and subject to fluctuation of levels and in consequence boating activities are limited. Bone, Overend and Swan Lakes are extremely shallow and have a slough-like appearance. Heavy algae growths have occurred in all Pembina Valley Lakes in Canada. Toxic algae were prevalent in Pelican and Rock Lakes in the summer of 1962. Residents of the northeastern part of North Dakota must travel considerable distances to recreational areas because few natural lakes exist in that part of the State.
Game Fish

Game fish production is marginal in Pelican and Rock Lakes despite good water quality and an apparently adequate food supply. The other lakes are incapable of supporting a year-round fish population. Lakes in this region with less than 10 feet of water regularly undergo severe winter kills in which nearly all fish are lost. Even lakes with depths ranging from 10 to 20 feet have heavy losses in 10% to 50% of the winters.

Fishing in the lower portion of the Pembina River is restricted to the period of spring high water when fish move upstream from the Red River. Present conditions are not conducive to the support of game fish of good quality.

Present Use

The water resources of the Pembina River Basin have been developed only to a modest extent. Current use is limited to supplying water for the communities of Altona, Gretna, Neche and Pembina, of which the combined population in 1960 was 3,800. The total capacity of their water treatment plants is 900,000 US gallons per day.
Water Treatment Plant at Neche, North Dakota

The River and its tributaries receive wastes from nine communities, all of which either treat or have plans for treatment of waste water.
Water Tower at Gretna, Manitoba
SECTION V

THE BOARD’S INVESTIGATION

The Board’s comprehensive investigation included topographic, soil and geological surveys; collection and analysis of hydrological and economic data; hydraulic studies, preliminary designs and cost estimates; evaluation of potential benefits; and project formulation studies. All segments of the field and office studies proceeded simultaneously. During the conduct of the investigation the Board, its engineering committee and representatives of the participating governmental agencies in both countries held numerous meetings to coordinate studies and procedures so the results obtained would be comparable. Details are in the Board’s report and its twelve appendices.

**Field Surveys**

Foundation drilling and seismic refraction surveys were undertaken at three dam sites. Laboratory tests were run on the soil samples taken to determine the stability of the embankment, foundation conditions, the design of the earthfill dams, the location of the spillways, conduits and sources of construction materials.

Topographic maps with a scale of 1:4800 and a contour interval of 10 feet were prepared from aerial photographs covering the Pembina River Basin. In addition, detailed topographic maps with one foot contours and a scale of 1:4800 in North Dakota and 1:2400 in Manitoba were prepared for the potential irrigable areas.

A detailed land classification was made to determine the extent, nature and class of land suitable for irrigation. The potential irrigable area was classified according to soil, topographic and drainage characteristics. The soil survey and land classification covered 38,000 acres in Manitoba and 26,000 acres in North Dakota.

Water samples taken from five stations were analysed to determine if the waters of the Pembina River were suitable for sustained irrigation without special practices and if they would meet the standards for drinking water. Measurements were also made to determine the suspended sediment and bed load material carried by the Pembina River. These data were used to calculate the sediment storage requirements.
Hydrology and Hydraulics

Climatic and hydrometric data were analysed to determine the magnitude and frequency of floods, the duration of low flows, water yield from various portions of the Basin and evaporation losses.

To assist in the determination of run-off, the drainage basin above Walhalla was classified into contributing or non-contributing areas. The non-contributing area was defined as that portion of the basin that would, on the average, contribute to stream flows not oftener than once in 10 years.

Frequency curves for annual peak flows and total annual volumes were computed statistically. Low flow frequency curves were prepared using historical references, observed flows and meteorological records. Probable maximum spring and summer floods were computed using either unit or synthetic hydrographs and the maximum probable run-off from snow melt and heavy summer storms. These reflected the most severe combination of meteorologic and hydrologic conditions that could be expected. In addition, the hydrograph of a standard project flood was computed for Pembilier Dam. Hypothetical hydrographs were prepared for flood frequencies ranging from 2 to 500 years for use in reservoir operation studies.

The maximum probable floods were routed through the reservoirs to determine spillway capacities and freeboard requirements. These data were used in the hydraulic design of spillways, conduits and control gates.

Flood Damage and Flood Control

The Board reviewed stream flow records of past floods, examined the drainage and run-off problems of the area between the Pembina Escarpment and the Red River and delineated the areas subject to flooding. The physical damages caused by the 1948 and 1950 floods to agricultural interests, and to residential, commercial and public properties were evaluated.

The evaluation of crop losses took into account reduction in yields due to late planting, reseeding costs, weed infestation and increased operating costs. Estimates of urban flood damage took appropriate account of reductions in the market value of residences, commercial establishments and public buildings. Account was also taken of physical damage to land, equipment, merchandise, streets, walks, parks and public utilities; and costs incurred through flood emergencies. Information was obtained by interviews and inspection. These data were supplemented by information contained in the Report of the (Manitoba) Royal Commission on Flood Cost Benefit, dated December 1958.

Analysis of the economy of the area indicated that future growth would proceed at a uniform rate. Projection beyond 50 years was not warranted because of uncertainties in forecasting future economic conditions. The Board projected the economic growth of the flood plain for the first 50 years and for the remaining 50 years of the project life used the highest level thus reached.
Discharge-area flooded and discharge-damage curves for the various areas and centres affected were prepared for floods of varying frequencies. Storage on the Pembina River would only on very rare occasions reduce the flood stage at Winnipeg since the construction of the Red River Floodway, Shellmouth Reservoir and Portage Diversion is expected to provide almost complete protection. For this reason flood control benefits for Greater Winnipeg were not considered.

The flood control measures investigated included storage at Pembina and Pembilier Reservoir sites and channel improvement in the lower 70 miles of the Pembina River. The Pembilier site which is nearest the area of damage was found to be the most effective. Downstream channel improvement was not feasible either as an independent project or when combined with Pembilier Reservoir.

Three reservoir sizes at the Pembilier site were used to determine the flood control benefits along the Pembina River. Floods were routed through reservoirs with capacities sufficient to control 12-, 40- and 200-year volume frequency floods. The resulting flood frequency curves, modified by storage in the reservoir, formed the basis for determining the average annual flood control benefits.

A similar but more complex method was employed to determine the flood control benefits along the Red River.

**Irrigation**

Investigation of the area between Walhalla, North Dakota and Winkler, Manitoba for irrigation took into account water requirements for irrigated crops, the reservoir storage necessary to support the irrigable area, the preliminary design and cost of the distribution systems, and the potential irrigation benefits.

The irrigable area was defined as the area which met all the land classification standards for irrigation and could be economically served by the project works. The productive area was defined as the land that would actually be irrigated after deducting the area needed for farm roads, ditches, drains, buildings and other such non-productive purposes. In Canada, the deduction for non-productive areas was 10%. In the United States where farm units were larger than in Canada, it was 6%. The productive area was used to derive the water requirements and benefits so that project formulation in each country would be directly comparable.

The water requirement per productive acre was determined by first computing the consumptive use by the Lowry-Johnson method. This amount was distributed monthly in accordance with accepted methods. The crop irrigation requirements for each month were then calculated by deducting the effective precipitation from the consumptive use for the period 1921-1962. The farm irrigation efficiency was assumed to be 57%. It took into account percolation, run-off, evaporation and losses in farm ditches. Monthly irrigation diversion requirements were then calculated for irrigable areas varying
from 7,000 to 32,000 productive acres. Seepage losses in canals and laterals were estimated by the Moritz formula. Operational losses were assumed to be 10%. Curves based on peak demand and other operational requirements were developed to determine the design capacities of canals and laterals.

The reservoir operation studies took into consideration the monthly irrigation diversion requirements, a limit on irrigation diversions when necessary during a critical drought period, an upstream reservation of 12% of the water yield for non-project purposes, an annual allowance of 10,000 acre feet for municipal and industrial water supply, and the multi-purpose use of a portion of Pemblier Reservoir capacity.

The maximum storage requirement was computed by assuming that the reservoir would be empty at the end of the critical period as a result of the withdrawals for irrigation and municipal demands and reservoir evaporation losses. Estimated inflows throughout the critical drought period were taken into account. As a check, reservoir operation studies for 10,000 and 20,000 productive acres were made for the full 42 year study period using recorded inflows, releases for various uses, evaporation losses, spillage and reservoir content by months. The results of all these calculations were plotted on storage requirement-productive acreage curves which were subsequently employed for project formulation purposes.

Comparable studies of irrigation distribution layouts were investigated by Canadian and United States agencies. Five separate irrigation schemes varying in size from 7,500 to 16,670 productive acres were examined in Canada. In the United States, a representative or median basic unit of 9,914 productive acres was studied in detail. The irrigation studies took into consideration land classification; the location and size of laterals; appurtenant works such as drops, checks, farm turnouts, bridges and culverts; surface and tile drainage; and land preparation on the irrigated farms.

The United States agencies prepared a detailed cost estimate for the basic unit of 9,914 productive acres. They assumed that the cost of distribution and drainage works and of land preparation, operation, maintenance and replacement costs for larger or smaller productive acreages would be proportional to the costs for the basic unit. On the other hand, the Canadian agencies prepared detailed cost estimates for the five alternative schemes. Cost estimates for intermediate productive acreages were obtained by interpolation.

The economic analysis to determine the irrigation benefits required a translation of physical effects into dollar values. The comparable appraisal of the agricultural economy in both countries took into account the type, size, tenure and value of the existing farms. It also considered the organization of the farms in respect to land use, livestock, crop yields, cultural practices, capital investment and farm income.

Detailed farm budget analyses were used to calculate the economic agricultural potential of the irrigable areas in both countries with and without irrigation. The increase in the net farm income due to irrigation was construed to be the irrigation benefit.
In Canada, the farm budget analysis was based on a composite 240 acre farm with 135 irrigable acres. For the purpose of the analysis the composite farm was assumed to be a small scale replica of the total irrigable area as far as soil classification, land use, crops and livestock were concerned. The Canadian analysis also assumed a 10 year farm development period and the 1959-61 price level for farm products and prices paid for imports.

In the United States, the farm budget analysis was based on all the 44.3 dry land or 58.5 irrigated farms in the basic unit containing 10,547 irrigable acres. All irrigated farms were assumed to be operated in conjunction with dry farmland. The United States analysis also assumed a development period of five years and a price index of 250 for prices received and 265 for prices paid by farmers. The farm budget method was also used to determine the payment capacity of irrigated farms in the United States.

The results of these computations provided estimates of direct benefits per productive acre which were used in the project formulation. In addition, the indirect and public benefits of irrigation were estimated for each country. Benefit-cost analyses were made, both with and without the indirect benefits.

**Municipal Water Supply and Water Quality**

The Board investigated the quality and quantity of available ground and surface water; examined the waste treatment facilities of communities within the drainage basin of the Pembina River; estimated the future needs of water for municipal and industrial purposes and water for quality control in the lower reach of the Pembina River; calculated the storage requirements to provide 10,000 acre feet annually for municipal, industrial and quality control purposes for the critical drought period; analysed six independent developments which could supply the Canadian needs, the only independent alternative to meet the United States needs, and two joint Canada-United States single purpose schemes to meet the needs of both countries.

A plan utilizing the multi-purpose reservoirs, the main supply canal and trunk pipelines to convey water to the various towns was formulated. The plan provided for two large dugout type reservoirs to be used for storage during the winter months and periods of high irrigation demand. The plan did not include water treatment plants nor distribution facilities within the local communities.

It was assumed that the benefits attributable to water supply and water quality control would be equal to the cost of providing equivalent water to meet the expected needs by the most economical alternative means that would likely be utilized in the absence of a possible cooperative development.

**Recreation**

The Board examined the utilization of existing facilities within the Basin and evaluated the potential recreational benefits and damage to existing facilities that might result from the reservoirs under consideration.
The selection of the recreational sites on the banks of the reservoirs took into consideration the fluctuation of water levels during the recreational season, the expanse of water fronts, scenery, accessibility and the suitability for swimming beaches, boat launching sites, camping facilities and picnic areas. Cost estimates were prepared for the development of each recreational site.

The recreational benefits were assumed to be $1.00 per visitor day. The estimate of the visitor days took into consideration the distance from major population centres, the competition for the recreational market and the growth of population within the zone of influence.

Fish and Wildlife

The investigation of fish and wildlife resources was based upon the results of separate studies and the views of representatives of fish and wildlife agencies in each country. Assessments were made of the wildlife losses which would be caused by each reservoir to the habitat of white-tail deer, game birds and fur-bearing animals. Evaluations were made of the benefits attributable to each reservoir in terms of increases in quantity and improvement of quality of game fish that would result from better flow conditions and the creation of deep pools.

Project Formulation

After selecting three principal reservoir sites, 15 plans were formulated to reduce the recurring flood damages caused by the Pembina River, irrigate arable lands between Walhalla and Winkler, provide adequate water supplies for communities east of the Pembina Escarpment, control the water quality in the lower reaches of the Pembina River, create water-based recreational facilities and improve the habitat for fish.

The Board assumed, for design purposes only, that the available water would be equally divided between the two countries; that the lower portion of the flood control space in the reservoirs would also be used for recreation and other water needs; that the project life would be 100 years; that the anticipated growth and development of the economy would be projected for the first 50 years and held at a constant level thereafter; that the price levels used in all cost estimates would be based on July 1, 1963 price levels in each country; that the value of the currency of each country would be equal; that an interest rate of 4 percent, the average of applicable interest rates in both countries, would apply; and that all analyses would be based on primary benefits.

The 15 plans considered included combinations of one or two reservoirs; pumping against a 58 feet head from the River near Walhalla to a canal flowing north to Winkler; diversion works permitting gravity flow to Winkler; and channel enlargement in the lower portion of the Pembina River. After a broad appraisal, five plans were selected for detailed examination.

Cost estimates were prepared for six sizes of Swan Lake Reservoir with capacities varying from 172,000 to 632,000 acre feet, five sizes of Pembina
Reservoir with capacities varying from 70,000 to 375,000 acre feet, and three sizes of Pembilier Reservoir with capacities varying from 75,000 to 450,000 acre feet. These estimates included the cost of land damages, relocation of services, reservoir clearing, placing of embankment, and construction of spillway and outlet works. Unit prices were based largely on experience with the South Saskatchewan River Project; dams on the Missouri River and irrigation projects in the Midwest of both countries. The construction period was assumed to be three years for major works and for the water supply systems and one year for recreation facilities.

The annual costs, including interest, amortization, operation, maintenance and replacement charges, for various reservoir capacities at each site were then plotted on a series of curves. These curves, in conjunction with curves developed for irrigation and flood control benefits, were used to determine the reservoir capacities and the combinations of reservoirs at which net benefits would be maximized.

The project formulation studies used variations in the extent of each benefit as well as the inclusion or exclusion of benefits for each reservoir in the five plans. For example, the optimum size of Pembilier Reservoir was determined by selecting a value of flood control storage, holding it constant and then adding increments of irrigation and water supply storage until the optimum value of the total storage was determined. This procedure was repeated for several values of flood storage. The point of maximum net benefits was then obtained by plotting the flood control storage versus the net benefits for each computation. The results were checked by using the same procedure but holding the irrigation and water supply storage constant and varying the flood control storage.

A similar procedure was used in determining the optimum size of Pembina and Swan Lake Reservoirs when used in conjunction with Pembilier Reservoir. The formulation studies were the basis of selecting the use and size of each reservoir in the plans examined.

**Plans Presented by the Board**

The Board presented three plans of development for the Commission's consideration. The principal components of each plan were a pressure conduit, a main supply canal, and either one or two dams. The flood control, municipal and industrial water supply, and fishery benefits were essentially the same for all three plans. The irrigation and recreation benefits varied with each plan. The differences in the benefit-cost ratios of the three plans were relatively small.

**Plan 1** provided for one multi-purpose reservoir, Pembilier, located in the United States. The reservoir would have an effective capacity of 279,000 acre feet with 115,000 acre feet reserved for control of spring floods and 164,000 acre feet for irrigation and water supply. After the passage of spring flood the reservoir would be drawn down so that 80,000 acre feet of its capacity would be reserved for summer floods and 35,000 acre feet of
water retained for irrigation and water supply purposes during the following 9 months. The reservoir capacity used both for the purpose of storing the spring flood and for the purpose of retaining 35,000 acre feet for irrigation and water supply is termed dual-purpose storage. The plan envisaged irrigating 18,300 productive acres.

Plan 2 provided for a reservoir in each country; namely, the Pembilier Reservoir in the United States and Pembina Reservoir in Canada. In this plan the total effective capacity of Pembilier Reservoir, 110,000 acre feet, would be reserved for the control of spring floods. About 65,000 acre feet would be reserved for summer floods and 45,000 acre feet retained as dual-purpose storage. Pembina Reservoir would have an effective capacity of 246,000 acre feet. It would be used for storage of water for irrigating 21,300 productive acres and for water supply.

Plan 4 also provided for a reservoir in each country; namely Pembilier Reservoir in the United States and Swan Lake Reservoir in Canada. Pembilier Reservoir in this plan would have an effective storage capacity of 130,000 acre feet, with 110,000 acre feet reserved for the control of spring floods and 20,000 acre feet of storage for irrigation and water supply. About 60,000 acre feet would be reserved for summer floods and 50,000 acre feet of dual-purpose storage would be retained for irrigation and water supply. The total effective storage capacity of Swan Lake, 540,000 acre feet, would be reserved for irrigating 25,300 productive acres and for water supply.

The costs of the component parts of each plan were assigned directly to specific purposes or, in the case of reservoirs were designated as joint-use costs. The joint-use costs allocable to flood control and recreation were divided between the two countries in proportion to the annual benefits realized in each country. The joint-use costs allocable to irrigation and water supply were divided equally between the two countries to reflect the Board's basic assumption of equal use of water in each country for these purposes. Costs assigned to specific purposes were divided between countries in proportion to the use by each country. For example, Canada was assigned all costs of the main supply canal in Manitoba and 2/3 of the costs of the main supply canal in North Dakota while the costs of the pressure conduit were divided equally.

The ratio of the benefits realized by each plan to the costs associated with that plan was computed. The benefit-cost ratios for each country, when based on primary benefits, the above distribution of costs, 4% interest rate and a common dollar value, were slightly above unity for each plan. But when the then prescribed interest rate of 3½% in the United States and the then prevailing interest rate of 5% in Canada were applied the benefit-cost ratios were substantially increased for the United States portion of each plan while the benefit-cost ratios for the Canadian portion of each plan decreased to less than unity. In other words, the costs to Canada exceeded the primary benefits realized. When secondary irrigation benefits were added, the benefit-cost ratio for each plan was above unity for each country.
SECTION VI

PUBLIC HEARINGS

Following receipt of the Board's report on the development of the Pembina River Basin, the Commission sent copies to appropriate officials and interested individuals and made copies available for inspection at the 13 public offices indicated in the published notices. In addition, a summary of the Board's report and a notice of the public hearings were mailed to a large number of individuals and to all municipalities and elected representatives in the area. In accordance with the Commission's Rules of Procedure, notice of public hearings was also published in the Canada Gazette, the United States Federal Register and local newspapers in each country.

The public hearings held at Manitou, Manitoba and Walhalla, North Dakota on June 9 and 10, 1965 were well attended. All those interested were given an opportunity to convey relevant information to the Commission and express their views orally or in writing. Statements were made by elected representatives from all levels of government in each country, officials of governmental agencies, local organizations and private individuals. In all, sixty-two witnesses were heard. A list of persons who gave testimony is in the Appendix of this report.

The preponderance of testimony presented at the hearings favoured Plan 2 as best meeting the requirements of both countries. No one expressed opposition to the proposed development of the Pembina River Basin.

Testimony stressed the urgent need in the area for flood protection, irrigation, reliable water supply and water related recreation. Some witnesses were concerned about the doubtful economic feasibility of the Canadian portion of the project and urged that consideration be given to improving the feasibility of the Canadian portion so that the cooperative development could be justified in both countries. One witness stated that benefit-cost ratios were not nearly as significant as obtaining the maximum use from available resources. Some statements urged that control dams be constructed in both countries. Others were concerned with compensation for lands that would be flooded by the reservoirs, the allocation of water, severance of
established north-south communications in the Swan Lake area if Plan 4 were implemented, and construction of small dams on Swan, Rock and Pelican Lakes if Plan 2 were adopted.

Verbatim transcripts of both hearings are on file at the offices of the Commission.
SECTION VII

BASIC CONSIDERATIONS

In its inquiry and deliberations, the Commission found the basic considerations outlined hereunder of major significance and dominant importance in accomplishing the objectives of the study. As previously outlined, these objectives involve primarily the formulation of a cooperative plan for optimum use of the water resources of the Pembina River Basin that would be mutually advantageous to each country as compared with available alternative courses of action.

**Optimization**

A plan of cooperative development should provide for optimum use of the water resources of the Basin. The size and location of the control and conveyance works should be both practicable and economically justified and should permit the most beneficial use of the available water.

The Board’s comprehensive investigations, particularly the hydrological, water requirements and irrigation aspects, were in sufficient detail to permit the formulation of an optimum plan of development. Similarly, the Board’s thorough evaluation of the flood control, water supply, irrigation, recreation, and fishery benefits was adequate to permit a valid economic appraisal of the multi-purpose development. The cost estimates, though preliminary in nature, were adequate for determining the relative feasibility of comparative plans.

Full utilization and complete control of the water resources of the Pembina River Basin would require uneconomic storage facilities of great size capable of long carry-over periods. The Board’s formulation studies were designed to establish the practicability of accommodating various functions and to determine the optimum size of each reservoir. The dual-purpose storage of Pemblier Reservoir makes maximum space available for spring floods and retains as much of the spring runoff as possible to meet a portion of the demand for the current year while still providing ample storage capacity for periodic summer floods. Dual-purpose storage avoids unnecessary waste of water and increases the irrigable area.

Irrigation benefits are of particular importance in any plan for the optimum use of the waters of the Pembina Basin. In this regard the Board
calculated that 21,300 productive acres could be irrigated under Plan 2. There are 26,000 irrigable acres available in Manitoba and 16,000 in North Dakota, each with the same productive capacity per acre. Since the total of 42,000 irrigable acres is beyond the carrying capacity of the available water, the Commission gave consideration to the best location of the areas to be irrigated. Using identical unit prices, comparable design and standards for irrigation works, the same ratio of productive to irrigable areas and the same rate of development, the Commission found that 21,300 productive acres could be irrigated at minimum cost if they were located so that approximately 17,000 would be in Canada and 4,300 in the United States. Costs associated with the extension of the main supply canal, length and size of laterals, and extent of surface and sub-surface drains were taken into account.

This would reduce or exclude the acreage with which the higher costs are associated and add a corresponding number of acres in the north, at a much lower cost. Such action would be consistent with accepted methods of planning a project located wholly in one jurisdiction. The Commission considered these factors in the formulation of its optimum plan of mutual advantage to the two countries.

**Mutual Advantage**

A cooperative development between countries would be of mutual advantage if each country could thereby realize greater net benefits than it could by acting unilaterally.

A cooperative development should, in its totality, be practicable and justifiable economically. The total direct benefits realized by each country should exceed the total cost borne by that country.

A cooperative development should recognize all the multi-purpose aspects and if possible should be operated to mutual advantage for all purposes.

It is advantageous in a cooperative development to have a fair share of necessary works and operational responsibilities in each country. This would enable each country to benefit from the expenditure of construction funds in its territory and to have physical control over an integral part of the project, thus adding strength and continuity to the cooperative approach.

Flexibility is important in any plan of cooperative development of water resources. As long as the works affecting both countries are constructed and operated in accordance with an agreed plan, each country should be free to use its share of the waters as it sees fit, provided that in so doing there is no interference with the other country's use of its share. For example, neither country should be inhibited from using, for additional irrigation, water allocated to it for anticipated municipal needs; nor from using some of its water for purposes not foreseen at the time the agreed plan was formulated. Such unilateral changes in the use of water should not be considered justification for changing the basic terms of the agreed plan of cooperative development.
Independent Alternatives

Either Canada or the United States could make use of all the available waters of the Pembina River to improve the existing conditions in its own territory. Unilateral developments are physically possible in each country to put to use the waters in its territory. For example, Canada could build a high dam at the Pembina site, pump water over the height of land to Dead Horse Creek and thence by gravity convey all waters stored in the reservoir to the area south and east of Morden. Established downstream uses need not be harmed. Similarly, the United States could build a low dam at the Pembilier site and use all the water it could thus control. Such independent developments, however, would limit the capabilities of each country to control and utilize the waters of the Pembina Basin as compared to cooperative action. Furthermore, there have been unilateral studies indicating that such major independent developments considered would not be economically feasible.

Equivalence of Benefits and Costs

Interest rates, and hence interest costs, as well as other costs of a project such as labour and materials, vary from time to time and from country to country. In calculating for each country the annual costs of works constructed and operated in its territory, such items as wage rates, value of currency, prices of materials, and interest rates prevailing in that country should be used in determining its costs. Account should also be taken of the extent to which expenditures, to realize specific benefits such as irrigation, recreation and water supply, and for settlers assistance and pre-authorization charges differ from one country to the other.

It is recognized that secondary, public and intangible benefits would result from the development of the Pembina River. However, the Commission considers that the primary or direct benefits should be controlling in the determination of the economic advantage to each country.

The estimates of benefits should take cognizance of differences between the countries in such factors as the value of property protected from floods, the value of water-related recreational facilities, the size of irrigated farms, the rate of their development and the agricultural price structure. The benefits derived from agricultural products vary not only with the demand for such goods in each country but also with the national policy of each country in such matters as price support.

All such differences in both costs and benefits in each country should be recognized and taken into account in determining the equitable apportionment of net benefits in a cooperative development.

As a means of identifying significant factors to achieve equivalence of benefits and costs, the Commission has adopted a concept of *separable economic gains* and has employed the terms *joint project works* and *supplemental works*. Accordingly:

The multi-purpose components of the plan of cooperative development which contribute to more than one benefit are referred to in this report as the *joint project works*;
The additional components of the plan of development that are necessary for the realization of only one specific benefit are referred to herein as supplemental works; and

The separable economic gain as used in this report is the value of a specific benefit less the cost of any supplemental works necessary for the realization of that benefit.

In a cooperative development the net benefits realized should be apportioned equitably between the countries. This objective can be achieved insofar as economic factors are concerned if the ratio of the sum of the separable economic gains to the cost of the joint project works is the same for each participating country.

The cost of construction of all works required in the development should be initially paid for by the country in which the works are located. Equalization of benefits and costs to each country can then be achieved by a transfer of money from one country to defray a part of the cost of joint project works in the latter country. The procedure to accomplish this is explained in Section VIII.

Apportionment of Water

Although the Commission did not ask the Board to suggest an apportionment of the waters of the Pembina River Basin it was necessary for the Board to make certain assumptions in order to proceed with its studies. Accordingly, as mentioned previously, and for design purposes only, the Board assumed an equal division of available water between the countries.

All the waters that could be controlled by a cooperative development need not be assigned to project purposes. A portion of the waters originating in each country should be reserved for use as that country sees fit, provided that such use does not cause injury in the other country. Officials from the Province of Manitoba and the State of North Dakota who participated in the Board's study were of the opinion that 12% of the total yield of the Basin above Pembilier Dam should be reserved for non-project purposes and the study proceeded on that basis. The Commission considers this reservation appropriate to the circumstances and benefits from the use of non-project waters are not included in the determination of the economic advantage of the cooperative development.

Under the terms of reference and subject to the conditions stated, the Commission was requested to recommend a plan of cooperative development of the water resources of the Basin and to recommend how the available water should be apportioned between the countries in order to achieve the benefits of that plan. In formulating the plan which is described in Section VIII, the Commission has necessarily taken account of the several factors which need to be considered in determining the apportionment of
water which would be appropriate and equitable under the circumstances. Some of these factors are discussed below.

About 60% of the total drainage area of the Basin above Pembilier Dam, the last point where flows would be controlled under the proposed plan, is in Canada and 40% is in the United States. Allowing for non-contributing areas in each country, 58.8% of the area contributing run-off to the Pembina River above the proposed dam is in Canada and 41.2% in the United States. Correlation studies indicated the run-off to be proportional to the contributing areas. Thus approximately 59% of the water yield originates in Canada and 41% in the United States.

The water yield from each country is available for use in that country and a cooperative development should not preclude such use, particularly if the other country is not adversely affected thereby. Canada could use beneficially all of the water originating in the Canadian portion of the Basin above Pembilier Dam and similarly the United States could use water equivalent to the amount originating in the United States portion of the Basin.

Under the cooperative development hereinafter proposed, each country would utilize and benefit from the topography and facilities provided in the other country. The contributions of each country in this regard are so close to being equal that neither country should be expected to surrender part of its water yield to compensate the other.

The cooperative development described in Section VIII would not curtail any of the existing uses of the waters of the Basin, which include water supply, waste disposal and recreation. Indeed it makes provision for expanded uses for these purposes as well as for additional uses not possible under existing conditions or independent development.

The economy of the Basin and nearby areas in both countries is not mature and available natural resources remain undeveloped. Forecasts of population growth and consequent economic and social needs, however meticulously developed, may appear quite unrealistic in a few decades and were not relied upon to any extent in the consideration of apportionment.

When formal agreement has been reached regarding apportionment, and in order to provide for the flexibility as mentioned earlier, each country should be free to determine the uses to be made of the water apportioned to it, provided the cooperative development is not impaired and there is no interference with the other country's use of the water apportioned to it.

The Boundary Waters Treaty of 1909 provides no guidance in the matter of apportionment of water in rivers which cross the international boundary. Article II states the principle that each country, along with its respective Provincial and State Governments, normally retains "exclusive jurisdiction and control over the use and diversion" of all the upstream waters on its own side of the boundary. In the case of the Pembina River waters, which cross
and re-cross the international boundary, each country is, in turn, an upstream country within the meaning of Article II; so that each would have to agree to limit the exercise of its jurisdiction in the interest of cooperative development. The basis for the apportionment required to bring about this cooperative development must be derived from sources outside the Treaty.

Customary international law has not as yet evolved a precise or binding formula. On the other hand, the general principles embodied in the "Helsinki Rules on the Uses of Waters of International Rivers", approved in 1966 by the International Law Association after an intensive study of some twelve years, furnish a helpful guide to contemporary international practice in this area. The Helsinki Rules affirm that each basin state should be entitled within its territory to a reasonable and equitable share in the beneficial uses of the waters of an international drainage basin, such share to be determined in the light of all the relevant factors in each particular case. The relevant factors set out in the Rules include geography, hydrology, past utilization of the waters, economic and social needs and the avoidance of unnecessary waste of water. The Commission has given due consideration to all of these factors.

*Formulation of an Optimum Plan of Mutual Advantage*

After review of the foregoing basic considerations, the report of the Board, the record of the public hearings and other pertinent information, the Commission proceeded with the formulation of its concept of an optimum plan as outlined hereunder.

The three most favourable plans presented in the Board's report offered generally comparable possibilities for reasonably full and optimum use of resources, for fulfilling various needs and purposes and for economic justification.

With respect to optimization, the Commission found that greater net returns could be obtained under all plans if more of the irrigable acreage were developed in Canada. Development costs would be lower in Canada and drainage problems and costs would be greater in the United States. Of the 21,300 productive acres that could be irrigated with the water available under the Board's Plan 2, 17,000 should be located in Canada and only 4,300 in the United States if net irrigation returns on a basin-wide basis were to be maximized. Any sacrifice of this degree of optimization should be justified by other considerations.

With respect to the requirement for mutual advantage, the Commission found that a plan providing a major reservoir in each country would be desirable. This was also favoured by the residents of the area.

Since there are no independent alternatives that are economically justifiable in themselves it was not possible to measure directly the net advantages of a cooperative development. The Commission therefore used the concept of *separable economic gains* to provide a basis for a determination of the commensurate net advantage to each country.
Finally, the Commission, after considering all factors such as origin of water, opportunity for use, need for use, and possibilities for basin-wide optimization for use, concluded that an apportionment of the water available for project purposes, 60% to Canada and 40% to the United States, would be equitable and permit reasonable optimization of a cooperative plan of mutual advantage to the two countries.

The Commission found that a modification of the Board’s Plan 2, as outlined in Section VIII, could be formulated to meet all these considerations.
The plan of cooperative development formulated by the Commission is the Board's Plan 2 modified in accordance with the considerations discussed in the preceding section. The Pembina and Pembilier Reservoirs and the Supply Conduit are identical to those presented in the Board's Plan 2. However, the Main Supply Canal has been extended and the areas to be irrigated have been relocated. See Figure 1.

The plan formulated by the Commission would reserve 12% of the total annual water yield above Pembilier Dam for non-project purposes, 5% for use in North Dakota and 7% for use in Manitoba. Under this plan 40% of the remainder of the water yield of the Pembina River Basin above Pembilier Dam, the lowest point of control, would be apportioned for use in the United States and 60% for use in Canada. The plan would make 10,000 acre feet of water available annually for municipal and industrial purposes, of which 4,000 acre feet would be for use in the United States and 6,000 acre feet for use in Canada. On the basis of this apportionment of water it would also provide for the irrigation of 21,300 productive acres, of which 8,500 would be in the United States and 12,800 in Canada.

**Joint Project Works**

The joint project works of the Commission's plan are the multi-purpose components of the total plan which contribute to more than one benefit. They are Pembina Dam, Pembilier Dam, the Supply Conduit and the Main Supply Canal.

The Supply Conduit and the Main Supply Canal convey water for irrigation in both countries and for municipal and industrial purposes in Manitoba.

**Pembina Dam** in Manitoba would create a reservoir 30 miles long with a usable storage capacity of 246,000 acre feet, of which 215,000 acre feet would be for irrigation and 31,000 acre feet for water supply. The conservation pool would provide a capacity of 4,000 acre feet for accumulated sediment. The flooded area at maximum water level, elevation 1256, would be 6,300 acres. The dam would be located 14 miles southeast of Manitou and 134 miles above the mouth of the Pembina River.
Pembina Reservoir would control 84% of the contributing area above Walhalla. The annual dependable yield would be about 49,000 acre feet. Its effect on flood peaks would be limited because it is 42 miles above Walhalla, where the area subject to flood damage commences.

The dam, shown in Figure 2, would be of compacted earth fill having a total length of 4,000 feet and a maximum height of 110 feet. The top of the dam would be at elevation 1264. The spillway would be of reinforced concrete with a controlled crest length of 182 feet at elevation 1244 and have a maximum capacity of 30,500 cfs (cubic feet per second). The reinforced concrete stilling basin would have a width of 206 feet and an over-all length of 100 feet. The reinforced concrete outlet works would have two 7-foot diameter horseshoe type conduits with a maximum capacity of 2,900 cfs. At the gatewell both conduits would be divided into two chambers equipped with slide gates, two of the four gates being available for emergency use.

Pembilier Dam in North Dakota would create a reservoir 22 miles long with a usable storage capacity of 110,000 acre feet which would be used primarily for flood control. Approximately 45,000 acre feet would be used also for water storage during the period between the recession of the spring flood and the late winter months. The conservation pool would provide a capacity of 20,000 acre feet for accumulated sediment. The flooded area at maximum water level, elevation 1096.5, would be 4,000 acres. The upper limit for flood control storage is at elevation 1075 and the upper limit for dual-use storage is at elevation 1046.5. The dam would be located 2 miles southwest of Walhalla, 94 miles above the mouth of the Pembina River and 21 miles below the international boundary.

At the international boundary the maximum water level would be approximately 35 feet above the river bed and 20 feet above the channel bank. This would represent an increase in the water levels prevailing at the boundary under natural conditions and in the absence of an agreement between the countries would require the approval of this Commission pursuant to the Boundary Waters Treaty of 1909.

The dam, shown in Figure 3, would be of compacted earth fill having total length of 2,060 feet and a maximum height of 145 feet. The top of the dam would be at elevation 1101.5. The spillway would be of reinforced concrete with an uncontrolled crest length of 131 feet at elevation 1075. The reinforced concrete stilling basin would have a width of 131 feet and an over-all length of 85 feet. The discharge with a reservoir elevation of 1096.5 would be 80,000 cfs. The maximum discharge during the standard project flood would be 25,000 cfs. The reinforced concrete outlet works would include a control tower with two service and two emergency slide gates, a 9.75-foot diameter horseshoe type conduit through the dam, and a bifurcation unit with wye gates for diversion of reservoir releases to the Supply Conduit and the River. The capacity when the water level is at the top of the conservation pool would be 870 cfs.
The Supply Conduit would be a precast concrete pressure pipe 8 feet in diameter with blowoffs and air vents. It would extend from the Pembilier outlet works to the Main Supply Canal, a distance of 2.6 miles. The design capacity would be 420 cfs.

The Main Supply Canal would be located at the base of the Pembina Escarpment, extending 11 miles from Walhalla to the northern end of the Winkler irrigation area; 5 miles of the canal would be in North Dakota, 6 miles in Manitoba. Its capacity of 420 cfs at the Conduit would gradually reduce to 230 cfs at the boundary and finally to a minimum of 100 cfs. Some canal lining would be necessary.

The elevation of the water surface at the international boundary would be approximately 970. Appropriate measuring devices would be provided near the outlet of the Supply Conduit and the international boundary. Appurtenant works would include checks, lateral turnouts and bridges. Inverted siphons and an interceptor drain would cope with runoff from the escarpment.

Supplemental Works

In order to put the waters of the Pembina River to use and realize all the benefits contemplated in the plan it would be necessary to construct works in each country in addition to those joint project works described above. Each of these additional works would be associated with only one purpose, i.e. water supply, irrigation or recreation. Such works are referred to herein as supplemental works. They would consist of facilities to convey water for municipal purposes to seven Manitoba communities, the distribution laterals and drains associated with the development of the irrigable area in each country, and the recreational facilities on the shores of both Pembilier and Pembina Reservoirs.

The Water Supply Facilities in Manitoba would entail the construction of a canal from the end of the Main Supply Canal to the Hespeler Waste-way, improving the Hespeler Wasteway, and construction of a canal from the Wasteway to Winkler Reservoir; placing 8 miles of 12-inch pipe from Winkler to Morden, 8 miles of 6-inch pipe from Winkler to Plum Coulee and 15 miles of 6-inch pipe from Neche to Horndean; and construction of dugout type reservoirs with pumping facilities at Winkler and Gretna. These contemplated works would not include water treatment plants or distribution works within the local communities.

Comparable water conveyance facilities are not required in North Dakota because the communities concerned would pump the water required for municipal purposes directly from the Pembina River to their distribution systems.

The Irrigation Works in North Dakota would irrigate 8,500 productive acres in two rectangular blocks, each about 1½ miles wide and 7 miles long separated by a strip of non-irrigable land approximately 1½ miles wide. The
irrigable area extends from Walhalla to the international boundary and lies east of the Main Supply Canal.

The irrigation distribution system would consist of approximately 10 miles of laterals carrying more than 50 cfs, 25 miles of laterals carrying less than 50 cfs, and ancillary structures such as drops, checks, turnouts, bridges and culverts. The surface drainage system would consist of approximately 25 miles of shallow surface drains, 30 miles of deep open collector drains to carry surface runoff to the River, bridges and culverts. Since the depth to the dense clay barrier is relatively shallow in over half of the irrigable area, the conventional surface drainage would be augmented by approximately 70 miles of subsurface drainage pipe and 6 miles of collector pipe.

The Irrigation Works in Manitoba would irrigate 12,800 productive acres in a compact rectangular block approximately 6 miles by 5 miles, immediately north of the international boundary and east of the Main Supply Canal.

The irrigation distribution system would consist of approximately 13 miles of laterals carrying more than 50 cfs, 42 miles of laterals carrying less than 50 cfs and ancillary structures. Since the depth to the clay barrier in Manitoba is much greater, the drainage system would consist of 33 miles of shallow open surface drains and 37 miles of open collector drains to a network of existing drains, bridges and culverts.

Recreation Facilities at Pembilier Reservoir would consist of 3 well developed sites with scenic drives, picnic and camp areas, swimming beaches and boat launching ramps. Facilities at the picnic areas would include parking areas, picnic tables, fireplaces, refuse containers, wells, comfort stations and shelters. The two camping areas would have in addition clearings for tents and trailers.

Recreation Facilities at Pembina Reservoir would consist of one site of minimal development near the proposed dam. The facilities would include one boat launching ramp, a picnic site and a modest camping site.

Operation of Joint Project Works

Operation of the two reservoirs would be coordinated so as to maximize the flood control water supply, irrigation, recreation and fishery benefits contemplated in the Commission's plan.

Pembina Reservoir would store water for irrigation and municipal and industrial supplies. In order to ensure sufficient supply during 10 consecutive years of low runoff releases would be restricted to these designated purposes except during high water periods. At the end of an average irrigation season the reservoir would be 20 feet below the maximum water elevation. The water then in storage would be carried over to a subsequent year. The gated spillway would only be operated when the reservoir is expected to exceed the maximum water level, elevation 1256. On the average, the volume of the spring flood reaching Pembilier Reservoir would be reduced by approximately 100,000 acre feet.
Water released from the Pembina Reservoir during the irrigation season would be conveyed for 25 miles in the River to the dual-purpose pool of Pembilier Reservoir. During the summer months Pembilier Reservoir would be operated as a balancing pool. This would decrease the time between the demand for water and its delivery to the point of need. Releases from Pembina Reservoir would limit the fluctuation of the water surface in Pembilier to 15 or 20 feet during the recreation season. At the end of the irrigation season, only sufficient water would be retained in Pembilier Reservoir to satisfy the requirements during the fall and winter months.

The Pembilier outlet works would constantly release water to the Pembina River for use by the North Dakota communities of Walhalla, Neche and Pembina and for quality control in the River. Water would also be released through the Supply Conduit to the Main Supply Canal on the basis of demand to meet the immediate requirements of the irrigable areas in North Dakota and Manitoba. The Main Supply Canal would not be operated in the winter months. During periods of low irrigation demand, water would be released to the Supply Canal for conveyance to Winkler Reservoir for subsequent distribution to the towns of Morden, Winkler and Plum Coulee in the summer and winter months. Similarly, additional water would be discharged to the Pembina River for pumping from Neche to Gretna Reservoir and subsequent use by the Manitoba communities of Gretna, Altona, Rosenfeld and Horndean.

Releases from Pembilier Reservoir would not exceed 2,000 cfs, the downstream channel capacity, as long as the Reservoir is below the uncontrolled spillway crest. To the extent practicable, outflows from Pembilier Reservoir would be reduced or discontinued during damaging flood conditions on the Red River.

During the late fall and winter Pembilier Reservoir would be drawn down to elevation 1014, the top of the conservation pool, to make all flood control space available for the storage of the spring flood. Spillage would only occur when the volume of the inflow into Pembilier Reservoir exceeds 110,000 acre feet, the storage capacity of the reservoir. Following the spring flood Pembilier Reservoir would be rapidly drawn down to the top of the dual-use pool, elevation 1046.5. This would provide sufficient storage capacity to control any recorded summer flood and reduce large fluctuations in level during the recreation season.

Continuous records would be maintained of water levels and releases from both reservoirs. Additional gauging stations would be established to enable water to be apportioned in accordance with the plan. To ensure optimum use of the dual-purpose storage in Pembilier Reservoir, forecasting procedures would be developed to prevent unnecessary spilling during periods of sub-normal runoff.

Cost of Joint Project Works
The estimated investment which includes interest during construction and the estimated annual costs are based on the July 1963 prices in each
country, the currency of the country in which the works are located, the prescribed United States interest rate in July 1963 of \(3\frac{1}{2}\%\), the Canadian interest rate prevailing in July 1963 of 5%, a project life of 100 years, and a construction period of 3 years. No attempt has been made to allocate any part of the costs of joint project works to specific benefits in either country.

The first costs and the annual operation, maintenance and replacement charges for Pembina Dam, Pembilier Dam and the Supply Conduit are those used by the Board. The first cost and annual charges for the Supply Canal have been derived by adjusting the figures used by the Board, to take account of the modifications made by the Commission in the Board’s plans.

The first costs required for the two dams include cost of land acquisition, reservoir clearing, river diversion, embankment, spillway, outlet works, relocation of power and telephone lines, and relocating a secondary highway bridge across Pembilier Reservoir; for the Supply Conduit the cost of right-of-way, pressure pipe, excavation and backfill; and for the Main Supply Canal the cost of right-of-way, excavation, lining, embankment and appurtenant works.

The investment required consists of the foregoing first costs plus interest during construction.

The annual costs consist of interest on and amortization of the investment as well as operation, maintenance and replacement charges. The estimated annual operation, maintenance and replacement charges are for Pembina Dam $12,000, Pembilier Dam $11,200, Supply Conduit $1,200, Supply Canal in North Dakota $6,600 and Supply Canal in Manitoba $6,700.

The investment and annual costs for the joint project works, expressed in the currency of the country where they are located, are summarized below.

<table>
<thead>
<tr>
<th></th>
<th>Investment</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Canada</td>
<td>U.S.A.</td>
</tr>
<tr>
<td>Pembina Dam</td>
<td>9,592</td>
<td>—</td>
</tr>
<tr>
<td>Pembilier Dam</td>
<td>—</td>
<td>10,570</td>
</tr>
<tr>
<td>Supply Conduit</td>
<td>—</td>
<td>2,732</td>
</tr>
<tr>
<td>Supply Canal</td>
<td>490</td>
<td>443</td>
</tr>
<tr>
<td>Totals</td>
<td>10,082</td>
<td>13,745</td>
</tr>
</tbody>
</table>

**Benefits and Separable Economic Gains**

Although the Commission recognizes that there will be secondary and intangible benefits, only primary benefits were considered in the economic
evaluation of the cooperative plan. Primary benefits, as used in this report, are the value of goods or services directly resulting from a project, less induced costs incurred in the realization of those benefits.

The separable economic gains to each country are the expression in dollar values of the effects of a project. They can be divided into two categories: those dependent on joint project works and those resulting from both joint project works and specific supplemental works. Flood control, fish and wildlife benefits are in the former category while water supply, irrigation and recreation are in the latter.

Separable economic gains dependent solely on joint project works are the same as the primary benefits of those works.

A separable economic gain dependent on both joint project works and specific supplemental works, as used in this report, is the difference between a specific primary benefit in either country and the cost of supplemental works in that country necessary to realize the benefit. It is a measure of the economic advantage of supplemental works built for one specific purpose.

The total of all separable economic gains when compared with the cost of joint project works is a measure of the economic advantage to each country of a cooperative development.

FIGURE 4 BENEFITS OF THE COOPERATIVE DEVELOPMENT
The values of the primary benefits associated with flood control, water supply, recreation, fish and wildlife are identical to those used by the Board. So are the first costs and annual operation, maintenance and replacement charges of supplemental works required for water supply and recreation. The benefits, first costs and annual operation, maintenance and replacement charges related to irrigation in each country have been derived by adjusting the figures used by the Board, to take account of the modifications made by the Commission in the Board's plans.

As in the case of calculating the cost of project works, the primary benefits and costs of supplemental works were also based on July 1963 prices in each country, the currency of the country in which the works are located, the prescribed United States interest rate in July 1963 of 3.75%, the Canadian interest rate prevailing in July 1963 of 5%, a project life of 100 years and a construction period of 3 years for irrigation works and water supply facilities and 1 year for recreation facilities.

**Flood Control** benefits are the difference between the damage that is expected to accrue throughout the life of the project with the degree of protection provided and the damage to be expected without this protection. There are no alternative means of providing similar protection that are economically justifiable.

In the United States flood control benefits would occur along the Pembina River at and downstream from Walhalla and along the Red River between the mouth of the Pembina and the international boundary. Benefits in Canada would be in the Gretna-Altona area and along the Red River between the international boundary and Winnipeg.

The storage allocation to flood control is sufficient to completely store a flood on the Pembina River with a 26-year frequency. It would eliminate a major portion of the damages expected from overflows on the Pembina River with a recurrence of the 1950 flood which had a volume frequency of 40 years and a peak frequency of 100 years. This degree of protection should be adequate for a predominantly agricultural area.

The estimated flood control benefits converted into an annual value would be $221,000 in the United States and $128,000 in Canada. The separable economic gain would be the same figure in each case.

**Fish and Wildlife** benefits are the economic gains resulting from improving the quality and quantity of game fish, less the value of any adverse effects on wildlife.

The creation of two deep pools would replace a poor quality stream fishery with a lake-type fishery. The improved habitats in both reservoirs should increase the natural production of fish after the initial stocking. If a cold water environment develops, the reservoirs may be managed for trout or bass.

Several thousand acres of prime wildlife habitat would be destroyed by flooding. White-tail deer, game birds and some fur-bearing animals would be
affected. The value of the reservoirs to water fowl would be limited to transient use. The estimated annual value of wildlife losses in Canada would be $12,000. In the United States there would be no net losses to wildlife because the plan includes compensating measures to offset them.

The resulting fish and wildlife benefits converted into an annual value would be $8,000 in the United States. The separable economic gain would be the same figure. Canada would have neither benefits nor separable economic gain since the wildlife losses would be about equal to the benefits to anglers.

Water Supply benefits would be realized only by the construction of specific supplemental works in addition to the joint project works. The separable economic gain to each country is the difference in cost between the most economic independent alternative available and the cost of the supplemental works required to deliver the same quantity of water to the same points of need.

The most economic alternative scheme to supply water to the seven Manitoba communities envisaged pumping a portion of the water from a small reservoir to be built on the Pembina River in Canada over the divide to an open channel to Morden Reservoir and thence by pipe to the towns of Morden, Winkler, and Plum Coulee. The towns of Gretna, Altona, Rosenfeld and Horndean would be supplied with water released from this small reservoir and pumped from the river at Neche. Storage at Gretna would eliminate the necessity of winter releases. It should be noted that a substantial portion of the supplemental works required under the Commission’s plan is identical with the works required for the most economical alternative.

The estimated annual cost, including depreciation and pumping, for the most economical alternative would be $193,000. These costs do not include treatment and distribution within the several communities. Under the Commission’s plan, the investment for supplemental works associated only with municipal and industrial water supply in Manitoba would be $2,387,000. The estimated annual cost is $129,000. Accordingly, the annual value of this separable economic gain to Canada is the difference between the most economic alternative and the Commission’s plan, $64,000.

The situation in North Dakota is not comparable. The most economic independent alternative available would require a dam just upstream from the mouth of the Little Pembina River. Both the most economic alternative and the Commission’s plan would release water from a reservoir to the Pembina River. The three North Dakota communities would then pump the water directly from the River to their distribution pipelines.

The annual value of this separable economic gain to the United States is $147,000, the annual cost of the most economic alternative.

Irrigation benefits would be realized only after specific supplemental works have been constructed in each country. The value of this separable economic gain is the increase in net farm income with irrigation as compared to the net farm income without irrigation, less the cost of related supplemental works.
The Board used a comparable and detailed farm budget analysis to determine the primary irrigation benefit per irrigated acre in each country. These basic figures were adjusted to convert irrigable acres into productive acres and to take into account a five year development period in the United States and a 10 year development period in Canada. The results of these computations multiplied by the productive acreage represent the average annual increase in the net farm income in each country for the life of the project. The estimated increase or primary irrigation benefit in Canada is $429,000 and in the United States $474,000.

The Board's cost estimates for the Main Supply Canal and distribution system in Manitoba were not separated. Therefore, it was necessary to examine the original calculations, separate the several costs associated with the Main Canal and distribution system, and using the same allowance for contingencies and engineering and the same operation, maintenance and replacement charges, recalculate the investment and annual costs. A straight line proportion between Schemes III and IV (11,975 and 15,370 productive acres), and the same period of construction were used to calculate investment required for 12,800 productive acres. The investment required in Manitoba would be $1,675,000.

The annual replacement charges were calculated using the same method employed by the Board. The annual operation and maintenance charges for laterals and drains are 90% of the operation and maintenance charges for the Supply Canal, laterals and drains. The annual cost including interest on the amortization of the investment plus operation, maintenance and replacement charges for the supplemental works required for irrigation in Manitoba is $133,000.

The cost of distribution works in North Dakota, unlike those in Manitoba, were shown separately from the Main Supply Canal costs in the Board's report. A straight line proportion between the Board's Schemes I and II (7,550 and 9,250 productive acres) and the same construction period were used to calculate investment for 8,500 productive acres. The investment required in North Dakota would be $4,796,000. The cost of surface and pipe drains accounts for nearly 60% of the investment as compared with 20% in Manitoba. The cost in North Dakota, unlike Manitoba costs, includes settlers assistance and pre-authorization investigation charges.

The annual operation, maintenance and replacement charges are $3.52 per productive acre, proportionately higher than in the Board's Plan I (9,150 productive acres). The annual cost, including interest on the amortization of the investment plus operation, maintenance and replacement charges for the supplemental works required for irrigation in North Dakota is $187,000.

The annual value of this separable economic gain to Canada would be $296,000, ($429,000 - $133,000), and to the United States $287,000, ($474,000 - $187,000).
RECREATION BENEFITS can only be realized when the picnic and camping sites are developed along the shores of both reservoirs. The economic gain is the assigned value of visitor days less the cost of the recreational facilities provided.

The two reservoirs would create water related recreational facilities now lacking in the Pembina Basin. During the recreation season the water surface area on the Pembina Reservoir may vary from 6,000 to 4,000 acres and on the Pembilier Reservoir from 2,000 to 900 acres. Water surface elevations may fluctuate as much as 20 feet. The annual value of the recreation benefits, based on the estimated number of visitor days, would be $11,000 in Canada and $33,000 in the United States.

The investment required for the development of modest facilities at one site in Canada would be $25,000 and for three well developed sites in the United States $458,000.

The annual cost of recreational facilities including interest on and amortization of the investment plus operation, maintenance and replacement charges in Canada would be $3,000 and in the United States $27,000.

The annual value of this separable economic gain to Canada would be $8,000, ($11,000 - $3,000), and to the United States $6,000, ($33,000 - $27,000).

IN SUMMARY, the annual values of the several separable economic gains, expressed in the currency of the country where they occur, are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Canada</th>
<th>U.S.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Control</td>
<td>128</td>
<td>221</td>
</tr>
<tr>
<td>Fish and Wildlife</td>
<td>Nil</td>
<td>8</td>
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<tr>
<td>Water Supply</td>
<td>64</td>
<td>147</td>
</tr>
<tr>
<td>Irrigation</td>
<td>296</td>
<td>287</td>
</tr>
<tr>
<td>Recreation</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>496</strong></td>
<td><strong>669</strong></td>
</tr>
</tbody>
</table>

Economic Justification

Under the Commission’s plan the cost of constructing both the joint project works and the supplemental works would initially be borne by the country in which they are located. The total of all separable economic gains in each country when compared with the joint project costs borne by that country is a measure of the economic advantage of the Commission’s plan to each country. Such economic advantages may be expressed as a ratio.
The ratio of the annual value of all separable economic gains to the annual cost of the joint project works in Canada is 0.9. In the United States the corresponding ratio is 1.4.

To achieve an equivalent economic advantage to each country under the plan, it would be necessary for the United States to transfer a sum of money to Canada to defray part of the cost of joint project works in the latter country. Based on the July 1963 value of currency in each country, i.e. 1.00 U.S. Dollars equalling 1.08 Canadian Dollars, the prescribed United States interest rate of 3 1/8% and an amortization period of 100 years, a transfer of $2,988,000 U.S. to Canada would result in a ratio of 1.2 for each country.

On this basis the cooperative plan formulated by the Commission for the development of the Pembina River Basin would be economically justifiable in each country.
SECTION IX

CONCLUSIONS

1. In response to the request in paragraph 2 of the Reference that the Commission determine what plan or plans of cooperative development of the water resources of the Pembina River Basin would be practicable, economically feasible, and to the mutual advantage of the two countries, having in mind: (a) domestic water supply and sanitation; (b) control of floods; (c) irrigation; and (d) any other beneficial uses, the Commission concludes that the plan of cooperative development which is described in Section VIII of this report would be practicable, economically feasible and to the mutual advantage of both countries, and would best meet the purposes and requirements stated in paragraph 2 of the Reference.

2. In response to the request in sub-paragraph (ii) of paragraph 3 of the Reference that the Commission make an estimate of the costs of carrying out such plan, the Commission estimates that the investment required to construct the joint project works, i.e. the multi-purpose components of the total plan which contribute to more than one benefit, would be $10,082,000 in Canada and $13,745,000 in the United States; and to construct the supplemental works, i.e. works required in addition to the joint project works for the realization of specific benefits, would be $4,087,000 in Canada and $5,254,000 in the United States.

The estimated annual costs, including interest and amortization payments and operation, maintenance and replacement charges for joint project works would be $526,000 in Canada and $469,000 in the United States; and for supplemental works would be $265,000 in Canada and $214,000 in the United States.

All of these estimates are based on—July 1963 prices in each country, the currency of the country in which the works are located, the prescribed United States interest rate in July 1963 of 3½%, the Canadian interest rate prevailing in July 1963 of 5%, a project life of 100 years and a construction period of 3 years for joint project and irrigation works, 3 years for water supply facilities and one year for recreation facilities.
3. In response to the request in sub-paragraph (iii) of paragraph 3 of the Reference that the Commission make an estimate of the benefits to each country of carrying out such plan, the Commission concludes that carrying out the plan of cooperative development described in Section VIII would:

(a) eliminate a major portion of the damages that would occur from overflows of the Pembina River during floods of the magnitude of the one which occurred in 1950;
(b) provide an assured supply of water of suitable quality for municipal and industrial purposes at seven communities in Manitoba and three in North Dakota;
(c) provide for irrigation of 12,800 productive acres in Manitoba and 8,500 in North Dakota;
(d) provide dilution water for the wastes discharged to the Pembina River from North Dakota communities, thereby improving the quality of water in the lower reach of the river;
(e) provide one water-related recreational site in Manitoba and three in North Dakota; and
(f) improve the quality and quantity of game fish in the two reservoirs and in the Pembina River below Walhalla.

The estimated annual value of all separable economic gains resulting from these benefits would be $496,000 to Canada and $669,000 to the United States.

4. In response to the request in sub-paragraph (iii) of paragraph 3 of the Reference that the Commission make an estimate of the adverse effects on each country of carrying out such plan, the Commission concludes that carrying out the said plan would have the following adverse effects as a result of the creation of the Pembina and Pembilier reservoirs:

(a) a reduction in the extent of the natural habitat for wildlife such as game birds and fur-bearing animals at the Pembina Reservoir site;
(b) some severance of farm holdings; and
(c) flooding of sections of a few minor roads.

5. In response to the question raised in sub-paragraph (iii) of paragraph 3 of the Reference as to how available water should be apportioned in order to achieve the benefits estimated to result from carrying out the said plan, the Commission concludes that:

(a) the run-off or water yield of the Basin which, under natural conditions, would contribute to the flows of the Pembina River above the site of the Pembilier Dam is the water available for apportionment;
(b) seven per cent of the total annual water yield of the Pembina River Basin above Pembilier Dam should be reserved for non-project
purposes in the Province of Manitoba and five per cent for non-project purposes in the State of North Dakota; the use of water reserved for non-project purposes to be as determined by the respective Provincial and State Governments; and
(c) the remainder of the annual water yield of the Pembina River Basin above the Pembilier Dam should be apportioned for project purposes, sixty per cent for use in Canada and forty per cent for use in the United States.

6. In response to the question raised in sub-paragraph (iv) of paragraph 3 of the Reference as to how the costs of carrying out such a plan might be apportioned between Canada and the United States, the Commission concludes that:

(a) initially, each country should pay for all works located in its territory; and
(b) subsequently, there should be a transfer of money from one country to the other to partially defray the cost of joint project works in the latter country so that, in the result, the ratio of the annual value of the total separable economic gains to the total annual costs of the joint project works will be the same for each country.
SECTION X

RECOMMENDATIONS

1. In response to the request in sub-paragraph (i) of paragraph 3 of the Reference that the Commission make recommendations concerning such plan or plans as would best meet the purposes and requirements stated in paragraph 2 of the Reference, the Commission recommends that the Governments of Canada and the United States enter into an agreement, as soon as may be practicable, to implement all features of the plan of cooperative development of the water resources of the Pembina River Basin that is described in Section VIII of this report.

2. In response to the request in sub-paragraph (iii) of paragraph 3 of the Reference that the Commission make recommendations as to how available water should be apportioned in order to achieve the benefits estimated to result from carrying out the recommended plan, the Commission recommends that the said agreement between the Governments provide for the apportionment of water as outlined in paragraph 5 of Section IX of this report.

3. In response to the request in sub-paragraph (iv) of paragraph 3 of the Reference that the Commission make recommendations concerning how the costs of carrying out the recommended plan might be apportioned between Canada and the United States, the Commission recommends that the apportionment of costs between the countries be based on the method outlined in paragraph 6 of Section IX of this report. In applying the method, prices (including interest rates) that reflect conditions existing at the time of the said agreement and more refined quantity estimates should be used.

4. The Commission recommends that, during the negotiation of the said agreement and prior to the commencement of operation of the joint project works contemplated therein, the Governments utilize the Commission and its procedures to the maximum extent consistent with their requirements, to facilitate agreement and coordination with respect to matters of mutual interest to the two Governments.
5. The Commission further recommends that it be authorized by the two Governments to establish and maintain continuing supervision on their behalf over the operation of the joint project works constructed and the measurement and apportionment between the countries of the waters of the Pembina River Basin.

Signed this 6th day of October, 1967.

A. D. P. Heeney
Matthew E. Welsh
Eugene W. Weber
D. M. Stephens
René Dupuis
Charles R. Ross
RECOMMENDATIONS

CHAPTER I

PART I

Section 1

1. It is recommended that the Commission make recommendations to the Government in regard to the construction, management, and operation of public utilities, including such matters as the establishment of rates, the regulation of service, and the promotion of efficient and economical operation.

2. The Commission should be empowered to investigate and report on the financial condition of public utilities, and to take such action as may be necessary to ensure their proper management.

3. It is recommended that the Commission be authorized to issue licenses for the operation of public utilities, and to prescribe the conditions and limitations under which such licenses shall be granted.

4. The Commission should have the power to require the furnishing of information concerning the operations of public utilities, and to take such action as may be necessary to enforce the provisions of the OAP.

5. It is recommended that the Commission be authorized to issue orders requiring the execution of certain works or the performance of certain services by public utilities, and to take such action as may be necessary to carry out such orders.

6. The Commission should have the power to levy penalties for violations of the provisions of the OAP and to enforce the payment of such penalties.

7. It is recommended that the Commission have the power to issue certificates of service, and to regulate the terms and conditions under which such certificates shall be issued.

8. The Commission should have the power to review and approve the rates charged by public utilities, and to take such action as may be necessary to ensure that such rates are just and reasonable.

9. It is recommended that the Commission be authorized to conduct hearings and to receive and consider complaints concerning the operations of public utilities.

10. The Commission should have the power to issue orders for the discontinuance of certain services by public utilities, and to take such action as may be necessary to enforce such orders.

11. It is recommended that the Commission have the power to suspend the operation of public utilities in cases of emergency, and to take such action as may be necessary to protect the public interest.

12. The Commission should have the power to require the furnishing of information concerning the financial condition of public utilities, and to take such action as may be necessary to ensure that such information is accurate and complete.

13. It is recommended that the Commission have the power to require the publication of certain reports and statements by public utilities, and to take such action as may be necessary to ensure that such reports and statements are accurate and complete.

14. The Commission should have the power to issue orders for the execution of certain works or the performance of certain services by public utilities, and to take such action as may be necessary to enforce such orders.

15. It is recommended that the Commission have the power to issue licenses for the operation of public utilities, and to prescribe the conditions and limitations under which such licenses shall be granted.

16. The Commission should have the power to levy penalties for violations of the provisions of the OAP and to enforce the payment of such penalties.

17. It is recommended that the Commission have the power to issue orders for the discontinuance of certain services by public utilities, and to take such action as may be necessary to enforce such orders.

18. The Commission should have the power to review and approve the rates charged by public utilities, and to take such action as may be necessary to ensure that such rates are just and reasonable.

19. It is recommended that the Commission have the power to conduct hearings and to receive and consider complaints concerning the operations of public utilities.

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23. It is recommended that the Commission have the power to levy penalties for violations of the provisions of the OAP and to enforce the payment of such penalties.

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25. It is recommended that the Commission have the power to issue orders for the discontinuance of certain services by public utilities, and to take such action as may be necessary to enforce such orders.

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50. The Commission should have the power to review and approve the rates charged by public utilities, and to take such action as may be necessary to ensure that such rates are just and reasonable.

51. It is recommended that the Commission have the power to conduct hearings and to receive and consider complaints concerning the operations of public utilities.

52. The Commission should have the power to issue orders for the discontinuance of certain services by public utilities, and to take such action as may be necessary to enforce such orders.

53. It is recommended that the Commission have the power to review and approve the rates charged by public utilities, and to take such action as may be necessary to ensure that such rates are just and reasonable.

54. The Commission should have the power to conduct hearings and to receive and consider complaints concerning the operations of public utilities.

55. It is recommended that the Commission have the power to issue orders for the discontinuance of certain services by public utilities, and to take such action as may be necessary to enforce such orders.

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58. The Commission should have the power to issue orders for the discontinuance of certain services by public utilities, and to take such action as may be necessary to enforce such orders.

59. It is recommended that the Commission have the power to review and approve the rates charged by public utilities, and to take such action as may be necessary to ensure that such rates are just and reasonable.

60. The Commission should have the power to conduct hearings and to receive and consider complaints concerning the operations of public utilities.
TEXT OF IJC REFERENCE

On April 3, 1962, the Minister for External Affairs, for the Government of Canada, and the Secretary of State, for the Government of the United States, sent the following Reference to the International Joint Commission through identical letters addressed respectively to the Canadian and United States Sections of the Commission:

The Governments of the United States of America and of Canada, pursuant to Article IX of the Boundary Waters Treaty of January 11, 1909, have agreed to request the International Joint Commission to investigate and report on what measures could be taken to develop the water resources of the Pembina River in the Province of Manitoba and the State of North Dakota. This reference is made by the Governments in the light of the conclusion of the Commission that detailed feasibility studies concerning development of the Pembina River Basin should be undertaken as communicated to Governments in letters from the Commission dated April 12, 1961.

The International Joint Commission is requested to determine what plan or plans of co-operative development of the water resources of the Pembina River Basin would be practicable, economically feasible, and to the mutual advantage of the two countries, having in mind; (a) domestic water supply and sanitation; (b) control of floods; (c) irrigation; and (d) any other beneficial uses.

In the event that the Commission should find that a plan or plans of co-operative development would be practicable, economically feasible and to the mutual advantage of both countries, the Commission is requested to make:

(i) recommendations concerning such plan or plans as would best meet the purposes and requirements stated in paragraph 2;
(ii) an estimate of the costs of carrying out any such plan or plans;
(iii) an estimate of the benefits to and adverse effects on each country of carrying out any such plan or plans; and recommendations, as necessary, how available water should be apportioned in order to achieve those benefits; and
(iv) recommendations concerning how the costs of any such plan or plans might be apportioned between Canada and the United States.

In the conduct of its investigations, and otherwise in the performance of its duties under this reference, the International Joint Commission may use the services of engineers and other specially qualified personnel of technical agencies of the United States and Canada. To avoid duplication of effort and unnecessary expense, the Commission will, so far as possible, make use of information and technical data which have been acquired by such technical agencies and by the Commission itself under the Souris-Red Rivers Reference of 1948.
MEMBERSHIP OF THE BOARD AND ITS ENGINEERING COMMITTEE

The International Joint Commission appointed the International Pembina River Engineering Board on April 3, 1962. As presently constituted the Board consists of:

**Canadian Section**

J. G. Watson, Chief Engineer, Prairie Farm Rehabilitation Administration, Canada Department of Agriculture, Chairman.

R. H. Clark, Chief Engineering Division, Inland Waters Branch, Canada Department of Energy, Mines & Resources.

W. V. Morris, Hydraulic Engineer, Engineering Division, Inland Waters Branch, Canada Department of Energy, Mines & Resources.

**United States Section**

N. B. Bennett, Jr., Assistant Commissioner, Bureau of Reclamation, Department of the Interior, Chairman.

E. L. Hendricks, Chief Hydrologist, Geological Survey, Department of the Interior.

J. W. Roche, Engineer, Corps of Engineers, Department of the Army.

*Previous Chairman* of the Canadian Section was G. L. MacKenzie (deceased), Special Assistant, Prairie Farm Rehabilitation Administration, Canada Department of Agriculture.

As authorized by the Commission, the Board established the International Pembina River Engineering Committee. When the Board submitted its report the Committee consisted of the following members:

**Canadian Section**

J. A. Griffiths, Director, Water Control and Conservation Branch, Manitoba Department of Highways, Chairman, (since deceased).

P. W. Strilaeff, District Engineer, Inland Waters Branch, Canada Department of Energy, Mines & Resources.

H. G. Riesen, Regional Engineer, Prairie Farm Rehabilitation Administration, Canada Department of Agriculture.

**United States Section**

Lt. Col. Leslie B. Harding, District Engineer, U.S. Army Engineer District St. Paul, Corps of Engineers, Chairman.

G. A. Freeman, Chief, Project Development Division, Missouri-Souris Projects Office, Bureau of Reclamation, Department of the Interior.
Milo W. Hoisveen, Secretary and Chief Engineer, North Dakota State Water Commission.

Previous Members were:
Col. William B. Strandberg, District Engineer, Corps of Engineers.
Clarence L. Sundahl, Chief, Project Development Division, Missouri-Souris Projects Office, Bureau of Reclamation.
PARTICIPATING AGENCIES

Valuable and cooperative assistance was provided by the following agencies:

In Canada

Canada Department of Agriculture
  Prairie Farm Rehabilitation Administration
  Economics Division

Canada Department of Energy, Mines & Resources
  Inland Waters Branch

Manitoba Soil Survey

Manitoba Department of Highways
  Water Control and Conservation Branch

Manitoba Department of Agriculture
  Agriculture and Economics Division

Manitoba Department of Health

Manitoba Department of Mines & Natural Resources
  Fisheries Branch
  Games Branch
  Parks Division

In the United States

United States Department of the Army
  Corps of Engineers

United States Department of the Interior
  Bureau of Reclamation
  Bureau of Outdoor Recreation
  Fish and Wildlife Service
  Geological Survey
  National Park Service
  Federal Water Pollution Control Administration

North Dakota State Water Commission

North Dakota Department of Health
PERSONS PRESENTING BRIEFS OR TESTIMONY
AT THE
INTERNATIONAL JOINT COMMISSION PUBLIC HEARINGS

Where witnesses testified at more than one hearing only one appearance is recorded hereunder.

June 9, 1965 at Manitou, Man.

George Muir, Member of Parliament, Lisgar
Hon. George Hutton, Minister of Agriculture and Conservation, Province of Manitoba
Hon. Thelma Forbes, Speaker of the Manitoba Legislature
H. P. Shewman, Member of Manitoba Legislature
Mrs. Carolyne Morrison, Member of Manitoba Legislature
J. M. Froese, Member of Manitoba Legislature
W. H. Hamilton, Member of Manitoba Legislature
A. W. Harrison, Member of Manitoba Legislature
H. A. Cochlan, Mayor of Morden
Alex Graham, Reeve of Municipality of Argyle
A. R. Godkin, Mayor of Morris
H. D. Dick, Deputy Mayor of Winkler
L. R. Skelton, Mayor of Carman
Allen Potter for Rural Municipality of Louise and Village of Crystal City
Representative of the Town of Emerson
D. K. Friesen for Lower Red River Valley Water Commission
A. C. Rekken for Community Development Committee
George Peach for Pembina Valley Development Corporation
Albert Durham for Village of Manitou and Manitou Community Chamber of Commerce
Leonard F. Dubourt for Pembina Flood Control Association of North Dakota
James H. Treble for Crystal City Chamber of Commerce
John Moore for Pilot Mound Chamber of Commerce
John Andries for Swan Lake Chamber of Commerce
Representative for Carman, Roland, Miami and Lorne Branches of Manitoba Game and Fish Association
Walter Krocker, Winkler
E. T. Nicholl, Pembina Valley
L. E. Penner, Winnipeg
R. W. MacIntosh, Winnipeg
Leonard Krueger, Thornhill
J. F. Yellowlees, Pelican Lake

June 10, 1965 at Walhalla, N.D.
Senator Quentin N. Burdick, United States Senate
Senator Milton R. Young, United States Senate
Representative Mark Andrews, United States Congress
Representative Rolland Redlin, United States Congress
Governor William L. Guy
Senator Grant Trenbeath, North Dakota State Senate
Senator Richard Forkner, North Dakota State Senate
Albert Christopher, State Representative and Mayor of Pembina
Herb Paulson, Mayor of Neche
Hugo R. Magnuson, Mayor of Grand Forks
Jim Shepard, Mayor of Walhalla
Robert Olson, Mayor of Cavalier
Milo Hoisvveen, North Dakota State Engineer
Representative of the Economic Development Commission, Bismarck, N.D.
O. S. Johnson for Cavalier County Water Management Board
W. J. Sturlagsson for Board of County Commissioners, Pembina County
E. A. Thomson for Pembina County Water Management Board and Drainage Commission
Cliff Jochim for Red River Basin Planning Committee
Vern Fahy for North Dakota Water Users Association
Larry Brown for Grand Forks Chamber of Commerce
R. C. Crockett for Greater North Dakota Association
Aldrich C. Bloomquist for River Valley Sugar Beet Growers Association
Edward M. Urlaub for Walhalla Recreation Committee
Martin Bjornstad for Red River Valley Potato Growers Association and
Walhalla Potato Growers Association
Jack Wood, Pembina
Allan Thompson, Walhalla
E. W. Anderson, Neche
Gregory Cook, Neche
Arlon G. Hazen, North Dakota State University of Agriculture and
Applied Science at Grand Forks
Jack Huffman, Walhalla
Howard Hughes, Neche
George Brown, Cavalier
J. C. Tanner, East Grand Forks
Dixon Best, Walhalla