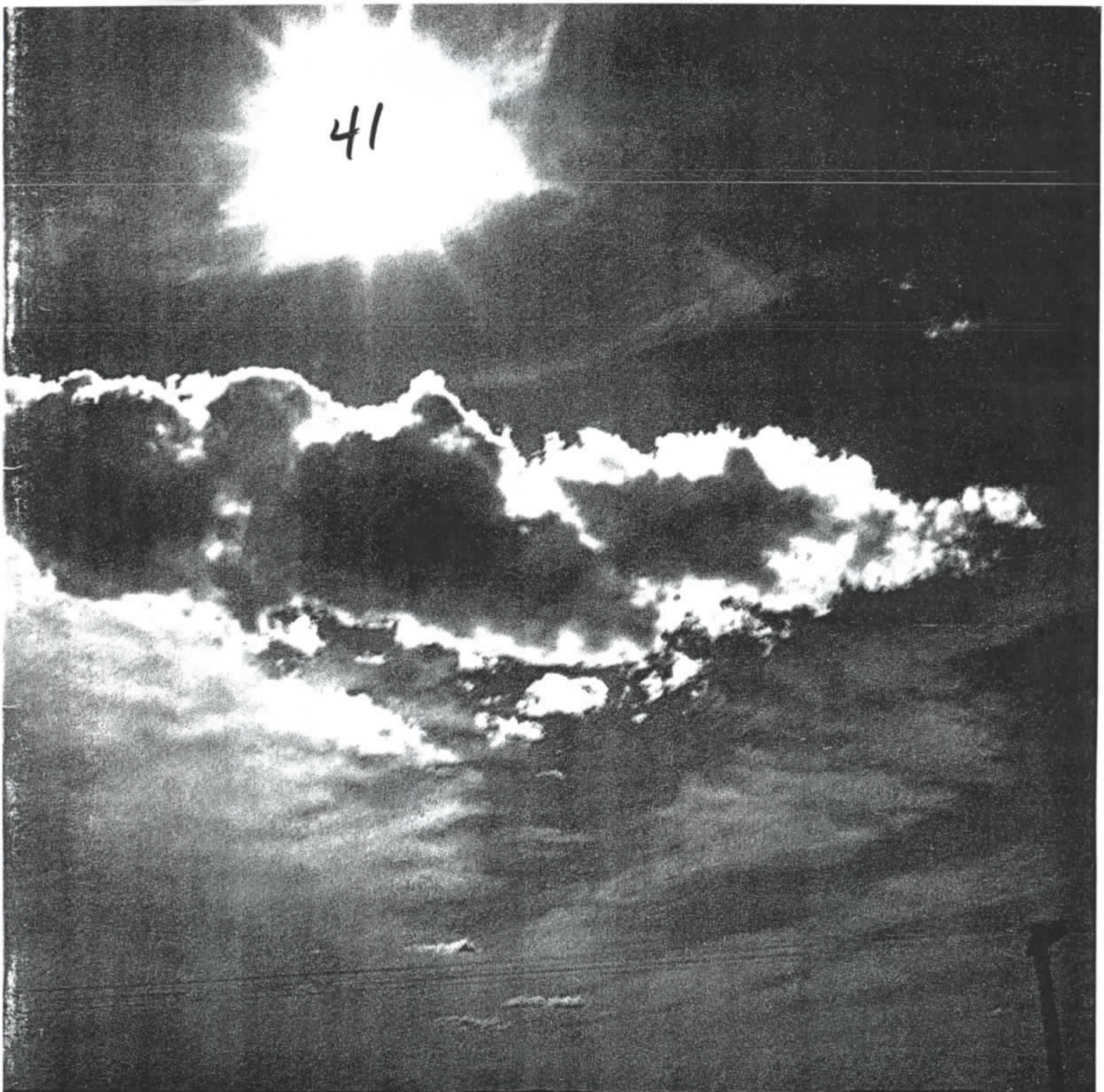
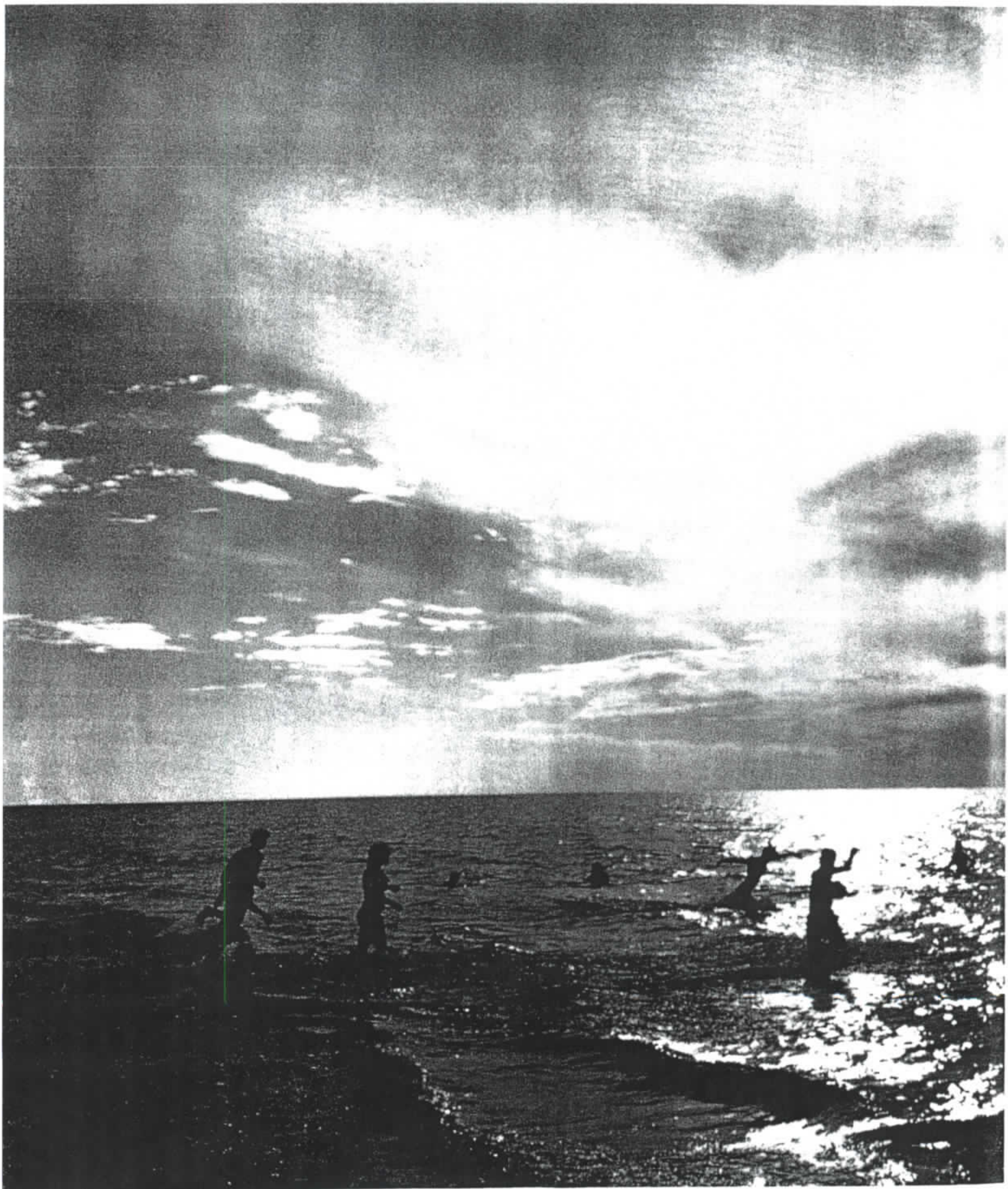


WATER SUPPLY FOR THE SASKATCHEWAN-NELSON BASIN

A SUMMARY REPORT 1972

CANADA ALBERTA SASKATCHEWAN MANITOBA



"A river is more than an amenity. It is a treasure. It offers a necess

f life that must be rationed among those who have power over it . . ."

From a decision given by Mr. Justice Holmes, in his decision in the case of New Jersey vs. New York, 283 U.S. 336, 342.

FOREWORD

This report, on a study of water supply for the Saskatchewan-Nelson Basin, was prepared by the Saskatchewan Nelson Basin Board which was established by Canada and the three provinces of Alberta, Saskatchewan and Manitoba and contains recommendations to the Committee of Ministers. While these recommendations do not commit the governments in any way to development policies, and do not singly or collectively represent the current policies of any or all of the governments sponsoring this study, nevertheless they will serve as a useful guide in framing future water policies in the basin.

The need for this study was recognized more than a decade ago. Then, as now, irrigation, hydro-power, industrial and municipal uses of water were increasing. But, to what extent had the flow of Prairie rivers been committed to these uses? If development were to continue in response to each new need, would there be future water shortages, or loss of environmental values, or both?

These concerns led to the signing of an agreement in October 1967 by the governments of Canada, Alberta, Saskatchewan and Manitoba to do a water supply study as a first step in preparing for the future. The agreement established a Board to do the study and a Committee of Ministers to be responsible for its overall direction.

Although the scope of the study was limited to water supply, the results point to a number of questions which remain unanswered.

What kind of society will develop in the future and what will be the extent of its water needs? Once it is known what is physically feasible, and environmentally acceptable, should development be encouraged where the water is, or should the water be conveyed to where the development is? Should research be encouraged toward processes which use less water? What are the environmental values that should be preserved or enhanced during the development process? Before answers to these questions can be found many conflicts in water management must be resolved.

This large basin enhances a bond of common interest among the provinces of Alberta, Saskatchewan and Manitoba. Each has its own development goals. Each is sensitive when its autonomy is limited in any way. But in this basin, only a co-operative approach to future planning and development can be successful in solving conflicts.

The study has shown that a co-operative approach works. Working collectively, some of the answers have been found to many water supply questions. In the future it will be possible to answer many of the planning and development questions with equal success by maintaining the spirit of co-operation which characterized this study.

The report describes what the water supply is right now by presenting an inventory of river flows at 145 points in this large and important basin. It records that many large dams and diversion works, having a replacement value of about $1 billion, have already been built to regulate the supply. It also presents the results of preliminary investigations of further possibilities for storing or diverting the flow of rivers to increase the usable supply of water. Finally it provides an inventory of possibilities for augmenting the water supply of the Saskatchewan-Nelson Basin.

Recognizing the importance of this information in future studies of water resources the participating governments have agreed that this report be published and that the technical data contained in the various supporting documents be made accessible as public information.

The Committee of Ministers

Canada
The Honourable Jack Davis, Minister of Environment

Canada
The Honourable H. A. Olson, Minister of Agriculture

Alberta
The Honourable William J. Yurko, Minister of Environment

Saskatchewan
The Honourable Neil E. Byers, Minister of Environment

Manitoba
The Honourable Sam Uskiw, Minister of Agriculture

Alberta
The Honourable Donald R. Getty, Minister of Federal and Interprovincial Affairs

Saskatchewan
The Honourable G. R. Bowerman, Minister of Natural Resources

Manitoba
The Honourable Leonard S. Evans, Acting Minister of Mines, Resources and Environmental Management

SASKATCHEWAN — NELSON BASIN BOARD
COMMISSION DU BASSIN SASKATCHEWAN-NELSON
CANADA • ALBERTA • SASKATCHEWAN • MANITOBA

Committee of Ministers,
Saskatchewan-Nelson Basin Study.

Gentlemen:

On behalf of the members of the Saskatchewan-Nelson Basin Board, I am pleased to report completion of the assignment that was given to the Board in the agreement signed by the Ministers representing Canada, Alberta, Saskatchewan and Manitoba on October 16, 1967.

I note with much satisfaction that all phases of our work have been marked by excellent co-operation between the agencies of the four governments, consultants and other organizations that have contributed to the study.

The report of the Board, which includes eight appendices, describes in considerable detail how we studied the feasibility and cost of improving the water supply to the Saskatchewan-Nelson basin. The document attached to this letter is a summary and presents the highlights of that report.

The Board wishes to express appreciation to the Committee of Ministers for its advice and encouragement throughout the course of this investigation.

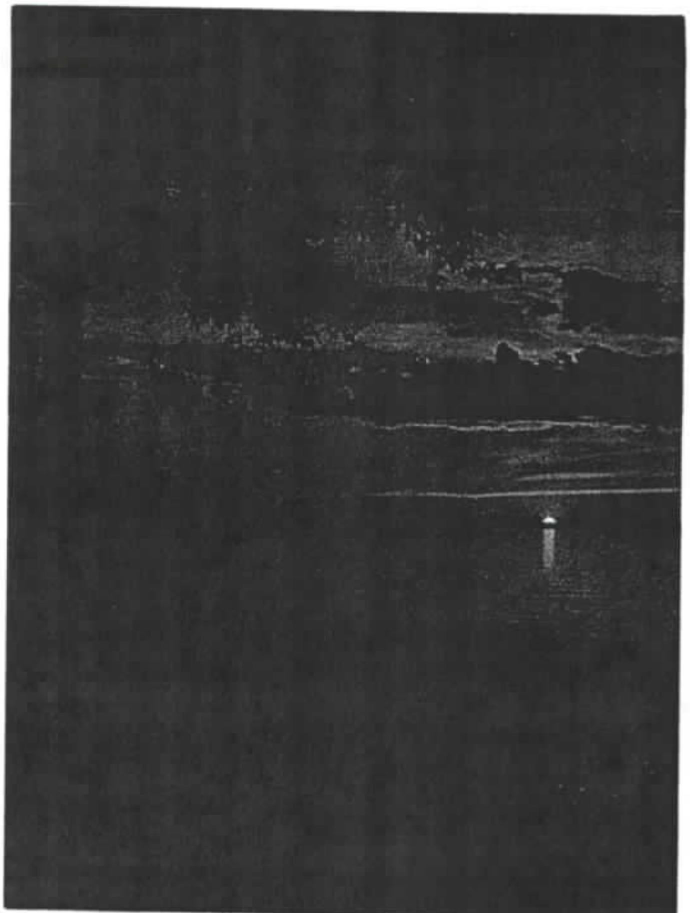
July 6/1972

Yours very truly,

A. T. Prince

A. T. Prince,
Chairman.

SYNOPSIS



Manitoba Government Photo — Clearwater Lake

The flow of Prairie rivers is small compared with other rivers in Canada. But the pace of hydro-power and irrigation development is increasing. The demand for more water by municipalities and industries is growing. People want improved recreational facilities and, at the same time, want wildlife to be preserved and to thrive.

So far, the use of Prairie waters has not caught up to the supply so major conflict among the various demands has not yet developed. But there is no question that the anticipated conflicts will have to be identified, faced and resolved.

In October 1967, the Governments of Alberta, Saskatchewan, Manitoba and Canada signed an agreement setting up the machinery for the first major intergovernmental study of the problem.

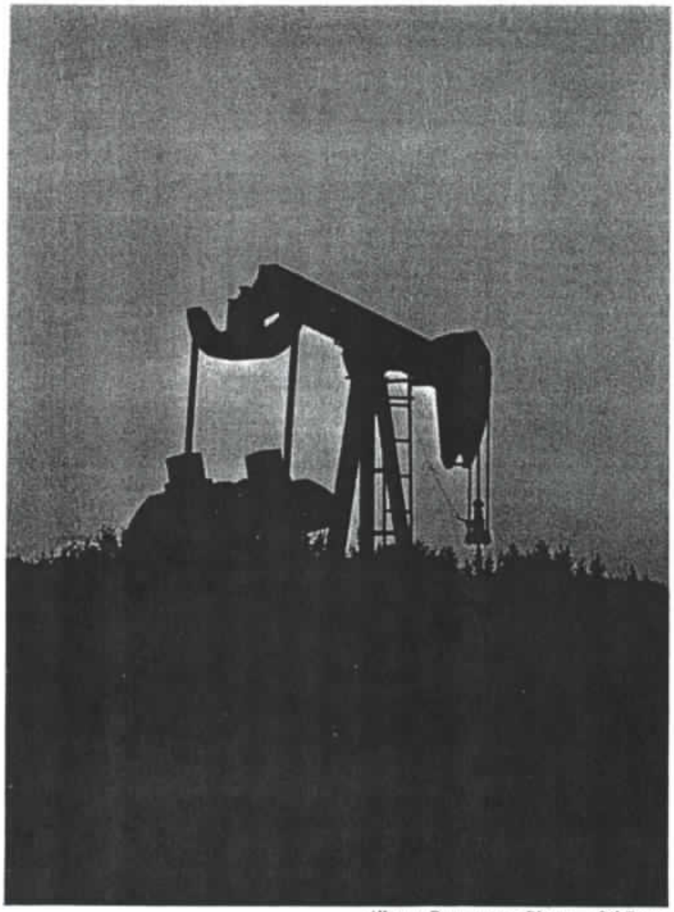
The task of preparing plans which were comprehensive enough to satisfy all the uses of the whole basin was too large to undertake all at once. So, the agreement stated that attention should be focused on water supply only.

The agreement authorized an expenditure of up to $4.8 million for a four-year water resources study of the Saskatchewan-Nelson basin, including the potential of additional supply by diversion or storage. There was to be an inventory of present water supplies, an investigation and inventory of storage and diversion works which could be used to increase the supply, and the determination of the effects of these works on the supply.

The Saskatchewan-Nelson Basin Board, established by the Terms of Reference, (on page 52) included one member for each of the three provinces and two, including the Chairman, for Canada. The Board directed the study and reported progress to the Committee of Ministers — also established by the Terms of Reference.

The Study is in four parts; project investigations, inventory of river flows, study of effects of projects on flows, and a review of environmental knowledge in the basin.

The project investigations — including 55 dams and 23 diversions — were done by Provincial and Federal agencies coordinated



Alberta Government Photo — Oil Pump

by the Board's staff. The investigations were done in sufficient detail to ensure physical feasibility and to make a cost estimate. The amounts expended on investigations were only 2 to 3% of the amount normally required to prepare construction plans.

The inventory of river flows includes a tabulation of flows at 145 points in the basin for each month of the period 1912 to 1967.

Methods were developed to compute the effects of projects, singly and in combination, on flows at 18 selected points throughout the basin. With the aid of computers, these methods were used to compute the effects of a large number of possible project combinations.

Background reports were prepared for the Board on fish and the biological system, wildlife, recreation, water quality, river regime, groundwater and effects on the donor basins of possible diversions from the Peace-Athabasca-Mackenzie and Churchill River systems. These reports comment on the extent of present knowledge, the kinds of things that could happen if projects were built and the kinds of fundamental studies needed before the consequences of development can be predicted.

The results of the study, which include project reports and tables of river flows, are described later in this summary.

After examining those results, the Board was able to make a number of findings. The principal finding of this report is that with major expenditures, large supplies of water could be made available throughout the basin, but the environmental consequences of storage regulation and diversion cannot be predicted with certainty at this time.

All of the Results, Findings and Recommendations are presented in short form later in this summary. They are presented more fully in the Board's complete report.

THE SASKATCHEWAN NELSON BASIN

How you see a river basin depends very much on how you use it. The farmer sees it as land with sufficient water to raise livestock and produce crops. A forester thinks of timber harvesting. He may also see forested areas as valuable for recreation and for wildlife production. The miner looks at the mineralized areas. The producer of hydro-electric power and the irrigator, on the other hand, see a river basin as a source of water. Their attention focuses on the flow of the rivers rather than on the land and its resources.

A boatman has a keen interest in rivers, although as long as they are wide and deep he is little concerned about the flow. And, while a fisherman may enjoy the scenery beside the rivers and lakes, his real interest lies in whether they provide a suitable habitat for the fish he is after.

Though each person, depending on his interest, would have a different answer to the question "what is a River Basin?", for the purposes of this summary, a river basin includes the main stem of the river itself, the streams and lakes that are tributary to it, and all the land that contributes runoff to the system.

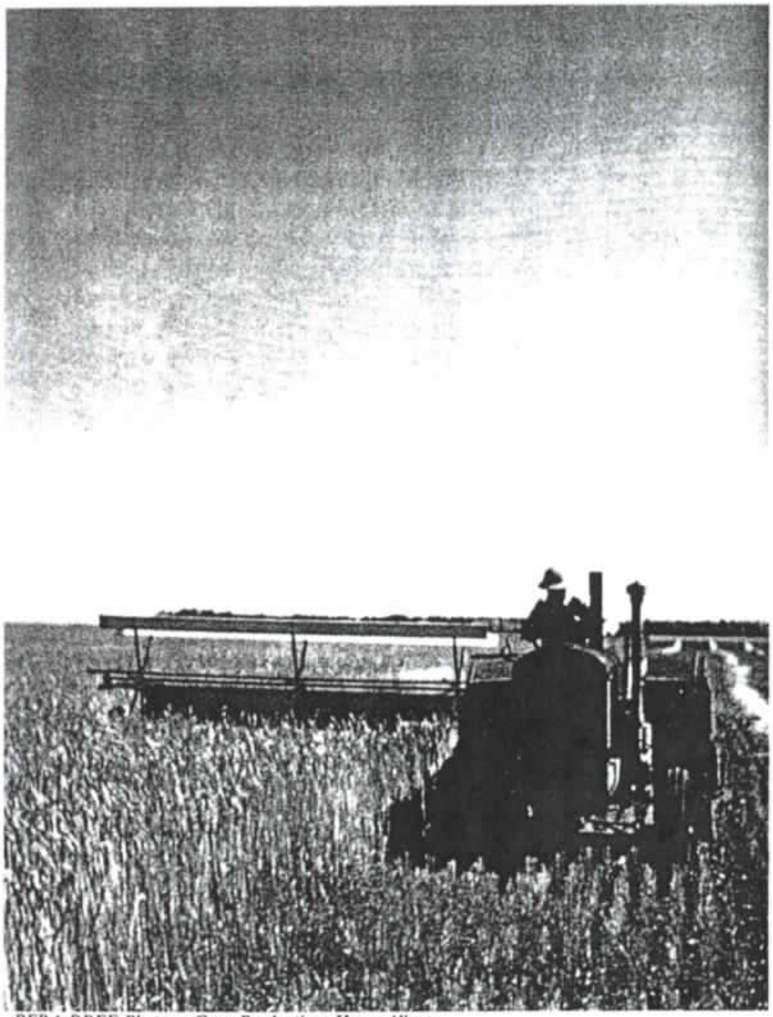
No two river basins are the same. They vary widely in size, in shape, in their drainage patterns, and in their land and mineral resources.

An overview of the Saskatchewan-Nelson Basin.

The area of the Saskatchewan-Nelson basin is 414,000 square miles, making it the fourth largest river basin in North America. However, the Nelson River ranks eighth in terms of flow which means the runoff is low compared with other river basins.

The climate of the basin varies from sub-arctic to near desert. The topography ranges from mountainous to flat-land. It has an astonishing variety of resources and supports a wide variety of human activities.

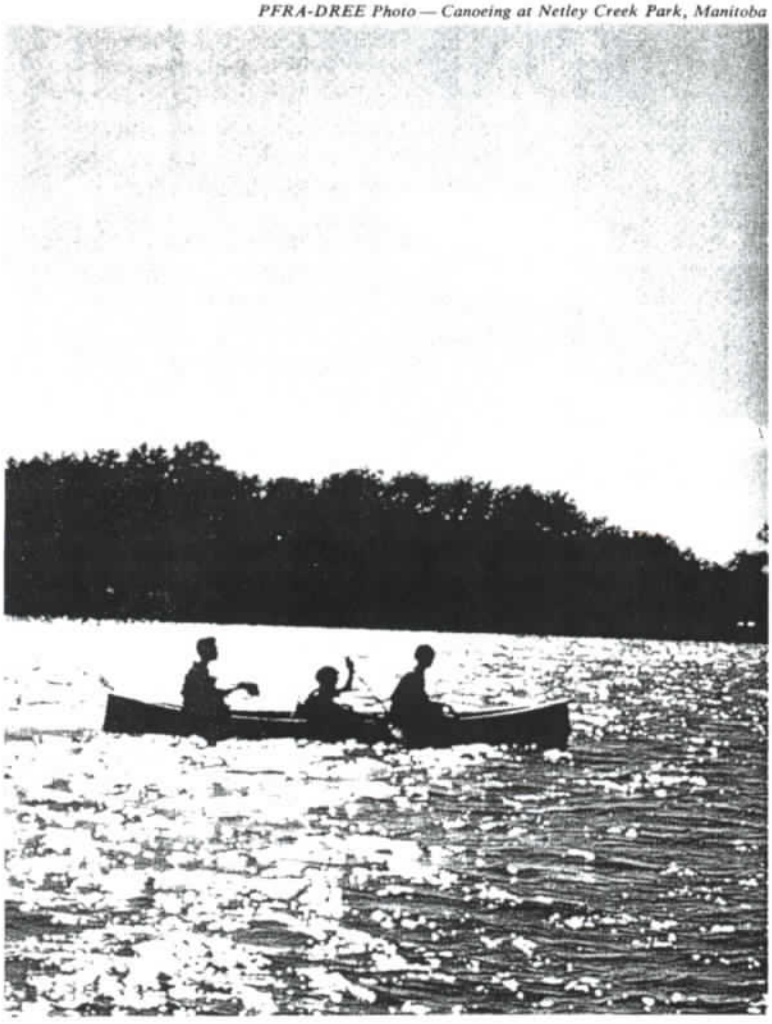
The western part of the basin is in the Rocky Mountains at the height-of-land boundary between Alberta and British Columbia. Moving eastward there is a rapid transition through the foothills into the plains. Further east, the plains slope gently downward to Lake Winnipeg in Manitoba. The east-



PFRA-DREE Photo — Crop Production, Hays, Alberta

Alberta Government Photo — Peyto Lake, Banff

PFRA-DREE Photo — Canoeing at Netley Creek Park, Manitoba



Sask. Museum of Natural History — Canada Geese

ern edge of the basin is in the rugged Canadian Shield—only 50 miles from Lake Superior. This rocky landscape with many lakes and forests slopes irregularly westward from an elevation of about 1,500 feet above sea level to the eastern shore of Lake Winnipeg at 715 feet.

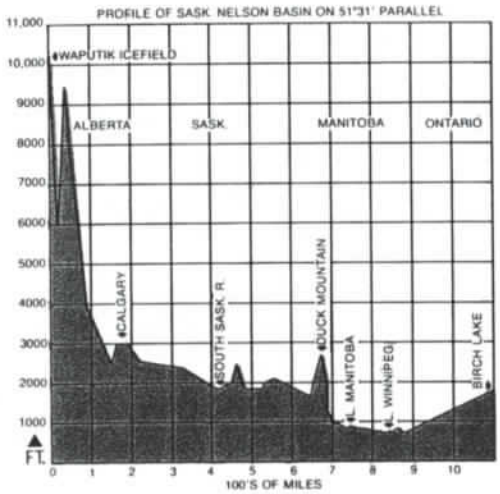
Along the northern fringe of the basin, there are extensive slow-growing forests where timber is now being harvested for the pulp and paper industry.

The southern rim of the basin reaches into the United States as far as the northern tip of South Dakota. From South Dakota to Lake Winnipeg, most of the basin is a flat, featureless, slightly-tilted plain, which slopes through a vertical distance of only 260 feet to Lake Winnipeg.

The rest of the basin is a narrow corridor of land joining Lake Winnipeg to Hudson Bay. Through most of this 380-mile corridor, the Nelson River has cut through the rugged rocks of the Canadian Shield. Nearing the ocean, the river passes through a flat lowland area, then it flows into Hudson Bay.

Many kinds of natural beauty and wealth.

The scenery of the mountain area at the western end of the basin is world famous. Artists, poets and writers have been inspired by it. Tourist brochures rave over it. Justifiably. Its natural characteristics have led to the development of a large tourist and recreation industry. The wealth of the area goes beyond its aesthetic appeal. Timber is harvested and there is considerable mining. In recent years, a start has been made on using the products of mountain and foothill forests for the



pulp and paper industry. Most of these forested areas are crown lands or are located in National Parks or Provincial forest conservation areas.

The plains area, which occupies most of the basin between the foothills and Lake Winnipeg, has been developed extensively for agricultural purposes.

Even here, variety is the keynote. The land forms are a legacy from the movement and melting of great continental glaciers. They moulded the flat clay plains, which were the beds of ancient lakes. There are plains of ice-smoothed glacial debris with various topographic forms including a Prairie trademark, the tree-ringed pothole, full of water in some years and dry in others. Hilly areas may be terminal moraines heaped up by the action of glaciers. There are sand dune areas, and many miles of old meltwater channels with small residual streams. In contrast to the plains, some of the rolling areas are high enough to cause increased rainfall. In these areas, non-commercial forests occur. Although often referred to as "the Plains", the topography is, in reality, quite varied.

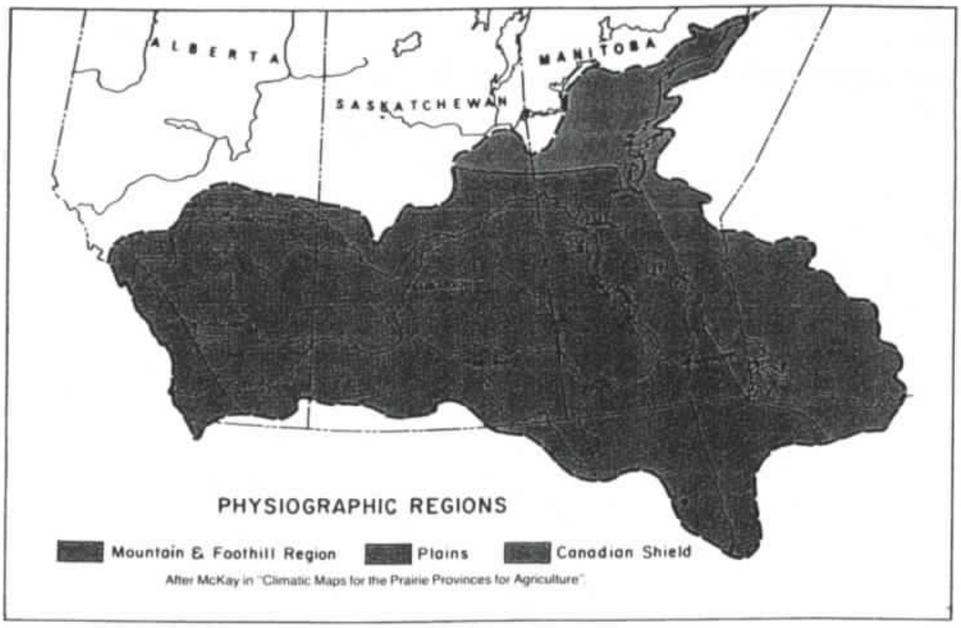
The northeastern and eastern portion of the basin is in the Canadian Shield, characterized by many bedrock outcrops. In this area, there is some mining activity and a modest amount of tourism centred around the many lakes and rivers.

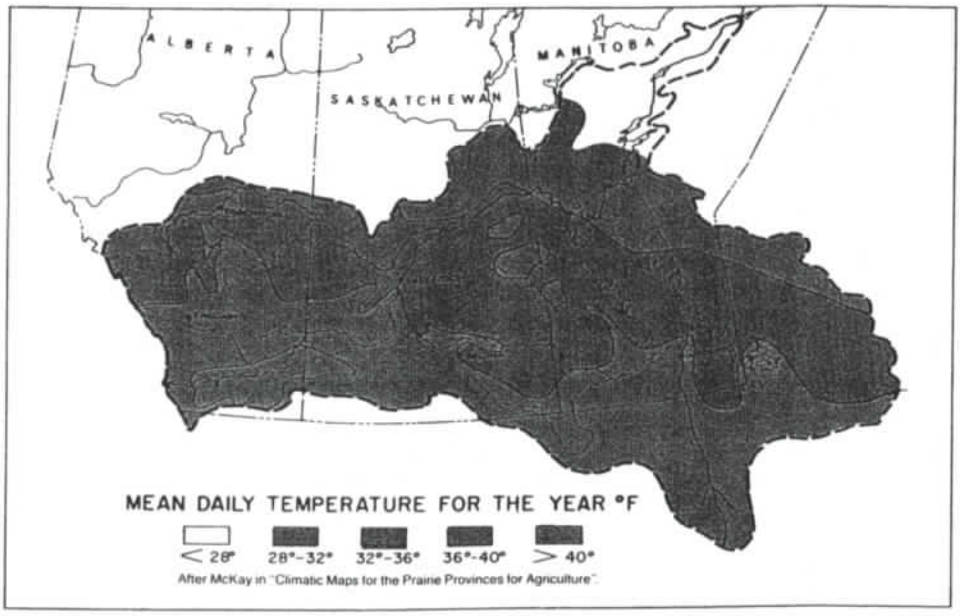
Alberta Government Photo — Tangle Creek, Banff

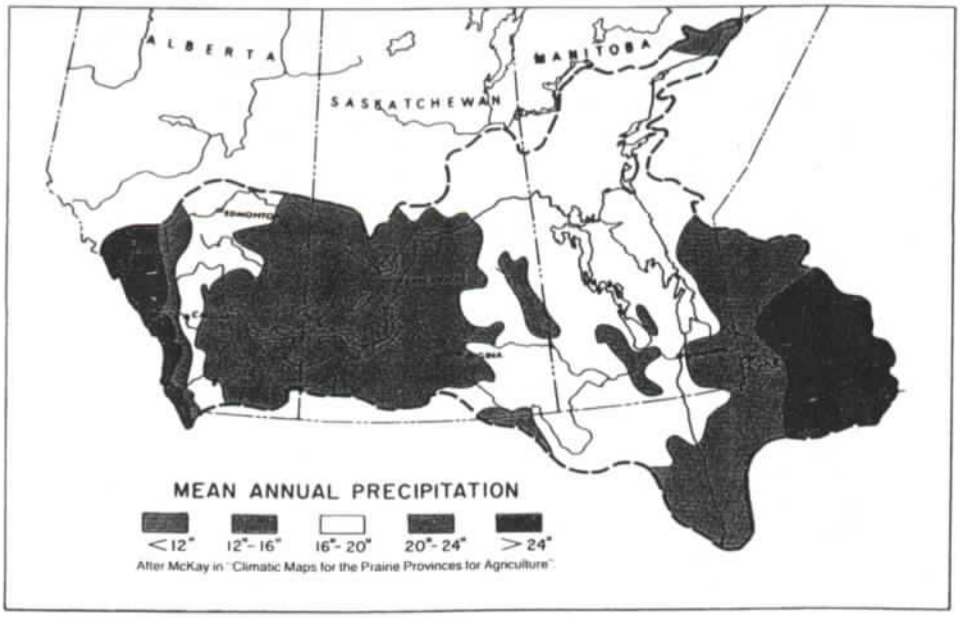
Geology & climate influence land use.

The great variety of land use is influenced partly by the underlying geological formations and surface glacial deposits. The Shield at the east end has little agricultural activity because the soil mantle is thin. But there is a mining industry, due to fairly extensive mineralization in the rocks. The rich soils and gentle undulations of the Great Plains, which occupy most of the basin, are ideally suited to agriculture. The rather spectacular land forms of the Rocky Mountains and foothills enjoy substantial rainfall and produce fast-growing forests upon which a flourishing timber industry depends. The many lakes and rivers contribute to the recreation potential of the region.

Climate has an important role in land use in the basin. Some parts of the Great Plains receive as little as eleven inches of precipitation per year. This dry core is near the point where the boundary between Alberta and Saskatchewan meets the Canada-U.S. boundary. Fanning outwards from this point, the moisture supply on the Canadian Plains increases to about twenty inches per year in a circle that encompasses Winnipeg, the northern fringe of the basin and the base of the Rocky Mountains.







Higher up in the Rocky Mountains, the annual precipitation is well over seventy inches, much of it falling as snow.

Of the total area of 414,000 square miles, 296,000 square miles are in the Interior Plains, 104,000 are in the Canadian Shield, and 14,000 are in the Mountains and foothills. About 45% of the Plains area has been developed for agricultural purposes.

The Rivers.

There are three major river systems in the basin, the Saskatchewan, the Red and the Winnipeg.

The Saskatchewan River system has its source in the Rocky Mountains and empties into the north end of Lake Winnipeg. The mountains lift the southeasterly winds in May, June and July, causing heavy precipitation in the headwaters of the Saskatchewan system. High in the mountains, much of the precipitation falls as snow, some of it on glaciers. The snow and glaciers melt late in the summer, sustaining the high flows caused by earlier rains. Most of the mountain and foothills area has a very high water yield.

The dry core of the plains area contributes very little runoff. Indeed, the warm summer temperatures, dry air and high winds cause an annual evaporation loss equal to 35 inches. Precipitation is much less than this, so there is a deficit, but some runoff may occur when there is intense rainfall, or snowmelt on frozen ground. In some years the flow of the Saskatchewan River system as it leaves the Plains is actually less than the sum of the flows produced in the mountains and foothills. However, there is a small contribution of runoff from the Plains, but it is erratic and unreliable.

The Assiniboine and Red River systems also rise on the Plains but some of their tributaries have been known to go through a two-year period with no runoff at all. The Red River system produces only one quarter as much runoff as the Saskatchewan River system, square mile for square mile.

The Winnipeg River system, which is almost entirely in the Canadian Shield, drains only 13% of the basin tributary to Lake Winnipeg, but due to higher precipitation and the rocky terrain, the runoff is substantial. The Winnipeg River system produces 39% of the flow into Lake Winnipeg. The Saskatchewan system contributes about the same amount. The Red River yields only 8% of the inflow, and the rest comes from many small streams mostly east of the lake.

The Bow River.

The Bow River starts in Bow Lake at an elevation of 6,500 feet in Banff National Park. Here the deep trenches of the Rockies gather up mountain runoff for the Bow and its tributaries. Some of the runoff enters the tributaries immediately, some soaks into the deep gravels of the intermountain trenches, and some seeps through porous layers of rock to reappear days or even months later as groundwater outflow to the streams lower down.

The high runoff and the steep stream gradients attracted hydro-power developers many years ago. In 1913, they began a series of hydro-power installations on the Bow and its tributaries. There are now 11 of these plants with a total generating capacity of 290,000 kilowatts.

The Trans-Canada Highway follows the valley of the Bow River. As you travel it you can see the astonishing beauty of Banff National Park with its quiet solitude, towering mountains and teeming wildlife. The park had 2,000,000 visitors in 1971 and the problem of sewage treatment is growing. The regulation of river flows for hydro-power production helps to dilute these wastes, particularly in winter when power reservoirs release many times the natural flow at that season. Eventually, advanced treatment may be necessary to remove nutrients in order to preserve the high quality of the Bow River for recreation purposes.

From the park area the Bow follows its course through the foothills to Calgary. On the way it passes through the Bear Paw Dam—a hydro power development which was built to produce power while giving some control over the flow through Calgary during winter. The Bow River and its tributaries provide the water supply for Calgary and its industries as well as water for cooling and the dilution of industrial and municipal effluent.

Although the Bow River downstream from Calgary has lost its mountain purity it is still a relatively clean river but its silt load becomes more noticeable. During periods of intense rainfall, eroded material is washed into stream channels, often forming sand bars in the beds of the streams or on the adjoining flood plains. From time to time, strong currents in the streams themselves, or flood flows in the flood plains will pick up this material and carry it downstream.

On the eastern outskirts of Calgary there is a large canal with the capacity of 1,200 cfs.* It serves an irrigation district whose irrigation works can reach 150,000 acres. A little further downstream, another canal serves an irrigation district with works that can serve 115,000 acres. Eighty miles downstream from Calgary there is a third irrigation canal, capable of carrying over 2,500 cfs and serving 200,000 acres of irrigable land. In addition, the river provides the water supply to and receives the effluent from a number of small communities between Calgary and Medicine Hat.

The South Saskatchewan River.

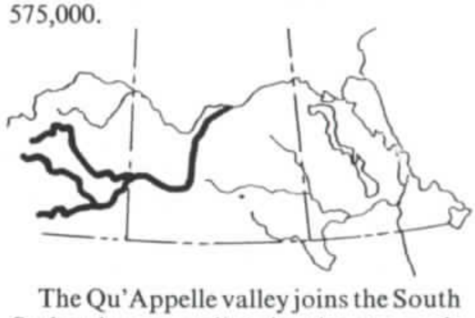
The Bow and the Oldman Rivers join to form the South Saskatchewan River just west of Medicine Hat. Before joining the Bow, the Oldman River has served an urban population of some 75,000 and its industries, as well as about 420,000 acres of irrigated land. A growing number of cattle feedlots and concentrated hog raising operations also contribute pollutants to the river. An outstanding recreation area in the Oldman Basin is the Waterton National Park in the headwaters of the Waterton River. Although not as heavily utilized as Banff National Park the number of visitors grows each year.

The South Saskatchewan is the source of municipal and industrial water for the 30,000 people of Medicine Hat. It also receives their wastes.

From Medicine Hat to the Alberta-Saskatchewan boundary, the river passes through a sparsely populated area. A few small communities are served by water from the river or its tributaries.

The South Saskatchewan is joined by the Red Deer River just to the east of the Alberta-Saskatchewan boundary. The Red Deer is the last major tributary of the South Saskatchewan system. It starts on the east slope of the Rockies, passes through the town of Red Deer, then flows southward and eastward to join the South Saskatchewan. It is similar in most respects to the Bow and the Oldman, except that, from Drumheller to Empress, it passes through an arid area characterized by erosional remnants of soft sedimentary formations. In this area, known as the "badlands", a large sediment load is picked up during periods of high flow.

Eastward from the Alberta-Saskatchewan boundary, the South Saskatchewan River widens as it enters Lake Diefenbaker, the reservoir created by the Gardiner and Qu'Appelle Dams. From the mountains to the reservoir the South Saskatchewan system has served a total urban population of 575,000.



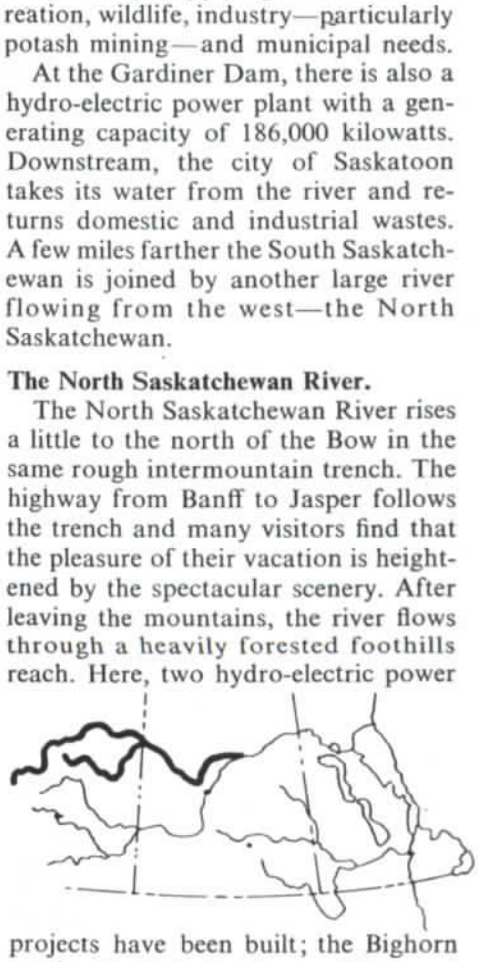
The Qu'Appelle valley joins the South Saskatchewan valley in the reservoir area from which flows can be released into the Qu'Appelle-Assiniboine system.

Irrigation development using water from Lake Diefenbaker reached 40,000 acres by 1971, and the potential totals 290,000 acres. In addition, a canal on the east side of the lake flows northward then eastward through the Blackstrap Valley supplying water for recreation, wildlife, industry—particularly potash mining—and municipal needs.

At the Gardiner Dam, there is also a hydro-electric power plant with a generating capacity of 186,000 kilowatts. Downstream, the city of Saskatoon takes its water from the river and returns domestic and industrial wastes. A few miles farther the South Saskatchewan is joined by another large river flowing from the west—the North Saskatchewan.

The North Saskatchewan River.

The North Saskatchewan River rises a little to the north of the Bow in the same rough intermountain trench. The highway from Banff to Jasper follows the trench and many visitors find that the pleasure of their vacation is heightened by the spectacular scenery. After leaving the mountains, the river flows through a heavily forested foothills reach. Here, two hydro-electric power



projects have been built; the Bighorn on the North Saskatchewan River and the Brazeau on a tributary—the Brazeau

**cubic feet per second.*

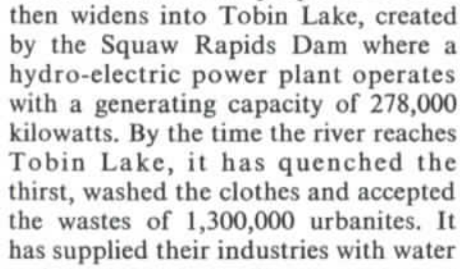
River. The Brazeau project has a generating capacity of 305,000 kilowatts, and the Bighorn,* a capacity of 108,000 kilowatts. Both projects increase low flows at the city of Edmonton.

Edmonton uses the river as a source of municipal and industrial water and for the assimilation of treated wastes. Between Edmonton and Prince Albert, the demands on the North Saskatchewan River are light, confined largely to municipal and industrial water supply and waste disposal.

The North and South Branches Become the Saskatchewan.

East of Prince Albert, the confluence of the North and South Saskatchewan Rivers marks the beginning of the Saskatchewan River proper. The river then widens into Tobin Lake, created by the Squaw Rapids Dam where a hydro-electric power plant operates with a generating capacity of 278,000 kilowatts. By the time the river reaches Tobin Lake, it has quenched the thirst, washed the clothes and accepted the wastes of 1,300,000 urbanites. It has supplied their industries with water and received their effluent, most of it treated.

Just west of the Saskatchewan-Manitoba border there is an extensive delta

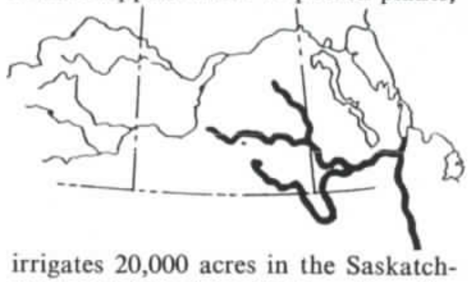


area formed by the silt-laden waters of the Saskatchewan River. The delta area teems with wildlife of many kinds. After flowing by the town of The Pas, providing water, and accepting wastes, the Saskatchewan empties into Cedar Lake, head pond of the 437,000-kilowatt Grand Rapids power plant. This is the last major fall in the river before it enters Lake Winnipeg.

The Red River.

The Red River is fed by the Qu'Appelle, Assiniboine and Souris Rivers as well as by its own basin which lies mostly in the United States. Each of these rivers is described separately.

Water can be released from Lake Diefenbaker, on the South Saskatchewan to the headwaters of the Qu'Appelle River system. The supplementary flow stabilizes the water levels in Eyebrow Lake, a wildlife refuge north of Moose Jaw and the levels of Buffalo Pound Lake, a water supply reservoir for the cities of Moose Jaw and Regina. It also supplies water to potash plants,



irrigates 20,000 acres in the Saskatchewan portion of the Qu'Appelle valley and stabilizes water levels in Last Mountain Lake.

East of Regina, there are six natural lakes used for recreation, sport fishing, and commercial fishing. Their supply of water is also supplemented by waters from Lake Diefenbaker. The natural flows of the Qu'Appelle, with the help of flows from Lake Diefenbaker, supply the water requirements of an urban population of about 200,000.

Almost all of the urban centres in the basin have secondary, or better, treatment of effluent but the mineral nutrients are not removed. Even with supplemental water from Lake Diefenbaker, the flow is low and the nutrient concentration high, so there is a major problem in maintaining good recreational water quality in the lower Qu'Appelle lakes.

The Assiniboine River which is regulated by reservoirs at Shellmouth and Rivers is joined by the Qu'Appelle as it enters Manitoba. Releases from these reservoirs, with the releases from Lake Diefenbaker help keep up the flow during dry periods stabilizing the supply for municipal and industrial purposes along the Assiniboine system in Manitoba.

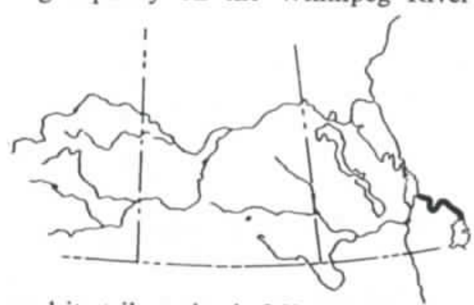
The Souris River rises on the plains south of Regina, loops through North Dakota, then flows north into Manitoba. East of Brandon the Souris River also joins the Assiniboine River. The flow is very small and in dry years sometimes drops to zero.

However, spring floods have caused extensive damage, so a floodway has been built near Portage La Prairie to divert Assiniboine floodwaters to Lake Manitoba.

In the city of Winnipeg, the Assiniboine joins the Red River which flows northward from the U.S.A. to Lake Winnipeg. Between the Canada-U.S. border and the city of Winnipeg, ring dykes have been built around several communities to protect them from flooding. A floodway has been built around the city of Winnipeg to reduce the probability of floodwaters spilling into the city. By the time the Red River leaves Winnipeg, it has served a total urban population of about 1,400,000.

The Winnipeg River.

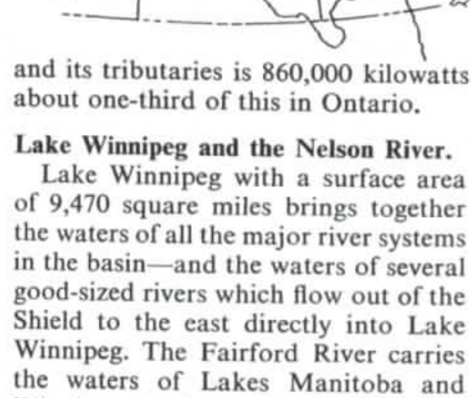
The Winnipeg River, which rises in Ontario about 50 miles west of Thunder Bay, drains a basin of lakes and short connecting rivers with many rapids. The lakes, particularly Lake of the Woods, are used for recreation. The rivers have been developed extensively for power purposes. The total generating capacity on the Winnipeg River



and its tributaries is 860,000 kilowatts about one-third of this in Ontario.

Lake Winnipeg and the Nelson River.

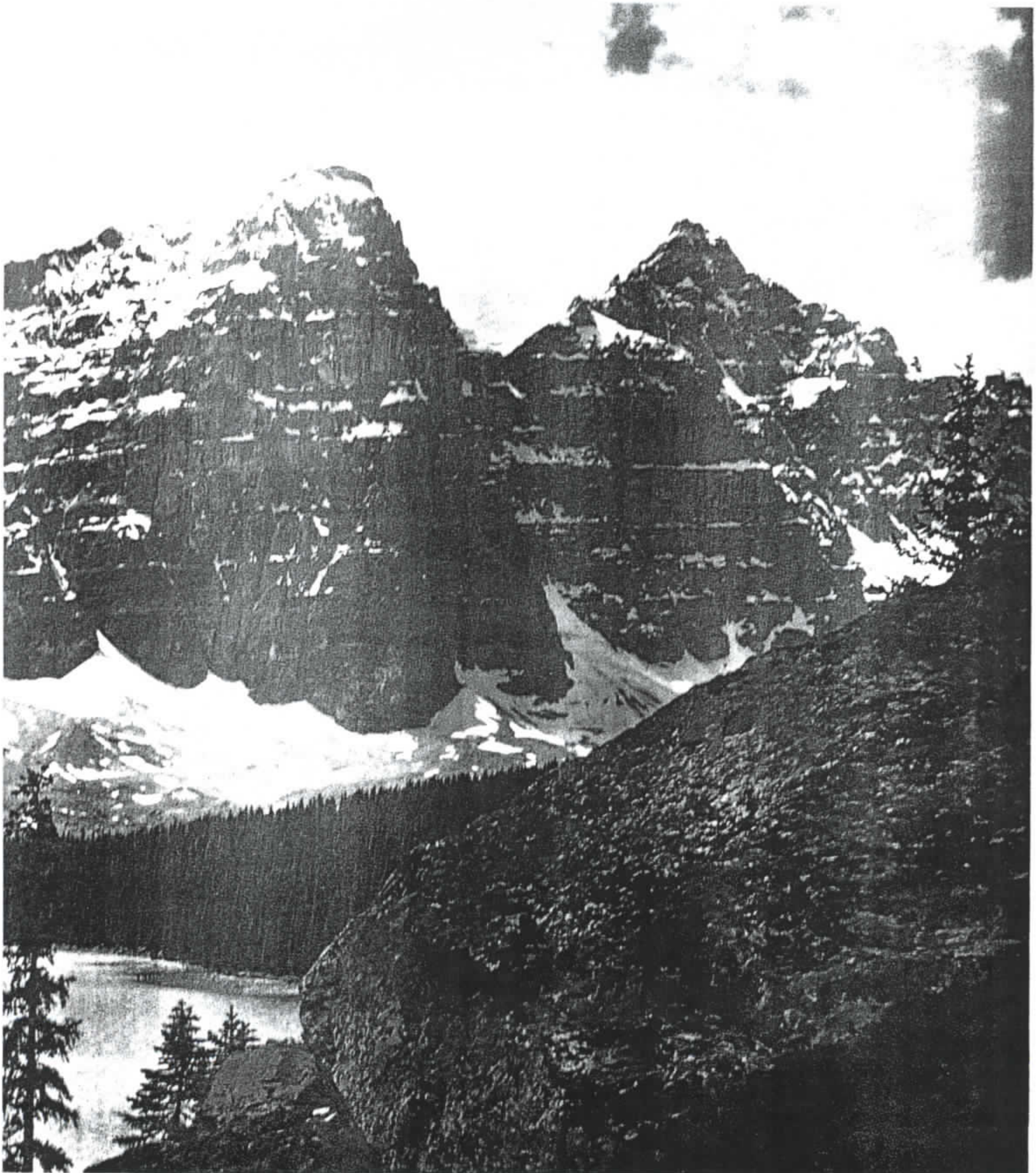
Lake Winnipeg with a surface area of 9,470 square miles brings together the waters of all the major river systems in the basin—and the waters of several good-sized rivers which flow out of the Shield to the east directly into Lake Winnipeg. The Fairford River carries the waters of Lakes Manitoba and Winnipegosis, immediately to the west into Lake Winnipeg. Then the waters of Lake Winnipeg are carried by the Nelson River to Hudson Bay. From the lake to the sea, the river drops more than 700 feet. Several sites on the Nelson have been proposed for hydropower development. At Kelsey and at Kettle Rapids, 610,000 kilowatts of



power generating capacity are already installed or under construction. The potential of the Nelson River is 6,000,000 kilowatts.

**to be completed in 1972*

CONFLICT AND CO-OPERATION



Alberta Government Photo — Moraine Lake, Banff

Before the Canadian Prairies were settled, the rivers were the highways. People used them as they found them. Their travels were limited only by where the rivers went and how fast they flowed.

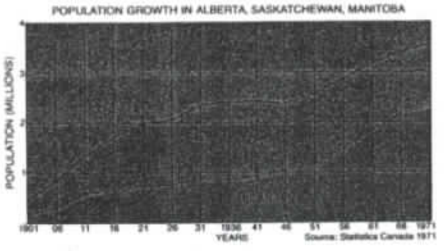
We are still limited by the rivers, but in a different way. A growing economy needs expanding water supplies. But, if greater and greater supplies cannot be found, co-operation becomes essential to share the water that is available. While there is considerable co-operation already, recent growth in water use on the Prairies suggests that conflicts may lie ahead and that even greater co-operation may be needed to resolve them.

Already, in some parts of the Prairies, there is no water left for new activities.

Population is Expanding.

The urban population in the basin is increasing steadily. Much of the growth has resulted from the movement of farm people to towns and cities.

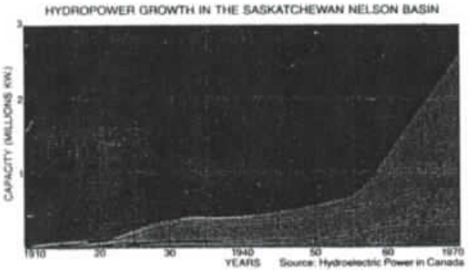
And, as disposable income and leisure time increase, city people are looking for more recreational activities. Among these are boating, fishing, water skiing, camping and many others which demand the use of lakes and rivers. In some cases, these might be a natural part of the basin, but there are fewer of these in the Prairies. Our natural recreational waters are limited, so more and more facilities will have to be man-made—or man-enhanced.



These could be part of the developments that serve irrigation, hydro-power or urban water systems, but ideally, constant reservoir levels and high water quality are needed for recreation purposes. This may be in conflict with the other needs served by the development.

Hydro-power is Increasing.

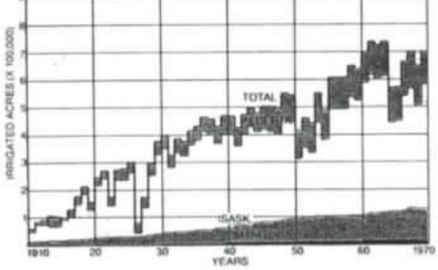
The first Hydro-electric generating plant was built in the basin in 1906. By 1970 the total installed hydro-power capacity had reached 2.7 million kilowatts. Until 1940, the growth rate was slow and steady, but during the last twenty years, the growth rate of hydro development has turned sharply upwards. This increase in power plant construction does not threaten the supply of water, but it can intensify the competition between uses situated either up-river or down-river. If a hydro plant is located downstream from places which consume water, its output is reduced. Every acre-foot* of water which is consumed through one



use or another represents energy that cannot be developed at the downstream power plant. If a hydro plant is located upstream, the reservoir usually converts surplus summer flow into winter flow to generate year-round power. In the rivers below the hydro plant, the high flows of June, July and August will be sharply reduced. The low flows of winter will be increased. This may be fine for dilution of wastes from urban centres, but it does not supply water when it is needed for irrigation.

Irrigation is Increasing.

Irrigation has been growing since the turn of the century. In 1970 the total irrigated area in the basin was 700,000 acres. The rate of growth is now about 10,000 acres a year. To give you some idea of the effect irrigation can have on the flow of a river, consider the South Saskatchewan. In an average year, irrigation consumes 27% of the flow. And recently there has been a slight



increase in the rate of irrigation development.

An Investment of $1 Billion.

Many large works have already been built to improve the reliability of flow for specific purposes, to take care of a local conflict between uses, or to improve the overall water supply to a region. Most of these projects are shown on the map on page 27.

Existing major projects in the basin would have a replacement value of more than $1 billion. This list does not include many hundreds of small projects.

1. The Brazeau Reservoir and the Bighorn Reservoir are located southwest of Edmonton in the North Saskatchewan basin. They were built for power production and to increase low flows in the Edmonton area.
2. There are seven reservoirs in the headwaters of the Bow River to serve hydro-power requirements, and a certain amount of their storage can be released for irrigation in low flow periods.
3. The Waterton and St. Mary Reservoirs in southern Alberta provide storage for irrigation.
4. Under the terms of Article VI of the Boundary Water Treaty of 1909, reservoirs and a diversion canal have been built in the United States to take some of the headwaters of the St. Mary River into the Milk River system and thence into the Missouri River.
5. Lake Diefenbaker was built on the South Saskatchewan River in Saskatchewan to supply water for irrigation, hydro-power, recreation, industrial and municipal use, and diversion to the Qu'Appelle system.
6. Just below the forks of the North and South Saskatchewan Rivers, Tobin Lake has been created by the Squaw Rapids Dam for hydro-power purposes.
7. The Grand Rapids Dam regulates

**An acre-foot of water would cover an acre of land one foot deep* the level of Cedar Lake for hydro-power purposes.

8. In the southern part of Saskatchewan there are many control works along the Qu'Appelle River which regulate local water levels mostly for recreation and agricultural purposes.

9. Reservoirs on the Assiniboine system at Shellmouth and Rivers are used to provide flood control and to supplement the low flows which often occur in this part of the basin.

10. Two major floodways have been built, one to convey Assiniboine River floodwaters at Portage la Prairie into Lake Manitoba, and one to convey Red River floodwaters around Winnipeg.

11. The Boundary dam was built on a tributary of the Souris River near Estevan to provide cooling water for thermal power production. A number of weirs have been built along the Souris River in southern Manitoba to create ponds for municipal purposes, recreation and stock watering.

12. The Fairford River Dam at the outlet of Lake Manitoba controls the outflow from Lake Manitoba into Lake Winnipeg.

13. There are two large power developments on the Nelson River, Kettle Rapids and Kelsey. In 1972, work began on the construction of works to control the level of Lake Winnipeg.

The Approach to Planning is Changing.

Most of these projects were built to serve one predominant use, or, in a small region, to serve many uses. As each was built, it was necessary, of course, to take into account the effects of projects built earlier. None of these projects were built to increase the supply of water for all uses in all parts of the basin. Even so, each large project alters the supply throughout the downstream river system.

A more comprehensive approach to planning is favoured today. But before going much further, one important question must be asked—"Should we bring water to where the development is, or should we encourage development where the water is?" This very complex question involves economics, climates, the desire of people for various amenities in their lives, their philosophy of living, the relative costs of other needs such as transportation. All of those considerations are beyond the scope of this study. In fact, no simple answer can be given, but the results of this study may provide a fund of technical information to assist the public, the planner, and the decision makers of the future in arriving at equitable solutions.

Jurisdictional Problems.

The Governments of Alberta, Saskatchewan, Manitoba and Canada signed an Apportionment Agreement in October 1969. In general terms, the agreement permits Alberta to consume 50% of the natural flow of a river before it enters Saskatchewan; Saskatchewan may consume 50% of the remainder and 50% of the added flow rising within its boundaries; and Manitoba receives the remainder. The Agreement also re-constituted the Prairie Provinces Water Board to administer the apportionment agreement and to make recommendations concerning other water problems requiring the co-operative action of the four parties.

The apportionment agreement establishes how much water supply each province can expect from its eastward flowing interprovincial rivers. However, there are a number of questions and potential conflicts which must be discussed before joint planning and development of waters on the Prairies can proceed.

If there is to be joint planning of water development, how is the problem of information exchange between people and the planning group to take place so the people of all three provinces have equal say in the planning process?

If a project is to be built in one province which will affect the other two, what will be the basis for determining the shares of each jurisdiction in the costs and benefits?

If a certain operating sequence at an upstream project could have a detrimental effect on activities in a downstream jurisdiction, what principles should be followed in planning for joint operations?

If the increasing use of groundwater causes a corresponding reduction in surface flows, what is the quantitative interconnection between ground and surface waters and how will the apportionment agreement be affected?

Irrigation has a softening effect on water, calcium in the diverted waters being replaced by sodium in the return flows. Waste disposal by industries and municipalities is affecting water quality. However, criteria for water quality on these interprovincial rivers as well as methods for monitoring water quality are now (1972) under study by the Prairie Provinces Water Board.

Perhaps the greatest problem of all will arise when comprehensive planning reveals that the benefits of one alternative for the whole region are greater than any other alternative, while within the boundaries of one province, another alternative may be greatly preferred. In such situations a great deal of negotiation will be required to reach a satisfactory compromise.

Fortunately, the Provinces and the Federal Government have established the Prairie Provinces Water Board as a framework for negotiation. It is now the responsibility of the Board to seek solutions or acceptable compromises as these problems are referred to it.

SOME CONFLICTS.

The Conflict Between Irrigation and Hydro-Power.

The use of water for irrigation reduces the flow available for the generation of electricity at downstream hydro-plants. Hydro-power reservoirs impound summer flows and release them in the winter when power demands are high. This reduces the supply available in the summer time for downstream irrigation projects. Thus, when water is in short supply, there is a conflict between irrigation and hydro-power regardless of which is upstream and which is downstream. In the future, summer power demands may be higher, particularly if heavy interconnections are made with the United States but as long as power generation continues to follow existing Prairie loads, the conflict will remain.

Both irrigation and hydro-electric power are very important to the Prairie economy. The importance of irrigation as an instrument for stabilizing the economy of large regions and for decreasing the emphasis on grain farming is well known. In recent years irrigation has been playing a growing role in the stabilization of the livestock industry, which in turn stabilizes the use of large areas of grazing. If people want to continue to use irrigation to develop stable communities, there will be continuing pressure for more irrigation.

We are consuming larger amounts of energy every year. If this growing energy demand is met with thermal power by burning of fossil fuels, there will be two by-products: increased air pollution and thermal pollution of streams and lakes. Nuclear power produces less air pollution but has a greater thermal pollution effect. If hydro-electric energy could be developed economically there would be no air or thermal pollution. And, in the Prairie environment at least, preliminary observations indicate that the construction and operation of hydro-power reservoirs may actually improve the environment for fish, both in the reservoirs and downstream. The growing demand for energy combined with the growing outcry against pollution are factors which could favour hydro-power development.

The conflict between irrigation and hydro-power should not be identified with provincial boundaries nor with vested economic interests. It is a conflict within society and can only be resolved through the classification of development objectives. It is difficult to do this right now because there is not enough background information to predict the consequences of adopting one objective over another. It will still be difficult when there is sufficient information because of the many different scales of value that competing interests may want to use.

The Conflict Between Clean Water and Waste Disposal.

There is a conflict between the increase of population on the prairies and the preservation of our river systems as suitable environments for fish and human recreation. At the time of this writing, there is still untreated sewage and industrial waste being discharged into the Saskatchewan River system. Even if all effluent were to receive secondary treatment, the rivers would still have to accept a heavy nutrient load. Tertiary or advanced waste treatment to remove nutrients is possible. When it becomes necessary, society must be prepared to pay for it.

Some nutrients are necessary to support life in the aquatic environment. But too much nutrient can lead to disaster. Pollution, then, is a matter of concentration. One teaspoonful of salt in a cup of water creates an obvious problem for a thirsty man, but one teaspoonful of salt in a swimming pool is hardly detectable. Similarly, increased river flows would increase the capacity of rivers to assimilate wastes. But this is not a permanent solution. If the increase in population continues, the point will be reached where the waste concentrations become undesirable even with flow regulation. At present it appears that more complete treatment of wastes is preferable to diluting it with increased flows. But these higher levels of treatment will mean higher costs which society as a whole must pay. In some cases the costs may be unacceptably high. So, economics may dictate consideration of both the treatment of wastes and increased flows to assimilate them.

The Conflict Between the Use of Water for Wildlife, Recreation and Other Uses.

The growing interests in recreation and the preservation of wildlife habitat will lead to a conflict in the operation of reservoirs for other uses. In the Prairie climate, the peak recreation months are July and August. If that demand is to be met, reservoirs will have to be maintained at reasonably constant levels during these two months. The operation of reservoirs to serve waterfowl interests is somewhat different.

For migratory birds, a stable or slightly dropping water level is required from early spring through to late summer so that nests are not flooded out. This regime is particularly important in the shallow parts of the reservoirs to provide the growth of certain flora which form a necessary part of the food supply for waterfowl.

On the other hand, almost all other uses of water would be better served by rising reservoir levels throughout June and July in order to impound as much as possible of the surplus floods for later release. Demands will grow for changes in present operating plans of large reservoirs to accommodate as many uses as possible. In some cases conflicts will make suitable compromises difficult to reach.

People may find the results of regulated flows and water levels undesirable from an aesthetic point of view. Eroded shorelines, unsightly sand bars and exposed mud flats may not be acceptable at some seasons. This, too, will influence reservoir operation plans.

The Conflict Between Diversion and Source.

This conflict is a simple one. If one area is to improve its water supply by importing water from another, where will the altruistic donors be found? In most river valleys, with flows as they are right now, human activities and the environment are in balance. If diversions cannot be operated so there will be little effect on the activities and environment in donor basins, conflicts will arise between receiving and donor basins. This potential conflict shows up when hypothetical diversions are discussed. It is likely that strong objections will be raised if and when actual projects are proposed.

A similar situation exists downstream from any proposed major storage project. Some activities may benefit from the elimination of floods and the improvement in low flows. Others may be tied to the old flow patterns, thus conflicts could arise between interest groups.

The Conflict Between Wildlife Habitat and Reservoirs.

A large portion of the natural wildlife habitat on the Prairies has been converted into agricultural land. After settlement evened out in the 1920s, large areas of natural habitat remained in the river valleys where steep slopes, brush and the risk of flooding combined to discourage farming. In the settled parts of the basin, river valleys still provide a major portion of the wildlife habitat. For this reason, proposals to construct reservoirs which flood out such habitats will meet with increasing resistance. Perhaps it will be necessary to consider turning back selected agricultural lands to natural conditions to compensate for areas designated for reservoir purposes.

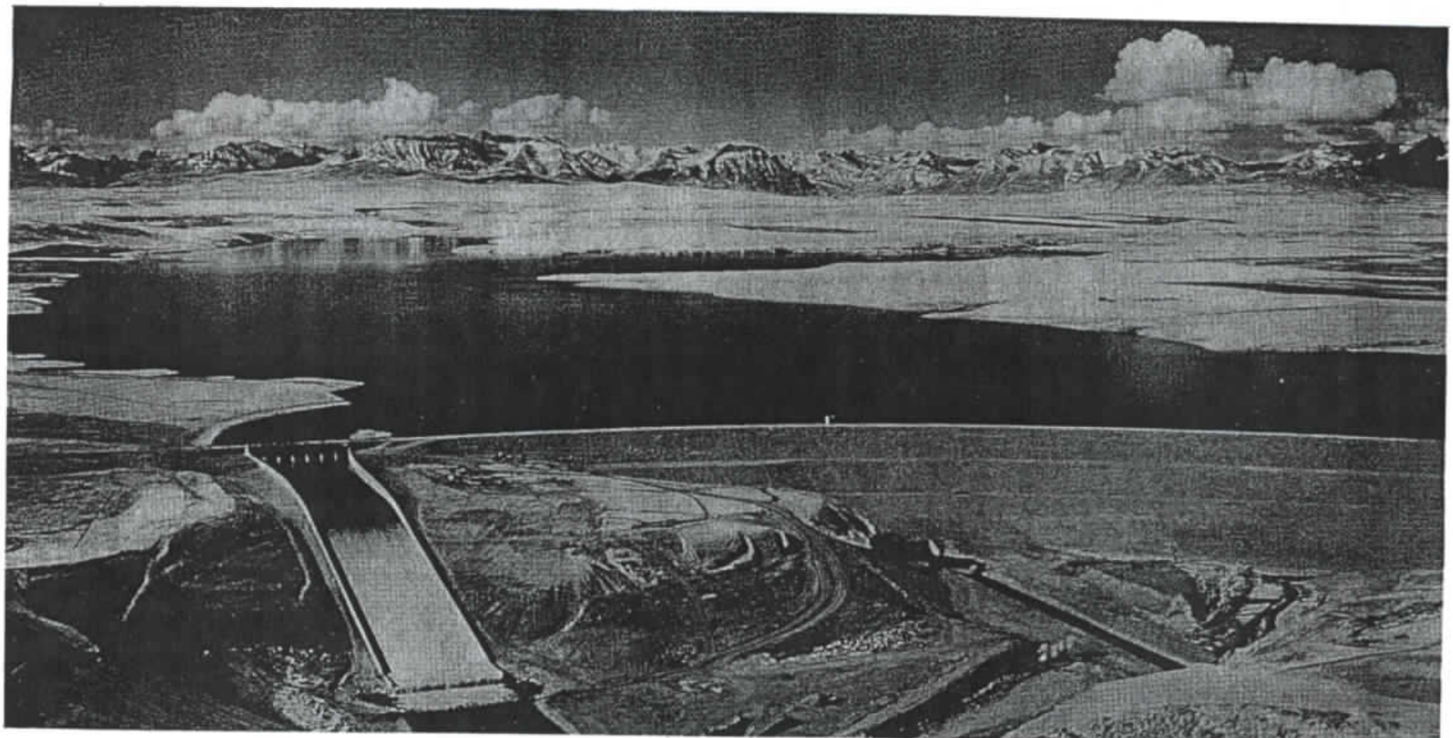
CO-OPERATION.

Water resources within provincial boundaries belong to the provinces although the Federal Government has prime responsibilities in fisheries and navigation. In the Saskatchewan-Nelson basin, several rivers flow through three provinces so no one province can claim exclusive ownership, resulting in some jurisdictional problems. The growing competition for water between various segments of society complicates the problem. *Good answers to water problems can only be found if all jurisdictions and segments co-operated.*

The four governments recognized this and, in 1948, established the Prairie Provinces Water Board to:—

"*. . . recommend the best use to be made of interprovincial waters in relation to associated resources in Manitoba, Saskatchewan and Alberta and to recommend the allocation of water as between each such province of streams flowing from one province into another province.*"

It was the Prairie Provinces Water Board which recommended in 1960 that the Saskatchewan-Nelson study be done. At the time the Apportionment Agreement was signed in 1969, the



PFRA-DREE Photo — Waterton Dam (St. Mary Irrig. Project)

Prairie Provinces Water Board was reconstituted with wider responsibilities:

"*The Board shall oversee and report on . . . the apportionment of waters flowing from one province into another province; shall take under consideration comprehensive planning, water quality management, and other questions pertaining to water resource management referred to it by the parties hereto; shall recommend appropriate action to investigate such matters and shall submit recommendations for their resolution to the parties hereto.*"

The duties of the Board are set out in more detail in the agreement and tend to give the Board an even wider scope. One such duty, for example, is: "*. . . to promote through consultation and the exchange of information the integrated development of water resources of interprovincial streams.*"

It is clear that the framework for co-operative study and action now exists in the Prairie Provinces Water Board. Although it is an advisory body, its recommendations go directly to governments, making it an effective instrument for furthering wise water development policies.

The Role of this Study.

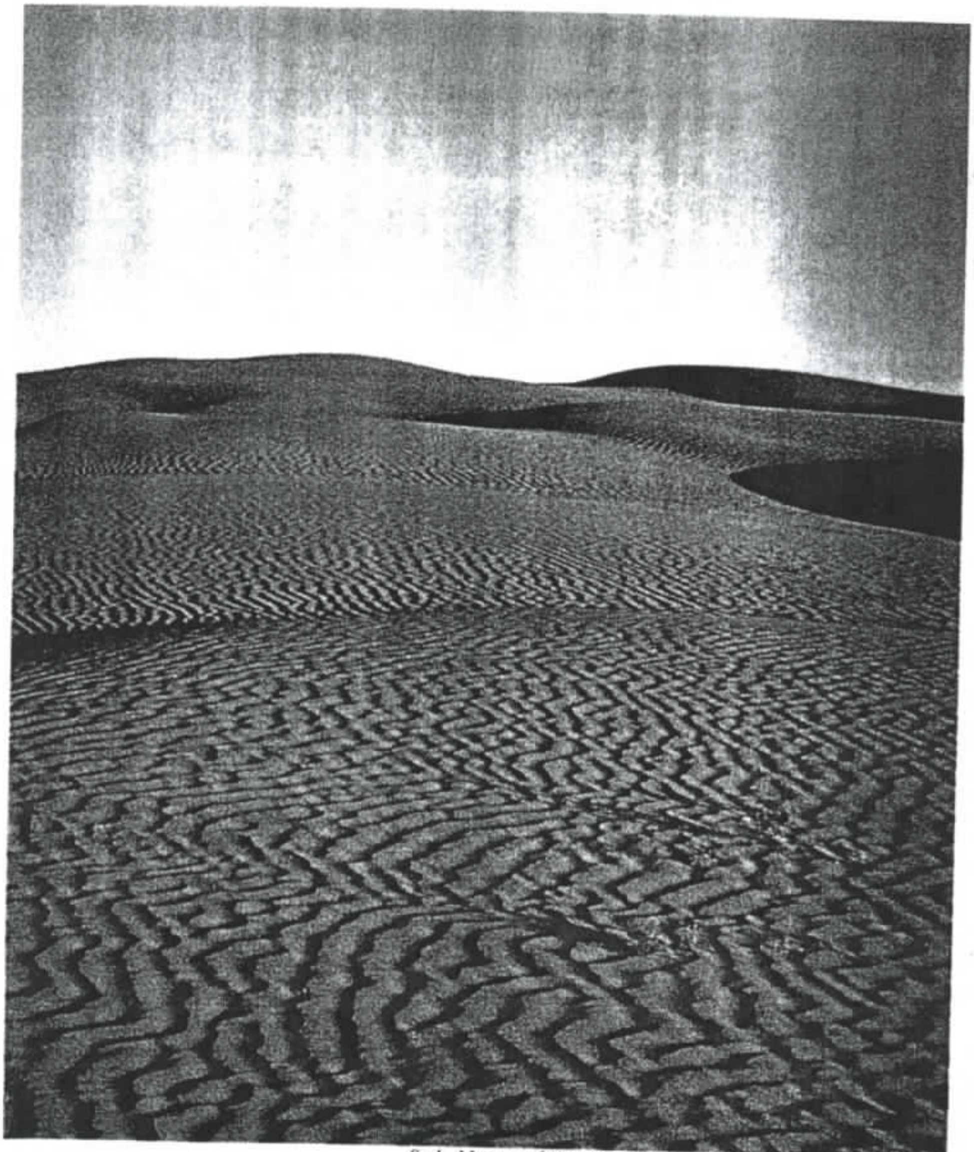
The planning and development of water resources in a basin as large as the Saskatchewan-Nelson is a complex process that has to be tackled in steps. A brief look at the overall planning process will identify these steps and illustrate what the role of this study might be in future planning.

People and their governments intercommunicate. As it applies to the Prairie water problems, people tell the politicians what they want directly, or through letters, magazines, newspapers, radio and television. To meet those needs, governments mold development policies which are passed on to the civil service force which translates the development policy into specific development objectives. Usually a technical planning group will put together a number of development alternatives. For each alternative a number of questions must be answered. How will the flows be affected throughout the basin? How will the water be used? Will the proposed development satisfy all of the uses? What is the cost? What changes will there be in people's incomes and in the environment? And finally, which alternative gives the best monetary returns, the largest number of intangible benefits, or both?

Alternatives which show promise are then presented to the governments. Again there will be interaction with the people in deciding whether or not it is time to build. Should a dam or a diversion be constructed as a result of this process it could change the way of life in a community or region. It could change people's incomes. It may cause environmental changes. Then, before another project could be seriously considered, the entire planning process would have to be repeated, incorporating the changes caused by building the previous one.

As a result of this study, for the first time the many possibilities for regulating and augmenting the supply have been identified, investigated, designed and priced. Further, in order to test the alternatives, a method has been developed for computing the effects of storages and diversions on flows throughout the basin. By using these techniques the perennial planner's question — "What other ways are there of doing it?" — has been answered, at least from a water supply point of view.

The storage and diversion costs in this report are based on preliminary designs, which are adequate for preliminary planning. The costs do not include the effect of projects on social and environmental values, nor do they include the losses (or gains) that might accrue to existing projects if the flow regime is changed. Accepting these limitations, many questions regarding the effects of projects and their operation on flows at downstream points are now answered, or can be answered on short notice. This represents a significant step toward the goal of continuous up-to-date planning as support for development decisions. If, soon, a similar study of water requirements were to be completed, there would be an even better foundation for preliminary planning.



Sask. Museum of Natural History — Great Sand Hills, Sceptre, Sask.

A JOINT APPROACH TO THIS STUDY

The concept of a joint approach to the study of water resources in this large basin had its beginnings near the turn of the century. In 1912, when Canada was still administering the water resources of Alberta and Saskatchewan, Mr. F. H. Peters, Commissioner for Irrigation, reported:—

"*In view of the possibility that the Dominion Government may turn over to the provincial governments the administration of their own natural resources, it may be permissible to record here a warning of the great troubles and difficulties that will be met if the Provinces of Alberta and Saskatchewan attempt each to control its own water resources.*"

Mr. Peters' report emphasized that not only was the supply of water limited, but the question of ownership of the waters was not resolved.

Eventually, in 1948, the Provinces and the Federal Government created the Prairie Provinces Water Board to recommend the best use of water and associated resources, and to recommend the allocation of water from streams flowing from one province into another. In its early years, the Board examined each new water development proposal, but it became obvious that a piece-meal approach would not work in this large basin. The Board recommended in 1960 to the four governments that they:—

"*. . . undertake jointly to implement a study which will lead to the formulation of an integrated development plan for the water resources of the Nelson River basin.*"

A Committee of Ministers, representing each of the three provinces and the Federal Government met in Regina in December 1963, to consider what could be done.

The Ministers were aware of the growing conflict between water users in this basin. But, in their view, economic yardsticks alone were not adequate to measure the values of various water uses, such as irrigation compared to hydro-power, or recreation and wildlife compared to irrigation. They were also concerned that the results of simple economic comparisons might prejudice a Province's claim to an equitable share of the available water. The question of ownership of interprovincial rivers was yet to be resolved.

There was one point which emerged as paramount—the supply of water would not much longer meet all the demands that were being placed on it.

They agreed to participate jointly in a study of the feasibility and cost of improving the supply to various points on the Prairies, and appointed a Technical Advisory Committee to draft a report outlining how to proceed with such a study.

The report was submitted to the Ministers in December 1964. In October 1967, an agreement was signed establishing the Saskatchewan-Nelson Basin Board to undertake an inventory of waters in the basin, including a study of the feasibility and cost of improving the supply of water in prairie rivers.

In 1969, another important step was taken toward comprehensive water planning in this basin. In October of that year, the three Prairie Governments and the Federal Government signed an Apportionment Agreement—settling the question of sharing of interprovincial waters.

Organization for Co-operation.

The Saskatchewan-Nelson Basin Board Terms of Reference (October 1967) established a Committee of eight Ministers, two representing each of the three Provinces, and two representing Canada; and a five-man Board, one for each province and two for Canada, to undertake this study. The Committee of Ministers met about once each year to consider the direction the study was taking and to approve the annual budget. The Terms of Reference gave them the authority to set the annual expenditure and, if necessary, to extend the reporting date.

The Board met frequently to consider proposed study programs, to settle administrative matters, and to give overall policy direction to the study. Early in the study, the alternate Board Members were named as an Engineering Advisory Group to advise the Study Director on technical programs and problems. The Board hired a staff of 17 to do the study.

The Terms of Reference stated that the annual expenditure would not exceed $1.2 million a year—making a four-year total of $4.8 million—and that the reporting date would be January 1972. It is interesting to compare this with the actual expenditure of $4.7 million and the extended reporting date of October 1, 1972. The extension helped to compensate for the delay from the signing of the Agreement on October 16, 1967, to the recruiting of a staff of working size by July 1968.

In keeping with these Terms of Reference, Canada paid one half the cost and the provinces shared the other half as equal partners.

These arrangements for the joint undertaking of a water supply study worked well. They provided opportunities for each party to influence the course of the study at the political, policy, administrative and technical levels. All possibility of real or imagined bias on the part of one government, or any of its agencies, was removed by placing the detailed direction of the study in the hands of a staff hired by and responsible to the Board.

The full text of the Saskatchewan-Nelson Basin Board Terms of Reference will be found on page 52. Immediately following the Terms of Reference, there is a record of the membership of the Committee of Ministers and the Board, and the Engineering Advisory Group.

Getting Started.

The objective of the study was:

"*To study the water resources of the Saskatchewan-Nelson Basin, including the potential additional supply by diversion or storage. In making this study, consideration will be given to the feasibility and cost of the many combinations of storage and/or diversion works needed to provide a firm water supply of varying amounts and with varying seasonal distributions, at various selected points along the river system.*"

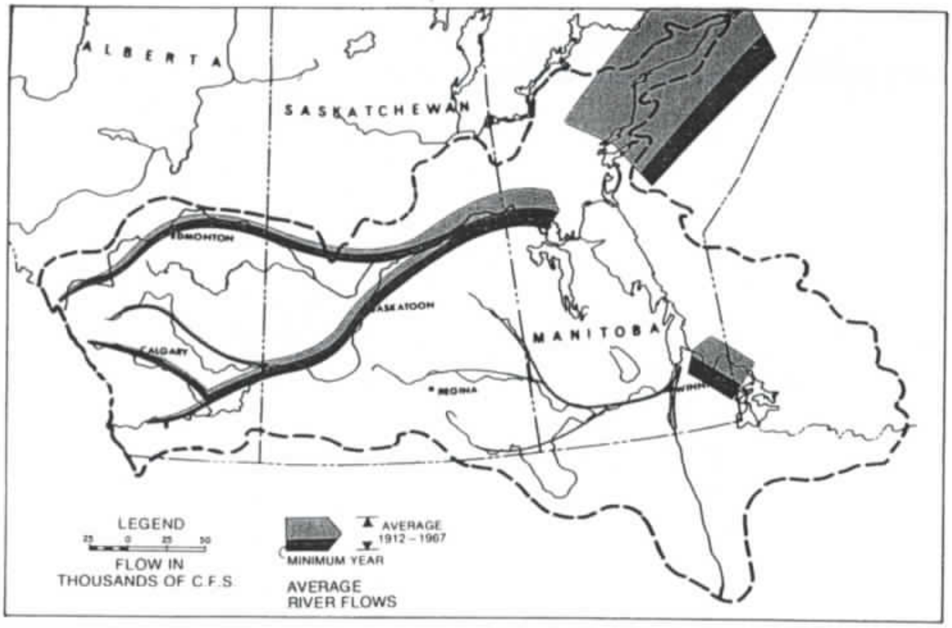
The study objective required that (1) a number of possible storage sites and diversions be chosen for investigation, that (2) the available flows at these projects be determined, and that (3) their effects on the flows throughout the basin be determined.

The first step in pursuing the objective was to select possible storages and diversions. The members of the Board and the Engineering Advisory Group had wide knowledge of investigations that had been done in the past. The Board and the E.A.G. also knew where water demands were increasing in the basin. They pooled their knowledge, making it possible to come up with a field investigation program within two or three months after the study started. Then the Board contracted with Provincial and Federal water agencies to undertake these investigations.

In this way the feasibility and cost were determined for 55 possible reservoirs for storing water during periods of surplus, and releasing water during periods of need, and 23 possible diversions. All reasonable possibilities for major storages within the basin and all reasonable possibilities for easy transfer of waters from nearby basins into the Saskatchewan-Nelson Basin or from one part of the basin to another have been examined.

Storage and Diversion Costs.

The amount of fieldwork and design that was done was enough to ensure the Board that the projects were feasible from an engineering point of view, and that a reasonable cost estimate could be prepared. A preliminary engineering report was prepared on each project and copies were filed with each of the agencies represented on the Board.



The first map shows the average natural flow for the entire period 1912-67, and the average for the minimum flow year, 1941. The second map shows all the points for which the flows were estimated.

Regulated Flows.

The next step in pursuing the objective was to compute the flows which could be delivered to various parts of the basin by various storage and diversion projects, individually or in combination.

Two separate problems were encountered. One was to choose a measure of flow improvement so the regulation effect of one combination of works could be compared with another. The second problem was to develop computer programs which could be used to find the regulated flows that many different combinations of storage and diversion could supply to various parts of the basin.

Choosing a measure of flow improvement was difficult. If it is not known what the water will be used for, of what value is the increased supply? A satisfactory answer for the purposes of this study was found by thinking of water supply and use in simple terms.

A river in its natural state has high flows and low flows. If a development needs a steady supply of water, it would be risky if it were designed to use more than the low flow. But if reservoirs or diversions were added to increase the low flow during drought periods, a larger reliable supply would be available for development. The larger supplies, called guaranteed flows, were used as a basis for comparison.

The amount of money spent on storage and diversion investigations was only 2 to 3% of the amount normally required to prepare construction plans.

The tables and map on pages 26 and 27, list the investigations that were done and give some figures on sizes and on costs.

What is the Available Flow?

The Federal Reclamation Service of the Department of the Interior, and the Dominion Water Power Bureau began measuring river flows in the Saskatchewan-Nelson Basin as early as 1908. Most key points on the river systems have continuous flow records from about 1912.

Most Prairie rivers were affected very little by man's activities when record keeping began. Today, water uses are many and the measured flows no longer represent the natural characteristics of the streams. Records of water-use covering the period 1912 to 1967 were gathered. Then, in order to find the natural flow available at each project, it was necessary to adjust all of the streamflow records according to man's growing uses. The final product was an estimate of the natural flows (and water uses) at each storage and diversion site for each month of every year from 1912 through 1967. Natural flows were estimated for 145 points in the basin. To present these data completely, together with the information used in making the estimates, requires more than 700 tables, each filling one page. These data were stored in computers to simplify computations in the next step of the study.

How Guaranteed Flow is Computed.

The method for computing the flow that can be delivered by a reservoir is straightforward—add up what flows into the reservoir and subtract what flows out, calculate what disappears through evaporation, or other reservoir uses, subtract that, and the remainder is the available supply.

If the steady outflow from a reservoir is too great, the reservoir will run dry and people downstream will have no water. If the reservoir outflow is too small, the reservoir will gradually fill until it overflows and wastes water. In this study, calculations were aimed at striking a balance between too much release of water and too little, so that a reservoir would operate through its full range but never go dry, and those occasions when water would be spilled would be kept to a minimum. The steady flow provided under these circumstances is the guaranteed flow.

It was necessary to develop procedures for using computers to determine the guaranteed flows for a large number of projects operated in many different ways. The computations spanned a period of 672 months from 1912 through to 1967. Furthermore, with say, 20 or 30 projects, extensive computations were necessary to keep track of how much was in storage each month in every reservoir. Add to this the possible interconnection of drainage basins by canals so that water can be transferred from one area to another, and the computations become staggeringly complex.

Even so, it was possible to compute the guaranteed flows that could be delivered by a large number of project combinations. A full presentation of the results requires hundreds of pages of graphs, charts and tables. To illustrate the kinds of results that were obtained, the maps on pages 30 through to 35 were prepared. The first map shows the flows that could be guaranteed by existing developments. The second map shows that the addition of new storage projects would increase the guaranteed flow. The third map shows the flow that could be guaranteed by new storage projects plus diversions.

A More Complete Investigation is Needed Before Anything is Built.

This study produces information on many projects, past uses of water, and flows, that will have continuing value for future studies.

But before decisions are made to build any of these storages or diversions, much more must be known. What would the effect of such works be, for example, on fish, on wildlife, on recreation, or on water quality? A more urgent question is whether or not there is enough background data or understanding of biological and physical processes in the basin to predict such effects. There have been no prairie studies, for example, of the overall change in fish and the biological system as a result of building a reservoir which converts a river environment into a lake environment.

Concurrent Environmental Reports.

The Board decided that a study of this magnitude must give consideration to some of these other matters, so reports were commissioned on: (1) fish and the biological system; (2) recreation; (3) wildlife; (4) water quality; (5) how a river shapes itself; (6) groundwater; (7) the effects of diversions on the rivers from which water is taken.

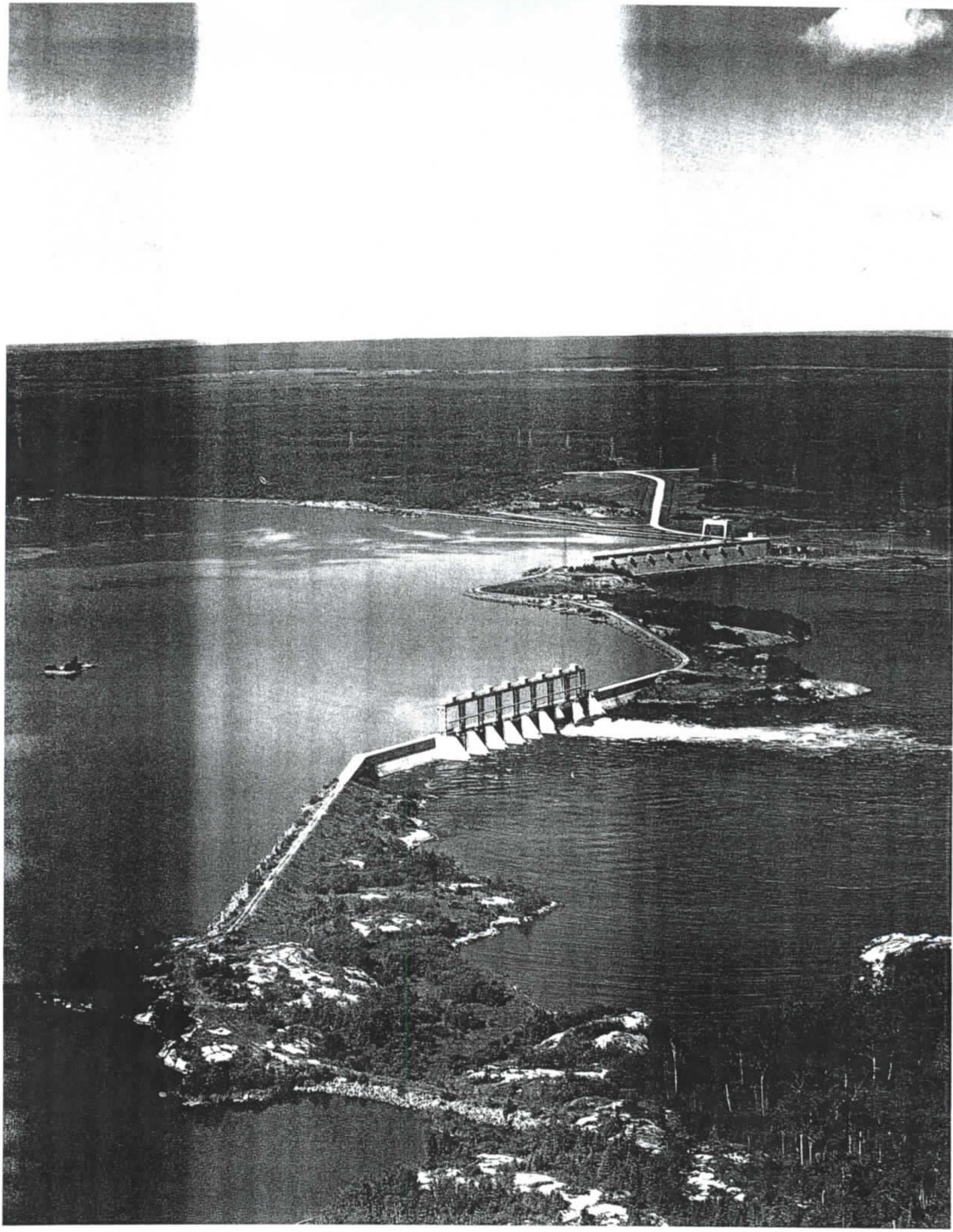
For the first five reports mentioned above, the authors were given the same terms of reference. They were asked first to describe the extent of present knowledge on their assigned subject, and in general terms, the extent of that particular resource in the Saskatchewan-Nelson Basin.

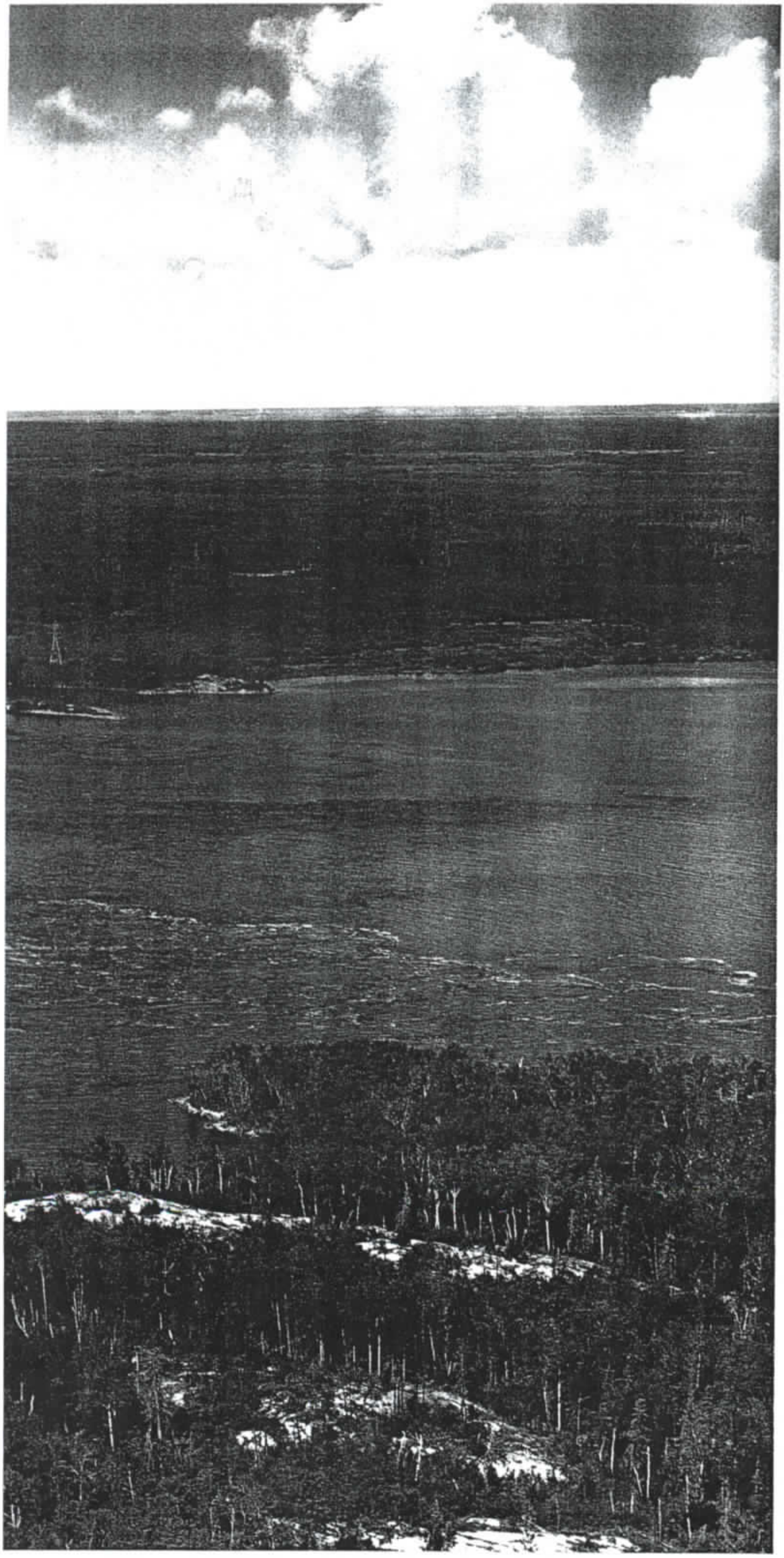
The second part of their report was to comment on the kinds of things that might happen when storages, diversions and flow regulation take place in a river basin. They were to comment on this generally, because the Board was advised that the basic scientific knowledge and data now available are not sufficient to support accurate predictions of what may happen.

The third part of each report was to outline and price the kinds of studies and investigations that should be undertaken now to provide a sound basis for future planning.

This series of reports gives an excellent background to the environmental problems which already exist in the basin, to the kinds of things that are happening or which might happen, as projects are built to satisfy society's growing demands for water.

Sask. Museum of Natural History — Prairie Lily





RESULTS

1. Preliminary engineering reports on 55 dams and 23 diversion projects have been prepared.

Reports have been prepared describing preliminary investigations of 55 storage possibilities and 23 diversion possibilities. The diversions would move water from one part of the basin to another or bring water into the basin.

Copies of these reports have been filed with each of the agencies represented on the Board. Each set of reports is an inventory of possibilities for improving the supply of water. There is no actual or implied commitment by anyone or any government that any of these projects be built.

The estimated capital and annual costs of each of these projects have been tabulated on pages 26 and 27. A glance at that table shows that the potential investment in water development could be very large. This emphasizes the importance of setting water development objectives for the basin as a whole, rather than seeking solutions to specific or localized water problems.

Eventually, some of the cost estimates will be out-of-date and new investigations may be required because of continuing technological advances in the design and construction of projects such as large dams. However, if the costs are reviewed from time to time they will have continuing value for planning. The reader is reminded that the cost estimates include all expenditures normally encountered in building major projects, but no attempt has been made to estimate the economic, social or environmental impacts.

The amounts spent on the investigations were only 2 to 3% of the amounts normally required to prepare final construction plans. Consequently, the cost estimates contain a sizeable contingency item. Nevertheless, these preliminary investigations were sufficient to ensure physical feasibility and to give reasonable confidence in the cost estimates.

2. Estimates have been made of the supply of water at 145 points in the Saskatchewan-Nelson Basin.

Streamflow records are available at many points in the basin for all or part of the period 1912 to 1967. Early in that period, the flows were affected only a little by various uses, but in

Manitoba Government Photo — McArthur Dam, Winnipeg River

Project Investigation in Alberta

Name of Project	Maximum Capacity	Cost (Million Dollars)	
		Annual*	Capital
Drayton Dam and Reservoir	1,420,000 ac. ft.	5.6	90
Ford Dam and Reservoir	100,000 ac. ft.	1.4	23
Three Rivers Dam and Reservoir	400,000 ac. ft.	2.1	35
Meridian Dam and Reservoir	2,910,000 ac. ft.	7.0	111
Peace River Diversion	Total Cost	75.0	853
Dunvegan Dam and Reservoir	5,000,000 ac. ft.	22.8	361
Diversion	15,000 cfs.	51.4	470
Lesser Slave Lake	unknown	1.4	22
Smoky River Diversion	Total Cost	34.3	635
Goodwin Dam and Reservoir	23,750,000 ac. ft.	31.5	514
Diversion	10,000 cfs.	6.5	103
Lesser Slave Lake	unknown	1.1	18
Upper Athabasca River Diversion	Total Cost	22.0	351
Athabasca (Oldman) Dam and Reservoir	1,600,000 ac. ft.	4.9	80
Diversion from Athabasca to McLeod	4,000 cfs.	7.4	117
McLeod Valley Dam and Reservoir	565,000 ac. ft.	3.1	50
Diversion from McLeod to Pembina	4,000 cfs.	1.6	25
Pembina Dam and Reservoir	277,000 ac. ft.	1.3	21
Diversion from Pembina to North Saskatchewan	4,000 cfs.	3.7	58
Lower Athabasca River Diversion	Total Cost	39.7	332
Moose Portage Dam and Reservoir	900,000 ac. ft.	4.6	74
Diversion	35,000 cfs.	35.1	258
North Saskatchewan River to Red Deer River Diversion	Total Cost	8.2	135
Rocky Mountain Dam and Reservoir	800,000 ac. ft.	5.6	92
Horseguard Dam and Reservoir	475,000 ac. ft.	1.8	31
Diversion	4,000 cfs.	0.8	12
North Saskatchewan-Battle-Red Deer Rivers Diversion	Total Cost	28.2	338
Carvel Dam and Reservoir	3,220,000 ac. ft.	11.4	181
Kelsey Dam and Reservoir	350,000 ac. ft.	1.1	18
Diversion	6,000 cfs.	15.7	139
Vermilion Diversion	Total Cost	45.9	673
Hairy Hill Dam and Reservoir	4,430,000 ac. ft.	13.5	221
Diversion	10,000 cfs.	32.2	452
Ardley Dam to Buffalo Lake Diversion	Total Cost	6.1	97
Ardley Dam and Reservoir	463,000 ac. ft.	4.2	68
Diversion	15,000 cfs.	1.3	18
Buffalo Lake	870,000 ac. ft.	0.7	11
Red Deer River to Bow River Diversion	Total Cost	11.5	133
Raven Dam and Reservoir	136,000 ac. ft.	0.8	12
Torrington Dam and Reservoir	30,200 ac. ft.	0.2	3
Diversion	4,000 cfs.	10.6	118
Bow River to Oldman River Diversion	Total Cost	7.2	112
Dalemead Dam and Reservoir	1,050,000 ac. ft.	5.1	84
Parkland Dam and Reservoir	71,000 ac. ft.	0.3	4
Diversion	2,000 cfs.	1.8	24

Project Investigation in Manitoba

Name of Project	Capacity	Cost (Million Dollars)	
		Annual	Capital
Zelena Dam and Reservoir	200,000 ac. ft.	0.4	7
Lennard Dam and Reservoir	202,000 ac. ft.	0.7	11
Clanwilliam Dam and Reservoir	338,000 ac. ft.	0.7	12
Alexander Dam and Reservoir	1,310,000 ac. ft.	2.1	35
Holland Dam and Reservoir	720,000 ac. ft.	1.1	18
High Souris Dam and Reservoir	53,000 ac. ft.	0.4	6
Lake Winnipeg Control	18,200,000 ac. ft.	39.6	267
Saskatchewan R. to Assiniboine R. Diversion	750 cfs.	0.5	7
L. Winnipegosis to Upper Assiniboine Diversion	Total Cost	22.3	134
Pelly Dam and Reservoir	375,000 ac. ft.	1.1	18
Diversion	3,000 cfs.	21.1	116
Assiniboine River to Souris River Diversion	1,000 cfs.	2.1	22
Souris River to Pembina Triangle Diversion	Total Cost	6.7	77
Coulter Dam and Reservoir	26,500 ac. ft.	0.2	3
Nesbitt Dam and Reservoir	350,000 ac. ft.	1.0	16
Diversion	2,000 cfs.	5.6	58
Lake Manitoba to Pembina Triangle Diversion	Total Cost	6.9	71
Hood Dam and Reservoir	64,000 ac. ft.	0.6	9
Diversion	2,000 cfs.	6.4	62
Lake of the Woods to Pembina Triangle Diversion	2,000 cfs.	11.0	128

*includes interest on investment, depreciation, operation, and maintenance.

recent years the effects are much greater through storage, controlled flow and use. For the purposes of the study, it was necessary to estimate what the flows would have been if the rivers had not been regulated or used. The resulting flows are termed natural and are used as a starting point for studying the effects of projects on flows.

The natural flows (particularly the minimum natural flows) are not a good measure of what the usable water supply is today. On most rivers in the Prairie area, the minimums have been increased by the operation of reservoirs.

Natural flows were computed at 145 sites in the basin for every month of the 56-year period 1912 to 1967. The top table on page 28 shows the average natural flows for the 56-year period at 18 selected study points. It also shows both the largest and the smallest monthly flows that occurred during the period.

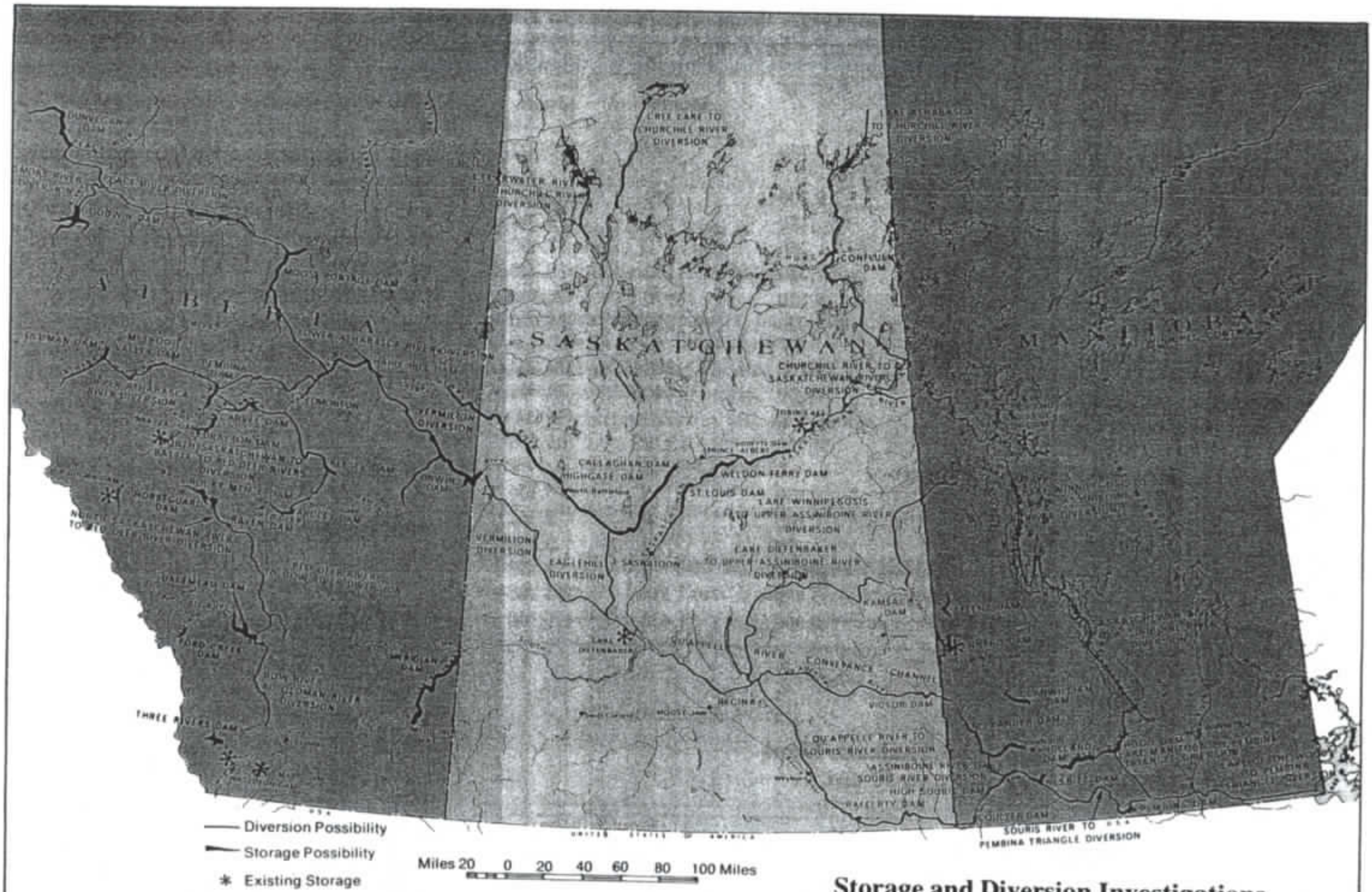
3. An estimate has been made of the effect of present irrigation, hydro power developments and diversions on river flows.

By 1970, the effects of irrigation use and hydro power regulation on the flow of the river systems were very large compared with other uses. For the purposes of this study, no data were compiled on other uses except for diversions.

The total annual consumption of water for irrigation at the 1970 level of development can vary from 1 million acre feet to almost 2 million acre feet, depending upon rainfall. The amount taken from the rivers is larger but a part of the water diverted returns as surface or groundwater runoff. Irrigation projects represent a permanent withdrawal from the stream-flow system. This loss becomes a corresponding gain to atmospheric moisture through evapotranspiration by crops.

Most hydro-electric power projects have large reservoirs. These reservoirs consume some water through evaporation, but, more important, they change the flow characteristics of a river system. Prairie power loads are high in winter and low in summer. Consequently, most of the existing hydro power reservoirs store summer flows for release in winter.

There are three diversions in the basin which have a significant effect on flows; one taking water out of the basin, one bringing water into the basin, and one transferring water from one part of the basin to another.



Storage and Diversion Investigations

The Boundary Waters Treaty of 1909 divides the flow of the St. Mary River equally between Canada and the United States. The United States share of about 270,000 acre feet per year is taken by canal to the Milk River which supplies a number of irrigation projects before joining the Missouri River in the Mississippi drainage basin.

In Ontario, a diversion from Lake St. Joseph in the upper part of the Albany River transfers, on the average, about 2,600 cfs into the Winnipeg River basin. This diversion has been in existence since 1957.

The Qu'Appelle River diversion began in a small way in 1958, when a pumping scheme was installed to bring water to the cities of Regina and Moose Jaw. By 1967, works were in place which would permit the release of up to 2,600 cfs from Lake Diefenbaker into the Qu'Appelle. The amount is presently limited by the capacity of the Qu'Appelle River channel which is less than 200 cfs at some points.

Project Investigation in Saskatchewan

Name of Project	Capacity	Cost (Million Dollars)	
		Annual	Capital
Highgate Dam and Reservoir	3,950,000 ac. ft.	7.6	123
St. Louis Dam and Reservoir	1,020,000 ac. ft.	3.1	50
Weldon Ferry Dam and Reservoir	930,000 ac. ft.	4.9	78
Codette Dam and Reservoir	2,574,000 ac. ft.	8.5	135
Lake Athabasca to Churchill River Diversion	20,000 cfs.	69.7	596
Clearwater River to Churchill River Diversion	Total Cost	1.3	22
Clearwater Dam and Reservoir	unknown	0.4	7
Turnor Lake	2,000,000 ac. ft.	0.5	8
Diversion	1,900 cfs.	0.4	7
Cree Lake to Churchill River Diversion	Total Cost	0.1	2
Cree Lake	1,470,000 ac. ft.	Nil	Nil
Diversion	1,200 cfs.	0.1	2
Churchill River to Saskatchewan River Division	Total Cost	2.4	39
Confluence Dam and Reservoir	34,500,000 ac. ft.	1.7	28
Diversion	15,000 cfs.	0.7	11
Eaglehill Diversion	Total Cost	46.8	346
Callaghan Dam and Reservoir	3,650,000 ac. ft.	5.4	88
MacDonald Creek Dam and Reservoir	63,000 ac. ft.	0.2	4
Diversion	15,000 cfs.	39.4	249
Lake Diefenbaker to Upper Assiniboine Diversion	Total Cost	8.3	88
Kamsack Dam and Reservoir	69,000 ac. ft.	0.1	2
Diversion	2,500 cfs.	8.2	86
Qu'Appelle River Conveyance Channel	Total Cost	3.5	57
Victor Dam and Reservoir	140,000 ac. ft.	0.6	9
Diversion	2,500 cfs.	2.9	48
Qu'Appelle River to Souris River Diversion	Total Cost	13.4	97
Boggy Creek Dam and Reservoir	2,800 ac. ft.	0.04	1
Sedley Dam and Reservoir	3,750 ac. ft.	0.06	1
Rafferty Dam and Reservoir	600,000 ac. ft.	0.7	11
Antler Dam and Reservoir	1,600 ac. ft.	0.03	1
Diversion	3,500 cfs.	12.6	83

Computed Natural Flow in CFS* (Period 1912-1967)

Selected Study Point	Average	Flow in Minimum Month	Flow in Maximum Month
North Saskatchewan River at Edmonton	7,780	580	42,700
North Saskatchewan River at Alberta-Saskatchewan Boundary	8,200	580	52,300
Battle River near Forestburg	80	0	2,700
Battle River at Unwin	260	1	7,490
Red Deer River at Red Deer	1,780	100	16,700
Bow River below junction with Highwood River	4,550	590	31,300
Oldman River at Lethbridge	4,020	220	35,500
South Saskatchewan River below junction with Red Deer River	10,700	830	74,500
South Saskatchewan River at Saskatoon	10,900	440	74,000
Saskatchewan River below the Forks	19,900	830	131,200
Saskatchewan River at The Pas	24,700	1,120	103,300
Qu'Appelle River at outlet from Lake Diefenbaker	0	0	0
Assiniboine River at Brandon	1,130	5	15,300
Souris River near Oxbow	100	0	2,760
Souris River near Melita	190	0	3,850
Souris River at Wawanesa	270	0	4,100
Red River below junction with Assiniboine River	5,780	130	116,300
Nelson River at Warren Landing	70,300	11,400	176,100

*Cubic feet per second.

Effect of Existing Projects and Uses on Minimum Flows For Period 1912-1967—See Map on Pages 30 and 31

Selected Study Point	Natural Flow		Flow in Minimum Month with existing Projects and 1970 Uses	
	Average	Flow In Minimum Month	A	B
North Saskatchewan River at Edmonton	7,780	580	2,600	4,900
North Saskatchewan River at Alberta-Saskatchewan Boundary	8,200	580	2,400	5,000
Battle River near Forestburg	80	0	0	0
Battle River near Unwin	260	1	1	1
Red Deer River at Red Deer	1,780	100	100	100
Bow River below junction with Highwood River	4,550	590	1,480	1,480
Oldman River at Lethbridge	4,020	220	400	400
South Saskatchewan River below junction with Red Deer River	10,700	830	1,500	1,500
South Saskatchewan River at Saskatoon	10,900	440	1,670	5,500
Saskatchewan River below the Forks	19,900	830	3,800	9,500
Saskatchewan River at The Pas	24,700	1,120	4,340	13,000
Qu'Appelle River at outlet from Lake Diefenbaker	0	0	20	20
Assiniboine River at Brandon	1,130	5	150	350
Souris River near Oxbow	100	0	0	0
Souris River near Melita	190	0	0	0
Souris River at Wawanesa	270	0	0	0
Red River below junction with Assiniboine River	5,780	130	500	770
Nelson River at Warren Landing	70,300	11,400	18,700	47,900

4. An estimate has been made of the supply of water remaining after present uses with existing storage and diversion projects.

This estimate was made to answer the question: "What would the minimum flows have been during the period 1912 through 1967 if water had been consumed at the 1970 level of development throughout the period, and if the flows were regulated with existing projects?"

The table (directly above) gives a comparison between the natural flows and the flows that could be sustained with existing works. The figures in Column A were computed assuming that existing works would be operated to serve the purposes for which they were built i.e. existing constraints. The figures in Column B were computed assuming that existing works would be operated to make the year-round flow as uniform as possible. Column B was prepared so that later in the study, the regulation capability of existing and hypothetical projects could be compared. It should be remembered that if the operation of the existing projects were changed from A to B, there would be a decrease in the value of the hydro-electric energy output.

5. How much the supply of water will be reduced when the provinces consume the water they are entitled to under the apportionment agreement has been computed.

The Apportionment Agreement was signed by the three Prairie Provinces and Canada in October of 1969. It gives a formula for sharing the waters of rivers flowing from west to east across provincial boundaries. In general terms, Alberta may consume 50% of the natural flow of a river before it enters Saskatchewan; Saskatchewan may consume 50% of the remainder, and 50% of the added flow rising within its boundaries; and Manitoba receives the remainder. For the Saskatchewan River system, the end result is that each Province may consume about ⅓ of the total natural flow computed at The Pas, Manitoba.

Using the apportionment agreement, the share of each province in the waters of the Saskatchewan and Assiniboine River systems was computed for each month of the period 1912 through 1967. Water supply studies were undertaken assuming that Alberta and Saskatchewan withdrew their shares, and that existing projects could be used to regulate the flow.

The top table (page 29) shows a comparison of supply in 1941 (Column 1), a low flow year under natural conditions, with existing projects and uses (Column 3), and with the provinces using the water they are entitled to under the apportionment agreement (Column 4). The resulting flows would be obtained if existing projects were operated for uniform flow (Column 3).

The suggested minimum flows for various points in the basin (Column 2) were set by the Provinces before these studies were done. These minimum flow requirements may change as uses change.

6. A system has been developed which can be used to compute the effects of many projects on river flows.

The computation of the effect of one project on river flows is a relatively simple task. The computation of the effect of several projects is quite complex, but can be handled effectively by computers. For this study, computerized procedures were developed which can accept 50 to 100 projects at a time. Many such analyses were done and the results show how much the supply of water can be increased by many combinations of storage and diversion projects operated in different ways. It must be remembered that the results of the computer studies are hypothetical. The results of three were selected for presentation in this summary.

1. The first set of results in Column A at right, and map on page 32 shows the flows that could be guaranteed if six new storage reservoirs were added — Carvel, Dalemead, Three Rivers, Meridian, Alexander and Nesbitt. These hypothetical reservoirs were picked because they would be reasonably efficient for flow regulation, and they could serve most of the selected study points. The reservoirs were operated by use of the computer to deliver to each study point a target flow equal to 75% of the average natural flow for the period 1912-1967. At some points, using the full capacity of the reservoirs, the regulated flow was less than 75%. At some points, it could have been greater, but the target was left at 75%. Hence the results are not necessarily the *best* flow that could be achieved at each point.

2. The second set of results in Column B at right, shows the flows that could be achieved if the six new reservoirs and five diversion were added: North Saskatchewan River to Red Deer Diversion, 3,000 cfs, summer only.
Red Deer River to Bow River Diversion, 1,000 cfs, summer only.
Bow River to Oldman River Diversion, 500 cfs, summer only.
Diversion from Lake Diefenbaker to Qu'Appelle River, 1,300 cfs, summer, 80 cfs, winter.
Diversion from Qu'Appelle to Souris River, 250 cfs, summer only.

The diversions were added in an attempt to bring the regulated flows closer to the 75% target mentioned previously. Nevertheless, the regulated flow at some points was still less than 75%. At some points, it could have been greater than 75%, but as before, the target flow was not increased.

Effect of the Apportionment Agreement on Minimum Flows
For 1941—A Low Flow Year—See Map on Pages 32 and 33

Selected Study Point	Natural Flow for Minimum Month in 1941	Suggested Minimum	With Existing Projects Operated for Uniform Flow: Existing (1970) Uses	With Existing Projects Operated for Uniform Flow: After Apportionment
North Saskatchewan River at Alberta-Saskatchewan Boundary	580	1,000	5,000	1,600
South Saskatchewan River below junction with Red Deer River	830	1,000	1,500*	1,500*
South Saskatchewan River at Saskatoon	440	1,500	5,500	1,500
Saskatchewan River below the Forks	830	3,500	9,500	2,000
Saskatchewan River at The Pas	1,120	3,000	13,000	4,000
Assiniboine River at Brandon	5	150	350	300
Red River below junction with Assiniboine River	130	1,000	770	750
Nelson River at Warren Landing	11,400	30,000	47,900	37,500

**The Apportionment Agreement requires that a minimum flow of 1,500 cfs be maintained here.*

Effect of Storages and Diversion on Minimum Flows
For 1941—A Low Flow Year—See Map on Pages 34 and 35

Selected Study Point	Flow for Minimum Month (cfs) in 1941: With Existing Projects	With Six New Reservoirs A	With 6 New Reservoirs & Internal Diversions* B	With 8 new Reservoirs, Int. Div., & Importation from other basins C
North Saskatchewan River at Edmonton	4,900	5,830	4,800	5,100
North Saskatchewan River at Alberta-Saskatchewan Boundary	5,000	6,150	5,000	12,300
Battle River near Forestburg	0	0	0	120
Battle River near Unwin	1	1	1	350
Red Deer River at Red Deer	100	100	1,250	2,200
Bow River below junction with Highwood River	1,480	1,750	2,270	2,800
Oldman River at Lethbridge	400	1,030	1,200	1,030
South Saskatchewan River below junction with Red Deer River	1,500	5,800	6,130	7,200
South Saskatchewan River at Saskatoon	5,500	6,160	5,300	10,000
Saskatchewan River below the Forks	9,500	12,400	11,500	26,000
Saskatchewan River at The Pas	13,000	15,200	15,200	33,000
Qu'Appelle River at outlet from Lake Diefenbaker	20	20	20	2,500
Assiniboine River at Brandon	350	500	950	1,700
Souris River near Oxbow	0	0	70	350
Souris River near Melita	0	0	150	230
Souris River at Wawanesa	0	80	200	400
Red River below junction with Assiniboine River	770	1,000	2,300	8,700
Nelson River at Warren Landing	47,900	49,100	50,000	71,900

**Internal diversions increase the supply in one part of a basin but reduce it in another. Hence, some figures in this column and to the right of it may be less than corresponding figures to the left.*

3. The third set of results (Column C, above and map on page 34) shows flows that are close to the maximum that could be achieved using projects selected from those investigated in this study. Hairy Hill and Callaghan reservoirs were added to the six new reservoirs in the previous computations. A number of internal and external diversions were added as shown on the map on page 34 including a total of 30,000 cfs from the Peace-Athabasca Rivers and 10,000 cfs from the Churchill River. All projects were operated by the computer to deliver to each study a target flow equal to 150% of the average natural flow. The target was not met at study points upstream from the diversions. For reasons already mentioned, the results at the other study points are not necessarily the *best* flow that could be achieved. But they illustrate two things: the versatility of the computation system, and the magnitudes that are possible in the increases of supply.

The effects of existing developments on the flow.

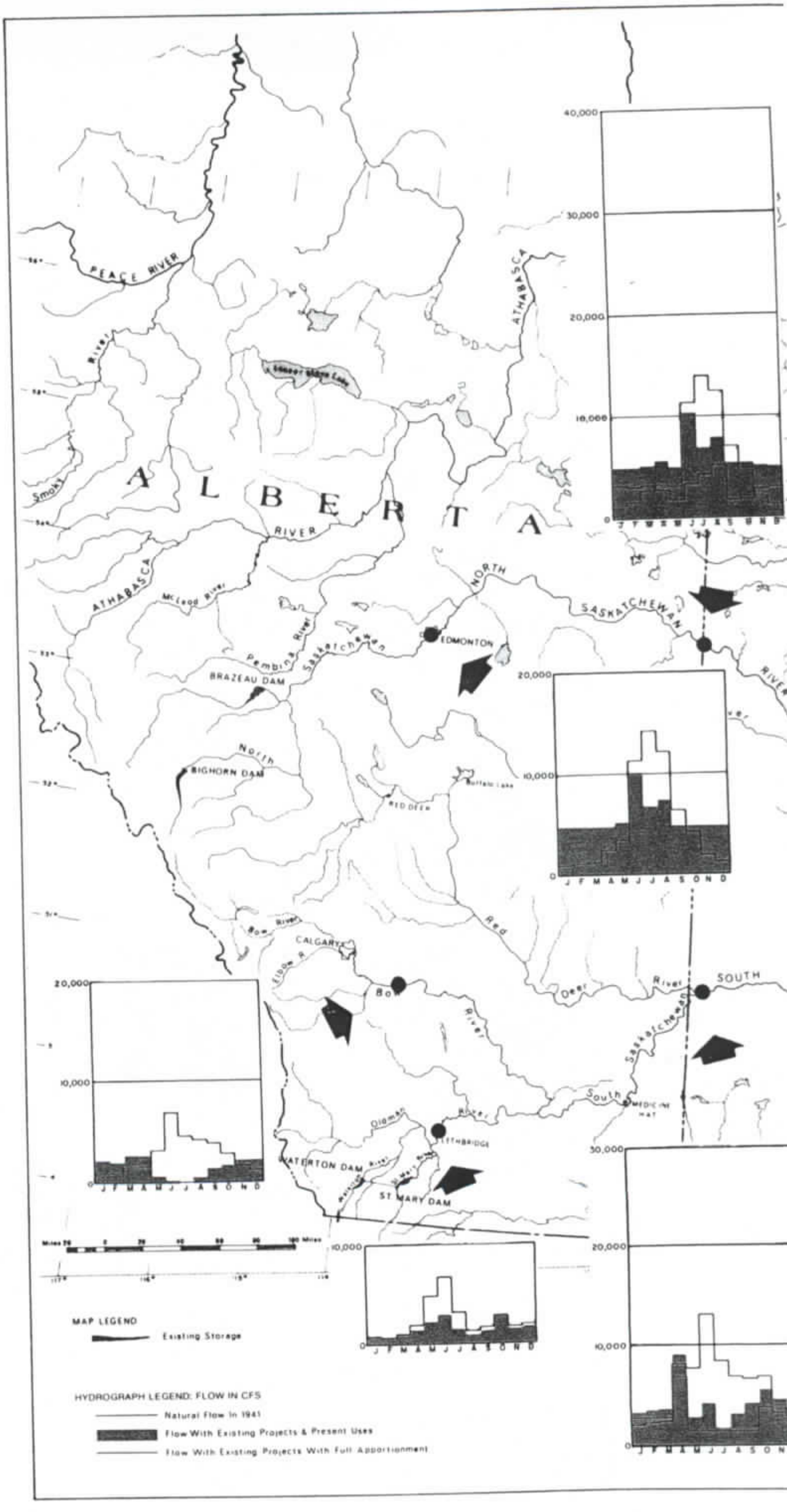
This map shows the location of existing projects. The inset graphs show the flows that could have occurred at 11 points in the basin under three sets of different conditions.

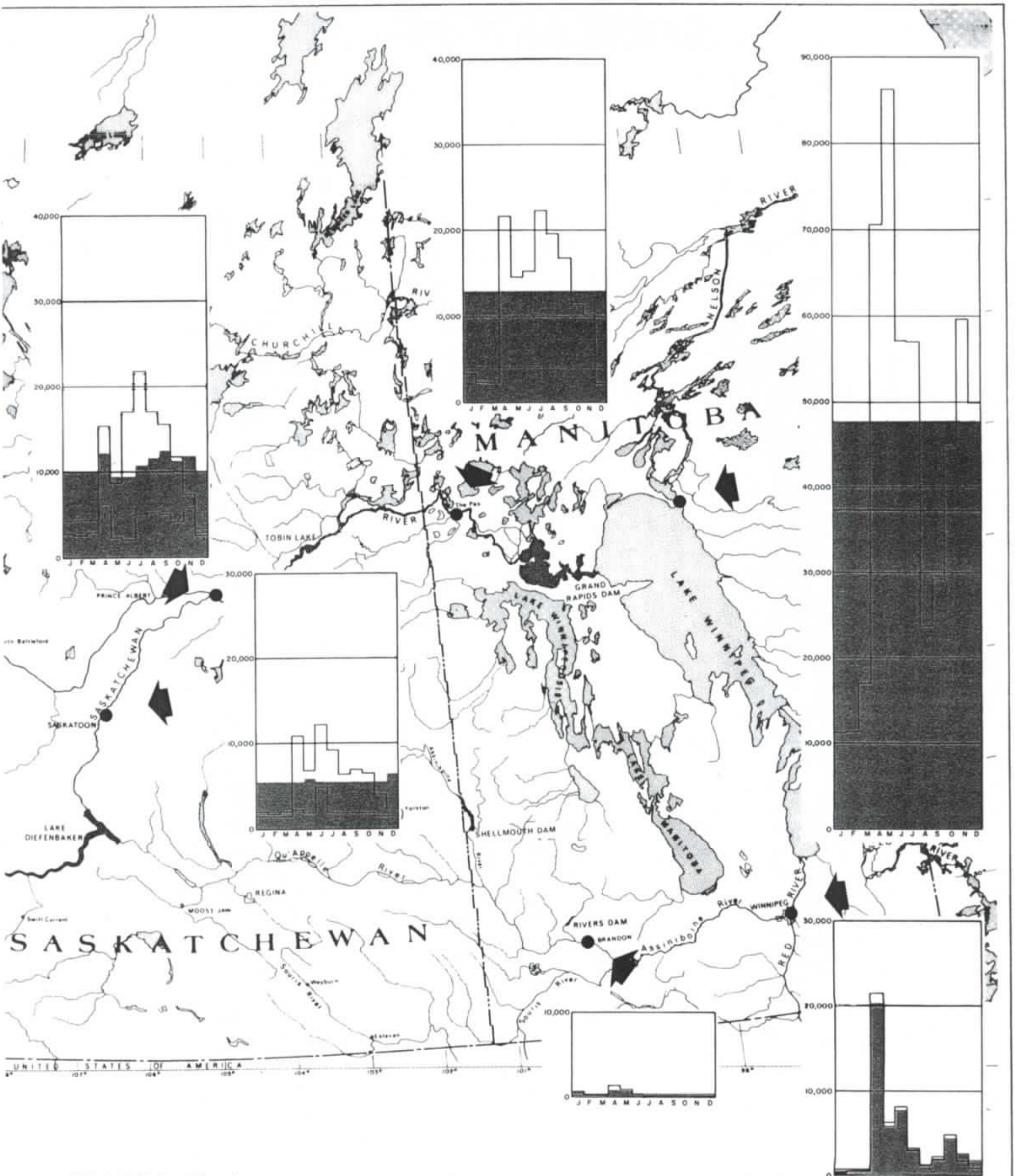
(1) The black line shows month-by-month, the natural flows for 1941 — a low flow year.

(2) The amber shading shows the flows that could be guaranteed by existing projects if they were operated for uniform year-round flow.

(3) The red line shows the flow that existing projects could guarantee if Alberta and Saskatchewan were to withdraw the full amount of the flow to which they are entitled under the Apportionment Agreement.

A comparison of the black line and amber area shows that existing projects are capable of making large changes in the flow pattern. Finding No. 2 on page 44 describes this in more detail. The red line, compared to the amber area, shows that minimum flows in the Saskatchewan River basin will be noticeably reduced when Alberta and Saskatchewan withdraw all of the water to which they are entitled by the Apportionment Agreement. The effects of apportionment in the Assiniboine system would be small (the Apportionment Agreement permits the withdrawal of a portion of the natural flow).





With Existing Development

The effect of new storage projects on the flow.

This map shows the location of existing projects and the six hypothetical storage reservoirs described in Result No. 6 on page 29. The cost of building these six storage projects at 1968 prices would be about $460 million. To obtain the results illustrated in the inset graphs, all projects were operated under four sets of different conditions for uniform year-round flow.

(1) The black line shows the natural flows which occurred each month of 1941 — a low flow year.

(2) The line blocked-in by amber shading shows the flow that could be guaranteed using just the existing projects after satisfying present uses.

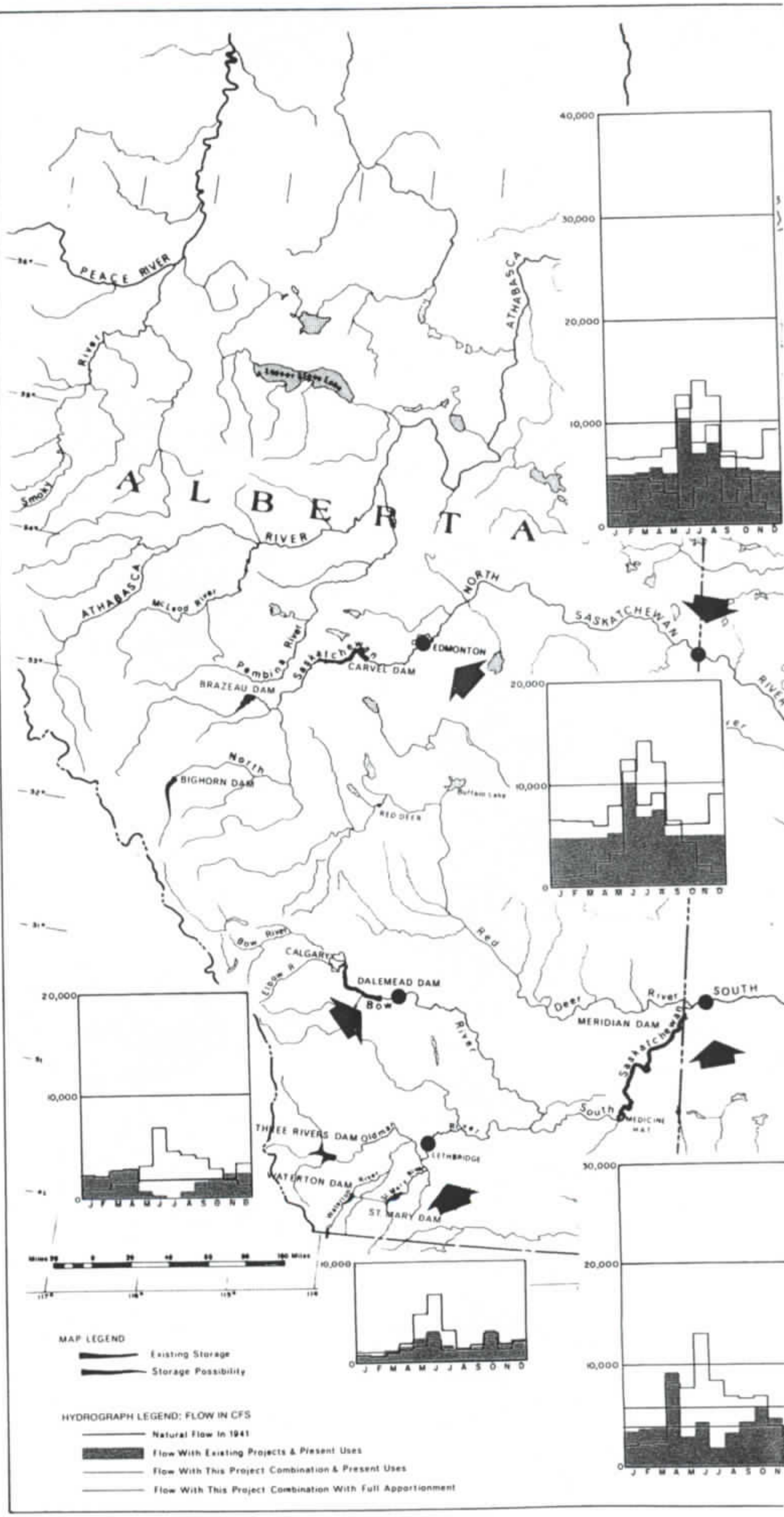
(3) The blue line shows the flows that could be guaranteed with both existing and hypothetical projects in operation after satisfying existing uses.

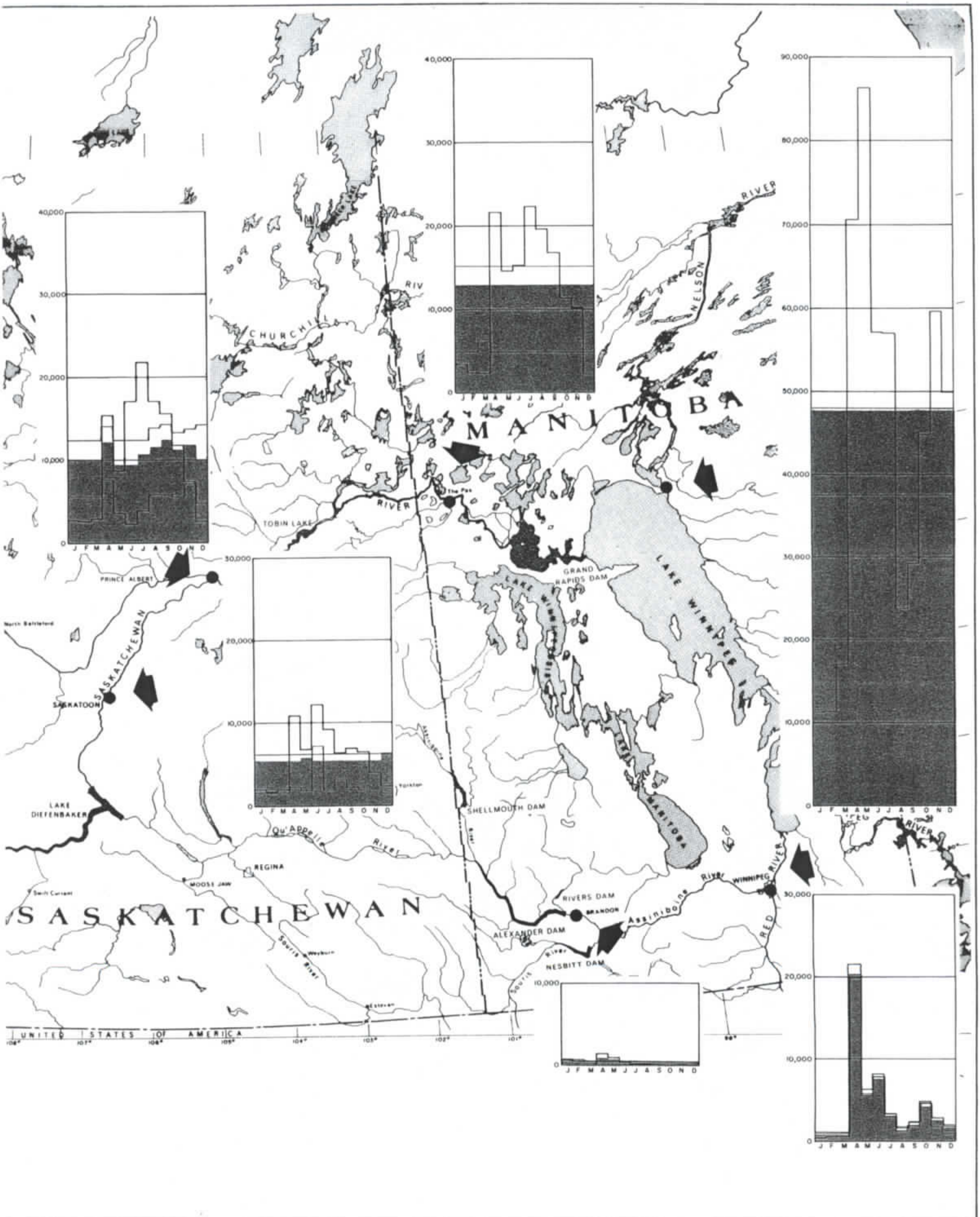
(4) The red line shows how much less the guaranteed flows would be, even with six new storage projects, if Alberta and Saskatchewan were to withdraw all of the water to which they are entitled under the Apportionment Agreement.

The addition of new storage projects gives a noticeable increase in minimum flows in the Saskatchewan River basin, even when apportioned waters are being withdrawn. With the additional reservoirs in operation, the minimum acceptable flows which have been set by the Provinces can be met, even after apportionment.

The effect of the Apportionment Agreement on the Assiniboine flows is quite small because the natural flow at the Saskatchewan-Manitoba boundary is small and the full withdrawal would be 50% of that small amount.

A special comment should be made regarding the graph for the Bow River. The amber area and the black line are flows that would remain *after* supplying all irrigation demands on the Bow River.





MANITOBA
SASKATCHEWAN
CHURCHILL
RIVER
NELSON
The Pas
TOBIN LAKE
GRAND RAPIDS DAM
LAKE WINNIPEG
LAKE WINNIPEGOSIS
LAKE MANITOBA
PRINCE ALBERT
North Battleford
SASKATCHEWAN
SASKATOON
LAKE DIEFENBAKER
SHELLMOUTH DAM
Qu'Appelle River
REGINA
MOOSE JAW
Swift Current
RIVERS DAM
BRANDON
Assiniboine River
WINNIPEG
RED RIVER
ALEXANDER DAM
NESBITT DAM
Souris River
Weyburn
Estevan
Yorkton
UNITED STATES OF AMERICA
J F M A M J J A S O N D

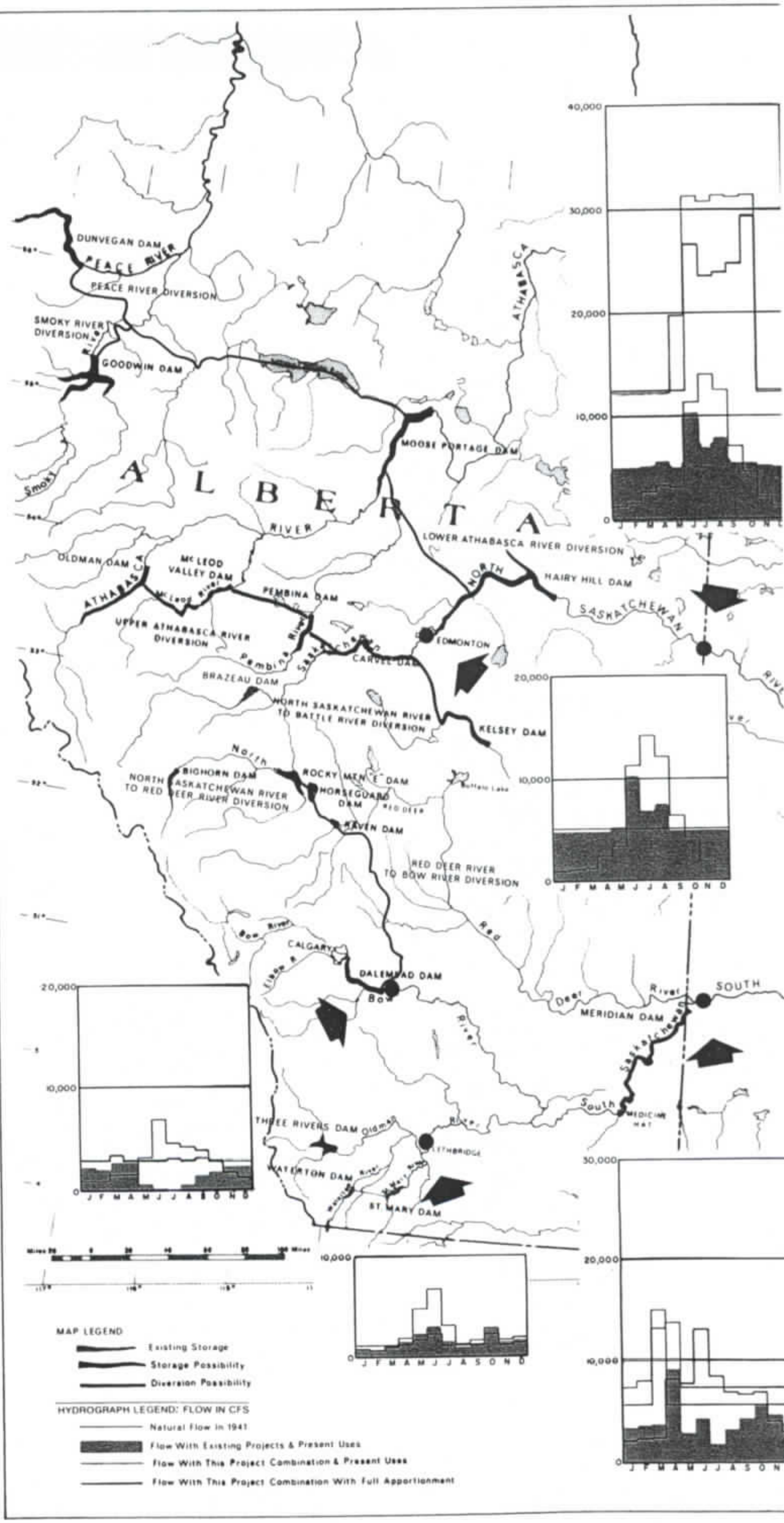
The effects of new storage and diversion projects on the flow.

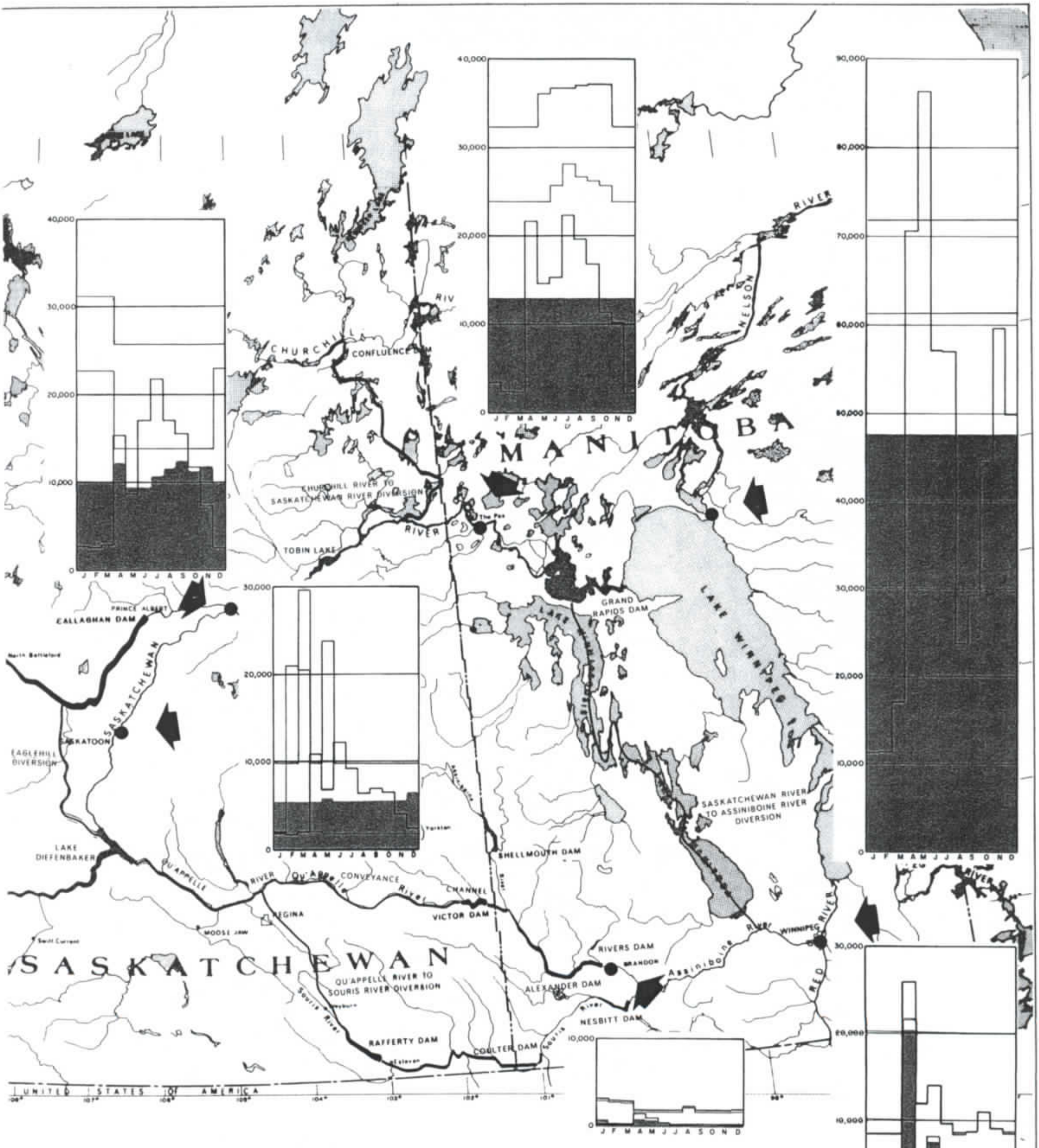
The Board computed the flows that many combinations of projects could deliver. For most parts of the basin, the projects shown on the map at the right gave the largest increase in supply. In addition to the existing projects, the map shows eight new reservoirs to increase winter flows. It also shows diversions from the Peace-Athabasca and Churchill systems during the open water season. The cost of building the reservoirs and diversions would be about \$2.9 billion. For this computation it was assumed that a total diversion rate of 30,000 cfs would be available from the Peace-Athabasca system, and a diversion of 10,000 cfs would be available from the Churchill. The graphs show the flows that could occur under four sets of conditions.

(1) The black line shows the natural flows that occurred in each month of 1941, a low flow year.
(2) The amber area shows the flows that could be guaranteed by existing projects after satisfying existing uses.
(3) The blue line shows the flows that could be guaranteed with both existing and hypothetical projects in operation after satisfying existing uses.
(4) The red line shows what the effect of apportionment would be if all these projects were in operation.

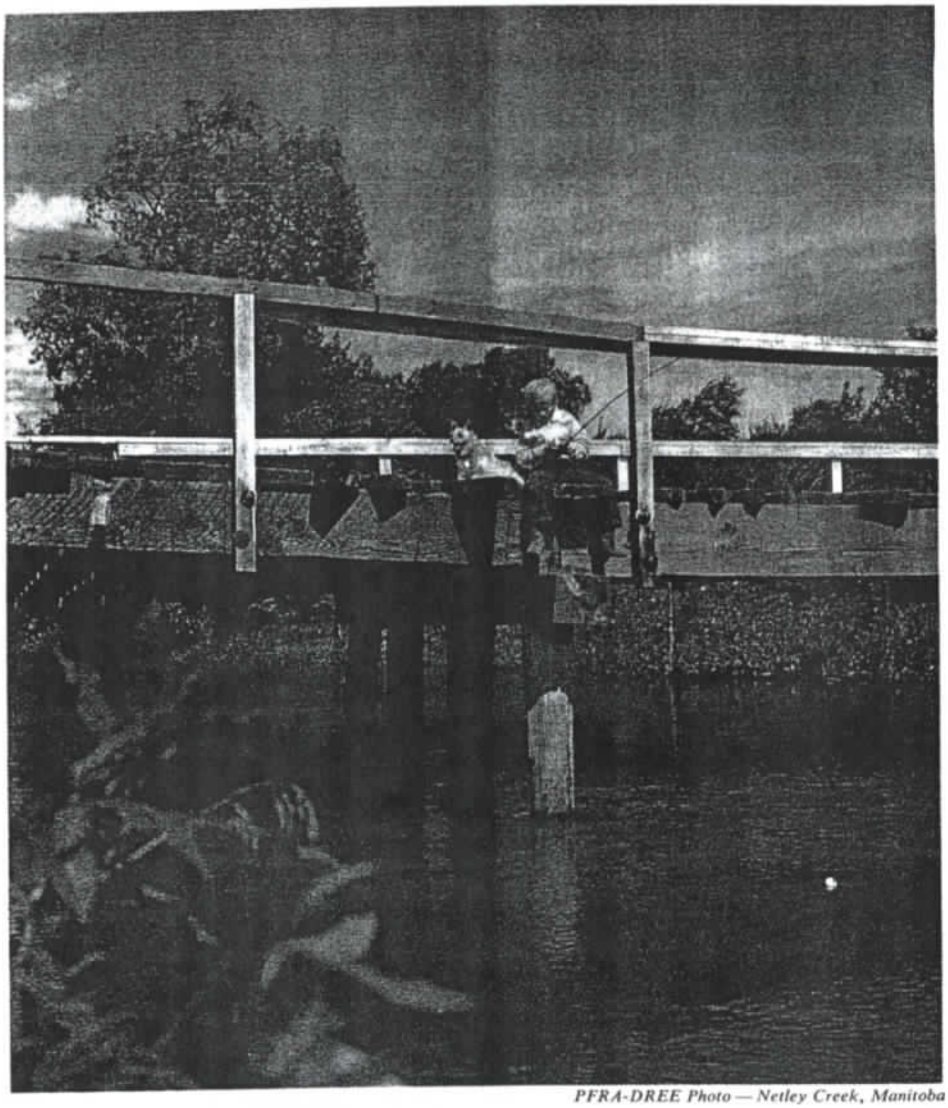
These additional projects give a very large increase in supply to all parts of the basin, except the upper North Saskatchewan River and the South Saskatchewan River. The improvement to the upper North Saskatchewan from the Upper Athabasca diversion is partially offset by the diversion from the North Saskatchewan to the Red Deer and Bow Rivers. The improvement to the South Saskatchewan is limited by the 3,000 cfs capacity of the North Saskatchewan to Red Deer diversion. Nevertheless, the guaranteed flow is substantially improved at most points.

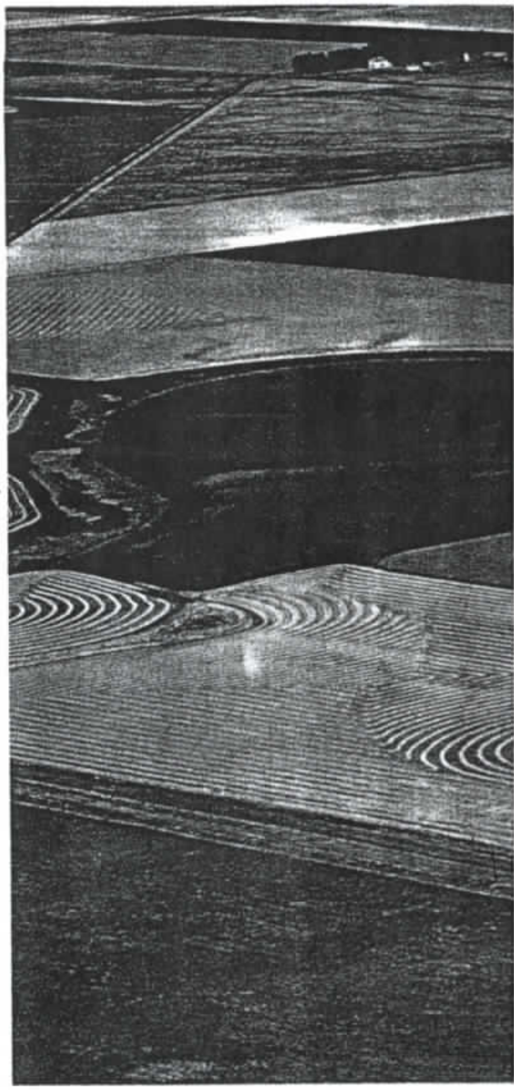
With all of these projects in operation, Alberta and Saskatchewan could withdraw all of their apportioned waters and the remaining flows would be well above the minimum acceptable.





With Eight New Storages and Diversions





PFRA-DREE Photo — Netley Creek, Manitoba

7. Preliminary reports on environmental and other considerations reveal large gaps in our knowledge.

The Board commissioned reports on recreation, wildlife, water quality, fish and the biological system, river regime, and groundwater. The reports were preliminary in scope and each had three main parts: an assessment of present knowledge, comments on the changes which may take place if storage and diversion projects were built, and the kinds of studies which must be done or data which should be collected so the consequences of constructing works could be predicted with confidence. Here is an abstract of each report.

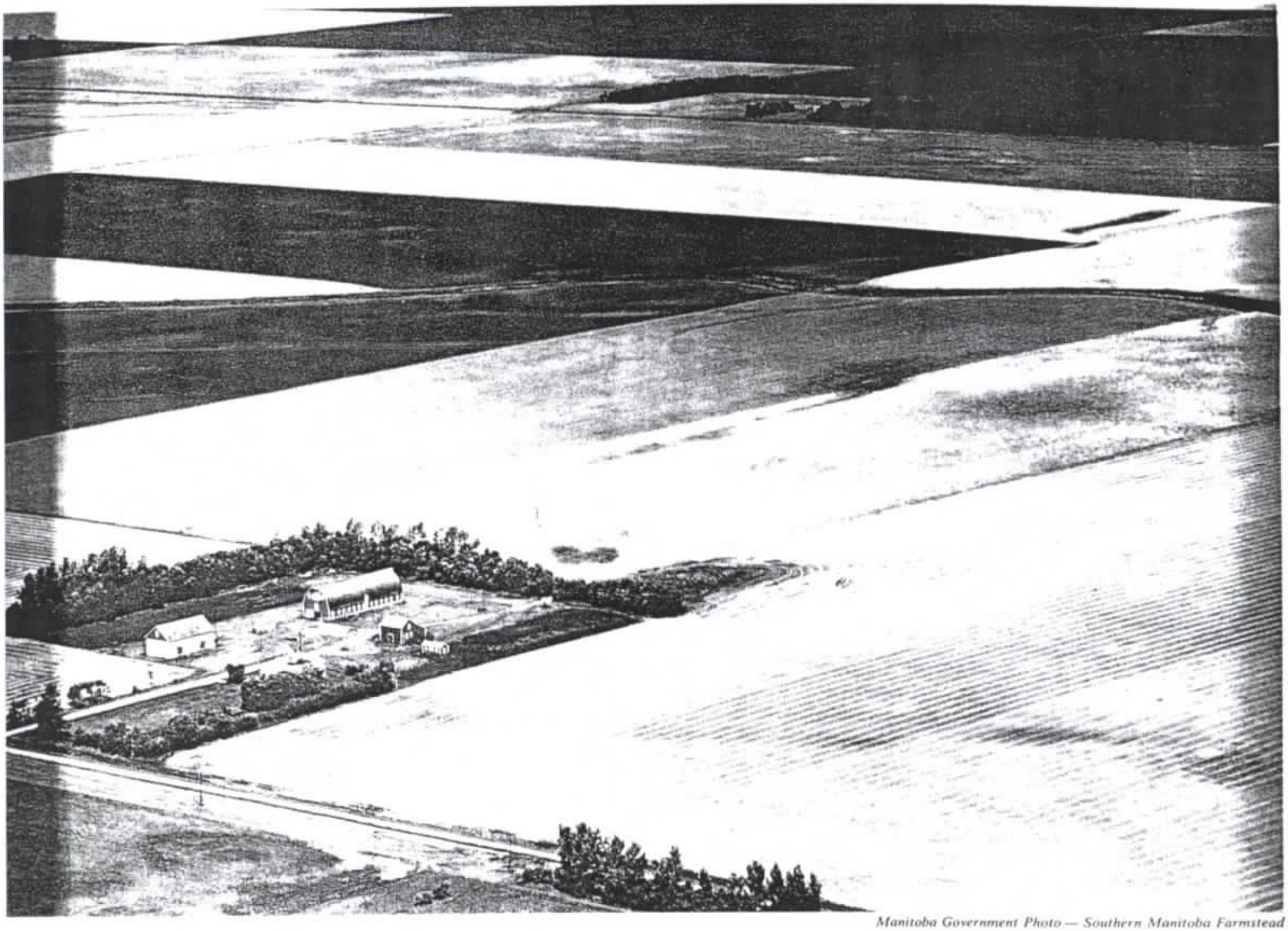
Recreation. Surveys of water-based recreation show that there is an unfulfilled demand for water-based activities. This type of recreational activity on the Prairies is below the national average. The indication is that there are not enough suitable water bodies available to meet the demand. The creation of reservoirs could help to meet this demand.

The recreation potential of each site should be based on a comprehensive evaluation of its capability to satisfy the recreation demands of a growing population, provincial and national planning objectives, and economic trade-offs with other uses.

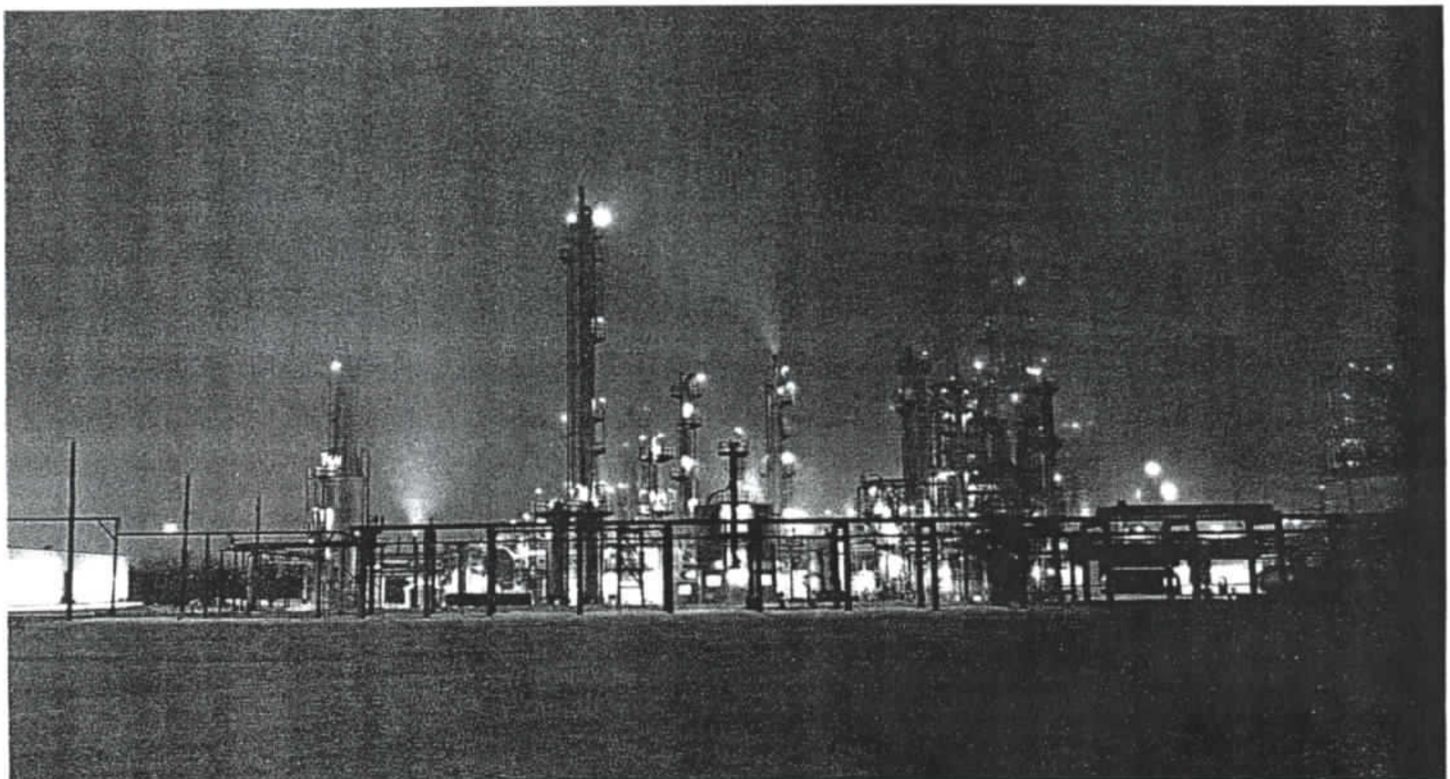
Wildlife. There is not enough knowledge of present wildlife populations, habitats or the overall ecology to permit specific predictions about the effect of building reservoirs and/or diversions in the Saskatchewan-Nelson basin. The changes in habitat that would result from building such works must be considered more seriously than has been done in the past. During the past 100 years, in the settled portion of the basin, the conversion of grassland to cultivated land, the drainage of wetlands, and the clearing of forested areas have combined to eliminate large areas of wildlife habitat. The river valleys now represent a significant percentage of available habitat, particularly for the wintering of ungulates (deer and elk, to name two). Therefore, the consequences of further losses due to inundation must be studied.

Looking at existing reservoirs, some have been detrimental to wildlife populations, while others have been mainly beneficial. As an example, reservoirs may destroy waterfowl habitat for nesting or staging, but they also offer opportunities for improving it. The loss of winter range for ungulates would appear to be the most difficult loss to compensate.

Water Quality. At the present time, there is a water quality sampling network of 165 stations on the Prairies — 55 in Alberta, 75 in Saskatchewan, and 35 in Manitoba. Most of them have been operated for a short time. They indicate that the waters of the Saskatchewan River system in the Rocky Mountains are medium to hard bicarbonate waters. Flow from the plains region adds alkali and sulphate, but not enough to change the rivers from



Manitoba Government Photo — Southern Manitoba Farmstead



Alberta Government Photo — Oil Refinery

Sask. Museum of Natural History — Red Fox Pups

being predominantly alkaline earth bicarbonate type. The waters rising in the Canadian Shield in the eastern part of the basin are of very good quality and help to dilute the more highly mineralized inflows to Lake Winnipeg coming from the west.

The effects of Lake Diefenbaker and Tobin Lake on water quality were examined to get some insight into what additional reservoirs might do. The limited amount of information available indicates that these reservoirs add oxygen to the river system, helping to maintain the dissolved oxygen at a desirable level throughout the winter.

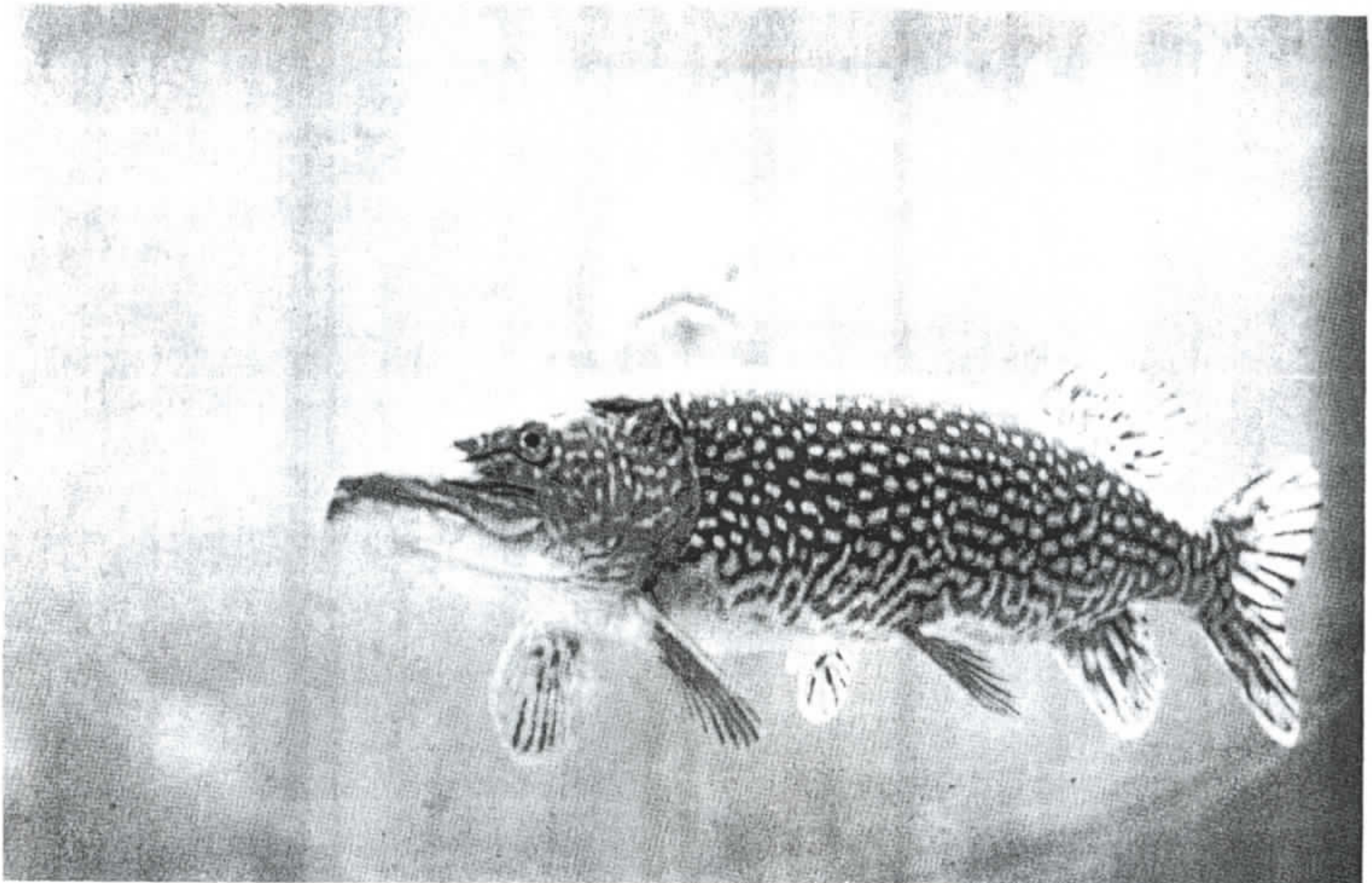
Fish and the Biological System. Right now there is insufficient background information available to describe the biological environment in Prairie rivers. No studies have been undertaken in the basin to compare a river environment with that created by the construction of a reservoir. Therefore, comments on the possible effects of reservoirs and diversions on fish and the biological system must be based partly on speculation and partly on what has happened to reservoirs in other parts of Canada, North America and the world. The information available indicates that a pattern develops after the construction of a reservoir; initial high production conditions affecting all levels, followed by gradual decline in productive capacity, with stabilization occurring within ten to fifteen years.

It appears that major disturbances, either within a lake or in its watershed cause significant changes in lake biota. Examination of sediment cores obtained from ten hydro-electric reservoirs in Canada indicate a return to steady conditions within a time period ranging from 15 to 30 years. However, if the reservoir is subject to large and frequent drawdown, the time required to reach equilibrium is much longer, if, indeed, it could ever be reached.

Groundwater agencies in Alberta, Saskatchewan and Manitoba have accumulated rather extensive knowledge of their major aquifer (underground reservoir) systems. Most of them have been delineated and their quality and yield estimated. Reports prepared for the Board by these agencies show that till or bedrock aquifers with a point yield of 1 cfs or more, and total dissolved solids of 4,000 ppm or less, underlie about 90,000 square miles in the Saskatchewan-Nelson basin — about 21% of the total basin area. Well over half of the total aquifer area runs through the interlake region of Manitoba and into Saskatchewan north and west of The Pas, Manitoba. This large aquifer underlies an area which is sparsely populated, except for its southern tip which reaches Winnipeg.

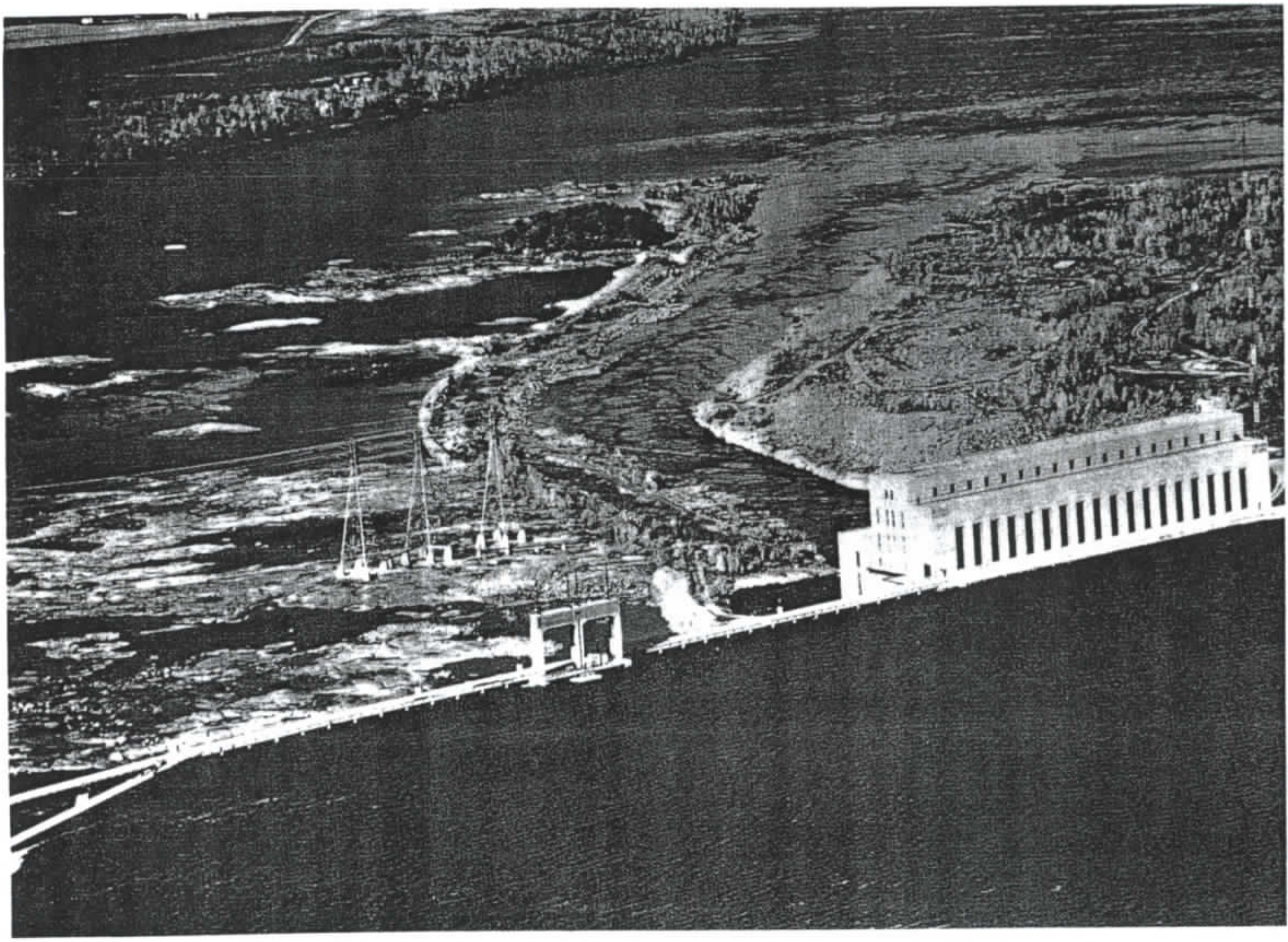
Present usage of groundwater supplies is small in comparison to estimated potential yields. In Alberta, present usage is estimated to be slightly more than 1% of potential yield. It's about the same in Saskatchewan, and about 5% in Manitoba.

The ground and surface water systems are interconnected. Where this



Sask. Museum of Natural History — Northern Pike

Alberta Government Photo — Big Horn Sheep



interconnection is strong, the possibility of recharge of aquifers from reservoirs, or discharge of aquifers into reservoirs must be considered.

River Regime. The headwaters of the South Saskatchewan River in the Rocky Mountains and foothills produce an average annual sediment load of about 7,500 acre feet. This is deposited in Lake Diefenbaker, which has a total capacity of 7.6 million acre feet. Downstream of Gardiner Dam, the river erodes an average annual sediment load of about 2,000 acre feet from the riverbed, with resulting degradation below Gardiner Dam of about one foot per year. This will soon moderate as the river gradient becomes milder and the riverbed material becomes coarser.

The North Saskatchewan River system produces an average annual sediment load of about 2,100 acre feet per year. At the junction of the North and South Saskatchewan, the average annual load is about 4,500 acre feet. This increases to about 5,000 through local erosion before being deposited in Tobin Lake, which has a storage capacity of 1.8 million acre feet. Downstream at Squaw Rapids Dam, some erosion is taking place.

Owing to two unresolved problems predictions of river regime changes are approximate. First, present techniques are not adequate for determination of bed load which could be as much as 50% of the total sediment discharge. Second, the origin of present sediment loads is not known.

8. Preliminary reports on the effects of possible diversions on the Peace-Athabasca-Mackenzie river system and on the Churchill river system reveal that diversions may have detrimental effects.

Effects of Diversion on the Peace-Athabasca-Mackenzie System.

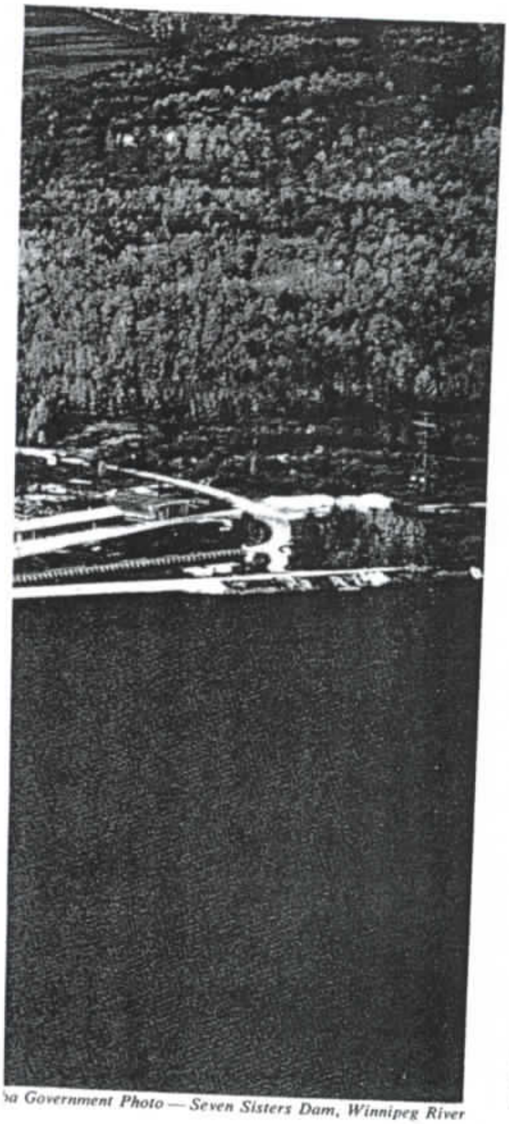
If water were diverted from the Athabasca and Peace Rivers in the North Saskatchewan, there would be two effects on the flows in the donor basin. The reservoirs necessary to elevate and divert the waters would moderate flood peaks, and the removal of water would decrease average flows. The effects of diversion on flows in the donor basins were computed assuming the Bennett Dam would be in full operation. Then consideration was given to the effect the changes in flow would have on various activities in the basin.

Water Quality — Minor.

Wildlife — Significant effects — some bad, some good, but data are not sufficient to permit quantitative predictions.

Transportation — A diversion of 5,000 cfs would have measurable effect only on the Athabasca River. A diversion of 30,000 cfs (max. rate) would effect water levels on the Slave and Mackenzie Rivers as well.

Fish — Significant effects — some bad, some good, but can't be predicted on basis of present information.



ɒa Government Photo — Seven Sisters Dam, Winnipeg River

Manitoba Government Photo — Nelson River

Effects of Diversion on the Churchill System.

If water is diverted from Churchill River basin via the Sturgeon-Weir River into the Saskatchewan River west of The Pas, that water will flow through Cedar Lake into Lake Winnipeg and thence down the Nelson River. However, it would reduce the flow through a proposed diversion in Manitoba into the Burntwood River and thence down the Nelson. The effects of the Sturgeon-Weir diversion on the Churchill River system were computed assuming the Manitoba diversion along the Burntwood was a reality. The report does not present the benefits which might be generated by diversion from the Churchill River through the Sturgeon-Weir route. But, the effect on the Churchill River below the diversion have been identified.

Power — There would be a sizeable loss in hydro-electric power potential along the Burntwood, but a simple figure cannot be given. The loss of hydro-electric power at the Island Falls plant in Saskatchewan was not computed. Neither was the possible gain in energy that might be obtained by developing hydro-electric energy along the Sturgeon-Weir diversion route, at Grand Rapids, and the Upper Nelson.

Tourism and Recreation — There would be little effect on the trophy fish population, the only factor in future tourism and recreation that might be affected by the diversion.

Wildlife — There may be some reduction in goose nesting on the Lower Churchill, but the overall effect on wildlife would be minor.

Commercial Timber — There would be a potential adverse effect of minor proportions due to deteriorated conditions for transporting timber. There is currently no such activity in the area.

Transportation — There would be minor effects because current water transport only makes use of small vessels.

Port of Churchill — It is speculated that there could be an increase in the length of the shipping season, more erosion in the harbour, and a deeper penetration of saline waters into the estuary. These effects would likely be minor.

Commercial Fishery — Significant loss of nutrients would be felt by fisheries in Granville and Southern Indian Lakes.

Trapping — Initially there could be a loss of up to 10% in fur revenue although there would be a possibility of recovery of populations following an initial period of adjustment.

FINDINGS

1. With major expenditures, large supplies of water could be made available to the basin, but the environmental consequences of storage, regulation and diversion works cannot be predicted at this time.

The effect on the supply was computed for a large number of project combinations. Three of these computations were selected for inclusion in the "Results" beginning on page 25. They show that the supply of water can be increased throughout the basin.

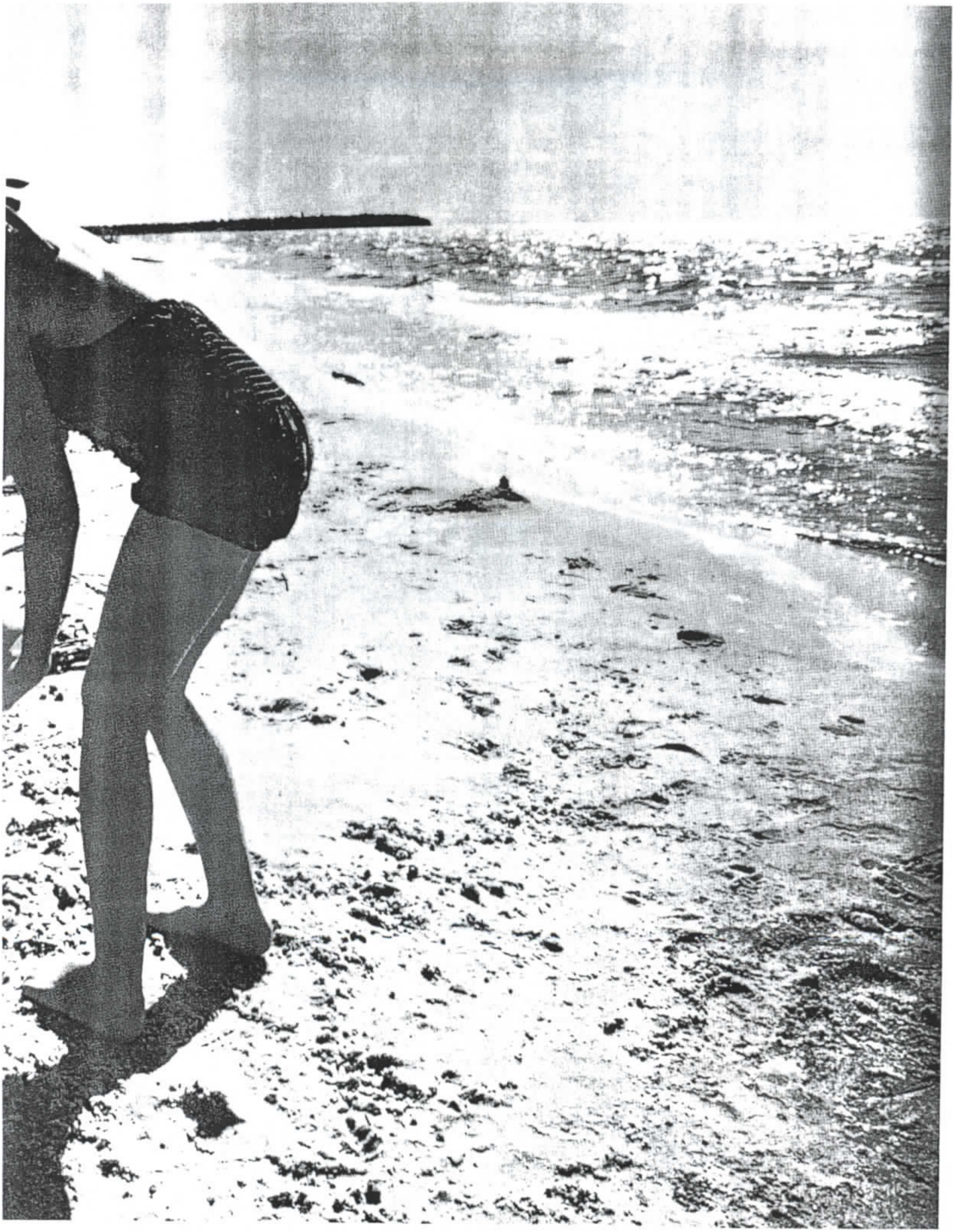
With the addition of six new reservoirs, a regulated flow of about 75% of the long term average could be delivered at most of the selected study points. The capital cost of the six new reservoirs (shown on the map on page 32) would be about $460 million [1968 dollars].

With eight new reservoirs and diversions from outside the basin (see map on page 34), a regulated flow of about 150% of the long term average could be delivered at most selected study points. The capital cost of the reservoirs and diversions needed to do this would be about $2.9 billion. The flows that could be guaranteed at each selected study point are listed in the second table on page 29.

Both of these possibilities represent a very large increase in the usable supply of water, and both would require major expenditures. Neither is suggested as a development plan at this time, they are merely used as illustrations of what could be done. These storage and diversion developments would affect recreation, wildlife, water quality, river regime, fish, and perhaps groundwater both in the Saskatchewan-Nelson basin and in donor basins. The effects could be either beneficial or detrimental, but until there is more basic information on these subjects and a better understanding of how they are affected by regulation, the consequences of new construction cannot be predicted with certainty.

Once this information is available, the very real costs (or benefits) of predicted changes can be added to the construction costs. Nevertheless, the construction costs provide a rough comparison between possible developments and the investment that has already been made in major water resource projects, which is about $1 billion.

The potential costs of improving



water supplies is large, underlining the importance of setting development objectives for this basin. If more water is needed to meet those objectives, this study shows that it could be made available, but the environmental and other consequences are largely unknown at this time.

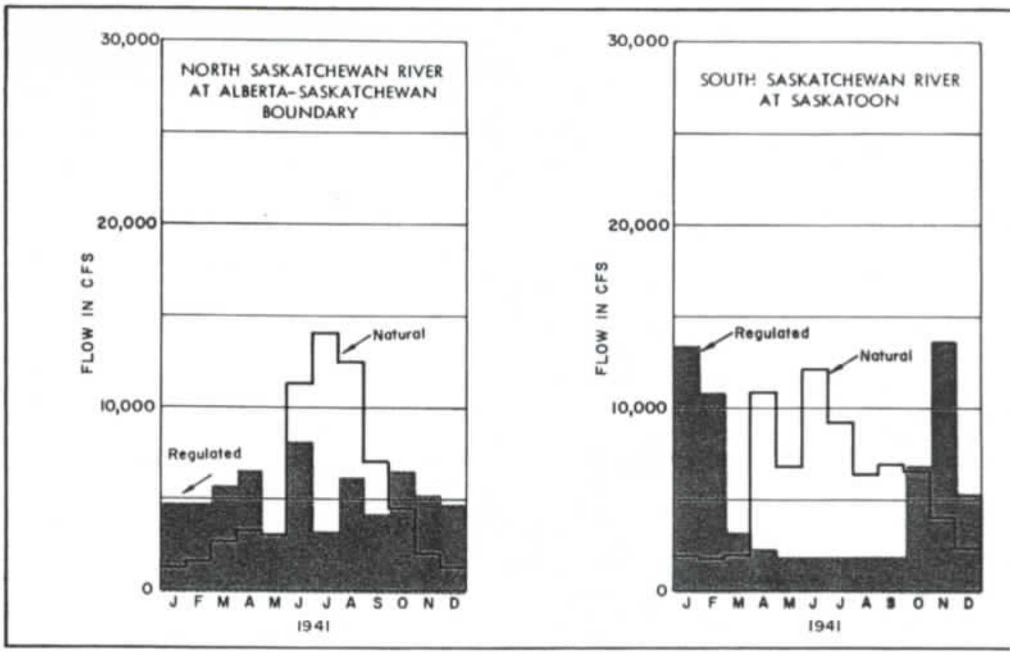
2. Many rivers in the basin are already highly regulated.

There are few streams in this basin which are not affected by storage or diversion works. On most rivers in the basin, existing projects have changed the flow characteristics markedly. Throughout the Saskatchewan and Winnipeg River systems, reservoirs have been built to increase winter flows primarily for power purposes. The flows on the tributaries of the South Saskatchewan River in Alberta are affected by both power regulation and irrigation withdrawal. The Qu'Appelle River flows may be supplemented by diversion and used to maintain steady summer lake levels for recreation and municipal purposes. Releases from the flood control reservoirs in the Red River basin increase winter flows.

The effect of existing projects and uses on the flows in a dry year such as 1941 is shown on the three graphs. The black line is the natural flow and the shaded-in line is the flow after regulation by existing projects. The North Saskatchewan has been converted to an almost uniform flow; the South Saskatchewan now has high flows in winter with low flows in summer. The graph for Saskatchewan River at The Pas shows the combined effects. In a high flow year the flow pattern on the South Saskatchewan would be about the same as in a dry year due to the large capacity of Lake Diefenbaker. On the north branch and at The Pas, there would be higher midsummer flows in a high flow year.

The choice of the flow pattern is now made by those who have invested in reservoirs within the terms of their licenses. If society had the need, it could change this flow pattern by building new projects or by compensating (or buying out) the original users. This might involve a search for new sources of power, the reversion of irrigation farming to dryland farming, strict controls on the recreational use of reservoirs, and so on.

3. The minimum flows could be increased by changing the operation of existing projects; some further increase could be obtained by adding new reservoirs; but diversions would be required to obtain large increases in supply.



Existing projects can serve existing uses, but water uses are increasing. Eventually, according to the Apportionment Agreement, two-thirds of the flow of the Saskatchewan River system could be withdrawn for various uses. If shortages are to be avoided, the supply must be increased to keep pace with increasing uses.

Development proceeds slowly; and initially new uses could be served by changing the regulation pattern provided by existing works. Actually, this implies that new uses would be served partly by reducing the effective supply for existing uses. If this procedure could be followed, the minimum flows could be increased from the values shown in column A to those shown in column B of the table at the top of page 45. However, if the full amount of apportioned waters were withdrawn by Alberta and Saskatchewan, the minimum flows would be reduced to the values shown in column C.

The addition of six new reservoirs (see map on page 32, together with the operation of existing projects for uniform year-round flow would make it possible to increase the minimums (after apportioned waters are withdrawn) to the values shown in column D.

Finally, the addition of eight new reservoirs and two major diversions into the basin (see map on page 34), would give a very large increase in minimum flows (after apportioned waters are withdrawn) as shown by the figures in column E.

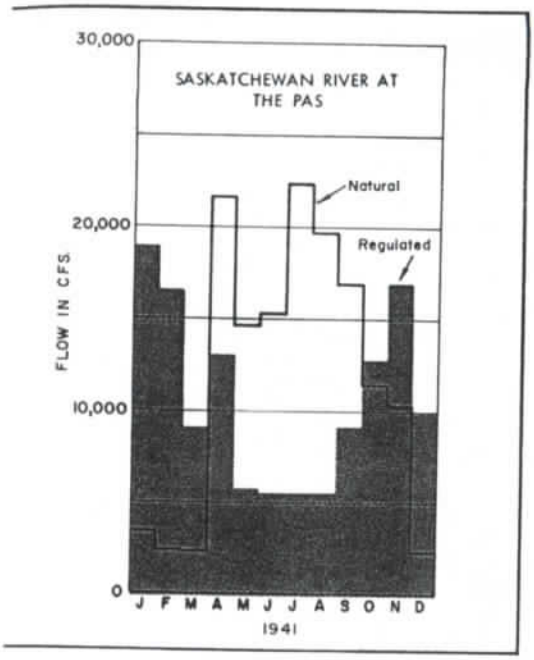
The flow that occurs within the basin can be manipulated by changing the operation of existing reservoirs, or adding new reservoirs. The result could be an improvement in the effective supply for some uses at the expense of other uses. If new water is diverted into the basin, a major increase in the effective supply for all uses can be obtained.

The use of reservoirs to regulate flows has a cost in terms of water supply due to evaporation losses from the water surface. Existing reservoirs in the Saskatchewan River basin have an estimated evaporation loss equivalent to about 400 cfs in an average year. With the addition of storage reservoirs at Carvel, Three Rivers, Meridian and Dalemead, the losses would increase to about 550 cfs. In some of the water studies, when many new reservoirs were included, evaporation losses were large enough to nullify most of the flow improvement that might have been achieved. These losses can be compared with the average annual flow of the Saskatchewan River at The Pas of 24,700 cfs, or with the present withdrawal of 2020 cfs for all uses in the South Saskatchewan River basin.

Evaporation losses are high in the middle of the South Saskatchewan basin and decrease to the north, west and east as shown on the map.

Reservoirs located in the western, northern and eastern fringes of the Saskatchewan-Nelson basin experience a much *smaller* evaporation loss.

4. The flow delivery pattern can be varied seasonally with only a minor



Effect of Existing Projects, Storages and Diversion on Minimum Flows.

Selected Study Point	Existing Projects & Uses, Existing Con-straints A	Existing Projects & Uses, Uniform Flow B	After Apportioned Waters Have Been Withdrawn: Existing Projects, Uniform Flow C	Existing Projects, 6 New Storages, Uniform Flow D	Existing Projects, 8 New Storages & Major Diversions E
North Saskatchewan River at Alberta-Saskatchewan Boundary	2,600	5,000	1,600	1,500	12,300
Battle River at Unwin	1	1	1	1	390
South Saskatchewan River below junction with Red Deer River	1,500	1,500	1,500	3,800	5,500
South Saskatchewan River at Saskatoon	1,670	5,500	1,500	1,500	2,000
Saskatchewan River below the Forks	3,800	9,500	2,000	2,300	14,000
Saskatchewan River at The Pas	4,340	13,000	4,000	4,800	24,000
Assiniboine River at Brandon	150	350	300	450	1,800
Souris River at Wawanesa	0	0	0	80	400
Red River below junction with Assiniboine River	500	770	750	1,000	8,700
Nelson River at Warren Landing	18,700	47,900	37,500	38,800	61,300

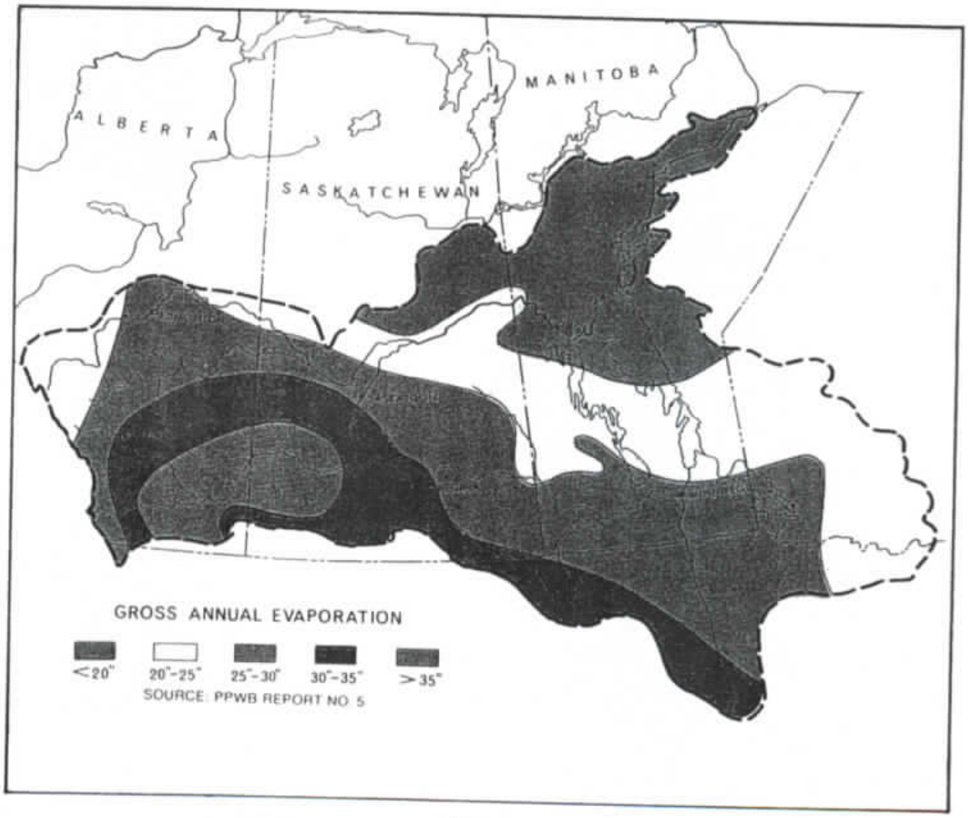
effect on the annual amount of water that can be guaranteed.

Most of the studies were done with the objective of attaining a *uniform* flow year-round. However, a few were done with a delivery pattern high in winter, and a few high in summer. For the examples studied, the three methods of operation produced results which differed by only a few per cent in the amount of water guaranteed annually.

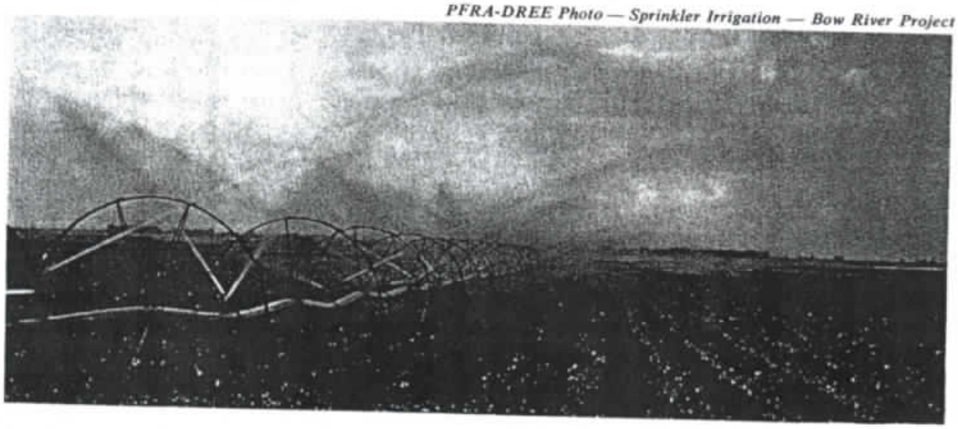
5. Miscellaneous findings at selected points.

(a) The Oldman River has three tributaries upstream from Lethbridge, the St. Mary, Belly and Waterton Rivers, which have been fully developed to serve irrigation. In the SNBB studies, it was assumed that, in dry years, the flow released from reservoirs on these tributaries would be sufficient to maintain a flow of 400 cfs at Lethbridge. Consequently, storage on the Oldman River proper, or a diversion from the north offered the only sources of flow improvement. Known storage opportunities on the Upper Oldman are few, and a diversion (in the SNBB studies) would not provide flows in winter. Hence, the study results show only a small possible flow improvement at Lethbridge.

(b) In this study, the Kelsey reservoir was the only one investigated on the Battle River. The Battle River has very little natural runoff in dry years. The Kelsey Reservoir, regulating the natural flow, could produce a guaranteed flow of 100 cfs. To improve the supply beyond 100 cfs, it would be necessary to divert water into the Battle from the



PFRA-DREE Photo — Sprinkler Irrigation — Bow River Project



North Saskatchewan.

(c) The SNBB investigations included a diversion from the North Saskatchewan River to the Red Deer. The study program did not include investigation of major reservoir sites in the Upper Red Deer basin. The only known sites would be very costly in relation to storage potential. If effective sites could be found, flow improvement through storage could be a worthy alternative to diversion.

(d) The Bow River below the junction with the Highwood River is fully committed in dry years to downstream irrigation demands. This has been known for some time. If irrigation expands, more water could be obtained by purchasing the release of water from upstream hydro-power reservoirs, building Dalemead Reservoir (or alternate storage) or importing water from the North Saskatchewan, or some combination of these possibilities. The choice will depend on economic and social circumstances at the time the decision has to be made.

(e) The South Saskatchewan River below the junction with the Red Deer River represents the total flow of the South Saskatchewan system from Alberta into Saskatchewan. If flow at this point were to be improved without regard to the rest of the Saskatchewan-Nelson basin, the Meridian Dam would have the least apparent cost. The diversion from the North Saskatchewan River to the Red Deer River would come second.

(f) The minimum flow of the South Saskatchewan River at Saskatoon could be increased moderately by changing the operation of Lake Diefenbaker, or by adding upstream storage. A major increase in guaranteed flow could only be met by introducing a diversion from the North Saskatchewan to the South Saskatchewan.

(g) The minimum flow of the Saskatchewan River at The Pas has already been increased significantly by existing projects. Further improvement will be minor if storages and internal diversions were added upstream. There would be a large flow improvement from either a diversion from the Lower Athabasca or one from the Churchill, although from the standpoint of The Pas only, the Churchill Diversion would be by far the cheapest.

(h) Brandon is the point at which flow improvement in the Assiniboine basin was measured. A modest improvement could be obtained through new reservoirs, but large improvement must come from diversions. Either the possible diversion from Lake Diefenbaker to the Upper Assiniboine River or the possible Qu'Appelle River Diversion would give large flow improvement at comparable construction costs.

(i) The construction of storage in the Souris basin would yield very little flow improvement. Through a long drought period, the natural flow is so small and the carry-over period so long that reservoir evaporation losses would consume most of the potential flow increase. If large demands are ever to be served in this basin, they must be served by imported water.

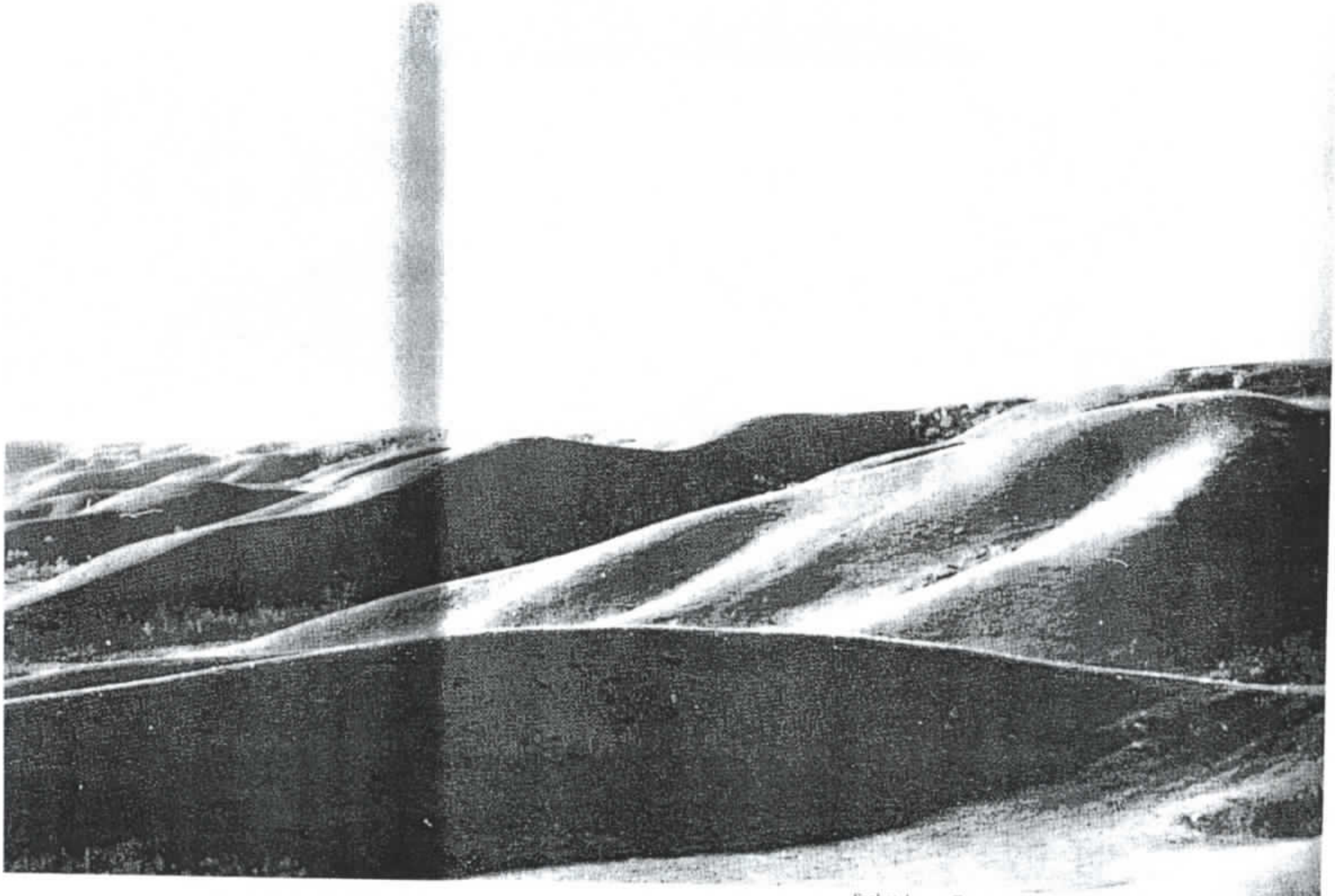
(j) The easiest way to improve the summer flows of the Red River below Winnipeg would appear to be the diversion of Lake Manitoba into the Assiniboine River with water entering the system from Cedar Lake. However, if this diversion could not be operated in winter, it would have to be supplemented by storage in the Souris and Assiniboine basins. Another attractive project (using the cost estimates prepared for this study) for improving the supply at Winnipeg would be the diversion of Lake of the Woods into the Roseau River and into the Red River. The Holland reservoir could also provide effective regulation, but this would not be completely compatible with use of the reservoir for flood control.

The Flow Computations are Preliminary.

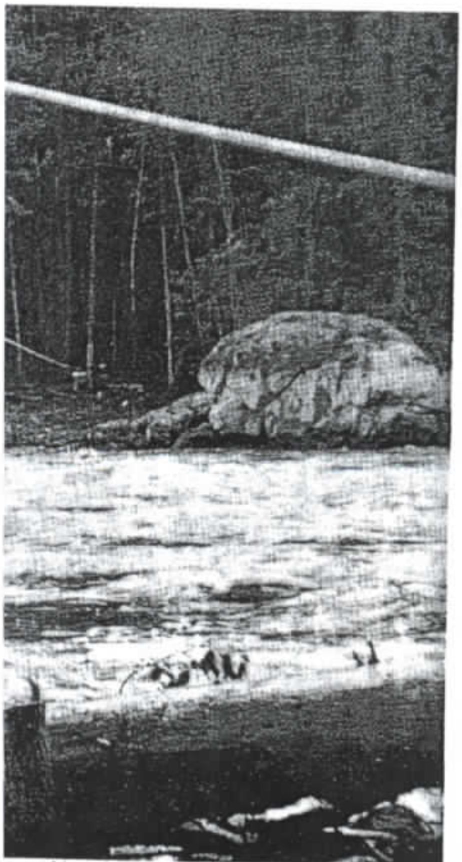
Most of the flow computations done for this study are illustrative. They show how reservoir and diversion information and computation methods can be used to answer planning questions. The figures describing the effects of projects on flows should not be thought of as final. From time to time, the flow figures could change due to changes in the management of existing projects. New reservoir and storage possibilities may be proposed and investigated opening up new regulation possibilities.

Even so, the results of the many studies done by the Board, only a few of which are shown in this summary, give a good picture of what the water supply is now and what it could be.

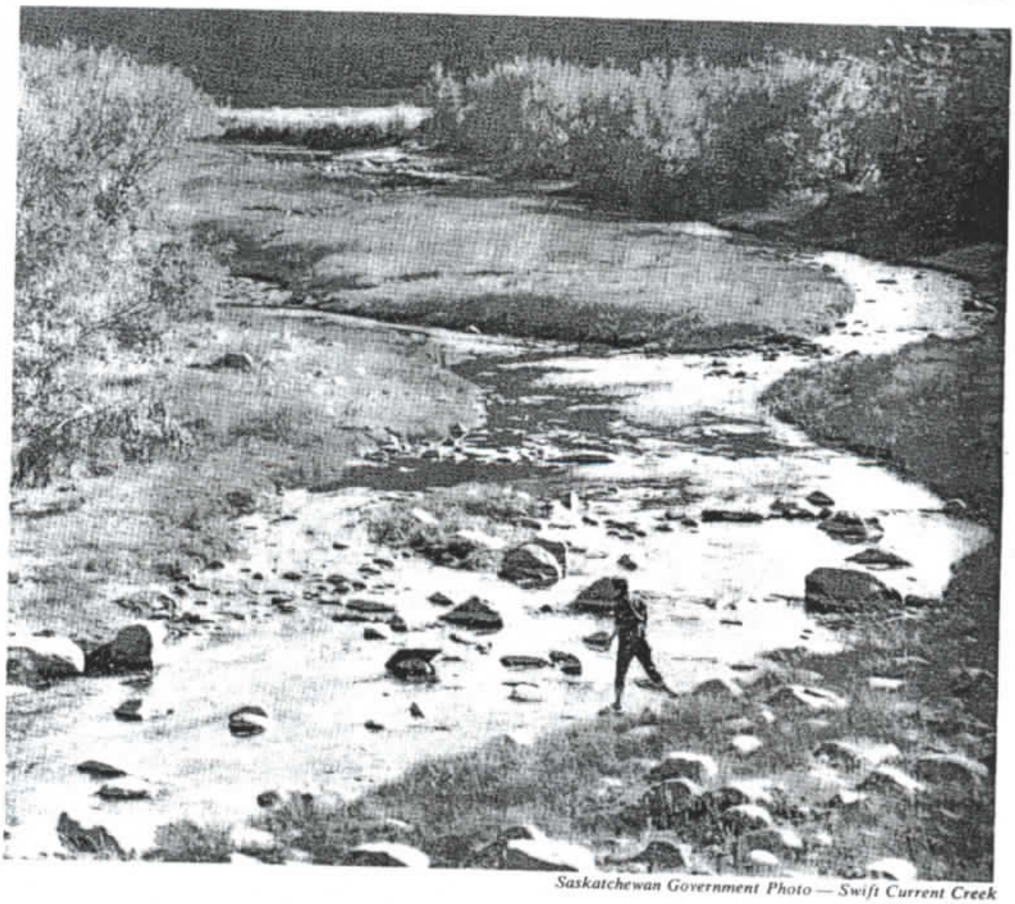
The study focused on the problem of large scale flow improvement for the basin as a whole. Only large projects were investigated because only that kind of project can make large changes in the potential supply. The part that many small projects play in supplying water to meet local needs was not studied.



Saskatchewan Government Photo — Qu'Appelle Valley at Echo Lake



Manitoba Government Photo — Measuring the flow



Saskatchewan Government Photo — Swift Current Creek

RECOMMENDATIONS

1. It is recommended that data on projects, flows and water uses be kept current for future planning.

Data on flows are useful in all phases of water planning and design. However, as time goes on, and new records are obtained on rivers throughout the system, average flows change, new droughts and new floods are experienced. Eventually, data prepared by this Board will become obsolete. In order to keep this important planning base alive, flow data should be brought up-to-date periodically.

In its continuing task of monitoring the apportionment of waters in the Prairie Provinces, the Prairie Provinces Water Board must keep an up-to-date file on flows and water uses. While the field data will be collected by the Water Survey of Canada, supplemented by data gathered by the provinces, the interpretation of this information for apportionment purposes will be something that must be overseen by the Board. One result of this activity will be an up-to-date file on river flows and water uses. This leads to the suggestion that the Prairie Provinces Water Board carry this one step further and use this file to revise periodically the data banks created for the Saskatchewan-Nelson Basin Board study.

From time to time new storage and diversion works will be built and proposals will be made for projects that have not been investigated in this study. These data should also be brought together and added to the files of the Prairie Provinces Water Board.

2. It is recommended that further work be done on SNBB methods for computing the effects of projects on flows and that a group maintain skills in applying these methods.

The use of mathematical models to simulate the operation of reservoirs and diversions is fundamental to future planning in this basin. In considering any proposed works, many questions must be answered.

What will this reservoir do to the flows if it is operated this way or that way?

What will this diversion do to the flows if it is made bigger or smaller?

What will the effect of this project be when compared to the effect of other projects?

How does the effect of both compare with the flows in a state of nature? These and other questions must be answered before the changes in flows can be translated into effects on fish, wildlife, power production, agricultural resources, and so on. The computer programs developed by the Board can be used to find the effects of storages and diversions on flows. The programs can handle several alternative methods of hypothetically operating reservoirs and diversions. They permit various levels of withdrawal to be used. They can accept a variety of delivery patterns to suit a variety of uses.

In the future, the use of these programs can be made more effective if two points are noted. First, advances in modelling techniques are continually being made and may provide even greater flexibility and better simulation of the system in the future. Second, the best results will be obtained by persons trained in the use of the models.

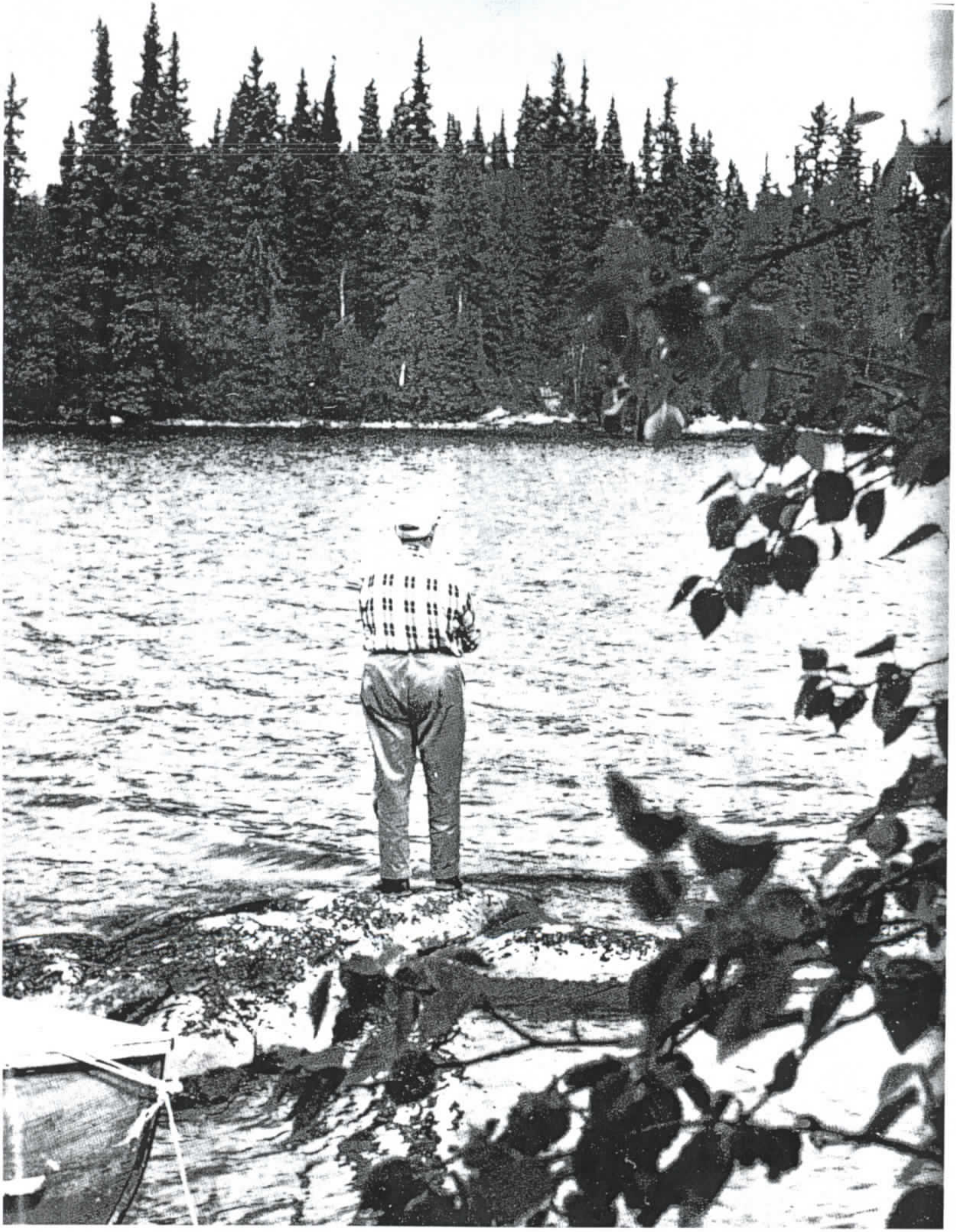
The Prairie Provinces Water Board has been given the job of determining the effects of various proposed developments on flows throughout the three Prairie Provinces, and of comparing alternative proposals for development. It follows that the Prairie Provinces Water Board could be considered the appropriate agency to maintain and extend the models developed by the SNBB.

3. It is recommended that the planning of reservoirs and diversions provide for an adequate assessment of their environmental impact including the effects on fisheries, recreation, wildlife, groundwater, water quality and river regime.

There needs to be a firm basis for predicting the effect of the construction and operation of storage and diversion projects. If these facts are not available, the prediction of effects will continue to be just a shade better than guessing. They will also be very much coloured by emotion. An adequate approach to planning should rely neither on guessing nor on emotional judgements.

If any of these projects are to be built in the future, it is imperative that ample lead time be allowed to measure their environmental and social impact.

The several reports commissioned by the Board on these subjects contained recommendations for studies and investigations. The highlights of these recommendations are summarized here. It should be noted that they may not include all of the environmental impact assessments that could be made.



Recreation. A comprehensive feasibility study of the recreation capability of proposed reservoir sites should become part of the normal planning and investigation process. The report prepared for the Board by the Canada Land Inventory suggests that the cost of undertaking a recreational feasibility study would range from a few thousand dollars to $25,000 for each of the reservoirs investigated by the Saskatchewan-Nelson Basin Board.

Wildlife. Before reservoirs are built, studies are required to evaluate wildlife resources and potentials in the reservoir area. These studies would have three phases: 1) the assessment of existing resources; 2) the prediction of potential effects of impoundment or diversion on those resources; 3) the preparation of guidelines and recommendations. An adequate study would require at least three years. These recommendations are taken from a report prepared by the Canadian Wildlife Service. That report also suggests that the cost of a study would be about $500,000 for a 100-mile stretch of a typical prairie valley (the probable length of a large prairie reservoir).

In planning diversion projects, opportunities for creating new wetlands adjacent to the canals should be studied. New works should be designed to avoid drainage of existing marshes.

Water Quality. Present information is really not adequate to permit a prediction of the effects of diversion on the water quality in donor and receiving rivers. The water quality network should be expanded in the Prairie Provinces, particularly on tributary streams, to support the planning of storage and diversion works.

It is recommended that detailed studies be carried out in Lake Diefenbaker during the next few years to obtain information in its physical, chemical and biological characteristics with a view to improving predictions of the effects of creating new reservoirs in the Prairie area.

More detailed information should be obtained on the quality of water in Cedar Lake, Lake Winnipegosis, and Lake Manitoba to assess the suitability of these waters for possible diversion to Southern Manitoba.

A review of available information in the Clearwater River basin is required to determine the location of salt beds before any extensive work is done on diversion planning.

Fish. The prediction of changes caused by reservoir construction requires intensive investigation of a site. The information gathered would then have to be compared with other relevant sources of information. An adequate study for a large reservoir site would require about five years. In the report prepared for the Board by the Freshwater Institute (Canada Department of the Environment) it is suggested that adequate preliminary or background studies would require an expenditure of over $400,000 the first year, tapering off to $350,000 in the final year. Studies at the proposed reservoir site after it is filled (to find out what changes take place) would require an annual expenditure of about $370,000 for several additional years until conditions are stabilized.

Their report suggests the total expenditure would exceed $3,500,000. The results of such an investigation for the first reservoir would yield basic knowledge which would reduce the investigation costs for subsequent proposals.

River Regime. A number of field and office studies should be done to obtain data for predicting the effects of reservoirs and regulation on riverbed changes. These studies could be used to assess the reliability of methods now being used for prediction. Professors Kuiper and Galay (University of Manitoba) who prepared the report on river regime for the Board, suggest that the annual cost of such studies would vary from a low of $80,000 to a high of $250,000, depending upon the priority given to this work and the urgency of obtaining answers.

Groundwater. Prior to construction of any dams or diversions, consideration must be given to the possible hydrogeological implications of the proposed works. Encouragement should be given to the further exploration, delineating and evaluation of the more important prairie aquifers. Prairie province groundwater agencies, in co-operation with other interested parties, should develop criteria for the determination of safe limits of development of important aquifers in terms of predicted effects on the hydrologic regime exterior to the groundwater system.

Effects of Diversion on the Mackenzie and Churchill Basins. The Mackenzie and Churchill Basins are outside the Saskatchewan-Nelson basin and are seen as possible sources of new water for the basin. Additional studies are required to assess the resources in these adjacent basins, the effect of diversions on them, and their relative place in any overall water management scheme. The effectiveness of possible works or water management plans to compensate for diversion also requires assessment.

A more comprehensive data collection system should be developed cooperatively by all agencies having an interest in the basins. Once basic data are available and studies completed, concrete proposals for optimum water management could be developed to take the fullest possible advantage of the available resources in the basin. Even if no diversions are made, substantial benefits would be realized from the development of such water management plans.

Summary. The total cost of answering all the questions posed is very large. There is bound to be a lot of overlap in the data collection and study programs. Studies related to specific proposals would likely be co-ordinated by the entity responsible for their investigation. But studies and data networks affecting large portions of the basin should be co-ordinated at a basin-wide level.

The Prairie Provinces Water Board has been given specific responsibilities regarding the monitoring of the Apportionment Agreement. The Board must also monitor and report on water quality. But the terms of reference are not specific when it comes to determining the effect of projects on other matters such as fish, recreation, wildlife, river regime and groundwater.

However, it would seem logical for the Prairie Provinces Water Board to accept responsibility for co-ordinating activities in these new areas. It is a recognized Interprovincial/Federal agency which has achieved considerable goodwill and co-operation over the years.

4. It is recommended that other studies be considered to strengthen the foundation for planning future water resources development.

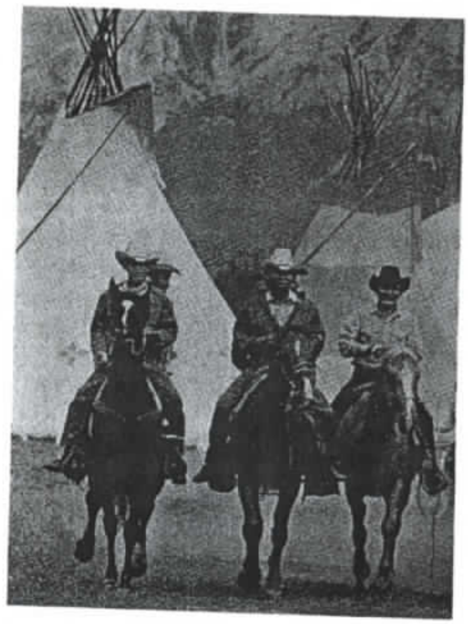
A study of future water requirements would be a valuable supplement to this water supply study. Having a broad understanding of both the supply possibilities and future needs, a planner could quickly put together many alternatives for evaluation by the Prairie Provinces Water Board.

Each provincial government has its own methods of receiving information from people. But are these adequate in the case of water projects which affect all three provinces? Perhaps some arrangement is needed to ensure that the people in all three provinces have equal opportunity to influence the course of development and, at the same time, receive similar or identical information on the effect developments or operation proposals will have on them.

The provinces have agreed to apportion the waters of streams flowing from west to east across their boundaries. But no apportionment has been made of waters that flow from east to west, such as in the Clearwater River in Northern Saskatchewan. There has be no agreement on the status of water that might be imported to the basin from rivers which are not entirely interprovincial, or not at all interprovincial. Both of these problems will require study and negotiation.

The Prairie Provinces should seek a method for allocating the costs and the benefits that accrue from projects that might be built interprovincially or Federally-Provincially.

When it comes to project operation there is also a gap. A downstream province may find that its need for water is minor at a particular time of the year yet rigid enforcement of the Apportionment Agreement would require that waters be delivered to it. Arrangements have not yet been made whereby the downstream province can request the upstream province to store waters that are surplus to both their needs and release it at a later date. A few ad hoc arrangements have been made in the past to co-ordinate operation of projects in one Province for the benefit of another, but there is a need to develop a framework within which joint operating plans can be developed. This could eventually mean the dispatching of water on a co-ordinated basis.



TERMS OF REFERENCE

This agreement made the 16th day of October, 1967,

BETWEEN:

The Government of Canada and
The Government of Alberta and
The Government of Saskatchewan and
The Government of Manitoba.

Whereas there is a greatly increasing demand for water in the Saskatchewan-Nelson Basin.

And whereas it is desirable and in the public interest to study the water resources of the Saskatchewan-Nelson Basin, including the potential additional supply by diversion or storage.

And whereas the parties hereto agree that this study would constitute a first step to ensure the future development of adequate water supplies for the prairie region.

Now therefore in consideration of the premises and the agreements herein contained the parties agree as follows:

1. A Committee of Ministers shall be established to represent the parties hereto and shall consist of two Ministers from each of the parties hereto.

2. The Saskatchewan-Nelson Basin Board (hereinafter called "the Board") is hereby established, the membership to be one representative appointed by each of the provincial governments, and two from the Federal government, one of whom shall be Chairman.

3. The Chairman of the Board shall be appointed by the Committee of Ministers.

4. The members of the Board shall name alternates to represent them and to vote for them at meetings of the Board which they cannot attend.

5. The board shall carry out a study of the water resources of the Saskatchewan-Nelson Basin including the potential additional supply by diversion or storage, as approved by the ministers committee from time to time, using as a guide the report of the Saskatchewan-Nelson technical advisory committee "Outline of Study of the Water Resources of the Saskatchewan-Nelson Basin", dated December 1964.

6. In carrying out the study, the board will consider the engineering feasibility and cost of the many combinations of storage and/or diversion works needed to provide a firm water supply of varying amounts and with varying seasonal distributions, at various selected points along the river system.

7. The Board shall report fully to the Committee of Ministers on the surveys and studies carried out under sections (5) and (6) thereof.

8. The Board may submit reports as it sees fit. The Board shall submit reports as required by the Committee of Ministers; and a final report of its findings shall be submitted by January 1, 1972, if possible, or by such later date as may be agreed to by the Committee of Ministers. It shall also submit copies of these reports to the Prairie Provinces Water Board.

9. The duties of the Board shall be terminated by the parties hereto within a period of three months from the submission of the final report unless extended by the Committee of Ministers

10. The Board shall make all possible use of reports, information and technical data presently available or that may become available during the course of its investigation in order to avoid unnecessary expense and duplication of effort.

11. The Board may utilize the services of employees of the departments of the parties hereto, at cost, including engineers and other specialists, whenever in the opinion of the party concerned the services of such employees are available.

12. In conducting its investigations and performing its duties in accordance with this agreement, the Board, subject to the concurrence of the Committee of Ministers by way of a budget or explicitly,

(a) may employ a Study Director and such specialists or other personnel as it may deem necessary;

(b) may incur such other expenses as may be required; and

(c) may pay for such services, employment and expense out of funds appropriated therefor.

13. The Board shall be authorized by the Government of Canada to carry out its duties with such powers and in such manner as may be necessary in order to enable it to effectively perform its function pursuant to the terms and conditions of this agreement.

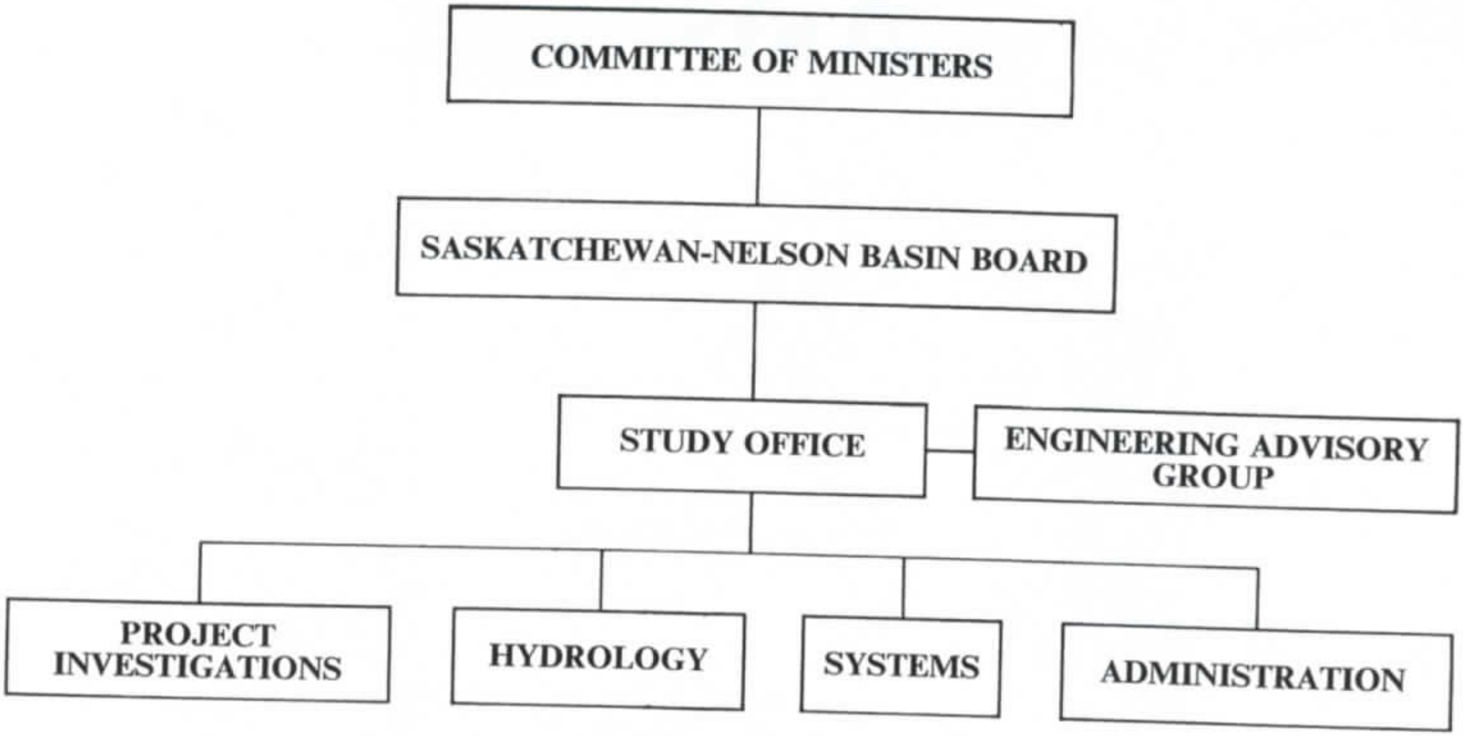
14. Except as may be agreed by the Committee of Ministers, total expenditures authorized by the Board shall not exceed $1,200,000 in any one fiscal year.

15. The parties hereto shall share in the cost of the investigations in the proportion of one-half by Canada and one-sixth each by Alberta, Saskatchewan and Manitoba. Payment of costs will be made in the first instance by Canada. Alberta, Saskatchewan and Manitoba shall each reimburse Canada for its proportion of the costs. Claims will be made annually by Canada to Alberta, Saskatchewan and Manitoba for their proportions of the payments made by Canada, starting March 31, 1968. Alberta, Saskatchewan and Manitoba may reimbuse claims made by Canada either during the course of the study or in a lump sum at the end of the study but, in any event, shall each reimburse Canada in full for claims made against it within six months of submission of the final report of the Board to the Ministers.

16. The parties hereto will, so far as their own requirements permit, authorize their appropriate departments to conduct studies and to provide information whenever requested by the Board, and to provide the services of their employees to the Board in compliance with section 11.

Signed in the presence of:

"B. S. Beer"	"C. M. Isbister" For Canada
"H. A. Ruste"	"H. E. Strom" For Alberta
"G. C. Mitchell"	"J. W. Gardiner" For Saskatchewan
"T. E. Weber"	"W. Weir" For Manitoba



COMMITTEE OF MINISTERS

CANADA

Honourable A. Laing, Minister of Northern Affairs and National Resources (1963-1965)
Honourable H. Hays, Minister of Agriculture (1963-1965)
Honourable Jean-Luc Pepin, Minister of Mines and Technical Surveys (1966-1967)
Honourable J. J. Greene, Minister of Agriculture (1966-1970)
Honourable H. A. Olson, Minister of Agriculture (1969-1972)
Honourable J. Davis, Minister of Environment (1971-1972)

MANITOBA

Honourable G. Hutton, Minister of Agriculture (1963-1967)
Honourable W. C. Weir, Minister of Highways (1967)
Honourable H. J. Enns, Minister of Mines and Natural Resources (1967-1970)
Honourable J. D. Watt, Minister of Agriculture and Conservation (1967-1970)
Honourable S. Green, Minister of Mines and Natural Resources (1970-1972)
Honourable S. Uskiw, Minister of Agriculture (1970-1972)
Honourable L. S. Evans, Minister of Industry and Commerce and Acting Minister of Mines, Resources and Environmental Management (1972)

SASKATCHEWAN

Honourable W. S. Lloyd, Premier (1963-1964)
Honourable I. C. Nollet, Minister of Agriculture (1963-1964)
Honourable W. C. Thatcher, Premier (1964-1971)
Honourable D. T. McFarlane, Minister of Agriculture (1965-1966)
Honourable J. W. Gardiner, Minister of Public Works (1966-1969)
Honourable A. R. Guy, Minister of Municipal Affairs (1969-1971)
Honourable G. R. Bowerman, Minister-in-Charge of Saskatchewan Water Resources Commission (1971-1972)
Honourable J. R. Messer, Minister of Agriculture (1971-1972)
Honourable N. E. Byers, Minister of Environment (1972)

ALBERTA

Honourable H. E. Strom, Premier (1963-1971)
Honourable N. A. Willmore, Minister of Lands, and Forests (1963-1965)
Honourable H. A. Ruste, Minister of Agriculture (1965-1971)
Honourable W. J. Yurko, Minister of Environment (1971-1972)
Honourable D. R. Getty, Minister of Federal and Interprovincial Affairs (1971-1972)

Chairman 1963-1971 Honourable H. E. Strom
Chairman 1971-1972 Honourable S. Green

SASKATCHEWAN-NELSON BASIN BOARD

CANADA

A. T. Davidson:	Assistant Deputy Minister (Water), Department of Energy, Mines and Resources	1967-1970
J. W. MacNeill:	Acting Assistant Deputy Minister (Water), Department of Energy, Mines and Resources	Acting Member 1968-1969
R. H. Clark:	Special Adviser, Inland Waters Directorate, Department of the Environment	Acting Member 1968-1969
A. T. Prince:	Director General, Inland Waters Directorate, Department of the Environment	1970-1972
M. J. Fitzgerald:	Director, Prairie Farm Rehabilitation Administration, Department of Regional Economic Expansion	1967-1970
J. G. Watson:	Director, Prairie Farm Rehabilitation Administration, Department of Regional Economic Expansion	1970-1972
N. H. James:	Acting Director, Water Planning and Management Branch, Department of the Environment	Secretary 1967-1972

MANITOBA

T. E. Weber:	Director General, Water Resources Branch, Department of Mines, Resources and Environmental Management	1967-1972

SASKATCHEWAN

G. C. Mitchell:	Deputy Minister, Department of the Environment	1967-1972
S. R. Blackwell:	Chief, Water Management Service, Department of the Environment	Acting Member 1971-1972

ALBERTA

R. E. Bailey:	Director, Water Resources Division, Department of the Environment	1967-1972

CHAIRMAN:	A. T. Davidson	1967-1970
	A. T. Prince	1970-1972
SECRETARY:	N. H. James	1967-1972

ENGINEERING ADVISORY GROUP

CANADA

J. G. Watson:	Chief Engineer, Prairie Farm Rehabilitation Administration, Department of Regional Economic Expansion	1968-1970
W. B. Thomson:	Chief Engineer, Prairie Farm Rehabilitation Administration, Department of Regional Economic Expansion	1970-1972
W. M. Berry:	Chief Planning Engineer, Prairie Farm Rehabilitation Administration, Department of Regional Economic Expansion	Acting Member 1971
R. H. Clark:	Special Adviser, Inland Waters Directorate, Department of the Environment	1968-1972

MANITOBA

N. Mudry:	Director of Planning, Water Resources Branch, Department of Mines, Resources, and Environmental Management	1968-1972
G. H. MacKay:	Head, Water Resources Section, Water Resources Branch, Department of Mines, Resources and Environmental Management	Acting Member 1971-1972

SASKATCHEWAN

J. M. Crook:	Chief Engineer, Saskatchewan Water Resources Commission	1968-1970
S. R. Blackwell:	Chief, Water Management Service Department of the Environment	1970-1972

ALBERTA

W. Solodzuk:	Chief Engineer, Water Resources Division, Department of the Environment	1968-1972
R. K. Deeprose:	Head, Hydrology Branch, Water Resources Division, Department of the Environment	Acting Member 1971

STUDY STAFF

E. F. Durrant:	Study Director
D. J. Berry:	Senior Investigations Engineer
R. B. Godwin:	Senior Hydrology Engineer
J. A. Kerr:	Senior Systems Engineer
J. N. G. Yu:	Investigations Engineer
A. T. McPhail:	Investigations Engineer
E. P. Collier:	Hydrology Engineer
R. J. Wettlaufer:	Systems Engineer
J. C. Y. Lee:	Systems Engineer

The foregoing is a summary of the report of the Saskatchewan-Nelson Basin Board. The complete report is composed of several parts as follows:-

Report On

"Water supply for the Saskatchewan-Nelson Basin"

Appendices

Appendix 1: Study background

Appendix 2: Project investigations
—Investigation Standards
—Project Design Floods
—Guidelines for Cost Estimating
—Cost of Power for Pumping

Appendix 3: Project catalogue

Appendix 4: Hydrology

Volume I —Streamflows
—Evaporation
—Hydrologic Aspects Generation

Volume II—Flow Tables
—Tables of Regression Coefficients

Appendix 5: Systems Analysis
—Data Storage and Retrieval
—Multireservoir Analysis
—Computer Facilities and Costs

Appendix 6: Regulation Studies.
—Study Criteria
—Results: Graphs and Tables

Appendix 7: Environmental and other considerations
—Fish and the Biological System
—Wildlife
—Recreation
—Water Quality
—River Regime
—Groundwater

Appendix 8: Effects of diversion on donor basins
—Mackenzie Basin
—Churchill Basin

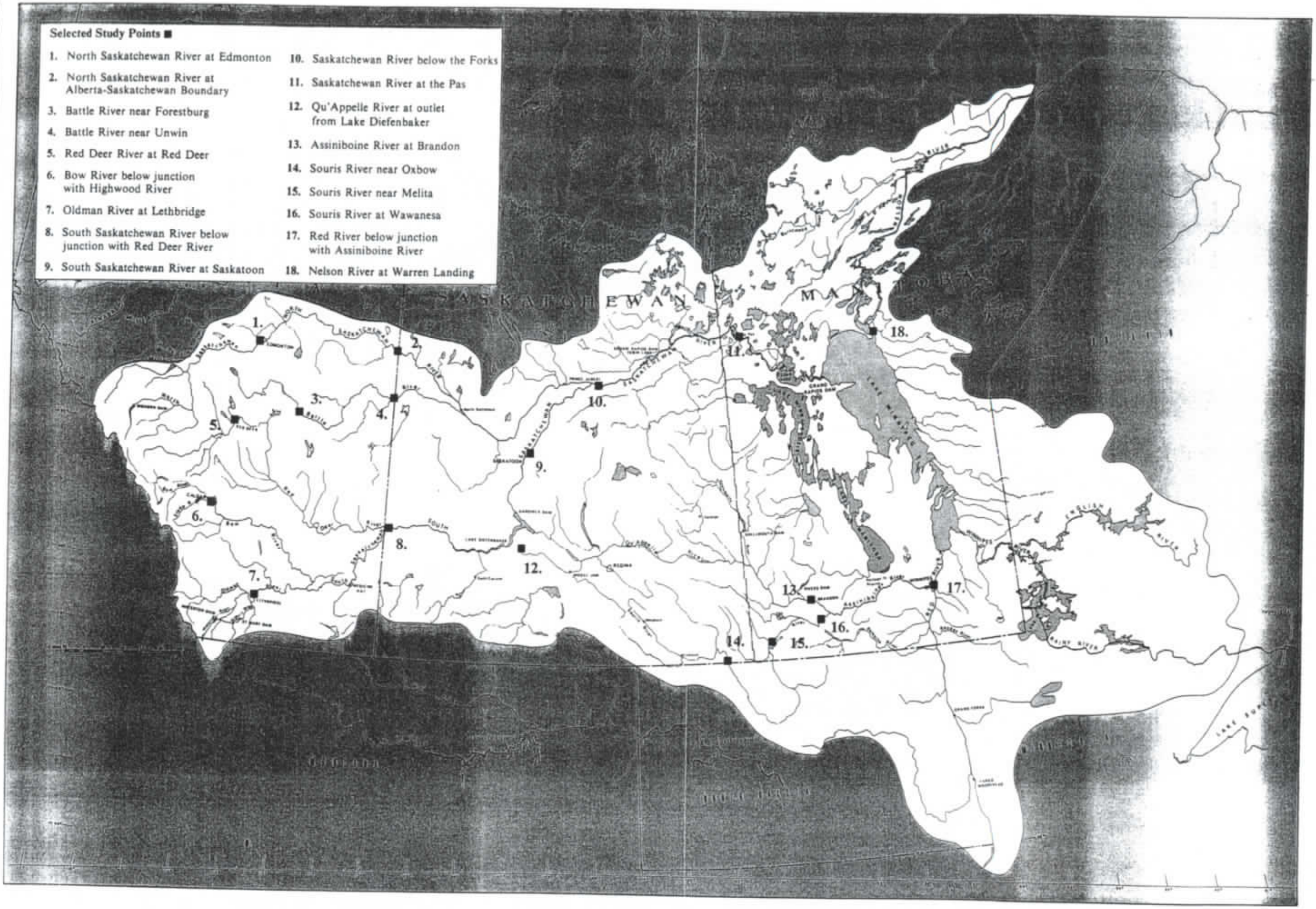
Enquiries regarding these reports may be sent to:

Information Canada—Ottawa, Ont.

Queen's Printer, Province of Alberta, Edmonton, Alberta

Queen's Printer, Province of Saskatchewan, Regina, Saskatchewan

Queen's Printer, Province of Manitoba, Winnipeg, Manitoba



Selected Study Points ■
1. North Saskatchewan River at Edmonton
2. North Saskatchewan River at Alberta-Saskatchewan Boundary
3. Battle River near Forestburg
4. Battle River near Unwin
5. Red Deer River at Red Deer
6. Bow River below junction with Highwood River
7. Oldman River at Lethbridge
8. South Saskatchewan River below junction with Red Deer River
9. South Saskatchewan River at Saskatoon
10. Saskatchewan River below the Forks
11. Saskatchewan River at the Pas
12. Qu'Appelle River at outlet from Lake Diefenbaker
13. Assiniboine River at Brandon
14. Souris River near Oxbow
15. Souris River near Melita
16. Souris River at Wawanesa
17. Red River below junction with Assiniboine River
18. Nelson River at Warren Landing
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