1996

ALBERTA STATE OF THE ENVIRONMENT REPORT

Alberta
ENVIRONMENTAL PROTECTION

AQUATIC ECOSYSTEMS

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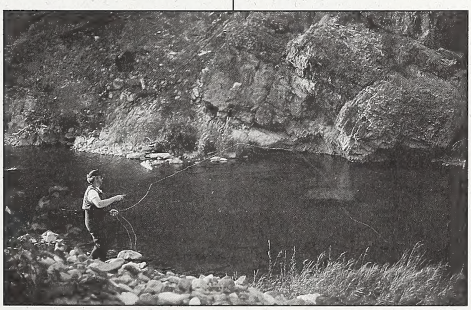
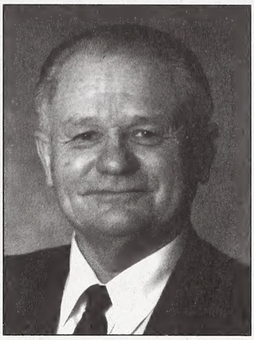


MESSAGE FROM THE MINISTER



I am pleased to present the 1996 Alberta State of the Environment Report.

The focus of the 1996 Alberta State of the Environment Report is Alberta's rivers, lakes, and wetlands, which form the province's aquatic ecosystems. The report details these ecosystems and their distribution, their environmental importance, how we use and infuence them, the role and nature of sound management in their preservation, and the steps taken or underway to ensure their continuing viability.

Alberta is particularly blessed with fresh water in a diverse array of aquatic ecosystems. These range from cold mountain streams on the province's western boundary to warm prairie lakes on the plains, from southern and central wetlands to the rich peatlands of the north. The importance of aquatic ecosystems to Albertans cannot be overemphasized. As the source of the water we use daily for drinking, they are essential to sustaining life. They are also the source of water used for agricultural, municipal, commercial, and industrial purposes. They provide a crucial habitat for many plants and animals. Many offer unparalleled sites for recreation, part of the significant contribution aquatic ecosystems make to the Alberta Advantage.

Managing this precious, limited resource is therefore a special responsibility, made more challenging by the uneven distribution of water throughout the province and throughout the year. The Government of Alberta continues to respond to this challenge. The new Water Act, developed after extensive public consultation, allows for better and more efficient water management, allocation, and conservation. Water quality is protected by regulating industrial effluents and assessing water quality against the Alberta Surface Water Quality Interim Guidelines. As this report indicates, other activities to protect aquatic ecosystems are ongoing. These include lake, water, and river basin management and planning, environmental studies and monitoring, ecological and species management, and cooperative research programs, such as the Terrestrial and Riparian Organisms, Lakes and Streams Program at the University of Alberta.

Everyone has a role to play in environmental protection. In that regard, this State of the Environment report contains extensive information about the current state of our rivers, lakes and wetlands that will be useful to students, businesses, individual Albertans, and all those who share our concern and commitment to the environment.

I would like to thank for their efforts all those who helped prepare or contributed to this document. A survey for readers is provided at the end of this report. I encourage you to complete and return it to the address given. Your responses and comments are welcome and important to future State of the Environment reports.

Ty Lund

Honourable Ty Lund
Minister of Environmental Protection

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PREFACE

The Department of Environmental Protection is committed to inform Albertans about the environment and produces many reports on the status of Alberta's environmental resources. This ensures accountability of the department's environmental policies and programs and gives Albertans important information for their own consideration and use. There is also a legislative basis for state of the environment reporting. Alberta's *Environmental Protection and Enhancement Act* states that the Minister shall report annually on the state of the environment.

Nationally, the Canadian Council of Ministers of the Environment have promoted a common approach to State of the Environment Reporting.

The purpose of State of the Environment (SOE) Reporting is to provide timely, accurate, and accessible information on ecosystem conditions and trends, their significance and societal responses, emphasizing the use of indicators.

This information will increase public understanding and education, and assist priority-setting and decision-making about matters related to the environment by providing objective and scientifically valid information. The information should also establish linkages between environmental conditions and socio-economic factors, reflecting the holistic and integrative nature of the relationship that exists between humans and the environment.

Education about the environment is an important goal of SOE reporting. In addition to facts and figures about the state of Alberta's environment, this report features background history and science to help the reader interpret the information presented.

SOE reporting makes extensive use of environmental indicators, key measurements that can be used to monitor, describe, and interpret change. Indicators can help us answer questions such as:

- What environmental trends are occurring?
- Why are they significant?
- What actions are being taken?

They can also help us better manage our environment by setting targets and tracking progress toward them. We can see what works best and adjust our programs where needed.

A comprehensive State of the Environment Report will be published once every five years, covering all aspects of the environment. The first of these reports was published in 1994 and the next comprehensive report will be published in 1999. In the intervening years, SOE reports will focus on particular themes. In addition to the annual reports, shorter fact sheets on specific issues or programs are published as part of the SOE series.

The theme of this year's report is **aquatic ecosystems**. Much of the information has been provided by Alberta Environmental Protection, Alberta Energy, Alberta Health, and Alberta Agriculture, Food and Rural Development. Additional information was provided by Alberta Public Works, Supply and Services, the Alberta Energy and Utilities Board, Ducks Unlimited Canada, the University of Alberta (Terrestrial and Riparian Organisms, Lakes and Streams Program), Alberta's Peat Management Task Force, Trout Unlimited Canada, the Bow River Water Quality Council, and the Canadian Sphagnum Peat Moss Association.

Readers are invited to provide comments on this year's report or any aspect of SOE reporting to Alberta Environmental Protection at the address below. A Reader Survey form is enclosed at the end of this report. Your feedback would be greatly appreciated.

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(Ducks Unlimited Canada, Patrick Lang)

1.0 INTRODUCTION

WHAT ARE AQUATIC ECOSYSTEMS?

Aquatic ecosystems include rivers, lakes and wetlands, and the variety of plants and animals associated with them. The presence of surface or near-surface water is their most obvious common element.

Life in the aquatic environment is influenced by a variety of conditions such as water temperature, light penetration, nutrients, pH (acidity or alkalinity), dissolved oxygen, and soil substrate characteristics. From mountain streams to shallow prairie lakes and wetlands, each body of water is unique.

Whether moving or still, water bodies are inhabited by many life forms. Aquatic communities, like those on land, are based on primary producers that convert sunlight and carbon dioxide into the materials of life - phytoplankton (microscopic floating algae), large multi-cellular algae that attach to other plants or to the bottom, aquatic mosses, and many kinds of vascular plants with stems, leaves, and flowers.

Animals that feed on these plants - the primary consumers - are also present throughout the aquatic environment, and range from free-swimming zooplankton to aquatic insects to vertebrates such as fish and birds. Secondary consumers, the animals that feed upon other animals, are also present and represented in each of these groups.

Lastly, scavengers and microorganisms recycle materials within the aquatic ecosystem.

The influence of water extends beyond the banks or shores of a water body to the bordering land, where a vast array of plants and animals also depends on the aquatic environment. There is no clear line that separates water and land environments. Many animals, being mobile, depend on aquatic or adjacent riparian environments for part of their life cycle - for example, the toad that returns to water to lay its eggs or the deer that winter in the forested floodplain of a prairie river.

WHAT ABOUT GROUNDWATER?

Groundwater is an extremely important water resource. Many surface water bodies are highly influenced by groundwater and vice-versa. However, groundwater has a very limited living component and is therefore not treated as a separate section in this report. The contribution of groundwater to particular water bodies, where known, is mentioned. In many other cases, its contribution has not yet been determined.

WHY FOCUS ON AQUATIC ECOSYSTEMS?

- **Our water resources are limited**
  Alberta contains only about two percent of Canada's fresh water **(Figure 1.1)** distributed among five major river systems, several thousand lakes, and numerous wetlands.

- **Our society depends on water resources for many uses**
  Water supplies Alberta's communities, farms, and industries with everything from drinking water and water for crops to water used in industrial processes and to generate electricity. In addition, some aquatic ecosystem components such as fish, waterfowl, semi-aquatic furbearers, and peat are important to hunters, anglers, trappers, and commercial businesses.

- **Aquatic environments are a source of recreation and enjoyment to many**
  A survey in 1992 found that 61 percent of Alberta households participated in at least one of eight water-based recreational activities: fishing, swimming, boating, canoeing, sailing, water skiing, windsurfing, or rafting. Camping, which often occurs near a body of water, was engaged in by 46 percent of households.

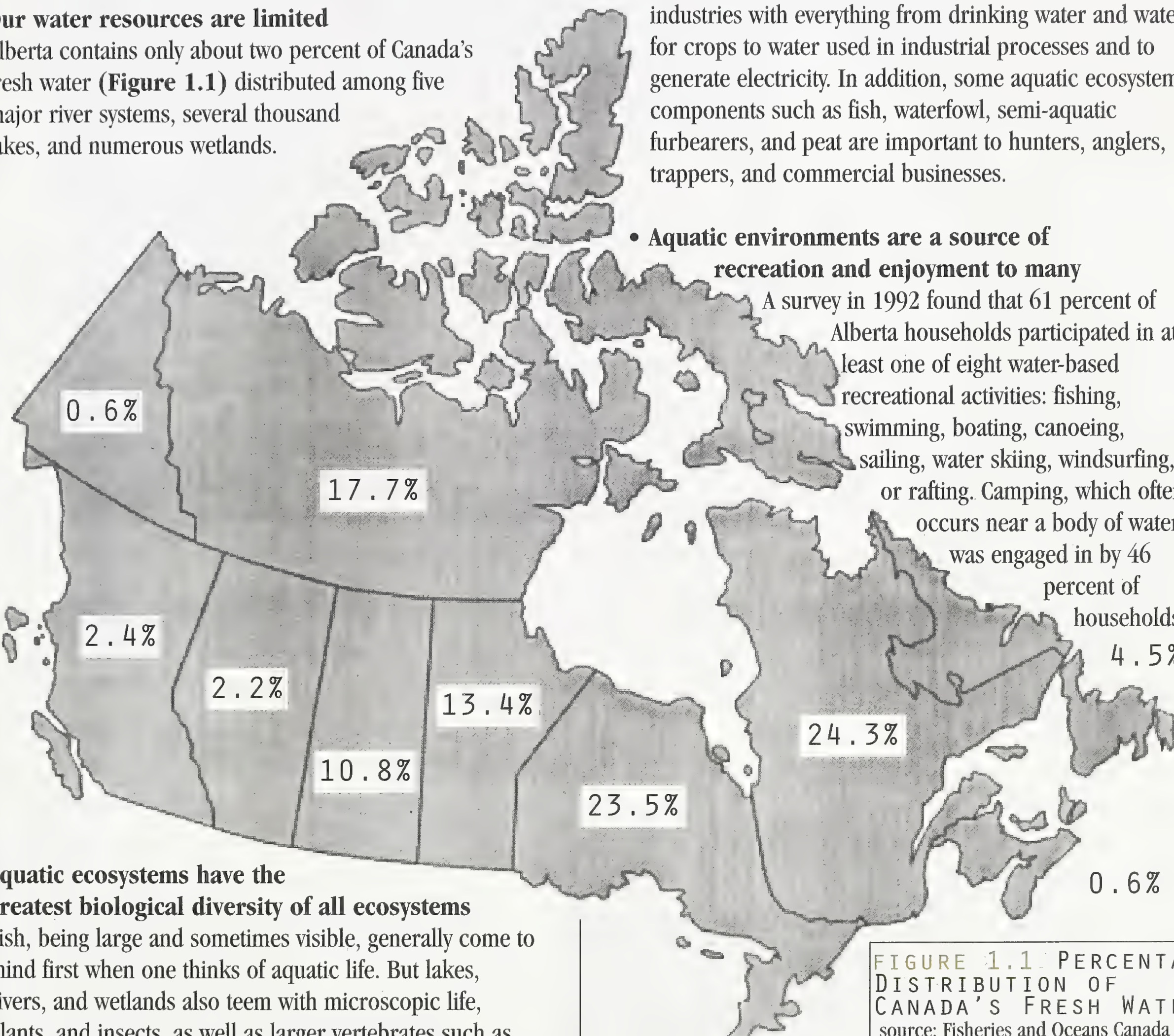


FIGURE 1.1 PERCENTAGE DISTRIBUTION OF CANADA'S FRESH WATER
source: Fisheries and Oceans Canada 1987

In 1994, one out of every 11 Albertans purchased a fishing licence. Licensed resident anglers in Alberta fished a total of about 5.2 million days and spent about $163 million on goods and services directly related to fishing.

- **Aquatic ecosystems have the greatest biological diversity of all ecosystems**
  Fish, being large and sometimes visible, generally come to mind first when one thinks of aquatic life. But lakes, rivers, and wetlands also teem with microscopic life, plants, and insects, as well as larger vertebrates such as amphibians, birds, and mammals. The range of species represented in some of these groups is not known. In a spring-fed wetland near Edmonton, 179 species of vertebrates, 2181 species of arthropods (insects, spiders and crustaceans) and 531 species of plants have been reported (Finnamore 1994). Much remains to be learned about species that inhabit aquatic habitats and their interactions.

In 1995, over 20 000 licences for waterfowl hunting were purchased in Alberta. Expenditures on goods and services related to this activity constitute a considerable portion of the total $156 million spent on hunting in Alberta in 1991 according to a Canadian survey (Filion et al. 1995). The value of waterfowl to Albertan hunters has been estimated by asking hunters what they would be willing to pay for their waterfowl hunting experience beyond their actual expenditures. This value was $4.8 million in 1991 (Filion et al. 1995).

Wildlife viewing is the fastest-growing wildlife-related recreational activity in the province. Albertans spent $431 million in 1991 on trips to view wildlife and another $248 million on contributions to preserve natural areas and wildlife (Filion et al. 1995). An unknown but probably large portion of these activities and expenditures would be associated with aquatic environments.

Wildlife is only a part of the value of aquatic environments to Albertans. The enjoyment Albertans derive simply from being near lakes, rivers, or wetlands is immeasurable. For some people, certain rivers and lakes have long held spiritual significance. For example, annual religious pilgrimages are made by many people to Lac Ste. Anne in central Alberta.

- **Prevention is easier than restoration**
  It's easier to protect a lake than to clean it up, or protect a fish population than restore it. If we want to pass on healthy aquatic environments to future generations, we need to make good decisions now regarding the use and protection of these resources. To do this, we need to see the "whole picture."

(Ducks Unlimited Canada, Bob Thomson)

Scope and Organization of Report

This report describes the aquatic ecosystems in Alberta, how society uses and affects them, and what is being done to preserve them. As water management and planning is generally done on a river basin approach, much of the information is arranged by Alberta's major river basins.

Section 2 gives a brief account of how present-day water bodies in the province came into being.

Section 3 presents an overview of the natural conditions of Alberta's rivers, lakes and wetlands and the life forms that depend upon them.

Section 4 examines how our activities affect these aquatic ecosystems.

Section 5 describes some of the provincial legislation, policies, and programs that have been established to ensure the sustainability of aquatic ecosystems.

Section 6 describes the major river basins in the province. Factors influencing the aquatic ecosystems in each basin are also discussed and the steps being taken to safeguard these resources are described.

Section 7 presents some overall conclusions and future trends that may affect Alberta's aquatic ecosystems.

2.0 ORIGIN AND DISTRIBUTION OF SURFACE WATER IN ALBERTA

2.1 ORIGIN

Water and climate acting over vast periods of time have influenced the distribution and characteristics of Alberta's water bodies. In the distant past, shallow seas advanced and retreated many times, depositing layer upon layer of sand and silt. These layers became compressed and hardened into the sandstone and shale formations found throughout most of the province **(Figure 2.1)**. From the remains of the abundant aquatic life present in the seas, pockets of oil formed in porous rock, sands, and coral reefs. Fossilized remains of plants and animals provide a permanent record of the aquatic ecosystems in the Palaeozoic and Mesozoic eras in Alberta.

With the uplift of land during the Cenozoic Era, the seas retreated. The tropical climate became temperate and a rich mammalian fauna developed. Massive uplift and eastward movements of the earth's crust in what is now British Columbia formed the Rocky Mountains. The resulting folded and broken rock moved far eastward, pushing the sandstone and shale into great ripples, forming the foothills. Rivers that once flowed into Alberta from the west were cut off by the rising mountains. By the end of this first part of the Cenozoic, or the Tertiary Period, the bedrock geology of the province was established and with it, many of the topographic features that affect the flow of surface water and groundwater today.

The Quaternary Period that followed brought a cooling of the climate and four glaciations to North America. Only the last, the Wisconsin Glaciation, is well known. During this glaciation, ice sheets converged from the north and west until all of the province was covered at some point with the exception of parts of the Cypress Hills and Porcupine Hills.

The influence of this glaciation on Alberta's water bodies is described in *The Atlas of Alberta Lakes* by Mitchell and Prepas (1990):

> As the ice sheets advanced and retreated over Alberta, they sculptured the land, carving and eroding the mountains, moving rocks and depositing gravel and silts until the landscape was virtually as we see it today. The last retreat of the ice, beginning 12 000 years ago, left behind enduring impressions on Alberta. As the ice sheets melted and retreated, they left behind a blanket of

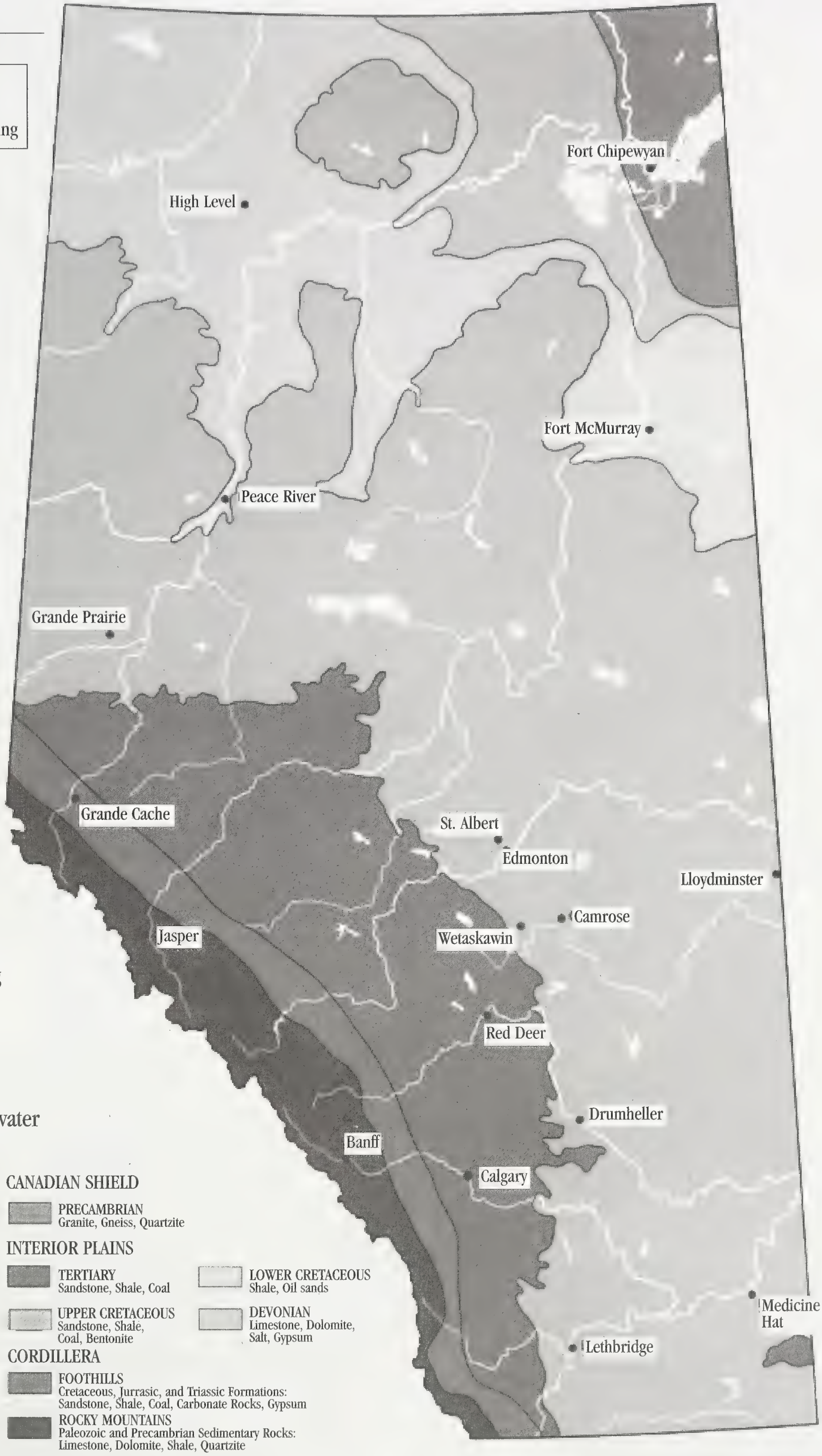


FIGURE 2.1 BEDROCK GEOLOGY OF ALBERTA
source: Alberta Bureau of Surveying and Mapping

glacial till up to 100 metres thick over most of Alberta east of the mountains. In southern Alberta, the till forms a ground moraine, leaving a gently undulating surface. Water drains into gentle depressions to form shallow lakes like Eagle and Tyrell lakes. In central Alberta, the terrain is more hummocky and rolling; examples are found around Red Deer, from Elk Island National Park to Cooking Lake and west of Stony Plain. In some areas, large blocks of ice were left by the retreating glacier and till piled up around the ice so when the ice melted, holes or kettles, were left in the landscape. Small lakes fed and drained by groundwater now fill these kettles; examples are Spring, Eden and Hubbles lakes. In some areas, glacial till blocked preglacial channels, impounding water to form lakes like Crowsnest, Rock and Baptiste.

As the glaciers melted, they produced huge volumes of meltwater which cut through the till plain and formed long, steep-sided, flat-floored river valleys. Many of these valleys are now dry, or nearly dry. An example on the southern prairie can be seen where Verdigris, Etzikom, Chin and Forty Mile coulees are part of one series of meltwater channels. A number of these channels are now dammed to form offstream storage reservoirs, for example, Milk River Ridge, Crawling Valley, Chin and Forty Mile Coulee reservoirs. Another conspicuous meltwater channel is now followed by the Battle River and includes Driedmeat and Coal lakes. Examples of lakes in smaller meltwater channels in northern Alberta include Long (near Athabasca), Narrow, Long (near Boyle) and Amisk lakes.

Huge lakes covered large portions of Canada and North America as a result of glacial meltwater. These lakes provided the routes by which fish returned to the midwest from southern areas which had not been covered by ice. One of these, Lake Agassiz, covered most of Manitoba and parts of Saskatchewan, Ontario, North Dakota and Minnesota. This glacial lake provided a connection from the south to Alberta via the North and South Saskatchewan rivers. Glacial Lake Edmonton connected the Peace-Athabasca river system and the Saskatchewan river system. Other dispersal routes included temporary connections between the South Saskatchewan and Milk (and thus Missouri River) drainages. From an unglaciated area on the Columbia River, fish were able to enter Alberta via the Fraser and Peace river systems.

FIGURE 2.2 DRAINAGE NETWORKS IN ALBERTA

Climate, water, and land still interact today. Climatic factors such as precipitation and temperature determine the amount of water in rivers, lakes and wetlands. Flowing rivers still cut through glacial till and bedrock, eroding the land. In turn, soil and minerals from eroding land affect rivers and lakes, as do changes to the landscape, whether natural or man-made.

2.2 DISTRIBUTION OF AQUATIC ECOSYSTEMS

Precipitation falls to earth in the form of rain, sleet, hail, and snow. Some of this water returns to the atmosphere by evapotranspiration (evaporation plus transpiration from plants), some seeps deep into the ground to become groundwater, and the rest runs over the surface or through the upper layers of soils. This water collects in channels, forming watercourses (brooks, creeks, streams and rivers). These connect to one another in a treelike pattern, becoming ever larger, until they form large rivers. **Figure 2.2** shows the network of watercourses throughout the province.

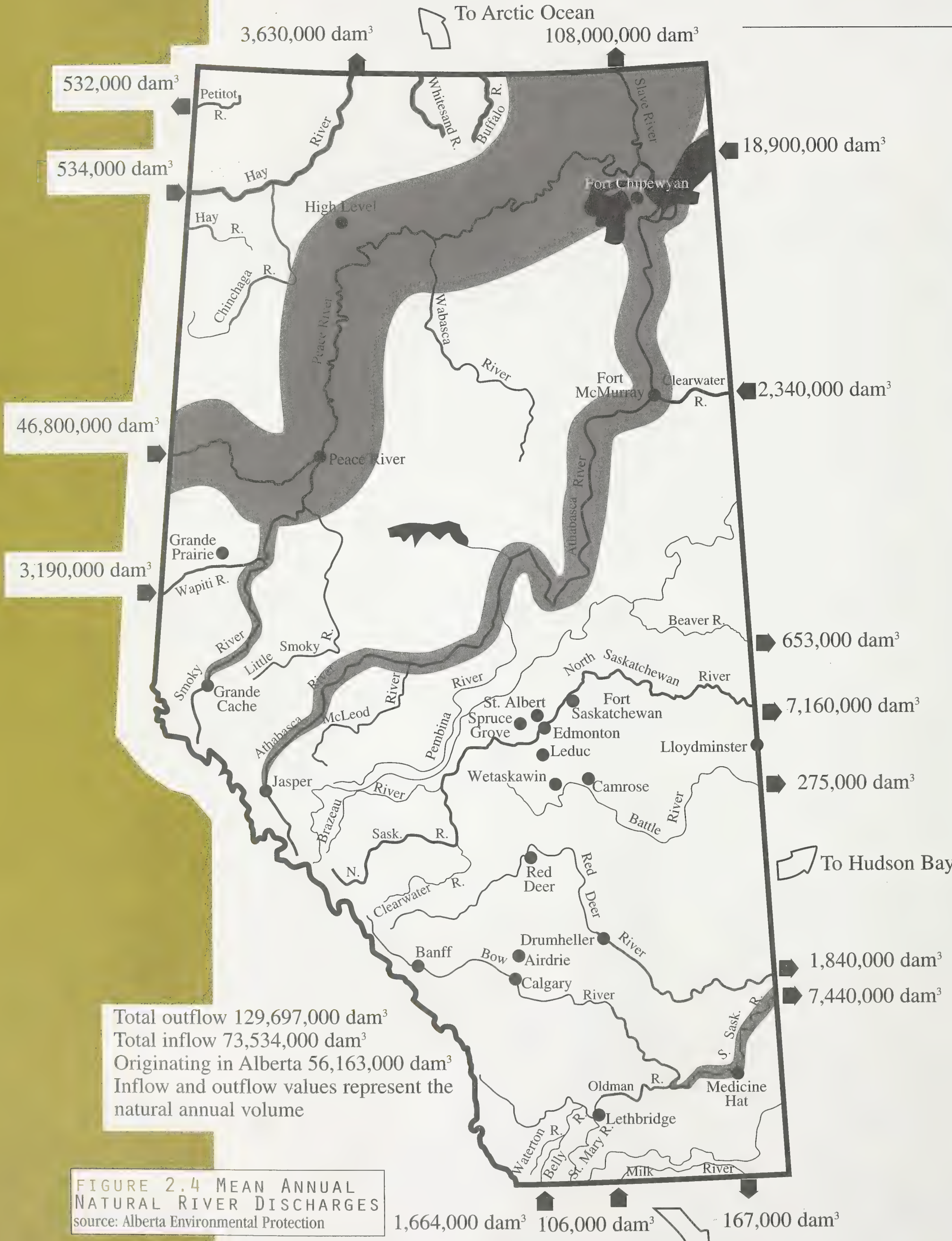
The total amount of land drained by a large river and its tributaries is termed the drainage basin or river basin. A river basin also includes the lakes and wetlands that drain into the network.

Alberta is generally divided into five major river basins on the basis of its five major river systems. These basins are in turn part of larger continental drainage basins **(Figure 2.3).**

- **The Peace-Athabasca-Slave River Basin** occupies 64 percent of the province and is the largest and most northerly river basin in the province. The large Peace River begins in the British Columbia mountains and flows northeast across Alberta to the Peace-Athabasca Delta. The Athabasca River begins at the Athabasca Glacier in Alberta and also flows northeast to the delta. The Slave River carries water from the Peace and Athabasca rivers into the Northwest Territories. The Peace-Athabasca-Slave River Basin is a part of the Mackenzie River Basin, which empties into the Arctic Ocean. Most of Alberta's river flow (86 percent) follows this route.

- **The North Saskatchewan River Basin**, in the central part of the province, occupies approximately 12 percent of the province. It is drained by one major river, the North Saskatchewan, which originates in the icefields near the British Columbia-Alberta border. The Battle River, which joins the North Saskatchewan River in Saskatchewan, rises in central Alberta. The entire basin has six percent of the total river flow in the province.

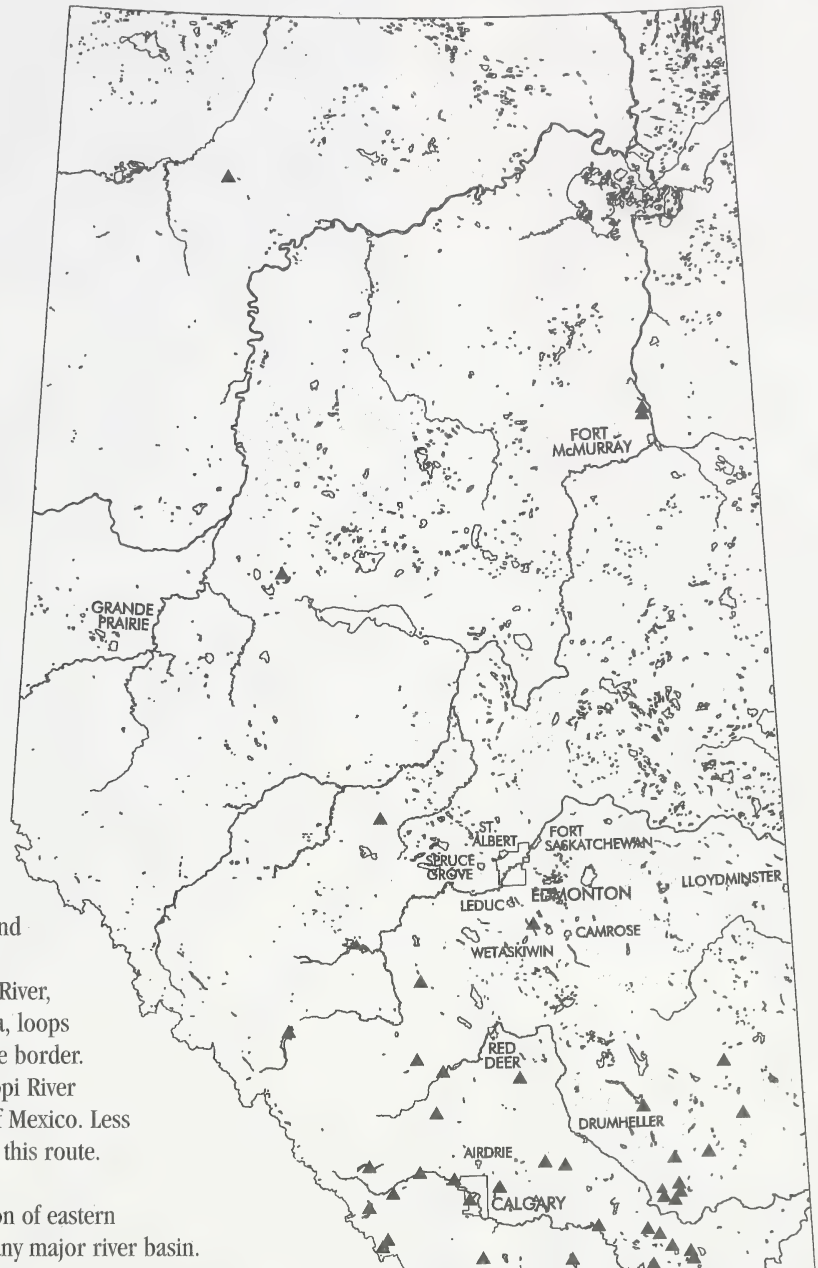
FIGURE 2.3 CONTINENTAL DRAINAGE BASINS IN WESTERN CANADA



Total outflow 129,697,000 dam³
Total inflow 73,534,000 dam³
Originating in Alberta 56,163,000 dam³
Inflow and outflow values represent the natural annual volume

FIGURE 2.4 MEAN ANNUAL NATURAL RIVER DISCHARGES
source: Alberta Environmental Protection

FIGURE 2.5 ALBERTA LAKES AND RESERVOIRS
source: Alberta Environmental Protection



- **The South Saskatchewan River Basin** in the southern part of the province occupies nearly 18 percent of Alberta's land area. It is drained by three major rivers, the Red Deer, Bow and Oldman, all of which originate in the Rocky Mountains. The South Saskatchewan River itself is formed by the confluence of the Oldman and Bow rivers. It flows east across the Saskatchewan border where it is joined by the Red Deer River. Farther downstream, the South Saskatchewan River joins the North Saskatchewan River, as part of the Saskatchewan-Nelson River system flowing to Hudson Bay. The South Saskatchewan River carries seven percent of Alberta's river flow.

- **The Beaver River Basin** is a small basin that occupies approximately three percent of Alberta in the Boreal Forest Natural Region. Its major rivers, the Beaver and Sand, originate in northeastern Alberta and are relatively small in volume; the river flow in the basin amounts to less than one percent of the province's total. The Beaver River flows eastward as part of the Churchill River Basin that empties into Hudson Bay.

- **The Milk River Basin** is the most southerly and smallest basin in Alberta, occupying about one percent of the province. It consists of the Milk River, which rises in the Rocky Mountains of Montana, loops north into Canada, and returns south across the border. The Milk River is part of the Missouri-Mississippi River Basin, which eventually empties into the Gulf of Mexico. Less than one percent of Alberta's river flow follows this route.

A small area in the Provost-Coronation-Oyen region of eastern Alberta is self-contained and does not drain into any major river basin. This basin, the Sounding Creek Basin, covers about two percent of the province.

The abundance and amount of surface water differs widely among Alberta's river basins. Rivers are largest in the north as illustrated in **Figure 2.4**. The largest lakes are also found in the north, whereas man-made reservoirs predominate in the south **(Figure 2.5)**. South of Calgary, almost all sizeable bodies

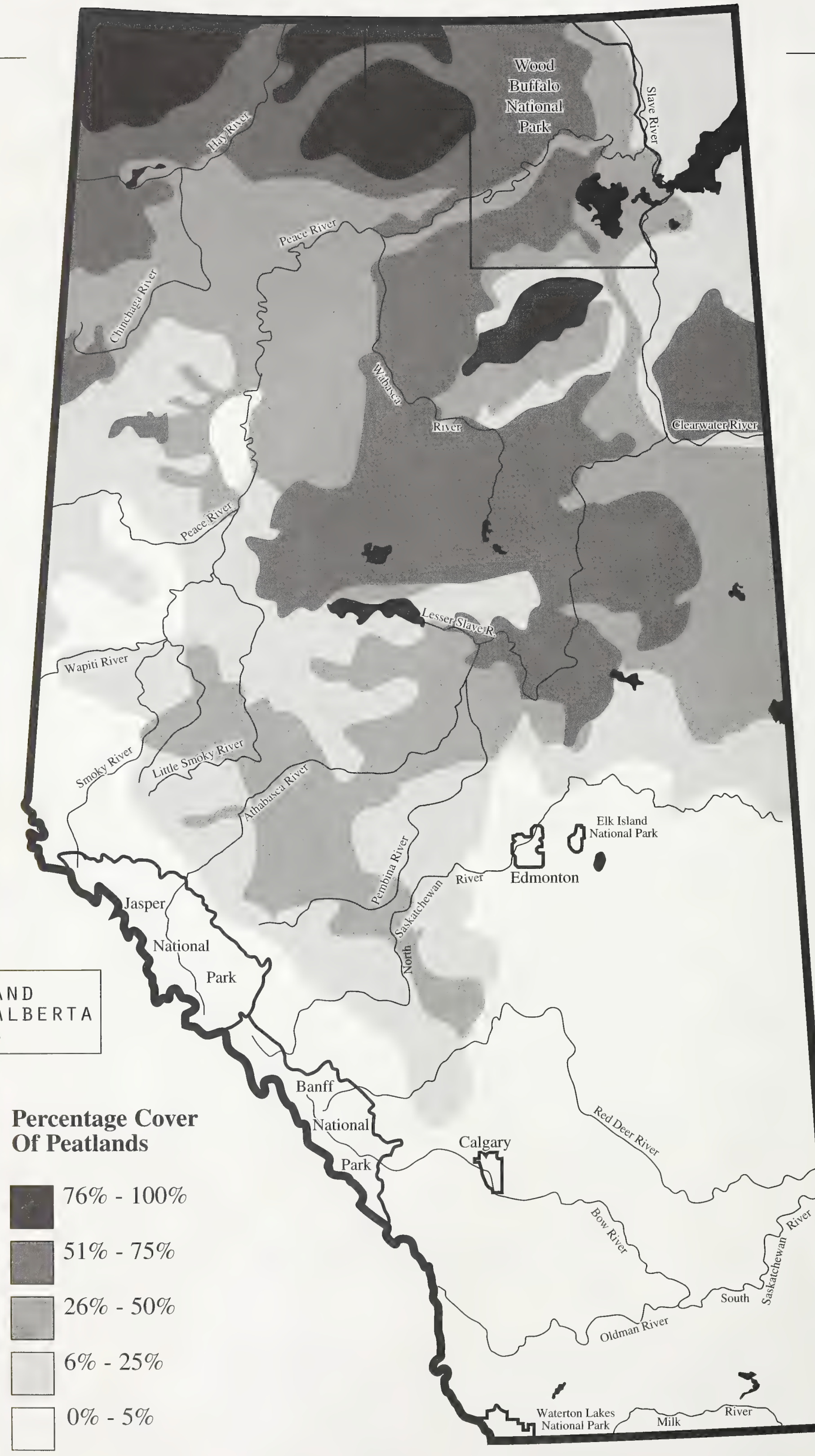
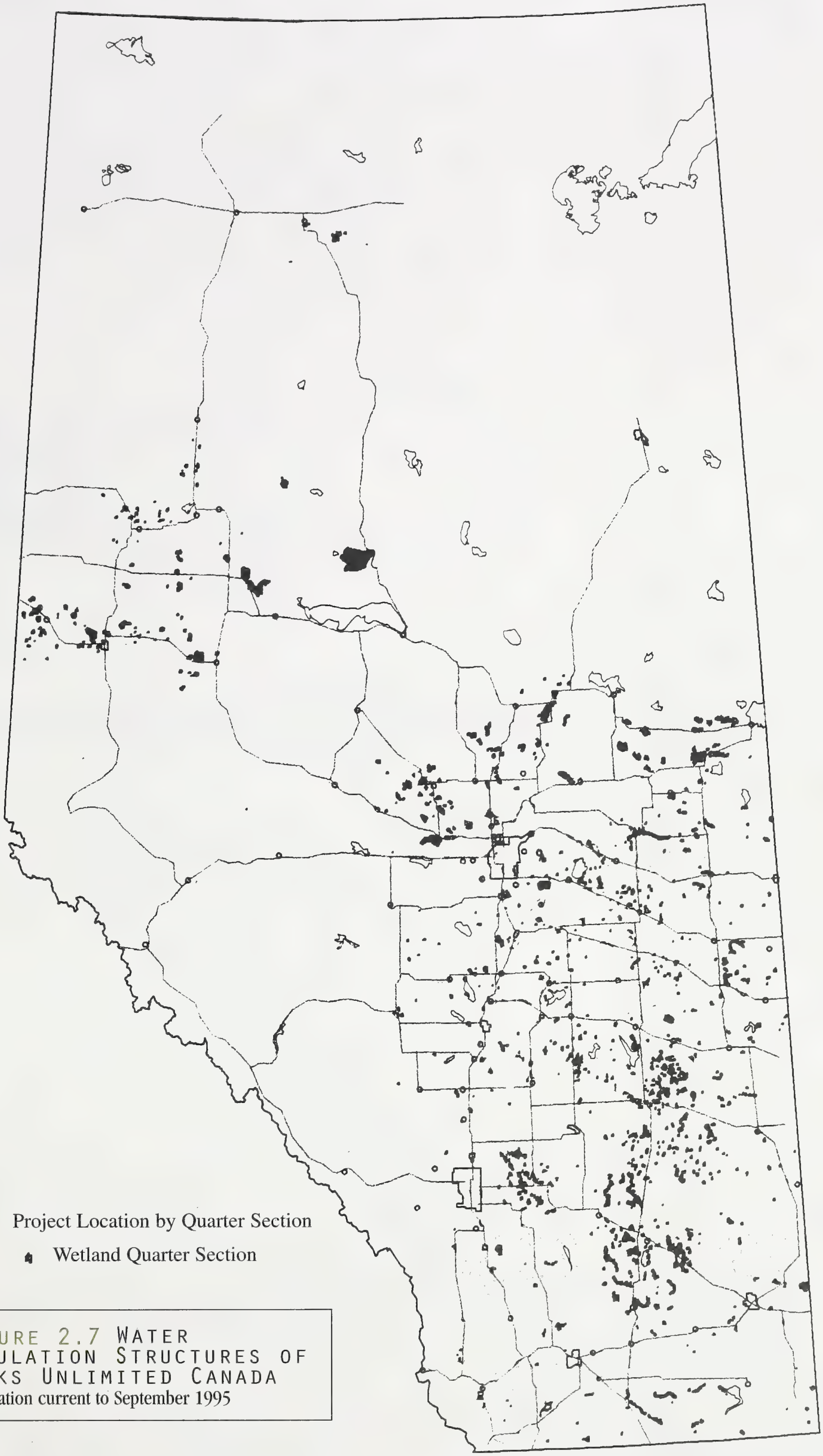


FIGURE 2.6 PEATLAND DISTRIBUTION IN ALBERTA
source: Turchenek and Pigot, 1988

of water are reservoirs, as few natural lakes exist there. Some of the 89 reservoirs in southern Alberta's irrigation districts have been formed from regulated natural lakes, others from impounded watercourses, and still others from water diverted from streams and rivers (McNaughton 1993).

The area covered by wetlands also increases greatly from south to north. In northern Alberta, large peatland complexes cover vast areas **(Figure 2.6; see also Section 3.3)**. In southern Alberta, on the other hand, an estimated 330 000 wetlands cover less than five percent of the total land area. Most of these are small and seasonal, shrinking as the summer progresses. Many of the larger prairie wetlands have been enhanced through cooperative efforts involving Ducks Unlimited Canada and other agencies **(Figure 2.7; see also Section 6.4)**. As one travels north, wetlands become larger and more permanent.



Project Location by Quarter Section

Wetland Quarter Section

FIGURE 2.7 WATER REGULATION STRUCTURES OF DUCKS UNLIMITED CANADA
information current to September 1995

Table 2.1 summarizes the distribution of surface water bodies in the province. With the exception of man-made water bodies, this distribution is the result of the glacial history described above and the action of present-day climate on landscapes. These climate-landscape-water patterns are reflected in Alberta's natural regions, as shown in **Figure 2.8.**

TABLE 2.1
DISTRIBUTION OF AQUATIC ECOSYSTEMS AMONG ALBERTA'S RIVER BASINS

River Basin	Rivers	Lakes	Wetlands
Peace-Athabasca-Slave	High	High	High
Beaver	Low	High	Medium
North Saskatchewan	Medium	Medium	High
South Saskatchewan	Medium	Low	Medium
Milk	Low	Low	Low

Total amount of water present
High Medium Low

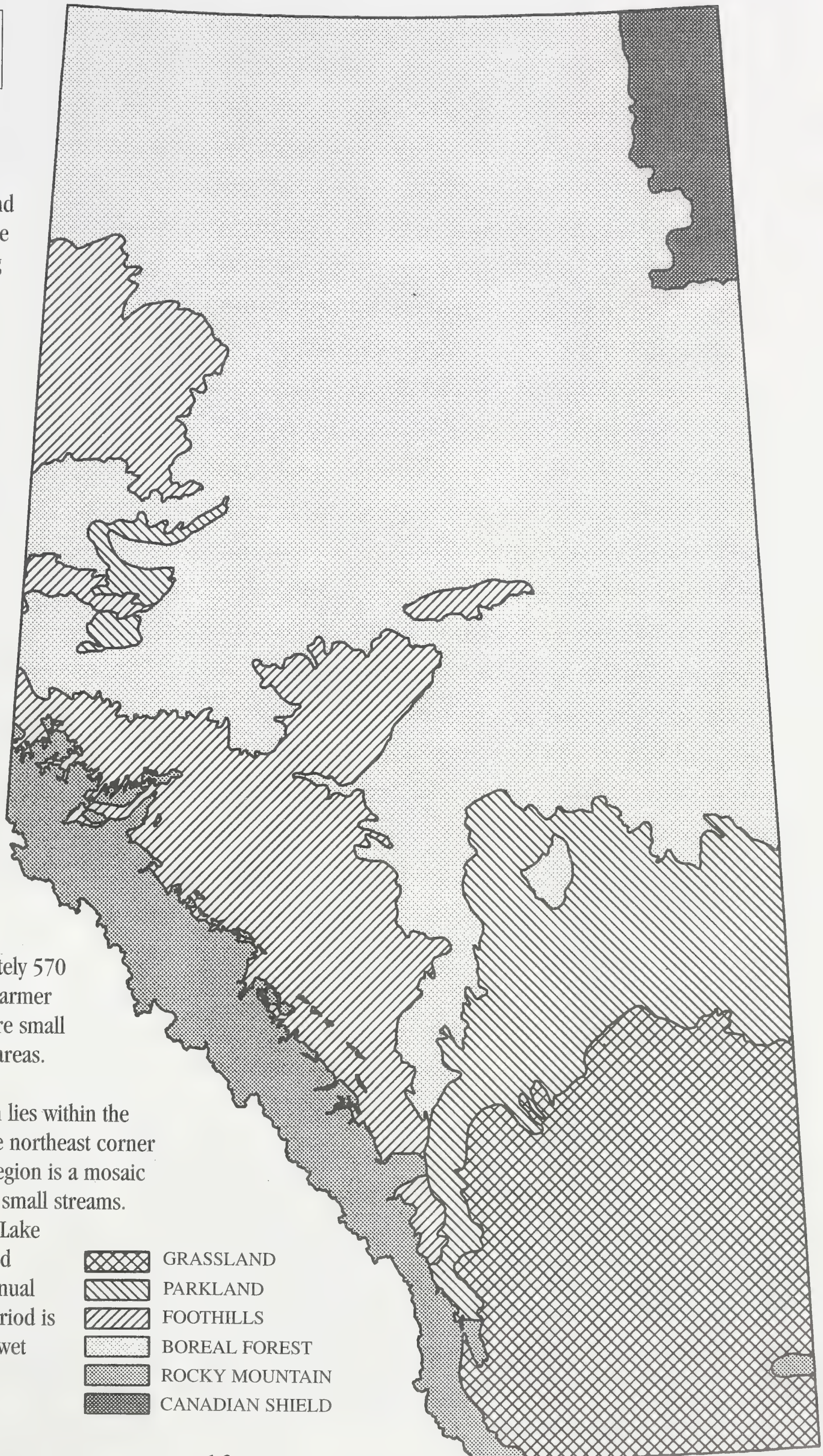
ALBERTA'S NATURAL REGIONS

The Grassland Natural Region has the driest climate in Alberta. The easternmost part of this region receives only about 300 mm of precipitation annually, the rest receiving only marginally more. Because evaporation exceeds precipitation in this region, there are few natural lakes among these flat to gently rolling plains. In wet years, there are many small wetlands scattered throughout the region, but in dry years, many of these disappear. The rivers of the South Saskatchewan and Milk river basins bring life-giving water from the mountains to this region.

The Parkland Natural Region occupies most of the North Saskatchewan River Basin and extends southward into the South Saskatchewan River Basin. An isolated northern patch, the Peace River Parkland subregion, lies between Grande Prairie and Peace River. The climate of the Parkland Natural Region is cooler and wetter than that of the Grassland Natural Region. Precipitation averages approximately 450 mm annually. Thousands of wetlands in small depressions dot the "knob and kettle" terrain created by the last glaciation. Melting snow fills these depressions in the spring, forming "pothole" sloughs. Many shallow lakes are also present along with a few larger ones.

The Boreal Forest Natural Region includes the Beaver River Basin and the Peace-Athabasca-Slave River Basin. The region has more precipitation and cooler temperatures than the Parkland Natural Region, and contains many large and small lakes. Small marsh wetlands are common in the

FIGURE 2.8 NATURAL REGIONS OF ALBERTA
source: Alberta Environmental Protection



southern portion, while areas of low topography in the north contain some very large wetlands. Large peatland complexes accumulate in the middle and northern parts of the region, which have a colder climate and snow cover lasting an average of 185 days a year. Organic soils on hills and plateaus in the northern portion remain frozen throughout the year.

The snowfields and glaciers of the **Rocky Mountain Natural Region** are the source of many of Alberta's major rivers. In the Alpine and Subalpine subregions, freezing temperatures occur in all months and the frost-free period is usually less than 30 days. Winter precipitation is the highest in the province with often more than 200 cm of snowfall. Lakes occur in glacially carved basins and preglacial valleys. Wetlands occur in depressions and valley bottoms.

Lying between the mountains and plain, the **Foothills Natural Region** is traversed by many of Alberta's major rivers. It is an area of relatively high precipitation (approximately 570 mm annually). Winters here are often warmer than those of the Boreal Forest. Lakes are small and wetlands are common in low-lying areas.

The **Canadian Shield Natural Region** lies within the Peace-Athabasca-Slave River Basin in the northeast corner of the province. The Kazan Upland Subregion is a mosaic of rock barrens, sand plains, lakes, and small streams. The Athabasca Plain Subregion south of Lake Athabasca is an area of sand deposits and dunes. Throughout the entire region, annual precipitation is low and the frost-free period is only 60 days. Peatlands are common in wet depressions.

3.0 ALBERTA'S AQUATIC ECOSYSTEMS

Measuring the Volume and Flow of a River

The quantity of water in a river is often measured in cubic metres. A container that is 1 m³ in size holds 1000 litres of water, about the amount that would fill four modern bathtubs. Other measures of volume are the acre-foot (1 acre covered by 1 foot of water) and the cubic decametre (dam³) (1 dam³ = 1000 m³ = 0.8 acre-feet).

Streamflow is measured in cubic metres per second (cms or m³/s) or cubic feet per second (cfs). 1 m³/s = 1000 litres per second, or about four bathtubfuls per second. A river flowing at 1 m³/s would take about 43 minutes to fill an Olympic-sized swimming pool (holding 2.6 million litres of water).

3.1 RIVERS AND THEIR ECOSYSTEMS

3.1.1 RIVERS

Many of Alberta's major rivers begin as streams carrying meltwater from snowpack or glaciers in the eastern slopes of the Rocky Mountains. Their volume is supplemented by tributaries bearing runoff from snow melt and rainfall within the river basin. As a result, river flows are highest in spring and summer, taper off by fall, and remain low over winter, as illustrated in the seasonal hydrograph of the Bow River at Banff **(Figure 3.1)**.

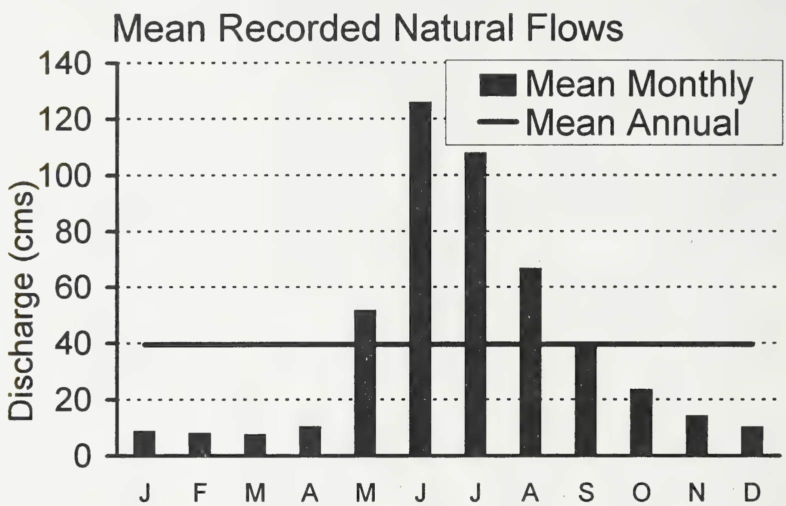


FIGURE 3.1 HYDROGRAPH FOR THE BOW RIVER AT BANFF, 1911-1994
source: Alberta Environmental Protection

Some of the province's rivers, such as the Beaver and Battle rivers, originate on the plains. Deriving their water mostly from the rain and snow that falls on the plains, these rivers are much smaller than those originating in the mountains. In addition, the amount of water flowing in them during the year can change greatly both within and between years, according to precipitation levels. **Figures 3.2** and **3.3** illustrate the differences in the annual flows of a river originating in the mountains (the Bow River) and one originating on the plains (the Beaver River).

During times of peak flow, a river often rises almost to the top of its banks. Occasionally, higher water levels spill out over the adjacent valley floor ("floodplain"). In Alberta, such flood events can result from rapid snow melt, heavy rainfall, or ice jams. A large proportion of floods in the province involve a combination of these conditions.

Flood Probabilities

It is impossible to forecast the year in which a major flood will occur because of the unpredictable nature of weather events or patterns causing such floods. However, it is possible to estimate the likelihood or probability of a flood of a particular size on a particular river. This is done mathematically using streamflow data from the past several decades to determine peak flows and all recorded floods on that river. Other historical evidence of flooding is also used, since the accuracy of the estimate increases with the amount of available data.

The likelihood of a flood of a particular size occurring is expressed as a percentage or ratio. A "1 in 100 year" flood refers to a streamflow magnitude that has a one percent chance of being equalled or exceeded in any year. Expressed another way, a flood of such magnitude would occur on average only once every 100 years. This does not mean that a 1:100 year flood could not occur two years in a row. However, it is highly unlikely.

Runoff volume can be influenced by land use changes such as urbanization within a watershed. Such changes require the use of more sophisticated models for estimating extreme runoff events, such as floods.

The characteristics of water in a river are influenced by natural factors, such as the bedrock and surface materials through which the river is flowing. During their journey through sedimentary rock formations, Alberta's rivers dissolve and transport ions such as calcium, magnesium, sodium, bicarbonate, and chloride, metals such as cadmium and mercury, and trace elements such as boron. Water running off the soil surface into streams and rivers adds nutrients, suspended sediments, organic compounds of plant and animal origin, naturally occurring bacteria, and other organisms such as *Giardia* (the cause of "beaver fever"). Monitoring studies have shown that in certain river reaches, background (natural) levels of some substances occasionally exceed maximum levels recommended for surface water by provincial or federal guidelines **(see Section 5.2 for a description of these guidelines)**.

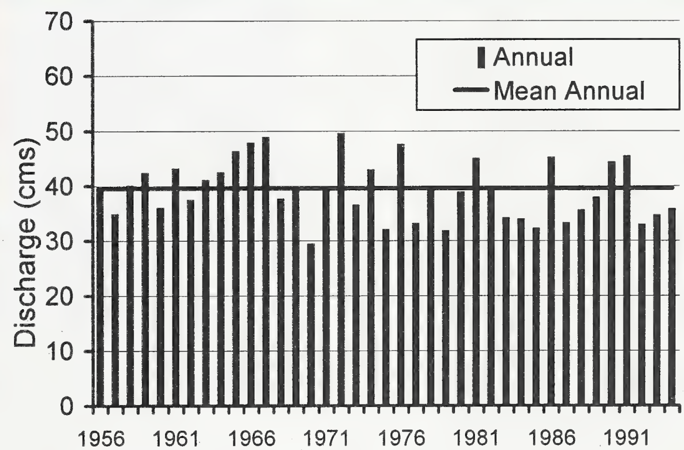


FIGURE 3.2 MEAN RECORDED NATURAL FLOWS IN THE BOW RIVER AT BANFF, 1956-1994
source: Alberta Environmental Protection

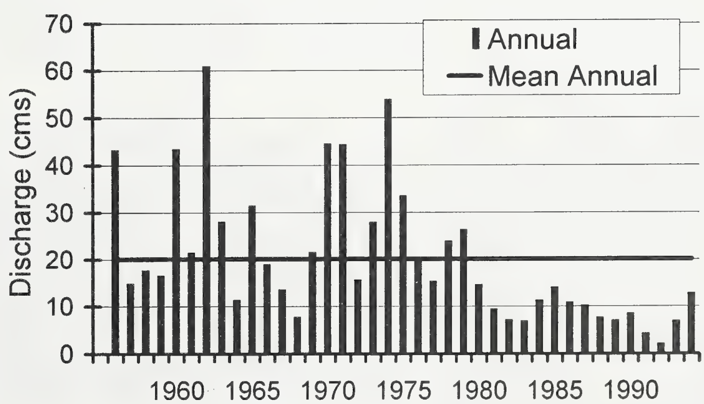


FIGURE 3.3 MEAN RECORDED NATURAL FLOWS IN THE BEAVER RIVER AT COLD LAKE RESERVE, 1956-1994
source: Alberta Environmental Protection

The June 1995 Flood in the South Saskatchewan River Basin

Most major storms in southwestern Alberta occur between late May and early July as warm, moist air from the Gulf of Mexico meets cold low pressure systems from the west coast. Between 10:00 p.m. June 5 and midnight June 6, 1995, an average of over 140 mm (6 inches) of rain fell in the headwaters of the Oldman River watershed, with up to 300 mm falling in some locations. This intense rainfall caused unusually high streamflow peaks along the Oldman, its tributaries, and farther downstream on the South Saskatchewan River. In fact, the maximum flow at the Oldman River Dam during this flood would be expected to occur only once in every 3000 years ***(Figure 3.4).***

Flood damage along the Oldman River would have been more severe without the dams on the Oldman, Waterton, and St. Mary rivers, even though these dams were not built for flood control purposes. The Oldman River Dam delayed the onset of flood flows immediately downstream of the dam by about six hours. These reservoirs also reduced the peak flows for downstream communities such as the town of Fort MacLeod and the cities of Lethbridge and Medicine Hat. For example, the peak flow of flood waters reaching the City of Lethbridge was reduced by about 15 percent, which resulted in a reduction in flood stage of about 0.5 m. The reduction was equivalent to reducing the frequency of the flood event at Lethbridge from a 1:850 year event to a 1:300 year event.

The flood resulted in the highest amount of damage compensation ever paid in Canada to that date under the Federal/Provincial Disaster Assistance Program. A comparison with the damage payouts for other disasters is shown in Table 3.1.

These figures do not include private insurance payouts, which, for the 1995 flood, were similar to the amount paid by the Disaster Assistance Program.

Water quality in a river is also affected by the time of year. For example, high flows during spring melt or summer storms carry increased levels of suspended solids and substances that adhere to them, such as heavy metals. At the same time, concentrations of dissolved substances such as ions may decrease as a result of dilution. In fall and winter, low flows result in higher concentrations of many substances in the water. The formation of an ice cover during the winter months often leads to dramatic decreases in dissolved oxygen levels.

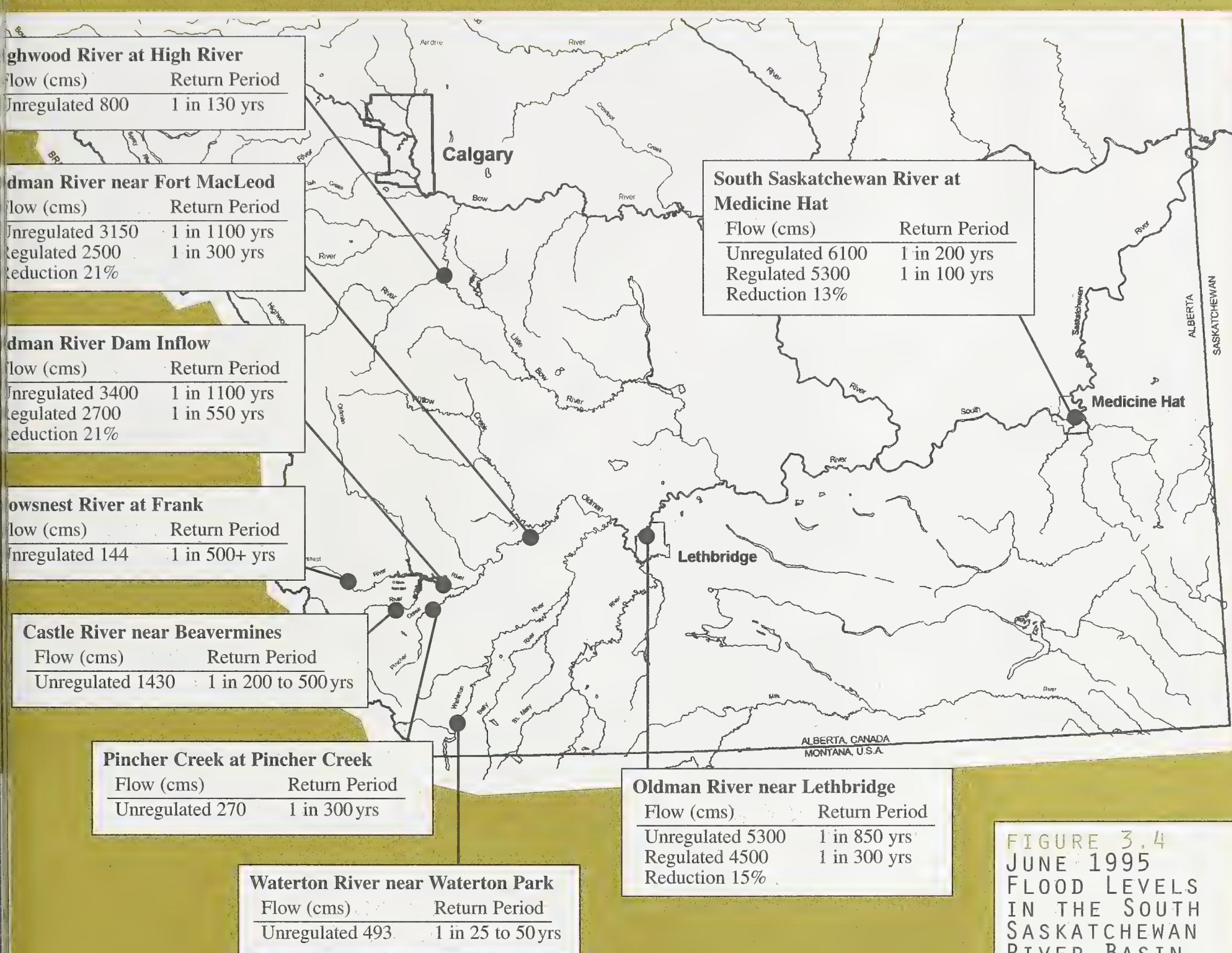


FIGURE 3.4 JUNE 1995 FLOOD LEVELS IN THE SOUTH SASKATCHEWAN RIVER BASIN
source: Alberta Environmental Protection

TABLE 3.1 DISASTER PAYOUTS

1995 Flood (South Saskatchewan River Basin)	$43 million
1987 Tornado (Edmonton)	$40 million
1986 Flood (North Saskatchewan)	$15 million
1988 Flood (Slave Lake area)	$12 million
1990 Flood (Northwest Alberta)	$12 million
1993 Flood (Mississippi River, USA)	$12 billion (est.)

Dissolved Oxygen

Aquatic animals need oxygen to live. Fish and many aquatic invertebrates have gills to take up oxygen that is dissolved in the water. A minimum concentration of dissolved oxygen (DO) must be present to sustain aquatic animals, but this amount differs from species to species. For example, trout, longnose suckers, and burbot require relatively high concentrations of DO, whereas species such as northern pike can survive under lower concentrations. Requirements also vary by life stage. For example, young trout (fry) require higher DO concentrations than adult trout. The DO levels needed by different kinds of benthic invertebrates also vary. The Alberta Ambient Surface Water Quality Interim Guidelines specify a minimum DO level of 5.0 mg/L, but recognize that dissolved oxygen requirements vary from one environment to another.

The Canadian Water Quality Guidelines suggest DO levels of 6.5 mg/L for protection of aquatic life, with the exception of salmonid (trout or salmon) spawning habitats, which may require up to 9.5 mg/L.

Dissolved oxygen concentrations in Alberta's lakes and rivers vary widely. Determining factors are temperature, ice cover, air pressure (elevation), salinity, and the presence of living plants and organic material in the water. Water can hold more oxygen at low temperatures than at high temperatures.

During the summer, DO levels in eutrophic rivers, such as lower sections of the Oldman, Bow and North Saskatchewan rivers, may range from well above saturation (the maximum amount of oxygen that can dissolve in water at a given temperature and pressure) at mid-day to much lower levels at night. These wide daily swings result from aquatic plants producing oxygen through photosynthesis during the day and then consuming DO at night. During times of low flow and relatively high water temperatures, large rivers can become seriously depleted of oxygen at night.

During summer, dissolved oxygen in highly productive lakes may be depleted near the bottom even though the water near the surface remains at or above saturation. Even deep, moderately productive lakes can suffer oxygen depletion, because the colder bottom layer of water (usually at depths below 10 m) is cut off from the atmosphere and cannot replenish its oxygen. Normally fish avoid these areas, but they cannot always escape from severe oxygen depletion associated with the die-off and bacterial decomposition of an algal bloom. This oxygen depletion is one of the main causes of "summerkill" of fish in lakes.

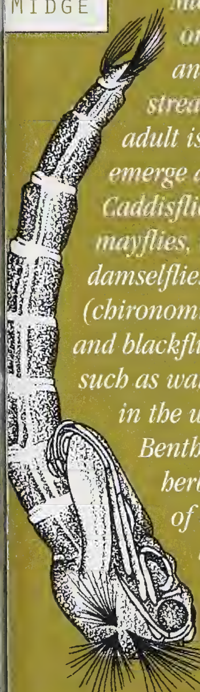
During periods of ice cover on lakes and rivers, oxygen replacement through re-aeration and photosynthesis slows or ceases. As winter progresses, oxygen is used up by bacterial decomposition of organic matter in the water and sediments. "Winterkill" of fish results when concentrations of dissolved oxygen drop below the level that fish can tolerate. Winterkill is most likely to occur in very shallow, highly productive lakes.

Benthic Invertebrates

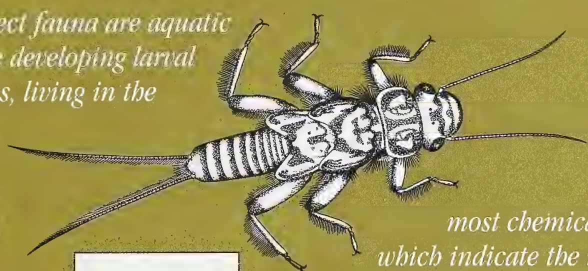
CADDISFLY

Worms, insects, crustaceans, and molluscs (such as snails and clams) inhabit the rocks, gravel, and sediments of streams and rivers. These benthic (bottom-dwelling) invertebrates also live in lakes and ponds, but species present in streams and rivers possess special adaptations for life in flowing water.

MIDGE



Many of the insect fauna are aquatic only during the developing larval and pupal stages, living in the stream until the adult is ready to emerge and fly away. Caddisflies, stoneflies, mayflies, dragonflies, damselflies, midges (chironomids), mosquitoes, and blackflies are examples. Other insects such as water beetles spend their entire lives in the water.

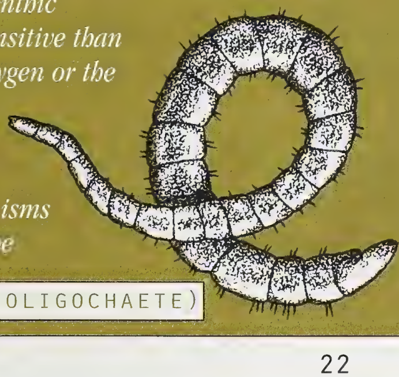


STONEFLY

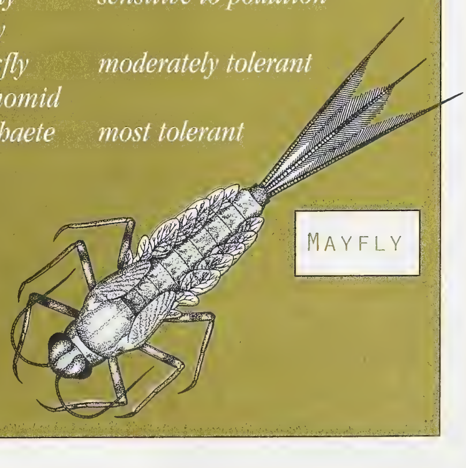
Benthic invertebrates range from herbivores (plant eaters) to predators of other invertebrates. Their diversity and range of sensitivity to environmental conditions make them a useful indicator of the state of a river. For example, some benthic invertebrates are more sensitive than others to low dissolved oxygen or the presence of organic pollutants. When conditions become unfavourable, these organisms die or move away. Thus the abundance and types of benthic invertebrates present in a river reveal some of its past and present conditions. Unlike most chemical or physical parameters, which indicate the river's condition at the time of sampling, benthic invertebrate sampling shows the cumulative effects of conditions over time. Benthic invertebrate sampling complements physical and chemical assessments of river water quality.

The degree of tolerance for organic pollution of a few benthic invertebrates is shown below (from least to most tolerant):

stonefly	*sensitive to pollution*
mayfly	
caddisfly	*moderately tolerant*
chironomid	
oligochaete	*most tolerant*



WORM (OLIGOCHAETE)



MAYFLY

3.1.2 RIVER ECOSYSTEMS

Rivers support life forms adapted to flowing water. In fast-flowing streams, algae attached to rocks are the predominant plant life. Some types of aquatic invertebrates burrow into the river bed and others cling to or dwell among rocks or adhere to vegetation and woody debris. These invertebrates are the major food source for many fish species.

The Bull Trout

The bull trout is one of two char species native to Alberta (the other is the lake trout). At the turn of this century, bull trout were widely distributed in Alberta's rivers from the Peace to the Oldman, and from headwaters to parkland and prairie reaches. Now the species is found only in the upper portions of rivers and tributaries on the eastern slopes of the Rocky Mountains and in cold mountain lakes.

Habitat changes have taken their toll on this species. Bull trout migrate into cold headwater streams to spawn over gravel beds. Such areas are susceptible to activities that cause siltation, such as road-building, warming due to removal of shade-giving vegetation, stream blockage, or reduction of flow.

Public attitudes have also had an impact. Bull trout have been heavily fished in the past. From the 1930s to the 1950s, the removal of bull trout from some streams was an accepted practice, as it was believed this would improve the survival of more favoured species such as the introduced brown trout.

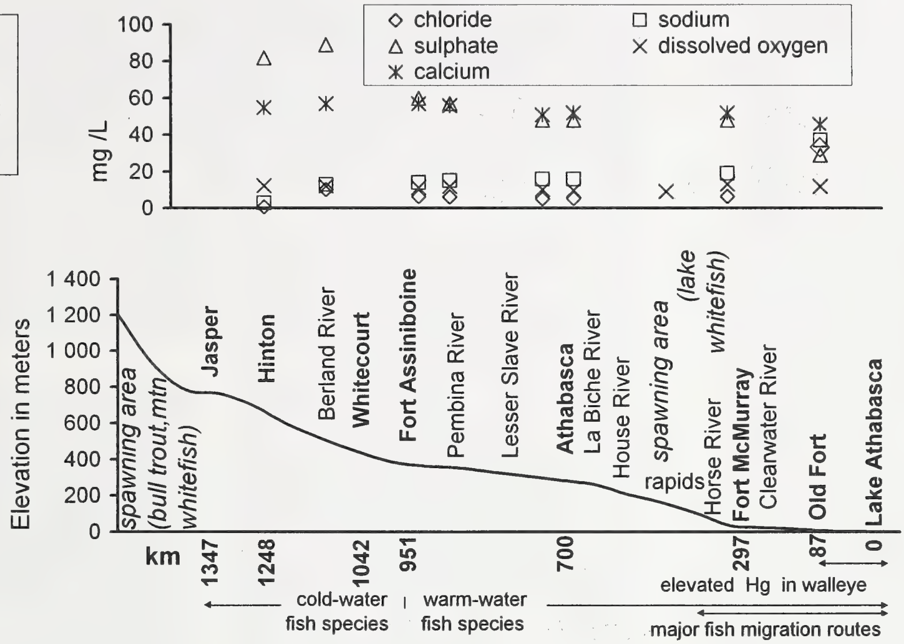
The bull trout is now considered a "species of special concern" throughout its range in the USA by the American Fisheries Society. In Alberta, it has been designated as the official provincial fish, and Alberta Environmental Protection has implemented a management program to re-establish its population (see Section 5).

Although much remains to be learned about fish distribution and habitat use within Alberta's rivers, fish are known to be present in about 34 000 km of streams and rivers in Alberta. Appendix A lists Alberta's fish species. In general, streams and rivers in the northern part of the province contain Arctic grayling, walleye, and pike. Trout streams are mainly located along the eastern slopes south of the Athabasca River. Larger rivers in the province contain goldeye, pike, walleye, sauger, mountain whitefish, and burbot. Some rivers and their tributaries also contain bull trout and sturgeon.

Case Study: The Athabasca River

The Athabasca River undergoes both natural and man-made changes in water quality along its course. Examples of some naturally occurring changes in its water and ecosystem are illustrated in **Figure 3.5**. At the river's origin, meltwater from the Columbia Glacier begins its journey to the Peace-Athabasca Delta 1375 km to the northeast. This journey takes approximately 38 days, depending on the volume of water and the rate of flow. The cold glacial meltwater bears suspended material that has been finely ground by the glacier, making the water turbid and milky blue in appearance. Passing over falls and down the steep mountain gradient, the river picks up high levels of dissolved oxygen. Tributary streams add high levels of sulphate from mountain springs.

FIGURE 3.5
LONGITUDINAL PROFILE OF THE ATHABASCA RIVER
source: Adapted from 1992 Winter Synoptic Survey



Bull trout, needing high oxygen and cold temperatures for their eggs to develop, spawn in the headwaters. Other coldwater species such as mountain and lake whitefish, the rare pygmy whitefish, and grayling are also present in the mountain and foothills reaches. The colourful harlequin duck nests near fast-flowing streams in this drainage.

On the forested plains, the gradient flattens and the river slows. Tributaries swell its volume, adding sediment, nutrients, and dissolved minerals such as sodium and chloride, while at the same time diluting the sulphate content of the water. Near the confluence with the Berland River, there is a transition from coldwater to coolwater fish species. Below this point, water temperatures can reach 23^{o}C in summer, and coolwater species such as walleye and goldeye prevail.

In winter, dissolved oxygen levels decline gradually from Hinton downstream, becoming quite low, until a series of rapids upstream of Fort McMurray re-aerate the river, adding as much oxygen as the water can hold.

Additional natural substances enter the river in the reach between Fort McMurray and the Peace-Athabasca Delta. Hydrocarbons from natural oil sands deposits near Fort McMurray seep or erode into the river. Between the city and the delta, streams draining vast areas of peatlands add dissolved organic matter to the river, turning it reddish-brown.

Fish from Lake Athabasca migrate to streams along this lower reach to spawn. Up to one million lake whitefish migrate from Lake Athabasca each year to spawn in the river near the rapids.

Mercury in Alberta's Rivers and Lakes

Mercury levels in some predatory fish in a few lakes and large rivers in Alberta exceed the Canadian guidelines for human consumption (0.5 parts of mercury per million parts of fish tissue). As a result, consumption guidelines have been issued for certain fish species in these water bodies.

Mercury is most often present in fish as methyl mercury. This form of mercury is produced by bacteria transforming inorganic mercury in the sediments. Methyl mercury accumulates in biological tissues and is found in highest concentrations at the top of the food chain, in predators, such as piscivorous fish. The mercury passes through the food web to fish from benthic invertebrates that accumulate it from plants, zooplankton, or directly from the water.

Inorganic mercury gets into surface waters via two main avenues runoff from the land and deposition from the atmosphere. Many soils throughout the world contain trace amounts of mercury. It can be dissolved in runoff or, being volatile, mercury diffuses as a gas from the earth's crust into the atmosphere. Volcanic eruptions also contribute to atmospheric mercury. Human activities, particularly the burning of fossil fuels, also account for some atmospheric loading. (Estimates range from 33 to 75 percent.)

In the past, mercury was in more common use, for example in fungicides used to treat agricultural seed, wood and other products. Although mercury-based fungicides are no longer used, dentistry and certain industries, such as electroplating and photography, still use mercury in their processes and trace amounts may be discharged with municipal wastewater.

(Ducks Unlimited Canada, Bob Thomson)

TABLE 3.2 AT-RISK FISH SPECIES ASSOCIATED WITH ALBERTA'S RIVERS

Species	River Habitat	Provincial Classification[1]	Action (Alberta)
Bull trout	Rivers, streams	Vulnerable	Management and recovery plan in effect
St. Mary's sculpin	Milk, St. Mary rivers	Threatened	Baseline data collected; management plan being developed
Lake sturgeon	North and South Saskatchewan rivers	Vulnerable	Management plan being developed
Arctic grayling	Northern streams	Vulnerable	Management plan being developed

[1]Species of special concern are considered "vulnerable"

In the lower reaches of the Athabasca River, mercury is present in the tissues of some larger predatory fish such as walleye. Health guidelines have been developed for consumption of these fish. Although the mercury is mainly from soils within the drainage basin, a small percentage is from man-made sources.

Table 3.2 lists some of the at-risk fish species associated with Alberta's rivers. Work underway to restore their populations is discussed in **Section 5**.

3.1.3 Riparian and River Valley Areas

The green strip of vegetation bordering rivers, streams, and lakes the -"riparian area"- plays a vital role in maintaining aquatic ecosystems. Its dense vegetation slows the flowing water's erosive force, provides shade, sheltering fish from predators and keeping water temperatures down, and reduces the amount of soil entering the water. Riparian vegetation also adds nutrients in the form of leaves and woody debris and provides habitat for aquatic insects.

Riparian areas usually have a greater variety of plant and animal species than adjacent uplands. It is estimated that 80 percent of Alberta's wildlife use riparian areas for some or all of their life cycle requirements.

Floodplains and dry river channels that are inundated during a flood support vegetation dependent on periodic flooding, such as cottonwood trees in southern Alberta. In this region, cottonwood stands are the only naturally occurring forests, and many wildlife species depend on them **(Section 6)**.

Unique features created by rivers, such as cutbanks, terraces, and canyon walls, support other species. Endangered or vulnerable wildlife associated with river valley cliffs in Alberta include the peregrine falcon (the *anatum* subspecies, recently reintroduced into southern Alberta river valleys), the prairie falcon, the eastern short-horned lizard (South Saskatchewan and Milk river valley rims), the western hognose snake, the prairie rattlesnake, and the plains, red-sided, and wandering garter snakes.

3.2 LAKES AND RESERVOIRS AND THEIR ECOSYSTEMS

3.2.1 Lakes and Reservoirs

Alberta contains an unusually wide range of lake types, from low-mineral alpine lakes to highly saline lakes of the prairies, from nutrient-rich lakes of the aspen parkland to nutrient-poor lakes of the foothills and subalpine regions, and from the clear lakes of the Canadian Shield to brown-water lakes of the Boreal Forest peatlands.

Alberta also contains many reservoirs, particularly in the South Saskatchewan River Basin. On-stream reservoirs have been built for hydroelectric power generation, irrigation water storage, and flow regulation. Off-stream reservoirs, which store water diverted from rivers via canals, are used primarily for irrigation, stock watering, and domestic purposes.

Alberta's lakes and reservoirs vary in their level of productivity, as shown in **Figure 3.6.** The *trophic status (see Glossary)*, is the result of many interactions among the lake's physical, chemical and biological properties, the nature of its watershed, and external factors such as climatic conditions. **Table 3.3** lists some characteristics that affect a lake's productivity.

A lake's drainage basin, or watershed, is the total land area from which water drains into the lake. As water moves over the land surface and drains into the lake, it can collect considerable amounts of sediment and nutrients, depending on how the land is being used, the type of soil, and the vegetation present. The ratio of drainage area to lake surface area can be used as one indicator of a lake's water quality. In general, lakes with large drainage area-to-lake ratios are more sensitive to land use in the basin than are lakes with smaller ratios.

Water balance *is the inflow of water into a lake or other water body minus the outflow, plus or minus the change that occurs during storage due to evaporation and precipitation. Inflow includes precipitation, surface and groundwater, and in the case of reservoirs, water from other sources. Outflow includes surface and groundwater, evaporation, and withdrawals.*

FIGURE 3.6 APPROXIMATE TROPHIC CATEGORIES* FOR ALBERTA LAKES AND RESERVOIRS
source: Alberta Environmental Protection
*Based on average summer chlorophyll *a* concentrations, 1983-1995

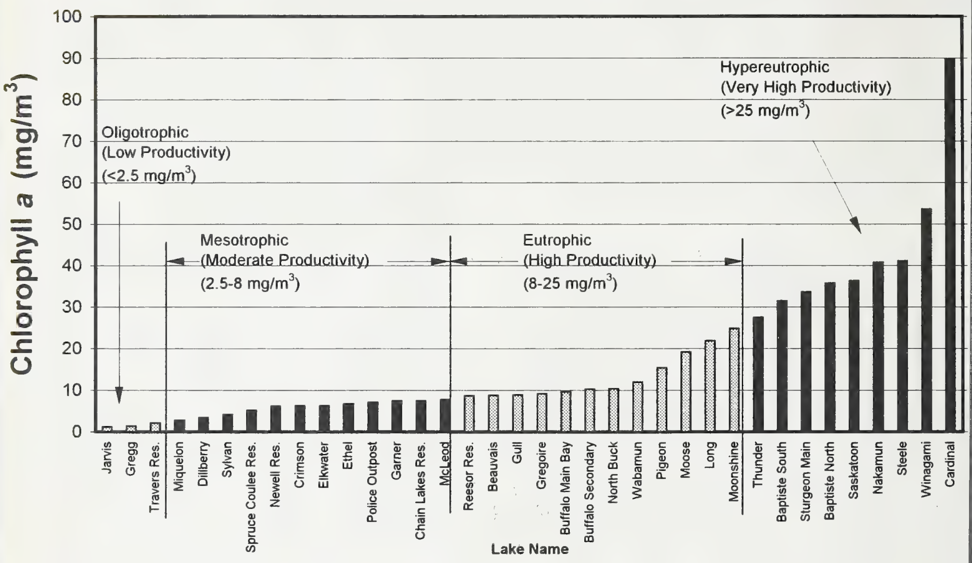


TABLE 3.3
CHARACTERISTICS OF LAKES

Characteristics	Description
Drainage Basin	Size; runoff; geology; ecoregions; soils; land use
Lake Basin	Size (area and volume); shape; bottom form; depth (mean, maximum, and depth of mixing); water balance; water levels
Water Quality	Major ions, salinity, pH, alkalinity, hardness; temperature; dissolved oxygen; nutrients (phosphorus, nitrogen, carbon); transparency; chlorophyll *a*
Water Quantity	Water balance; depth; volume; water use; water residence time; flushing rates; water withdrawals
Biology	Aquatic plants (phytoplankton; macrophytes); aquatic invertebrates; fish; wildlife

Residence time
is the average time required to completely replace the total volume of the lake or reservoir (less evaporation) with fresh water. Residence time is calculated from water inflow and outflow. For some lakes, residence time can be as long as 50 to 100 years, but for others, and especially for reservoirs, it may be a matter of months.

Water quality in Alberta's lakes also differs from region to region. Many deep mountain lakes are situated in preglacial valleys and are flushed out by snowmelt and heavy rains. The geological formations in which they are situated weather very slowly, resulting in little movement of nutrients and other materials into these lakes. Many of these lakes are nutrient poor or *oligotrophic.*

In contrast, lakes of the Parkland Natural Region are typically shallow and warm. Situated within basins containing fertile soil, they contain relatively high levels of minerals and nutrients. Their flushing rate is generally low due to the relatively dry climate. Water residence time in these lakes may exceed 100 years. Most are eutrophic and may experience algal blooms or extensive growth of aquatic macrophytes. It is often assumed that these conditions are evidence of lake deterioration due to pollution. However, the high levels of phosphorus that cause these conditions may be from natural sources such as surface runoff, groundwater, and/or bottom sediments. In fact, phosphorus released into lake water from bottom sediments during the summer governs water quality in most shallow lakes in central Alberta. This process of phosphorus release, referred to as "internal loading," has also been observed in lakes far removed from areas of human settlement and is thus believed to be a largely natural phenomenon.

Productivity
is the capacity to support the growth of aquatic plants and animals. Productivity is determined by measuring either the concentration of phosphorus (the major limiting factor to growth of aquatic plants) or chlorophyll a, which indicates the amount of algal growth in the lake. Based on these measurements, lakes are categorized as ***oligotrophic*** *(low productivity),* ***mesotrophic*** *(moderate productivity),* ***eutrophic*** *(high productivity), or* ***hypereutrophic*** *(very high productivity).*

Saline lakes are present in the eastern part of the province. Groundwater contributes sodium, sulphate, and carbonate ions and high rates of evaporation increase the ion concentrations. Many saline lakes in the Parkland Natural Region are "borderline" saline and have ecosystems similar to those of non-saline lakes. However, highly saline lakes have a much different and reduced flora and fauna. One such lake, Oliva Lake, near the town of Viking, is two to three times more saline than seawater (Mitchell and Prepas 1990).

Water levels in Alberta's lakes often fluctuate in response to climate. Several dry years may lead to lower water levels, whereas several cool, wet years may have the opposite effect. Natural water-level fluctuations in Lac La Biche are shown in **Figure 3.7**.

Very high or low water levels in a lake can hinder recreational activities, and high water levels may threaten shoreline property and adjacent farmland. Nevertheless, these natural fluctuations are not necessarily detrimental to a lake's ecosystem and in some cases may be beneficial. For instance, low water levels expose or encourage the growth of aquatic vegetation, which provides waterfowl habitat. Fluctuating water levels suppress the growth of certain aquatic weeds.

Blue-Green Algal Toxicity

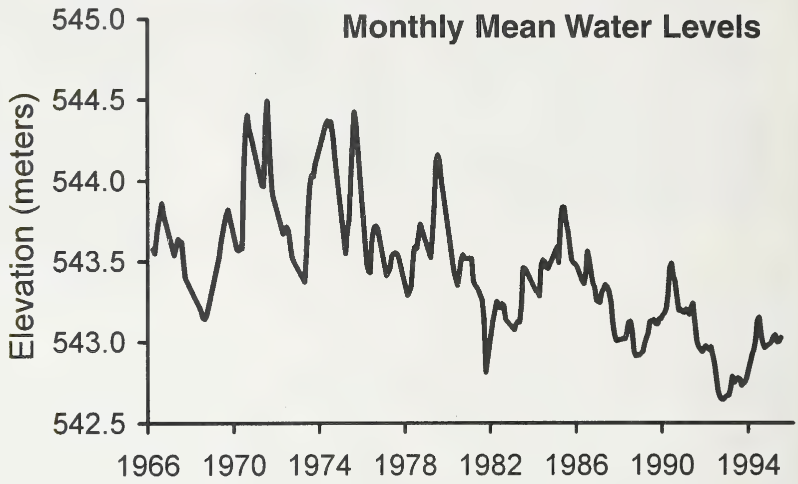
Many species of algae are present in Alberta's waters, including blue-green algae. As with other algae, blue-greens sometimes proliferate into algal blooms covering lakes and wetlands, particularly in central Alberta. Of the 100 species of blue-greens found in Alberta, three may cause blooms capable of producing toxins that cause poisoning. These species are Aphanizomenon flos-aquae, Microcystis aeruginosa, and Anabaena flos-aquae. Only certain strains of these algae produce toxins.

Poisoning occurs when animals drink substantial amounts of the water containing these algal blooms. The toxins are of two types: one that affects the nervous system and one that affects the liver. Common symptoms are lethargy, pallor, haemorrhaging, and swelling of the liver.

Although humans are susceptible to the toxins, there are no recorded human deaths from this cause. The unpleasant odour and appearance likely discourage anyone from drinking the water. People who contact the algae while swimming or wading, or ingest a small amount of water containing the algae may experience headaches, stomach cramps, and other symptoms for two or three days.

Determining whether an algal bloom contains toxic strains cannot be done visually, but requires laboratory testing. Most blooms are short-lived and are thus best avoided during the episode.

FIGURE 3.7 NATURAL LAKE LEVELS IN LAC LA BICHE, 1966-1996
source: Alberta Environmental Protection



3.2.2 Lake and Reservoir Ecosystems

A lake is a dynamic system composed of water, light, chemicals, and plants and animals, both microscopic and visible. Sunlight drives the system, penetrating the water and enabling phytoplankton and aquatic macrophytes to grow. A host of tiny organisms that swim in the open water (zooplankton) and larger aquatic invertebrates feed on these plants. These organisms are in turn eaten by fish. Dead plants and animals may be consumed by scavengers of many types, or decomposers (bacteria and fungi) that release their nutrients back into the food cycle.

Aquatic Macrophytes

Aquatic plants come in all sizes, from microscopic algae to the common cattail which can reach a height of 2.5 m. Those large enough to be seen with the naked eye are called macrophytes, meaning simply "large plants."

Cattails, bulrushes, sedges, and reed grass are known as ***emergent*** *macrophytes, because they root in or very near water and their stems emerge from the water. They are found at the shoreline or in shallow water, and provide nesting habitat and shelter for ducks and other birds, and spawning habitat for fish, such as pike.*

Also near shore are ***floating-leaved*** *plants such as the water lily and water smartweed. These are rooted in the lake bottom but need their leaves to be exposed to the air.*

Plants in the ***free-floating*** *category have no roots and float either on the surface or underwater. Common duckweed - a favourite food of many ducks - is an example. This plant consists of very small individual flat, round leaves that float on the surface, often in large patches.*

Growing underwater, often invisible from shore, are ***submergent*** *macrophytes. These plants are rooted or otherwise attached to the lake bottom. They do not extend above the water's surface, except when flowering at which time they rely on flying insects for pollination. Submergent macrophytes come in a variety of forms, from the short stubby stonewort to the tall, heavily branched pondweed that almost reaches the water's surface.*

(Ducks Unlimited Canada, Patrick Lang)

Shallow bays and areas sheltered from wave action or high streamflow are the most favourable sites for macrophyte growth. Each lake, reservoir, or stream has its own aquatic plant community, depending on water chemistry, bottom sediments, and wave action.

Although many people regard these plants as weeds that should be eliminated, macrophytes and algae are fundamental to aquatic ecosystems. Using only sunlight, carbon dioxide (or dissolved bicarbonate), and minerals, they produce complex organic matter for their growth and in turn for the animals that consume them. Close examination of a macrophyte usually reveals many tiny organisms on the stems and leaves. These creatures, small but essential parts of the food chain, depend on the larger plant for their living space.

Larger animals also depend on these plants. For example, the leaves of the yellow water lily are eaten by deer and moose, its rhizome (root) by muskrats, and its seeds by birds. The plant's large floating leaves also provide shade and cover for fish and aquatic invertebrates.

When a macrophyte dies, decomposer organisms - bacteria and fungi - in the bottom sediments consume the dead plant material and release the plants' complex molecules into the water. These molecules are taken up by single-celled organisms and thus sustain another part of the aquatic food chain.

Excessive plant growth in a lake or river is generally the result of an excess of plant nutrients (phosphorus or nitrogen) in the water. Human activity can contribute these nutrients in the form of lawn fertilizers, agricultural runoff, faulty septic systems, and treated or raw sewage. The resulting heavy macrophyte growth can be a nuisance to boaters, plug water intake systems, and may deplete the water of oxygen as it decomposes, sometimes resulting in fish die-offs. Restoring balance to the lake or river ecosystem usually involves finding ways to reduce these external nutrients' sources.

Piping Plover

Pebble, gravel, or sand beaches along sparsely vegetated lakeshores are chosen as nesting grounds by the rare piping plover. Due to significant population declines, this shorebird is on Alberta's Red List and is classified as threatened or endangered throughout its North American range.

In Alberta, piping plovers nest in the Parkland and Grassland natural regions. Breeding pairs are often clustered along suitable lakeshores, and birds often return to the same location year after year. However, encroaching vegetation can make a site unsuitable. Nesting success is also hindered by disturbance from humans, dogs, livestock, or wild predators, and the flooding of nests by rising reservoir or lake water levels.

Approximately 50 of the 59 fish species in Alberta **(Appendix A)** are found in provincial lakes. Seventeen of these species are considered sport fish. Lake trout, for example, are found in a few deep lakes mostly in northern Alberta. Lake whitefish are found in lakes throughout the north, and also in reservoirs of southern Alberta. A closely related species, tullibee (also known as cisco) also inhabits some northern lakes. Northern pike and yellow perch are common in lakes throughout Alberta. Walleye are found mainly in the north, but are present in lakes and streams throughout the province. Burbot, a member of the cod family, is also found throughout the province.

Nongame species include members of the minnow, sucker, stickleback, sculpin, perch, trout-perch, catfish, and lamprey families. Most of these are essential elements in the food chains of *piscivorous* (fish-eating) fish, birds, and other animals.

Lakes are also important in the life cycles of many bird species. Ducks, geese and swans use lakes for foraging, nesting, brood-rearing, moulting, and staging (gathering prior to migration). The shallow, marshy areas of lakes are particularly important for waterfowl. Piscivorous species such as loons, grebes, and mergansers frequent the larger lakes, nesting among aquatic plants near shore, whereas "dabbling ducks" such as mallards prefer shallow lakes and wetlands **(see Section 3.3.3)**.

International piping plover surveys began in 1991 and are conducted every five years. Results of the 1996 survey indicate that, despite sharp population declines in other jurisdictions, the Alberta piping plover population is currently stable. A detailed status report on the species will be issued in 1997.

A recovery plan for the species is underway in Alberta. To help the birds' nesting success, some nesting sites are being fenced to reduce disturbance from livestock and people. Vegetation is being controlled and gravel placed on some traditionally used sites.

TABLE 3.4
PIPING PLOVER POPULATIONS

Year	No. of Adult Piping Plover[1]	No. of Water Bodies Surveyed
late 1980s	220 (estimate)	
1991	180	47
1996	276*	83 *

[1]modified from Prescott *in press*
*on the 47 water bodies surveyed in 1991, 210 adults were found

Trumpeter swans, considered at-risk throughout North America, nest in grassy lake margins and wetlands with little human disturbance. In Alberta, their nesting areas are located near Grande Prairie and Peace River, and to a lesser extent in the Edson-Whitecourt and Pincher Creek-Waterton Lakes National Park areas. A survey of the Alberta trumpeter swan population in 1995 found a total of 779 (563 adults and 216 cygnets – young swans), compared to 466 in 1990. This increase is attributed largely to improved management of their wintering grounds in the USA (Beyersbergen pers. comm.).

Large flocks of migrating shorebirds, such as plovers and sandpipers, stop to rest and feed at some of the province's lakes and wetlands while en route from South and Central America to their summering grounds in the Arctic and sub-arctic. Lakes visited annually by more than 20 000 shorebirds include several near the Saskatchewan border (Killarney/Reflex Lakes area), Beaverhill Lake **(see Section 6)**, and Kimiwan Lake in northwest Alberta. Other lakes in the province also serve as shorebird stop-over and nesting sites.

Semi-aquatic furbearing mammals also depend on lakes and other water bodies. Muskrats feed on cattails, bulrushes, and other emergent macrophytes along lake margins throughout the province. Beaver may inhabit lakes, especially lakes with convoluted shorelines, as well as streams and wetlands throughout most of the province. River otters inhabit lakes and streams in the Boreal Forest and Foothills natural regions **(see Section 6)**.

The riparian vegetation bordering lakes produces many of the same ecological benefits that it does along rivers and streams, such as intercepting overland runoff and reducing erosion **(see Section 3.1)**. Many kinds of wildlife are associated with this vegetation, including frogs, salamanders, mink, weasels, water shrews, snakes, and a wide variety of songbirds.

Several wildlife species associated with Alberta's lakes are considered at-risk **(Table 3.5)**. These include species classified as such by Alberta provincial policy, or by the national Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The provincial classification includes species in serious trouble (Red List) and species facing threats that are less immediate (Blue List). COSEWIC classifies species as vulnerable, threatened or endangered.

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Species	Provincial Listing[1]	COSEWIC Status[2]	Action (Alberta)
Golden trout		Vulnerable[3]	Restrictive regulations
Shortjaw cisco		Threatened[4]	
Piping plover	Red List	Endangered	Surveys (National Piping Plover Recovery Plan)
Trumpeter swan	Blue List	Vulnerable	Reintroduction (Elk Island National Park); captive breeding program

[1]See Appendix B for a fuller explanation of provincial listing
[2]Committee on the Status of Endangered Wildlife in Canada
[3]Vulnerable – few in number or found only in very restricted areas
[4]Threatened – likely to become endangered if stresses are not reversed

The American White Pelican

The American white pelican, one of the world's largest birds, nests in colonies on islands in lakes of the Boreal Forest, Parkland, and Grassland natural regions. Although the species was removed from the national list of threatened species in 1987, it is still considered vulnerable in Alberta due to the small number of breeding colonies and its sensitivity to disturbance when nesting. Of 20 known nesting islands in Alberta before the 1950s, only four were found in 1970 and six in 1993.

The birds often use the same nesting island year after year and share it with other colonial species such as gulls and cormorants. However, if a site becomes too barren or is disturbed, the pelicans will abandon it. Changing lake levels may also cause loss of habitat if the island is either flooded or a land bridge develops. As recreation on lakes increases and cottage development proceeds, the availability of alternative nesting sites is decreasing. In past years, human activity contributed to the abandonment of colonies on Lac Ste. Anne, Miquelon Lake, Lac La Biche, Buffalo Lake, and Lake Newell.

Pelicans feed on a wide range of fish and aquatic animals; sticklebacks, perch, northern pike, lake whitefish, salamanders, frogs, and aquatic invertebrates are the usual fare. Contrary to popular belief, pelicans do not consume large quantities of game fish.

Habitat protection and public support are essential to maintaining pelican populations in Alberta. Since 1977, seven pelican nesting areas have been designated as Seasonal Wildlife Sanctuaries, making it illegal to enter or approach within 800 m (one-half mile) of these sites between April 15 and September 15. Nesting habitat is also developed by raising the surface of flooded islands. This work is financed through the Buck for Wildlife Program and the Wildlife Management Enhancement Fund.

Management plans for species at risk are designed to sustain populations and help them recover. Many plans are in place and some are described in **Section 5.6**. Other sensitive species that require special management include the American white pelican, bald eagle, osprey, and Caspian tern.

Reservoirs are ecosystems either created by humans or greatly modified from natural water bodies. However, because of their fluctuating water levels, reservoirs often lack the shoreline components of a natural lake and the aquatic organisms dependent on them. Many of the large reservoirs in Alberta are *mesotrophic* or *oligotrophic*, being relatively deep and filled with water from cold mountain rivers. Northern pike have invaded irrigation reservoirs from the South Saskatchewan River system, and yellow perch are also present in many reservoirs. Walleye and rainbow trout are stocked in some reservoirs and other trout species may be present in low numbers.

Some of the larger irrigation reservoirs in southern Alberta are important habitat for grebes (Poston et al. 1990). The large amount of shoreline (780 km) created by reservoirs in the irrigation districts, although limited in vegetation, nevertheless provides some shorebird habitat (Nerbas 1993). Birds that nest in colonies, such as pelicans, cormorants, and great blue herons, nest on islands in irrigation reservoirs as well as lakes.

3.3 WETLANDS AND THEIR ECOSYSTEMS

3.3.1 WETLANDS

A wetland is any land saturated with water long enough to promote wetland or aquatic processes. Wetlands are characterized by poorly drained soils, *hydrophytic* (water-loving) vegetation, and various kinds of biological activity adapted to a wet environment (National Wetlands Working Group 1987).

In Canada, wetlands can be divided into five major classes (adapted from National Wetlands Working Group 1987): bogs, fens, marshes, swamps, and shallow open water (less than two metres deep).

Peatlands, commonly referred to as muskeg, include bogs and fens and any areas of shallow open water within them. Peatlands are areas in which dead plant remains have accumulated over time as a result of the very slow decomposition of plants in poorly drained (waterlogged) soil. The depth of peat increases when the plant material decays more slowly than the rate at which plants die and accumulate. Peat accumulation is extremely slow - rates of 0.3 to 0.7 mm per year are common (AWRC 1993b). Peatlands typically have accumulations of at least 40 cm of peat, although depths range from shallow deposits in the Parkland Natural Region to deep deposits with permafrost in subarctic regions of northern Alberta.

As peat accumulates, surface vegetation becomes isolated from underlying soils and rocks. The resulting environmental changes are often reflected in changes in vegetation. The chemical composition of peat is influenced by the type of plants from which it was formed, and by moisture conditions during and following peat accumulation. The moisture content of peat is usually high. Sphagnum peat, for example, can hold over 10 times its dry weight and 95 percent of its volume in water. Because of differences in vegetation, the water chemistry of peatlands also varies.

Bogs are peatlands in which sphagnum mosses are the major vegetation and where most of the surface water comes from rainfall, which typically is low in minerals. Vegetation has built up over the years to the point where it is no longer in contact with the groundwater.

Fens are peatlands in which most of the water supply is from groundwater. The vegetation consists of sedges, grasses, reeds, sphagnum, and/or brown mosses. Shrubs and/or a tree layer may also be present.

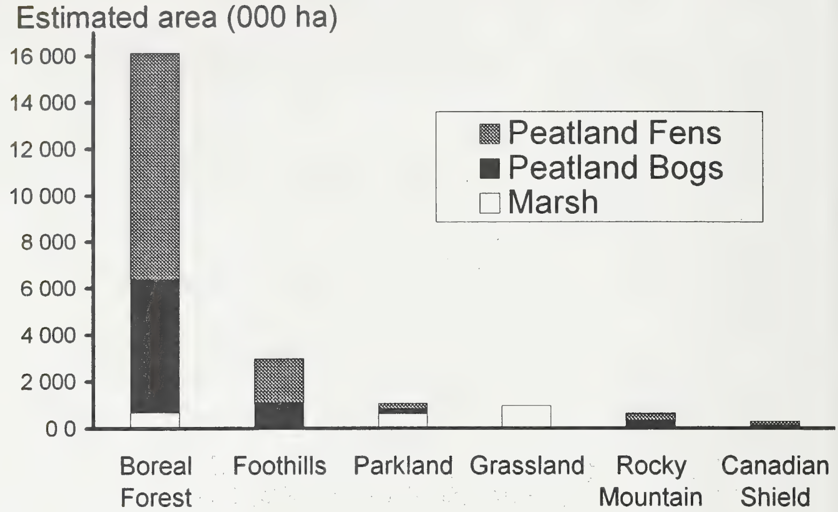
Marshes, also called **sloughs,** are wetlands periodically flooded by standing or slow-moving water. They are rich in nutrients. Reeds, rushes, and/or sedges predominate in alkaline marshes that contain calcium and bicarbonate. Saline marshes, which contain high sodium or sulphate, are also present in Alberta.

Shallow open waters less than two metres deep are another type of wetland. They are usually located between a lake and marsh.

Swamps are treed areas flooded at least seasonally by standing or slow-moving water. Swamps are uncommon in Alberta except in bog-fen transition zones.

Within these main wetland classes, different types exist. Distinctions between wetland classes are often unclear, and wetland complexes may contain several types. This complexity is especially true in northern Alberta, where peatlands often form complexes of bogs, fens, and sometimes swamps.

FIGURE 3.8 WETLAND DISTRIBUTION BY NATURAL REGION
source: Alberta Environmental Protection



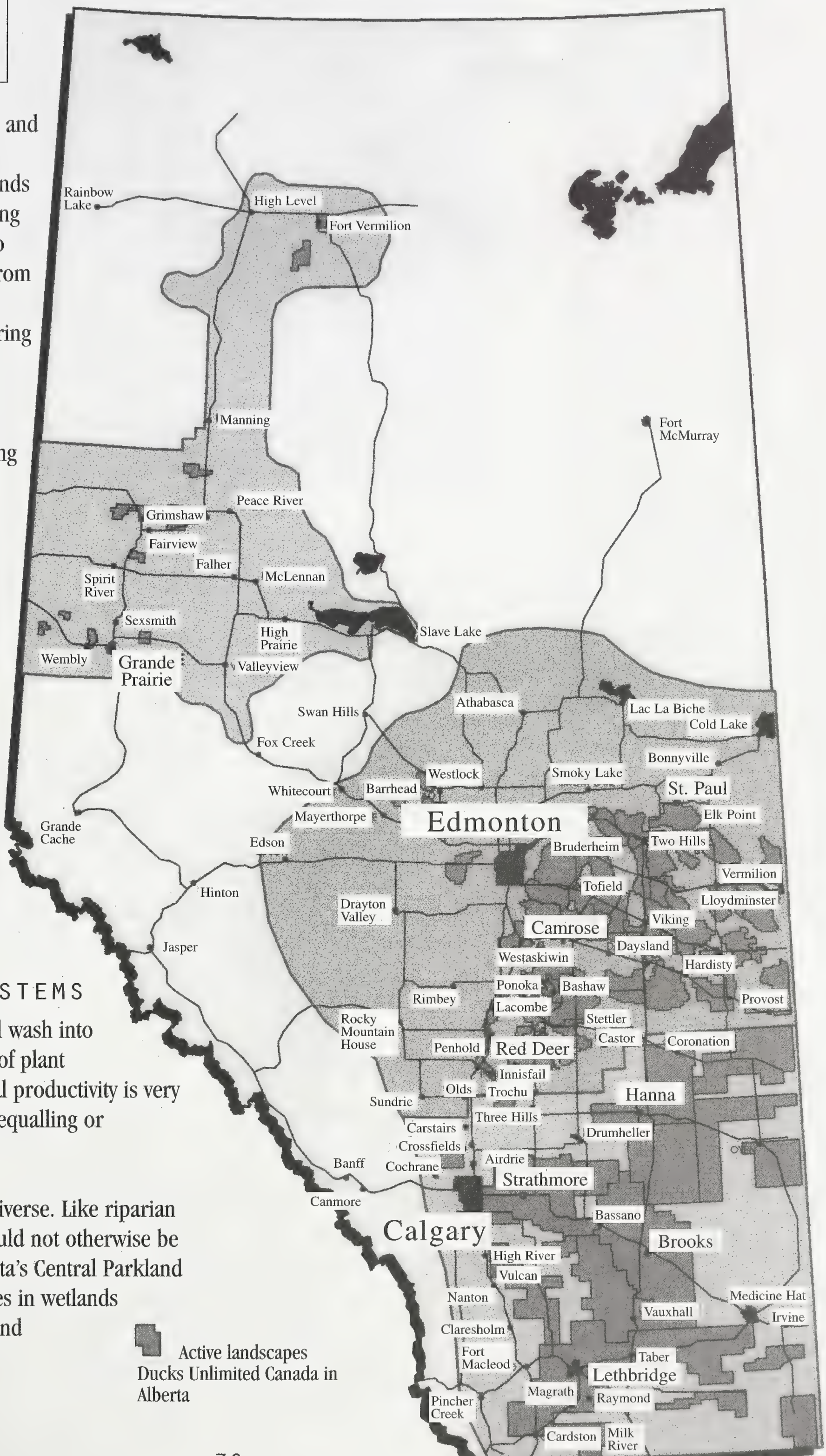
Peatlands occur primarily in the Boreal Forest Natural Region in the north, whereas most marshes occur in the Parkland and Grassland natural regions of central and southern Alberta **(Figure 3.8)**. In total there are approximately 10.3 million hectares of peatlands (Vitt et al. 1996) and 1.1 million hectares of marsh/slough wetlands in the province. Over 80 percent of marshes in the settled region of the province are less than two hectares in area.

3.3.2 WETLAND FUNCTIONS

Wetlands are a land-water linkage of great importance. In a natural system, water reaches a wetland through rainfall, surface flows or groundwater discharge and leaves by way of recharge to a groundwater aquifer, discharge to a watercourse, or evapotranspiration. The function that wetlands play in the water cycle varies widely from place to place and over time. As rainfall and evapotranspiration vary, so does the water input-output balance in a wetland. Wetlands vary in size and depth seasonally, annually, or over longer time periods with changes in climate. In areas with high groundwater tables, wetlands may act as groundwater discharge areas and contribute to surface water flows. Where groundwater levels are low, wetlands may serve as groundwater recharge areas.

Slough/marsh wetlands strongly influence water quality. They reduce the velocity of water flowing through them and, as a result, sediments and heavy metals are deposited. Cattails, bulrushes, and other marsh vegetation take up contaminants and reduce nutrients before these substances reach adjoining lakes and rivers.

URE 3.9 IMPORTANT
ERFOWL PRODUCTION
AS IN THE AGRICULTURAL
AS OF ALBERTA



'eatlands soak up flood and meltwater, and 'elease it gradually to the water table.)epending on water table levels, peatlands :an control runoff from storms, changing he volume and timing of discharge into treams. In some cases, transpiration from)eat vegetation can also significantly educe stream discharge from bogs during he intense summer growing period AWRC 1993b).

'eat also reduces erosion by intercepting ainfall, consuming water through ranspiration, dissipating the energy of lowing water, and stabilizing soil with oots. Peat is able to adsorb and hold ontaminants and has been used as an bsorbent and in the clean-up of ndustrial waste.

'lants convert carbon dioxide into lant material. As plant material ccumulates, the amount of stored arbon in the peat increases. It is stimated that Alberta's peatlands tore an amount equivalent to about hree percent of the carbon dioxide missions in the province.

.3.3 WETLAND ECOSYSTEMS

linerals and decaying organic material wash into etlands, creating a substantial supply of plant utrients. As a result, wetland biological productivity is very igh, exceeding that of grasslands and equalling or xceeding that of many forests.

Vetland habitats are biologically very diverse. Like riparian abitats, wetlands have species that would not otherwise be resent. For example, a survey in Alberta's Central Parkland atural Subregion found 57 bird species in wetlands ompared to 13 in adjacent cropland and ve in hayland (Prescott et al. 1995).

Amphibian Decline

Amphibian populations worldwide are declining due to unknown causes. The case of the northern leopard frog in Alberta is a dramatic example of this phenomenon. Large numbers of leopard frogs used to be common along lakes and rivers in prairie, parkland, and even forested areas of the province. However, in 1979 the species began to disappear from sites in central Alberta. Although historical data are limited, estimates place the overall population decline at 80 to 90 percent. In 1990, 32 sites in Alberta were known to still have leopard frogs, but only half of these had evidence of breeding. Most of these sites are in uncultivated, natural habitats in the Mixed Grassland Natural Region and the Cypress Hills.

Amphibian decline is under investigation in many parts of the world. Factors being investigated include disease, loss of habitat, global climate change, changes in ultraviolet radiation levels, and contamination of water, soil, and air.

Alberta Environmental Protection has established the Amphibian Monitoring Project to enlist the support of the public in reporting sightings of leopard frogs and other amphibians. Department biologists are developing a management plan specifically for the northern leopard frog. There are plans to amend the Wildlife Act to designate the northern leopard frog as an endangered species in Alberta, a measure that extends legal protection comparable to that for peregrine falcons and other high profile, high-risk species. Protection of remnant populations and wetland habitat will be critical.

Wetland flora is diverse and includes many rare species. Twenty-one species of vascular plants growing in wetlands in the Parkland and Grassland natural regions in Alberta are considered rare (Packer and Bradley 1984). One of these, western blue flag, is on the endangered species list for Canada. To date, 438 species of plants have been identified in Alberta's peatlands, including many mosses. Of these species, 11 percent are considered rare (Vitt et al. 1996).

Alberta's marshes/sloughs have traditionally produced about 20 to 25 percent of North America's population of dabbling ducks, including about two million breeding mallards and 1.5 million breeding pintails. Of particular importance are wetlands in the North and South Saskatchewan river basins **(Figure 3.9)**. These shallow marshes warm rapidly in the spring, providing the abundant invertebrate populations required as food by egg-laying female ducks. The cycle of flooding and drying in these wetlands speeds the decomposition of plant material, releasing nutrients needed to provide a food source for these invertebrates. A number of large wetlands in this area are also very important for duck production. Marshes in the Boreal Forest Natural Region are less numerous but produce as many waterfowl as those to the south. The Utikuma Lake complex (north of Lesser Slave Lake) is an important waterfowl area.

Some Alberta wetlands are of national and international importance for migrating waterfowl. In 1981, the Ramsar Convention on the Conservation of Wetlands of International Importance was signed by Canada. Of 17 wetland sites around the world designated as internationally significant "Ramsar" sites, four are in Alberta: Hay-Zama Lakes, the Peace-Athabasca Delta, the summer territory of the whooping crane, and Beaverhill Lake **(Section 6)**. Wetlands of national importance in Alberta include four wetlands used annually by over 20 000 moulting ducks, 31 wetlands used by over 20 000 staging ducks, and nine wetlands used by over 10 000 staging geese (Poston et al. 1990).

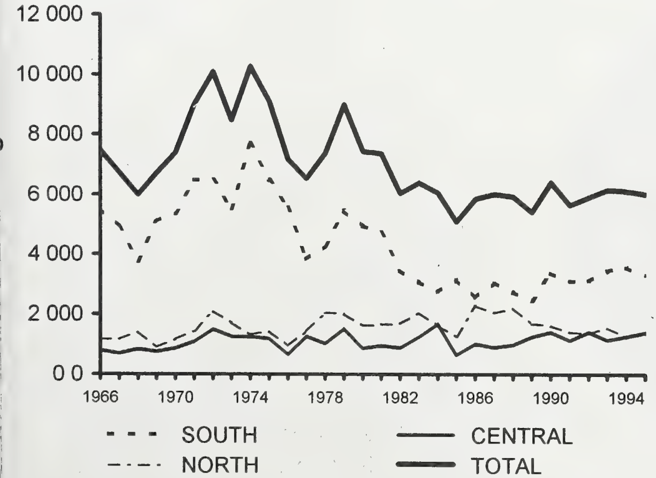
Species	Provincial Listing[1]	COSEWIC Status[2]	Action
Whooping crane	Red List	Endangered	Federal-provincial Recovery Plan
Woodland caribou	Blue List	Vulnerable[3]	Habitat mapping; Caribou Conservation Strategy
Great plains toad	Red List	—	Surveys
Plains spadefoot toad	Blue List	—	Surveys
Spotted frog	Blue List	—	Surveys
Canadian toad	Red List	—	Surveys
Northern leopard frog	Red List	—	Surveys

[1]See Appendix B for a fuller explanation of provincial listings
[2]Committee on the Status of Endangered Wildlife in Canada
[3]Vulnerable – few in number or found only in very restricted areas

TABLE 3.6 SPECIES-AT-RISK ASSOCIATED WITH ALBERTA'S WETLANDS

Large population declines of mallards, pintails, and other dabbling ducks have occurred, the result of a loss of wetland habitat both in the prairie provinces and in overwintering areas in the United States **(Section 4). Figure 3.10** shows the trend in numbers of breeding ducks in southern, central, and northern Alberta between 1966 and 1995. Actions addressing this trend are described in **Section 5.**

Most of Alberta's amphibian species also depend on wetlands, at least in the egg-laying stage. Of the 10 species in Alberta, three are known to be declining (the northern leopard frog, great plains toad, and Canadian toad), and two may be in decline (the spotted frog and plains spadefoot toad). Small isolated populations of these declining species still exist in the province and have become highly important to the survival of these species in Alberta.

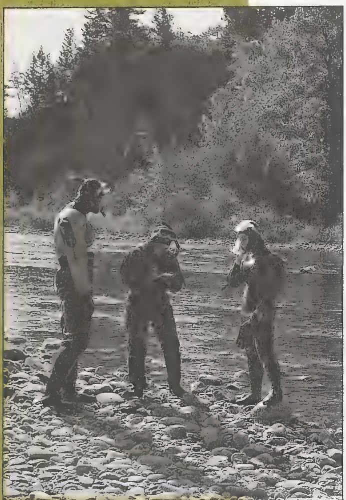


Mammalian species associated with marshes include the beaver, muskrat, river otter, and mink. Woodland caribou, inhabiting the northern Boreal Forest Natural Region, depend on bogs containing mature black spruce forests that harbour lichens, an important food for the caribou (Edmonds and Bloomfield 1984).

Several wildlife species associated with Alberta's wetlands are considered at-risk **(Table 3.6)**. These include species classified by Alberta provincial policy or by the national Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The provincial classification includes species in serious trouble (Red List) and species facing less immediate threats (Blue List). COSEWIC classifies species as vulnerable, threatened, or endangered.

FIGURE 3.10 MAY DUCK BREEDING INDEX IN ALBERTA, 1966-1994
source: US Fish and Wildlife Service; Canadian Wildlife Service; Alberta Environmental Protection

4.0 HOW WE USE AND INFLUENCE AQUATIC ECOSYSTEMS



Water is not only a bearer of life but also a provider of many valuable services to society. In using these services, we sometimes withdraw, divert, or impound water, and return used water back into the drainage system. In so doing, we may influence its quantity and/or quality and in turn may affect aquatic ecosystems.

We may also affect aquatic ecosystems by using their resources directly, for example, by fishing, harvesting wild rice, or removing peat moss. Activities within drainage basins, such as land clearing, use of agricultural chemicals, and garbage disposal may also affect aquatic ecosystems.

4.1 HOW WE USE WATER

4.1.1 Water Withdrawal and Allocation

The ownership of all water in the province is vested in the Crown. The right to withdraw water is obtained by means of a licence from Alberta Environmental Protection. The licence specifies the amount of water that can be withdrawn, and this amount is considered "allocated" for the purpose of keeping track of the total volume committed to certain uses. Evaporation and water required to maintain adequate stream flow may also be figured into the allocation calculations.

Not all allocated water is removed from the system. For example, a licensed user may not need all of their permitted volume of water in a given year and so withdraw only part of their allocation. As well, some withdrawn water is later returned to the drainage system. For example, much of the water withdrawn for irrigation or municipal use is later returned as irrigation return-flow or treated wastewater.

Water is licensed or allocated by Alberta Environmental Protection for many uses, including irrigation, other agricultural purposes, industrial use, municipal use, domestic use, power generation, and storage. A licence is also required for drainage or diversion projects. **Figure 4.1** shows the proportion of water allocated for various uses in 1996. The growth in surface water use in the province is shown in **Figure 4.2.**

FIGURE 4.1 Surface Water Allocation in Alberta, 1996
note: Much allocated water is returned, particularly that allocated to industrial, power, and municipal uses (see text).
source: Alberta Environmental Protection

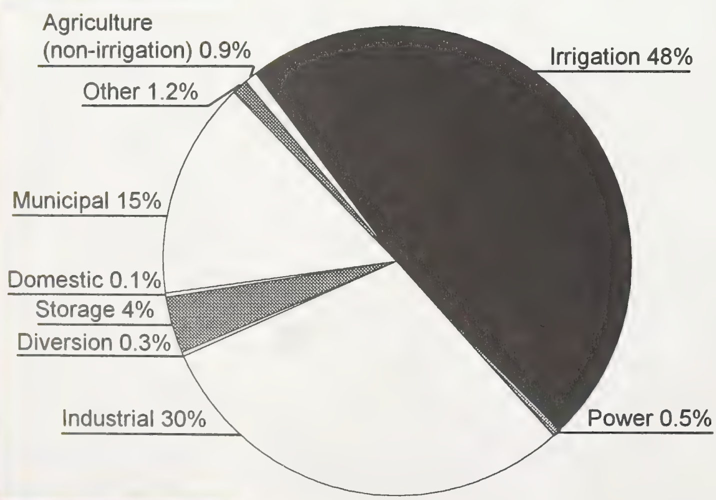
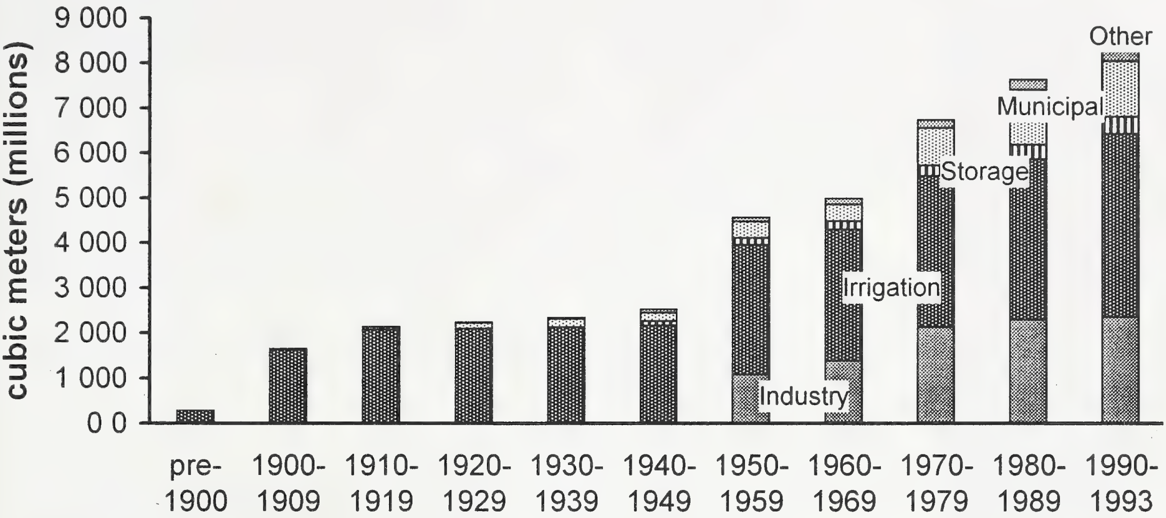


FIGURE 4.2 SURFACE WATER ALLOCATION IN ALBERTA, PRE - 1900-1993
source: Alberta Environmental Protection



Rivers are the source of most (85 percent) of the water allocated in Alberta. Lakes provide 12 percent and groundwater three percent of allocated water. Of the total volume of water allocated in the province in 1996, 59 percent was in the South Saskatchewan River Basin. This volume, 5.2 billion m^3, was allocated primarily for irrigation and came almost entirely (97 percent) from rivers. The second highest amount allocated, 28 percent, was in the North Saskatchewan River Basin. Of this, 76 percent was obtained from rivers.

4.1.2 DIVERSION AND REGULATION OF FLOWS

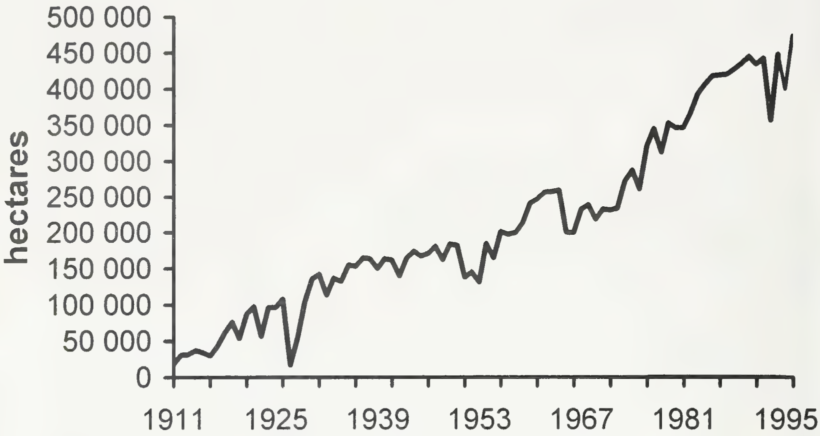
To provide water for crops, hydroelectric power generation, and stable flows for industry and municipalities, some Alberta rivers are regulated by dams or partially diverted to offstream reservoirs. As a result, their flows are now very different from historical natural conditions, which in turn may affect their respective ecosystems. Reservoirs created by dams have many consequences, such as converting river habitat to reservoir habitat and modifying the downstream flow regime. However, with careful management, reservoirs can benefit the downstream environment, for example by supplementing low natural flows **(see Section 5.4).**

4.1.3 DISPOSAL OF WASTEWATER

Water is also used to assimilate substances discharged from specific ("point") sources such as a wastewater discharge pipe from a factory. The discharge of wastewater into a surface water body requires a government approval, and this effluent must meet standards set by Alberta Environmental Protection **(see Section 5.2).**

Assimilative capacity
the ability of water to process organic and inorganic materials over a period of time.

FIGURE 4.3 TOTAL HECTARES IRRIGATED WITHIN IRRIGATION DISTRICTS, 1911-1996
source: Alberta Agriculture, Food and Rural Development

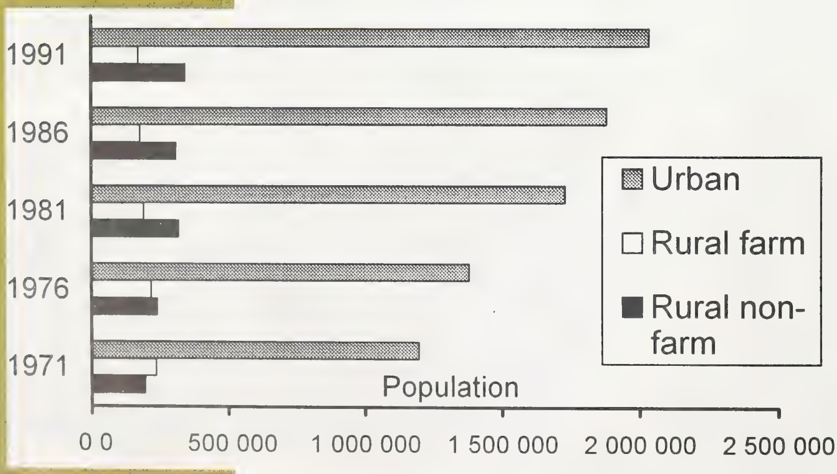


4.2 USES OF WATER AND AQUATIC RESOURCES

4.2.1 AGRICULTURAL USE

Irrigation began in Alberta in the 1870s with small, private irrigation projects, but by the early 1900s large-scale irrigation systems were in operation. Today about 60 percent of Canada's irrigated acreage is located within the 13 irrigation districts in southern Alberta covering approximately 520 000 hectares (1.3 million acres). Another 95 000 hectares (234 000 acres) in the province outside these districts are also irrigated. **Figure 4.3** shows the growth over time in the amount of land actually irrigated within the irrigation districts.

Located entirely within the South Saskatchewan River Basin, these irrigation districts obtain most of their water from the basin's rivers. Storage reservoirs and canal systems throughout the basin carry water to dozens of communities and thousands of farmsteads for domestic use, drinking water, as well as irrigation.



Irrigation return flows, which consist of excess water from irrigation canals and water draining from irrigated land back into the canals, may affect water quality in the receiving water body. Return flows can contribute coliform bacteria, nutrients, pesticides, heavy metals, and dissolved solids to

FIGURE 4.4 ALBERTA'S URBAN AND RURAL POPULATION, 1971-1991
source: Statistics Canada

the receiving water. Recent studies in the Lethbridge Northern and Bow River Irrigation Districts found that most substances in return flows were acceptable under the Canadian Water Quality Guidelines for human consumption, irrigation, and protection of aquatic life. However, there were frequent exceptions involving coliform bacteria and occasional exceptions of several heavy metals and one herbicide.

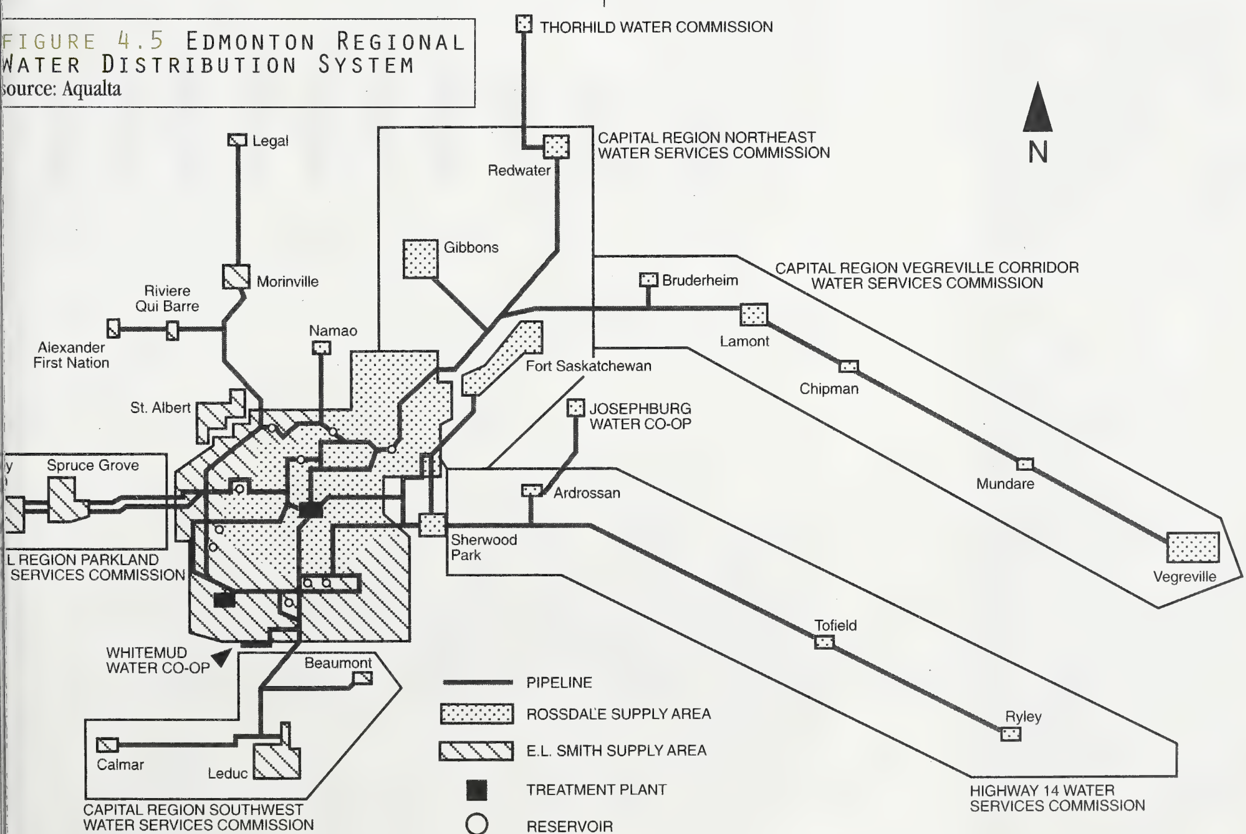
Water allocated for other agricultural uses, such as stock watering, represents only about one percent of total water allocated in the province. This amount does not include water used by the many farms withdrawing a small volume, less than the amount for which a licence is required.

4.2.2 Municipal Use

About two million people live in Alberta's towns and cities, and the steady growth of our urban population is expected to continue **(Figure 4.4).** Today's urban household uses several hundred litres of treated water per day. This water is supplied by the local municipality from a surface or groundwater source. Treatment of the water involves settling of particles, filtration to remove turbidity, and chlorination to kill disease-causing microorganisms. In some cities, treatments such as activated charcoal and ozone disinfection are used **(Section 6).**

About 15 percent of the total volume of surface water allocated to users in the province goes to municipal water supply systems **(Figure 4.1).** Large supply systems exist around some cities. For example, water from the North Saskatchewan River is treated in Edmonton and pumped to communities as far as 90 km away **(Figure 4.5)**. Many rural communities obtain their water from smaller streams with limited capacity and therefore store the water.

FIGURE 4.5 EDMONTON REGIONAL WATER DISTRIBUTION SYSTEM
Source: Aqualta



About three-quarters of the water withdrawn by municipal supply systems becomes wastewater. Prior to treatment, this wastewater is typically 99 percent liquid and may contain dissolved and suspended inorganic and organic solids, phosphorus and nitrogen, ammonia, heavy metals, and disease-causing viruses, bacteria, and protozoa. Effluent from small industries using municipal water supplies is also treated in some municipal wastewater systems.

Municipal wastewater is treated to certain standards of quality before being discharged to rivers. Wastewater treatment systems in the province are of two types: mechanical and passive. Mechanical wastewater treatment plants, used by cities, larger towns, and some smaller communities, treat large amounts of wastewater in a relatively short period of time and rely on large inputs of energy to do so. Effluents are discharged continuously to the receiving river under approval from Alberta Environmental Protection. As urban centres have grown, the number of these plants has increased **(Figure 4.6).**

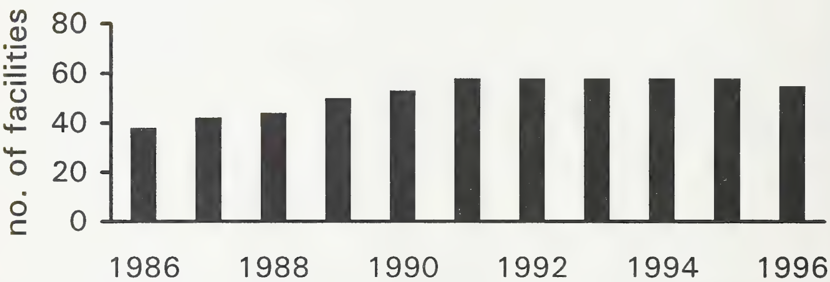


FIGURE 4.6 NUMBER OF CONTINUOUS MECHANICAL DISCHARGE SEWAGE TREATMENT PLANTS IN ALBERTA, 1986-1996
source: Alberta Environmental Protection

Three levels of treatment may be used to minimize adverse effects on the receiving water:

- **Primary treatment** - removal of solids and suspended material.

- **Secondary treatment** - removal of biodegradable material and additional suspended material. The effluent still contains pathogenic organisms, phosphorus and nitrogen, and oxygen-depleting substances. Secondary treatment is now the minimum standard for municipal wastewater in Alberta **(Section 5.2)**.

- **Tertiary treatment** - further reduction of phosphorus and nitrogen, sometimes including disinfection.

Biochemical Oxygen Demand (BOD)

a laboratory test performed on water or effluent to determine the level of pollution from organic matter. The test measures the amount of oxygen required by microorganisms to break down organic material in the water. BOD_5 is measured at 20^oC over a five-day period.

Because of its large volume, municipal effluent from large population centres generally has a considerable impact on the receiving river. Phosphorus and nitrogen are still present, although much reduced, in wastewater that has undergone tertiary treatment. These elements can diminish a river's oxygen by encouraging excessive growth of aquatic plants, which subsequently decompose, using up oxygen in the process. This oxygen depletion is of particular concern in winter. Municipal effluents can also add ammonia, heavy metals, trace organic compounds, and pathogenic organisms to a river, depending on the types of industrial and municipal discharges to commercial sewer systems and the effectiveness of municipal treatment facilities.

The passive type of treatment facility utilizes a wastewater stabilization pond (lagoon). There are about 400 lagoons currently in use throughout rural Alberta, mostly in communities of fewer than 2000 people, although some communities are as large as 12 000. Lagoons are built to strict specifications and depend on natural processes involving bacteria, algae, and other organisms, which digest organic material and remove many pathogenic organisms. The resulting effluent quality is similar to, or better than, that resulting from secondary treatment in mechanical treatment plants. Lagoons are allowed to discharge into a stream or river within a specified three-week time period once or twice a year. This time period is based on water quality and fisheries considerations in the receiving water.

To illustrate the effect of municipal wastewater, the differences in overall water quality in four rivers upstream and downstream of major urban centres (Edmonton, Calgary, Lethbridge and Red Deer) from 1984 to 1994 are shown in **Figure 4.7**. This figure is based on a comparison of the number of tests meeting Alberta Surface Water Quality Interim Guidelines for 19 water quality variables upstream versus downstream of the cities. The comparison includes nutrients, heavy metals, dissolved oxygen, pH, coliform bacteria, and phenols. Differences due to human activities around cities are clearly evident. However, in spite of the growth of these cities during this decade, the difference between upstream and downstream compliance rates remains similar over the years. This is due mainly to improvements in wastewater treatment made during this period. It should be noted that substances such as trace organic contaminants and pesticides are not included in the guidelines, although these substances are often monitored. The development of new guidelines **(see Section 5.2)** may yield different results in the future.

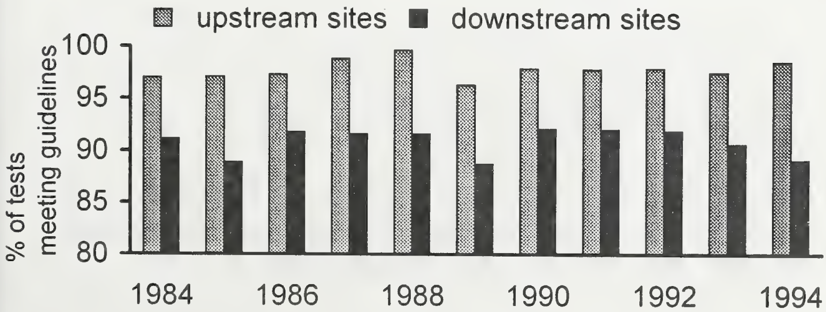


FIGURE 4.7 COMPLIANCE WITH WATER QUALITY GUIDELINES UPSTREAM AND DOWNSTREAM OF FOUR CITIES*

*Edmonton (North Saskatchewan River), Red Deer (Red Deer River), Calgary (Bow River), and Lethbridge (Oldman River)
source: Alberta Environmental Protection

4.2.3 Industrial Use

In Alberta, significant industrial demand for water began in the 1950s and major increases occurred in the 1970s. In 1996, 30 percent of the water allocated to users went to industrial uses such as food processing, oilfield injection, cooling and other industrial processes. The majority of water used by industry today is obtained from the North Saskatchewan River Basin, followed by the Peace-Athabasca River Basin.

The greatest amount (about 67 percent) of the water allocated to industry is dedicated to the thermal electric power sector, followed by the manufacturing sector (about 25 percent) and the mining sector (about eight percent). Pulp and paper mills and chemical plants are the major water users in the manufacturing sector, and enhanced oil recovery operations (secondary recovery of oil by steam or water injection) are the major users in the mining sector.

Water for hydroelectric power generation is not included in the above allocation statistics. Water used to generate electricity passes through turbines and returns directly to the river. The large hydroelectric facilities on the upper Bow and North Saskatchewan river systems are used mainly to supply power during periods of peak demand. Today, small generating facilities also exist, making a total of 20 dams that produce hydroelectric power in Alberta: 11 in the Bow River Basin, one on the Red Deer River, two in the North Saskatchewan River Basin, one in Jasper National Park, and five on irrigation facilities. Combined, these facilities produce about 1800 million kilowatt-hours of electricity per year, or about three percent of the electricity generated in Alberta.

Coal-fired generating plants in the central part of the province supply more than 90 percent of the electricity produced in the province. Gas-fired, waste wood, and gas-fired industrial on-site and co-generation facilities also exist in Alberta. For those generation units that use steam technology, cooling is provided by water in either a closed or open system. Much of this water evaporates. For example, about 27 million m^3 per year evaporates from TransAlta Utilities' coalfired plants.

Most (87 percent) of the water used by industry is returned to surface water sources. This wastewater is discharged under licence and is treated to meet effluent standards set by Alberta Environmental Protection **(see Section 5.2)**. The substances discharged vary in quantity and type from industry to industry **(Section 6)**.

Many industries recirculate water, thus reducing water demand. The best water "recyclers" are the thermal power plants, refined petroleum and coal products industries, and chemical and chemical-products industries.

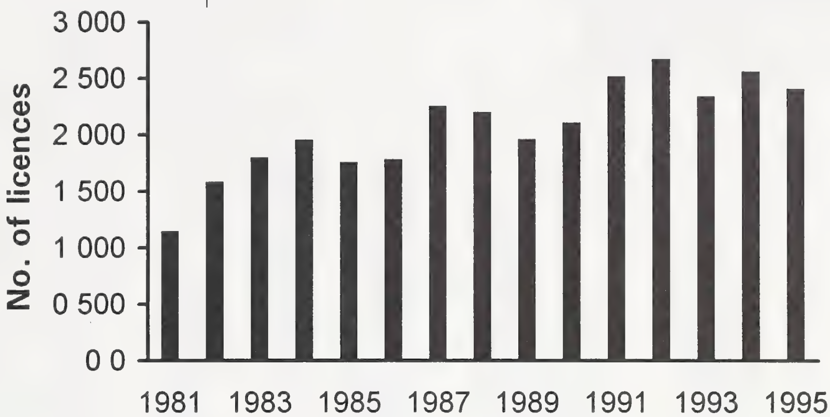


FIGURE 4.8 DOMESTIC FISHING LICENSES ISSUED IN ALBERTA, 1981-1995
source: Alberta Environmental Protection

4.2.4 SUBSISTENCE AND COMMERCIAL USE OF AQUATIC RESOURCES

Harvesting the living components of aquatic ecosystems is another way we use and influence aquatic ecosystems. Harvesting for commercial and personal use includes the following activities:

- **Domestic fishing** - The traditional activity of fishing for food is referred to as "domestic fishing." Licences are now required for domestic fishing as well as for recreational ("sport") fishing. The First Nations' domestic fishery was established in 1930 and a Métis domestic fishery in 1939. In addition, a general domestic fishery licence allows Alberta residents to take fish for food where there is a demonstrated need when living in isolated areas or under poor economic conditions. About 2500 residents, mostly of northeastern Alberta, obtained domestic fishing licences in 1995 **(Figure 4.8)**.

- **Commercial fishing** - Commercial fishing takes place on designated lakes and reservoirs. Most commercial fishing today occurs on lakes in the Peace-Athabasca River Basin. The primary species harvested is lake whitefish. Because this species spawns in shallow water in the fall, it is also able to reproduce in reservoirs. Many irrigation reservoirs were stocked with whitefish between 1940 and 1960 and a commercial harvest is now conducted at 15 reservoirs. In 1994, approximately 2000 tonnes of fish, mostly lake whitefish, were harvested from Alberta lakes and reservoirs **(Figure 4.9)**, having an average annual total value of about $3 million. About $500 000 of this was generated by commercial fishing in reservoirs (Nerbas 1993). Commercial harvest is regulated by limiting (since 1983) the total number of licensed commercial fishermen and by restricting the type and amount of equipment used.

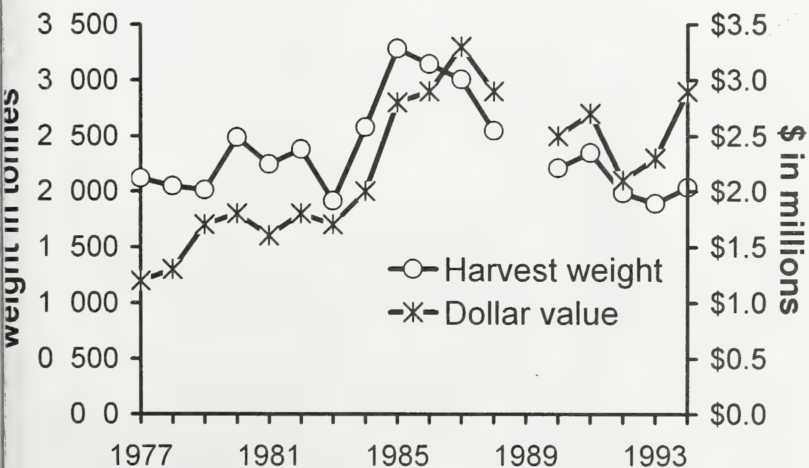


FIGURE 4.9 HARVEST WEIGHT AND LANDED VALUE OF COMMERCIAL FISHERIES, 1977-1994
source: Alberta Environmental Protection

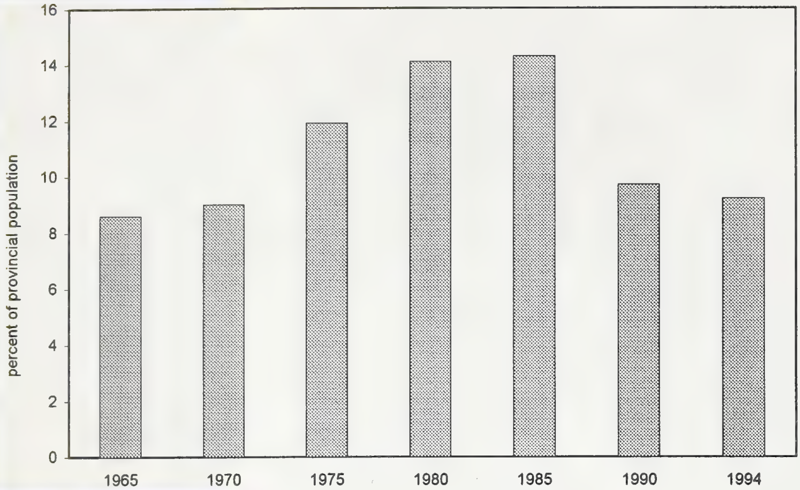


FIGURE 4.10
SPORTFISHING LICENCE SALES IN ALBERTA 1965-1994
source: Alberta Environmental Protection

- **Guided Fishing** - Fishing lodges and fly-in tent camp operations rely mostly on lake fisheries. In 1989, 11 permanent lodges and 10 fly-in campsites were operating in Alberta. Commercial fishing, fly-in fishing, and recreational fishing in Alberta also support hundreds of workers and small businesses providing goods and services related to fishing. Private and commercial game fish farms raise thousands of trout each year. About 50 operators harvest and sell bait fish (minnows and other specified types).

- **Licensed trapping** - Licensed trappers in the province harvest semi-aquatic furbearing species. In 1995-96, some 42 000 beaver, 25 000 muskrat and 372 river otter pelts were harvested in the province, valued at a total of $1.6 million. About three-quarters of the province's 4000 licensed trappers reside in the Peace-Athabasca-Slave River Basin. Alberta Environmental Protection controls the number of trappers and traplines and a quota system is used to protect furbearer populations.

- **Peat moss harvesting** - Peat moss is a valuable material for horticulture because of its water-holding capacity. To date, peat moss has been harvested commercially in Alberta primarily in the North Saskatchewan and Athabasca river basins. Peat moss production in Alberta increased from about 15 to 23 percent of the total Canadian production between 1990 and 1994, and its value increased from $13.2 million to about $29 million during those years. In 1990, the industry contributed about 300 jobs to the Alberta economy (AWRC 1993b).

  The peat deposits available in the settled area of the province for commercial development are limited. Since peat forms very slowly, peat moss harvesting greatly affects the peatland from which it is harvested. Research into the restoration of harvested sites is underway **(see Section 5.7.3)**.

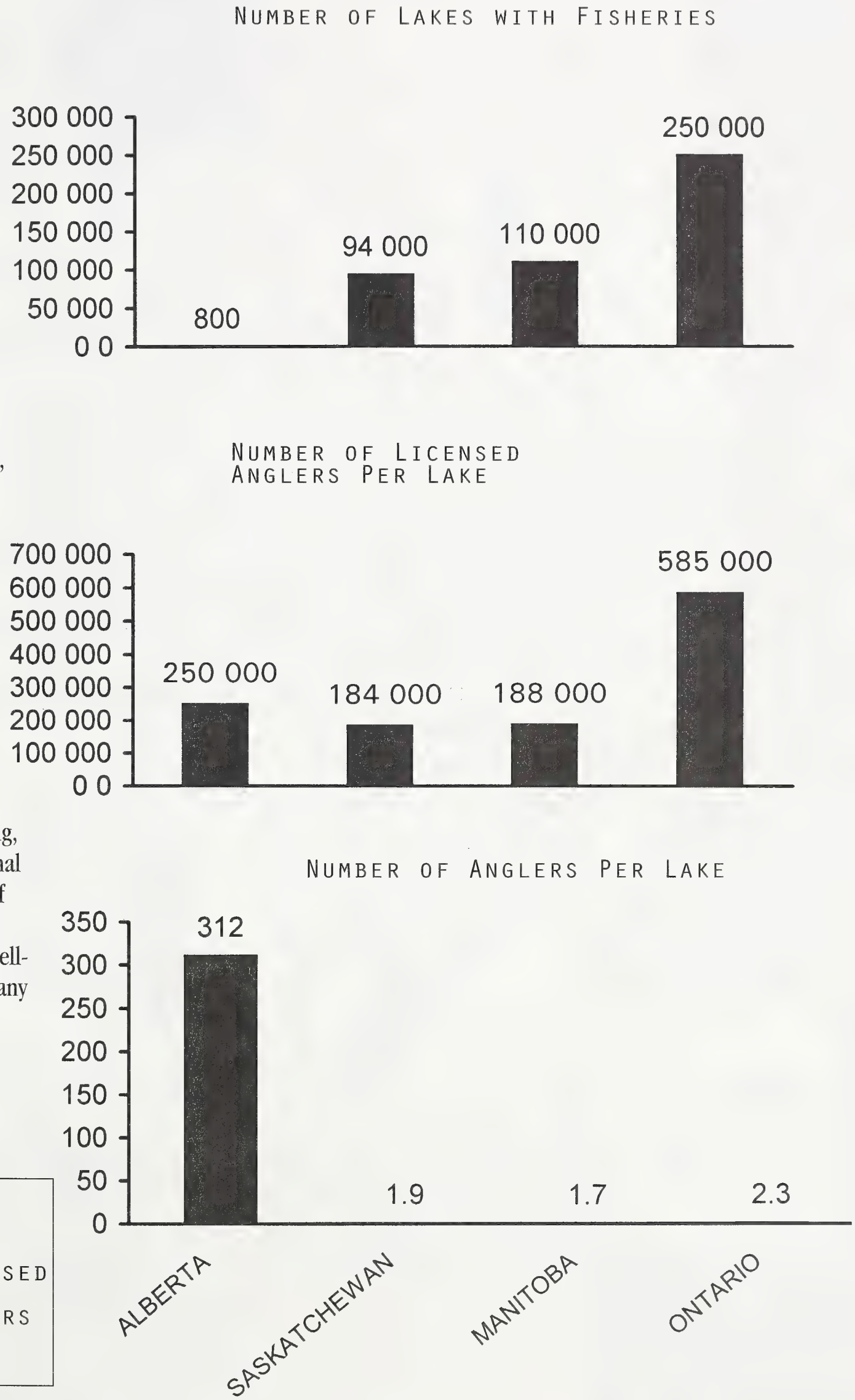
- **Wild rice** - Wild rice harvesting occurs in many parts of the province, especially in the northeast region. It is grown for commercial production in the shallow margins of about 400 Alberta lakes. In 1996, there were approximately 90 authorized operations, most involving several lakes each. This activity has little impact on lake ecosystems.

4.2.5 Recreational Use

Alberta's water resources are heavily used for recreation, as described below.

- **General Recreation** - According to a 1992 provincial survey, over 60 percent of Alberta households engage in at least one water-based recreational activity, including swimming, boating, fishing, sailing, canoeing, water skiing, windsurfing, and rafting. Lakes are the most popular type of water body for many of these activities. Camping facilities at lakes are numerous and well-used. In addition, the number of privately owned lake properties has increased in recent years.

  In southern Alberta, many reservoirs are also used for camping, boating, fishing, picnicking, and/or swimming. Public recreational facilities exist at over one-quarter of the irrigation reservoirs and range from facilities for informal use to well-developed sites. Reservoir users, many of whom are urban residents from Calgary and Lethbridge, spend on average 18.3 days at irrigation reservoirs each year (McNaughton 1993).



IGURE 4.11
TOP) NUMBER OF LAKES ITH FISHERIES, 1995
CENTER) NUMBER OF LICENSED NGLERS PER LAKE, 1995
BOTTOM) NUMBER OF ANGLERS ER LAKE, 1995
urce: Alberta Environmental Protection

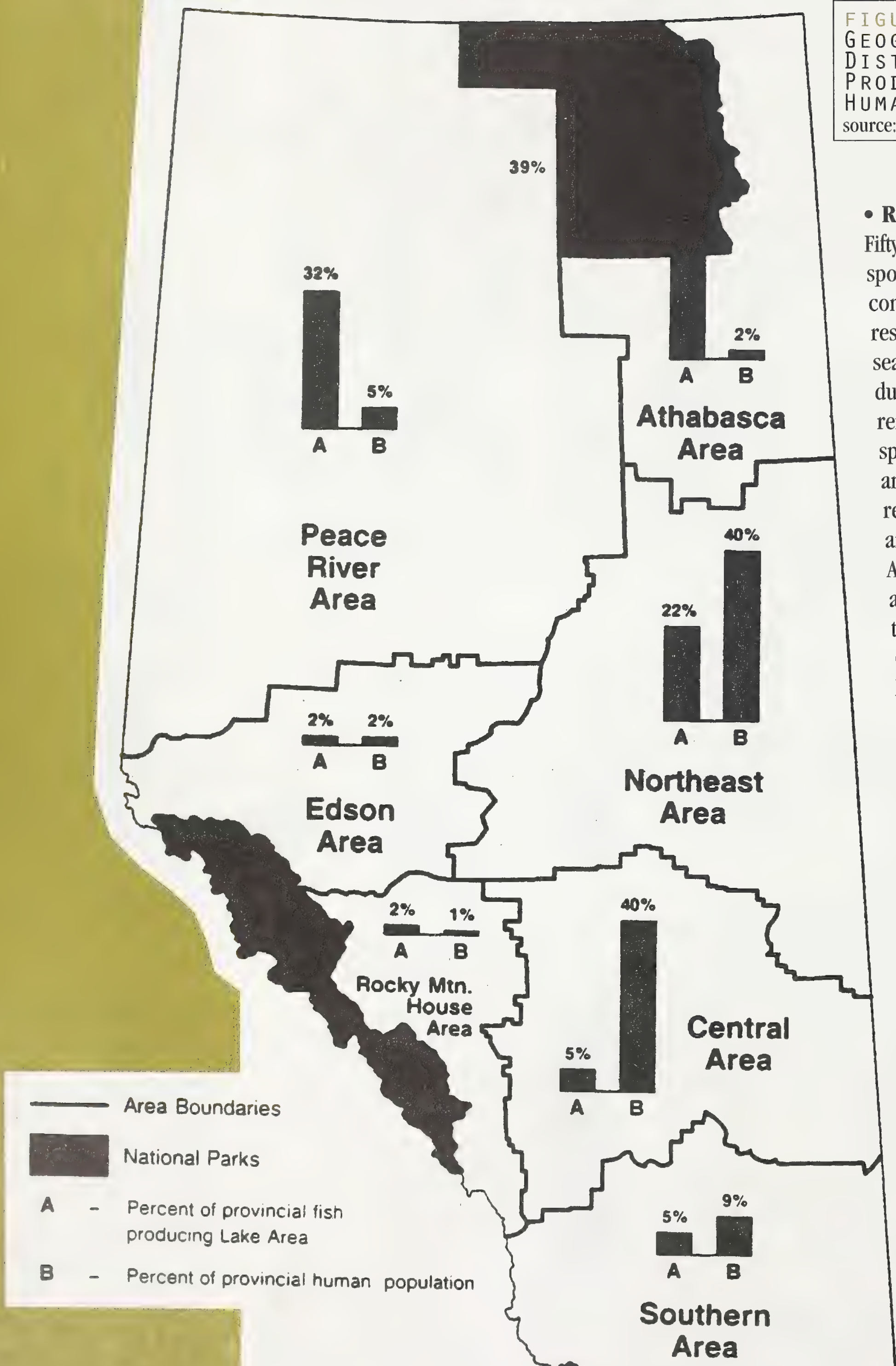
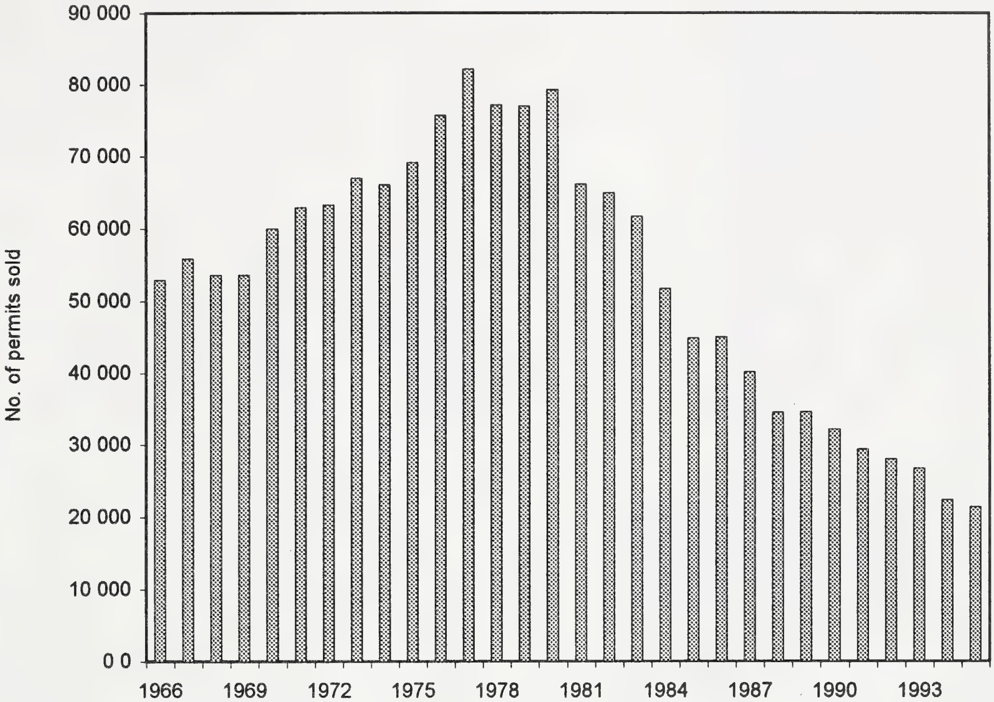


FIGURE 4.12
GEOGRAPHIC DISTRIBUTION OF FISH PRODUCING LAKES AND HUMAN POPULATION
source: Alberta Environmental Protection

• **Recreational angling** - Fifty percent of Alberta's sportfishing in Alberta is conducted on lakes and reservoirs during open-water season and 16 percent during winter ice-cover. The remaining 34 percent of sportfishing occurs on rivers and streams. Irrigation reservoirs are popular with anglers in southern Alberta. An estimated 250 000 days are spent by anglers at these reservoirs each year (Bishop, pers. comm. in Nerbas 1993). In 1994, one out of every 11 Albertans, or 9.2 percent of the population, held a sportfishing licence in 1994 **(Figure 4.10)** catching an estimated 23 million fish. Overall, licensed Alberta anglers spent approximately 5.2 million days fishing in 1994 and spent $163 million on goods and services directly related to fishing.

Alberta's lakes experience high fishing pressure, the number of anglers per lake greatly exceeding that in the other prairie provinces and Ontario **(Figure 4.11)**. In addition, most of

FIGURE 4.13 MIGRATORY GAME BIRD PERMIT SALES IN ALBERTA, 1966-1995
source: Alberta Environmental Protection



Alberta's fish-producing lakes are in the north at a considerable distance from large population centres **(Figure 4.12)**. As a result, lakes closest to urban centres receive heavy use and in some cases have experienced reduced fishing success and a deterioration in their water quality.

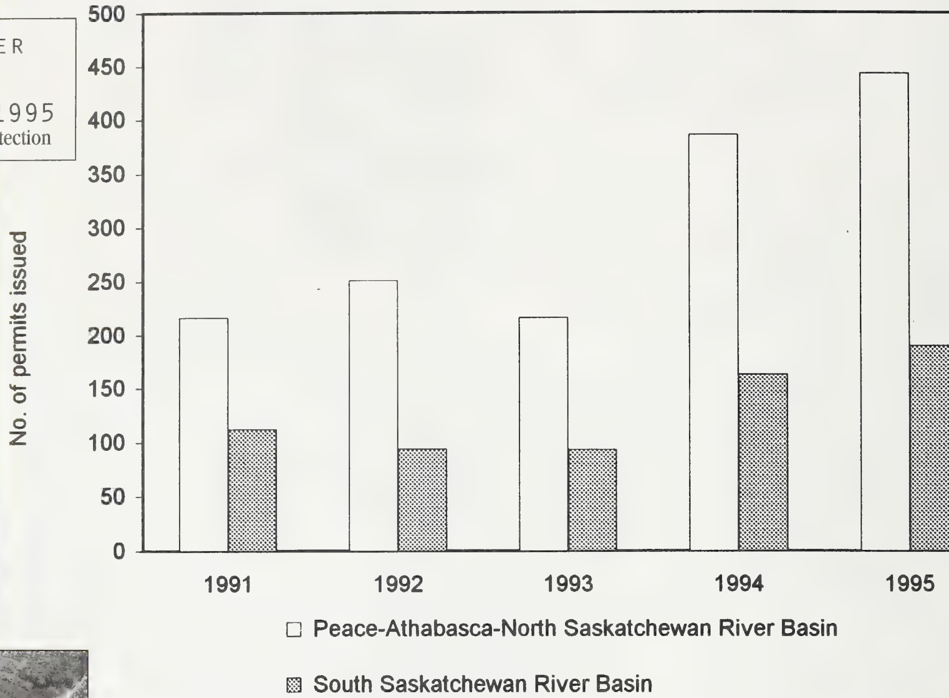
Waterfowl Hunting - In 1995, Alberta's lakes and marshes produced waterfowl providing recreational hunting for 20 000 persons, based on the number of migratory bird permits sold **(Figure 4.13)**. The value of waterfowl to Albertan hunters in 1991, based on their willingness to pay for their waterfowl hunting experience beyond their actual expenditures, was estimated at $4.8 million (Filion et al. 1995). The amount actually spent by waterfowl hunters in the province is not known, but is likely a significant portion of the $156 million spent by all hunters in the province in 1991 Filion et al. 1995).

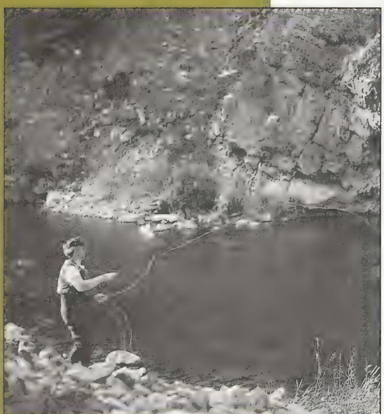
Other Activities - Activities that do not involve hunting or water-related sports, such as viewing scenery and wildlife, are also important aspects of recreational use. "Watchable Wildlife" viewing areas have been established near marshes and lakes, reflecting the growing participation in this activity. In 1991, Albertans spent $431 million on trips to view wildlife and another $248 million on contributions to preserve wildlife and natural areas (Filion et al. 1995).

4.3 LAND USES AFFECTING AQUATIC ECOSYSTEMS

Land-based activities may affect water and aquatic life, depending on their location within a watershed, soil types, and other factors. Contaminants or nutrients may enter lakes or streams by running off or leaching from the land, or by atmospheric deposition. These diffuse ("non-point") sources are not easily controlled and can contribute substantially to water quality problems. Water quantity may also be affected by land-based activities that influence runoff volume and duration.

FIGURE 4.14 Number of Permits for Pipeline Stream Crossings, 1991-1995
source: Alberta Environmental Protection

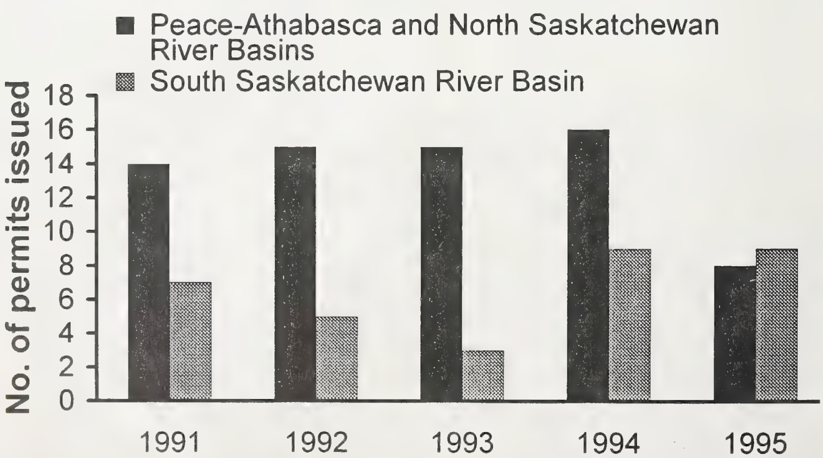




4.3.1 Activities Affecting Shores and Beds of Lakes and Watercourses

Most of the beds and shores of permanent, naturally occurring water bodies are public land. Lakeshore owners often wish to transform this land by adding sand for beaches, removing aquatic vegetation, and constructing boathouses and docks. Projects disturbing the natural characteristics or dimensions of a lake's bed or shore, such as placing or removing materials or constructing permanent structures, require authorization from Public Land Services of Alberta Agriculture, Food and Rural Development and the Natural Resources Service of Alberta Environmental Protection. Land and water management agencies work with landowners to minimize the impact of these activities on lakeshores and the fish and wildlife habitat they provide.

FIGURE 4.15 Water Resources Act Permits Issued for Gravel Removal, 1991-1995
source: Alberta Environmental Protection



Road or pipeline construction across a watercourse also requires a permit from Alberta Environmental Protection. In recent years, the number of permits issued for watercourse pipeline crossings has increased **(Figure 4.14)**. This upward trend reflects not only an increase in the number of pipelines being constructed, but also increasing awareness of the requirement to obtain a permit. In addition, installation methods that avoid disturbing watercourse banks, such as boring a pipeline underneath a watercourse, are being used more often.

The removal of gravel from a watercourse also requires a permit. **Figure 4.15** shows the number of permits issued under the *Water Resources Act* for this activity from 1991 to 1995.

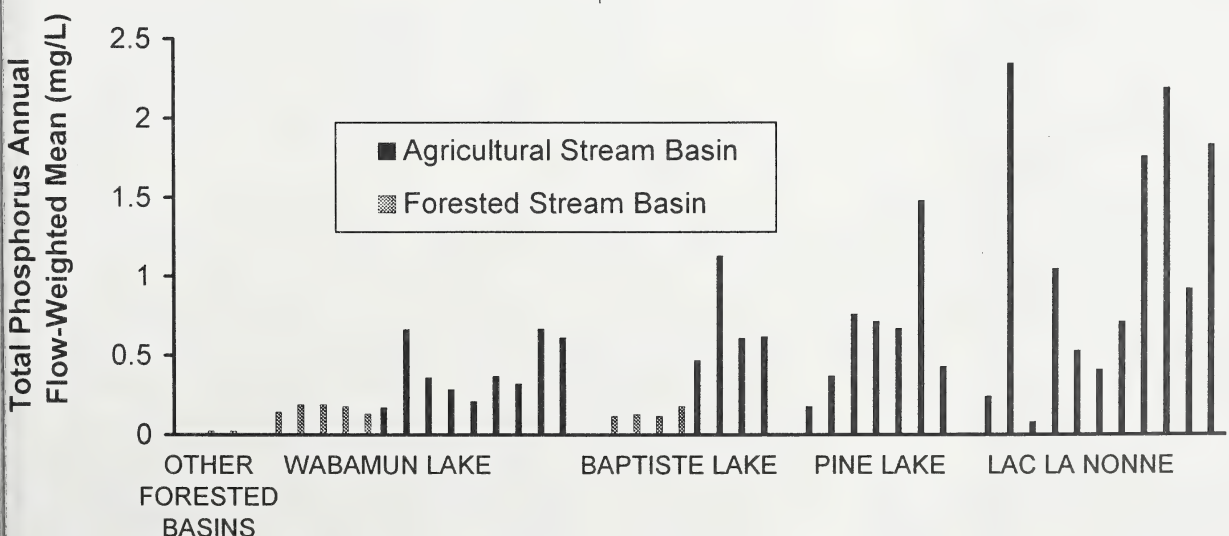
FIGURE 4.16 CONCENTRATIONS OF TOTAL PHOSPHORUS IN SOME CENTRAL ALBERTA STREAMS IN FORESTED AND AGRICULTURAL DRAINAGES
source: Alberta Environmental Protection

4.3.2 FORESTRY

Large-scale timber harvesting can alter aquatic and riparian ecosystems in many ways. Removing trees and other vegetation affects transpiration and evaporation rates and exposes soil to erosion. In addition, surface or sub-surface runoff patterns can change, nutrients entering lakes and streams may increase, and cut-over areas may allow predators better access to riparian forests. Provincial standards and guidelines in the *Forests Act* protect water bodies and riparian habitat from these adverse effects. Studies within the Terrestrial and Riparian Organisms, Lakes and Streams Program (TROLS) are underway to improve our understanding of the role of riparian forests in boreal ecosystems **(see Section 5.7)**.

4.3.3 AGRICULTURE

Runoff from agricultural land within a watershed may carry high levels of nutrients. This is evident by comparing phosphorus concentrations from various inflowing streams for several Alberta lakes (Baptiste Lake, Wabamun Lake, Lac La Nonne, and Pine Lake; **Figure 4.16**). Average phosphorus concentrations in the streams draining forested land were lower and less



Sediment in Streams

Silt, clay and other particles carried in water are known as suspended sediment. Water naturally picks up these materials as it moves along stream banks and shores and receives runoff from the surrounding land. However, unnaturally high sediment loads in water can be harmful to an aquatic ecosystem in several ways:

- *Suspended sediment acts like sandpaper, scouring and dislodging plants and aquatic insects from the stream bed. Abrasion removes the protective mucous covering the eyes and scales of fish, making them vulnerable to infection, and irritates gills, causing the fish to secrete additional mucous. Prolonged exposure of fish to high sediment concentrations can result in death, due to excessive stress and reduced oxygen absorption. Although a few fish species such as suckers can live in water having high sediment loads, most species cannot.*

- *Suspended sediment absorbs radiant energy, thereby increasing water temperature, which can place further stress on fish. Murky water can also interfere with fish migration and lower the feeding efficiency of fish that use sight to find their prey.*

- *When moving water slows, for example in pools below riffles, sediment settles on the stream bed, filling the spaces between stones and gravel. This reduces the quality of these pools for spawning because the clogged spaces prevent oxygen from reaching developing fish eggs. It also makes the stream bed inhospitable for many types of aquatic insects associated with clean water.*

- *Chemical contaminants, both natural and man-made, tend to adhere to soil particles. Soil erosion from land treated with pesticides and fertilizers, or contaminated with other substances, can carry these contaminants into aquatic ecosystems.*

variable than those draining agricultural land. For all the lakes, phosphorus concentrations tended to be highest in streams draining areas containing livestock operations or cattle pasture. The stream concentrations at Lac La Nonne suggest that as cattle numbers in the watershed increase, phosphorus concentrations in the inflow streams also increase. Studies under the Canada-Alberta Environmentally Sustainable Agriculture Agreement which address agriculture's effects on water are described in **Section 5.7.2**.

Wetlands are also affected by agricultural practices. In the past, many wetlands in Alberta were drained for a variety of reasons: to provide more land for agricultural production, improve weed control, give farmers earlier access to fields, to make it easier to work the land with farm equipment, or to facilitate even crop maturation. As well, waterfowl feeding on nearby crops gave added incentive to drain wetlands.

Since European settlement began, about 60 percent of sloughs/marshes in the settled area of the province have been lost.

- In various parts of the **Grassland Natural Region**, between 5 and 55 percent of wetlands have been lost. In the irrigation districts between 1977 and 1984 (a period that included several years of drought), some 45 percent of wetland losses were due to natural drying and succession, 30 percent to fall/winter grazing, nine percent to cultivation, six percent to canal rehabilitation, five percent to drainage, and the remainder due to unknown causes. Additional wetlands created by irrigation canal seepage have since disappeared as a result of canal system improvements under the Water Management Systems

Improvement Program. Under this program, leaking canal systems are upgraded to achieve better water conservation and reduce soil salinity problems. The remaining wetlands in the Grassland region are considered vulnerable due to the possible effects of changing climate on these generally shallow basins.

- In the **Parkland Natural Region**, many "prairie potholes" have been lost to drainage and drought. Between 1970 and 1990, wetland losses within this region ranged from 21 to 48 percent. The combination of a high density of good quality, small wetland basins and highly productive agricultural areas makes remaining wetlands here vulnerable to loss.

- In settled parts of the **Boreal Forest Natural Region** (other than the Peace River area, which has not been surveyed) losses of sloughs/marshes have ranged from seven to 42 percent. Most of this loss reflects the impact of intensive farming, including the clearing and conversion of forested land to agricultural use. This region, including the Peace River area, is considered more susceptible than others to marsh wetland losses from agricultural activities because of the region's good conditions for arable agriculture and the less permanent nature of the region's marsh wetlands. Drought conditions during the last decade have substantially reduced the region's wetlands, including large lakes and water bodies. Some peatlands have also been converted to agricultural land.

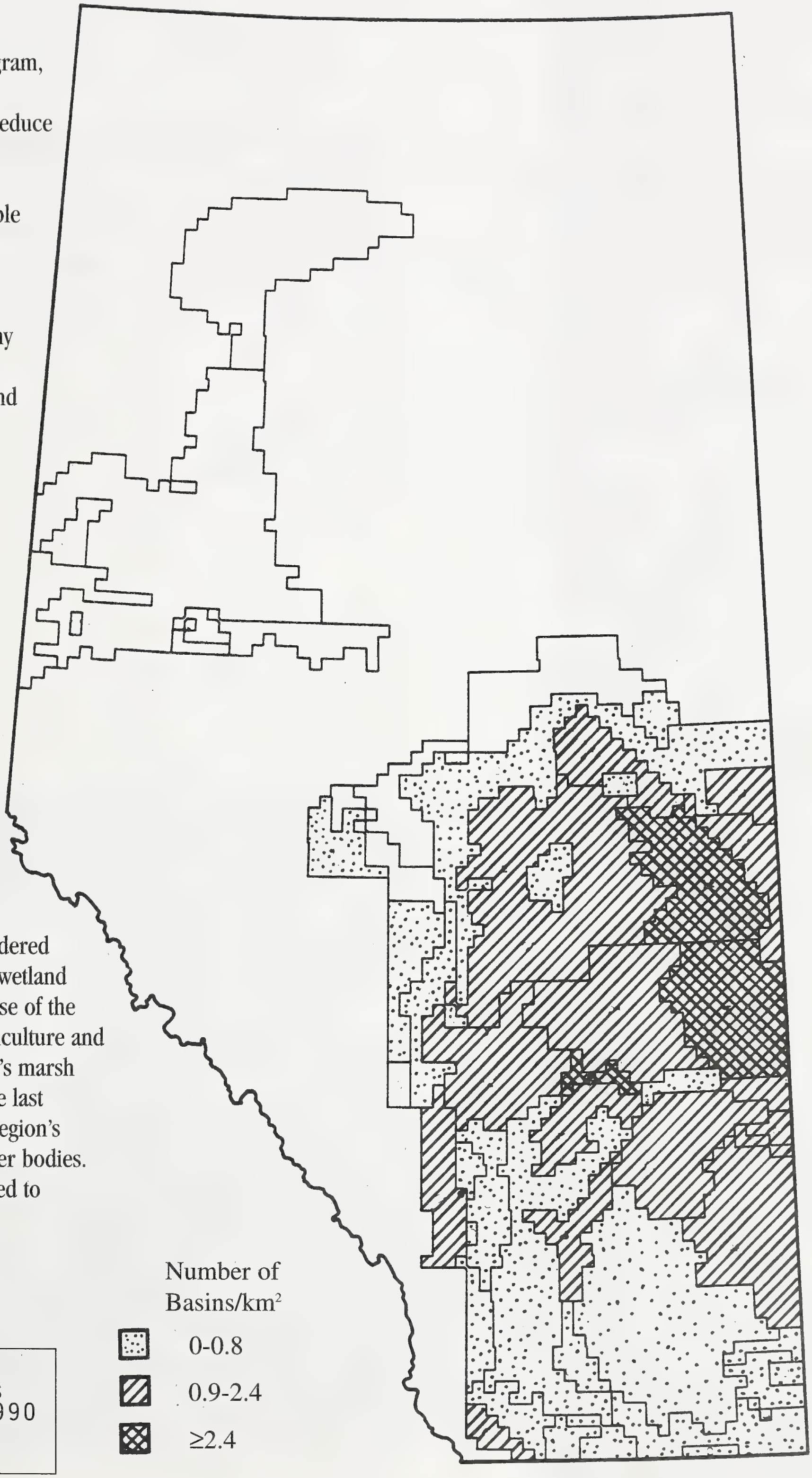


FIGURE 4.17 ESTIMATED NUMBER OF WETLAND BASINS LOST BETWEEN 1970 AND 1990 DUE TO HUMAN ACTIVITY
Source: Strong, *et al.* 1993

Figure 4.17 shows the extent of wetland loss from human activity during the 1970s and 1980s.

The ecological value of wetlands is also influenced by cultivation, burning, haying, or heavy grazing of the land immediately surrounding a wetland. This land normally serves as a buffer zone between the natural area and cropland, and provides nesting cover and habitat for waterfowl and other species using the wetland.

In the agriculture community, attitudes towards wetlands are changing. Many producers recognize the benefits of wetlands for soil moisture, groundwater recharge, and wildlife. A growing number of landowners are participating in cooperative arrangements designed to enhance both wetland habitat and agricultural production **(see Section 5.6)**.

4.3.4 Other Factors Affecting Wetlands

Climate variability has played a significant role in wetland loss. Wetlands that dry out during drought years generally refill in wet years. However, many wetlands are converted to other uses before refilling can occur. Some are drained and filled for roads, housing, and other developments throughout the province. Until recently, there has been little incentive for local governments and developers to avoid or preserve these natural areas in the face of the economic reasons for draining them **(see Section 5.6)**.

4.3.5 Atmospheric Deposition

Industrial and motor vehicle emissions are major sources of substances that enter the atmosphere and are carried over various distances before settling on the landscape, including water bodies.

4.3.5.1 Acidic Deposition

Some industrial emissions contain sulphur and nitrogen oxides, the main sources of acidic deposition (commonly known as "acid rain"). This deposition can occur in either "wet" (rain, snow, fog) or "dry" (solids, gases, or aerosols) form. In Alberta, dry deposition predominates and occurs mainly in the central Alberta and Fort McMurray areas (Cheng 1994). Acid deposited on surface waters may affect aquatic ecosystems, depending on the ability of the water and surrounding soils and bedrock to neutralize the acid. When this buffering capacity is exceeded, water becomes acidic. Research in other jurisdictions has shown that in surface waters exceeding certain levels of acidity, many aquatic species decline and the entire ecosystem undergoes drastic changes in structure and function.

Most soils and lakes in Alberta have good buffering capacity. However, some lakes are exceptions, as described in **Section 5.5**. Although oil sands plants in the Fort McMurray area have been the largest emitters of sulphur dioxide in the province, emissions are declining. For example, Suncor Inc. reduced sulphur dioxide emissions by 75 percent in 1996. However, the fact that acidifying emissions could increase with the future expansion of oil sands developments has led to continued work in monitoring and protecting Alberta's surface waters **(see Section 5.5)**.

4.3.5.2 Long-Range Atmospheric Transport

Some air pollutants are transported over thousands of kilometres (international and inter-continental transport). This long-range transport of acidifying substances does not pose a significant threat to Alberta water bodies. However, based on sediment and global air trajectory analyses, the Northern River Basins Study found that global air currents may carry and deposit persistent organic pollutants into the northern river basins' aquatic ecosystems. Several international agreements and protocols address this long-range transport of air pollutants.

5.0 MANAGEMENT OF AQUATIC ECOSYSTEMS

5.1 RECENT DEVELOPMENTS IN LEGISLATION AND POLICY

(Ducks Unlimited Canada)

5.1.1 *THE WATER ACT*

The *Water Resources Act*, in effect since 1931, incorporated an approach to water management dating back to before the turn of the century. The Act's primary aim was to ensure the orderly allocation of water and provide a secure water supply to water users. These goals were considered appropriate for the time but pose difficulties for managing water in the manner and for the multiple purposes society now considers important.

The process of updating Alberta's water management policies and legislation began in 1991. Public input was sought for developing new policies and legislation to address current and future water management needs. The extensive public consultation process included public workshops, open houses, distribution of discussion documents, and the appointment of a stakeholder advisory committee to provide advice and recommendations on proposed policy and legislation. With the public input, a new water management policy was developed, and new legislation, the *Water Act*, was passed to implement the policy. The Act is awaiting final proclamation.

Some of the differences between the *Water Resources Act* and the new *Water Act* are shown in **Table 5.1**.

5.1.2 AMENDMENTS TO THE *WILDLIFE ACT*

In 1996, amendments to the *Wildlife Act* were passed that allow for evaluation, designation, and management of any species of fish, wildlife, invertebrate, or plant threatened with extinction in Alberta. This legislation completes the legal framework designed to prevent the loss of any native species from Alberta.

5.1.3 WETLANDS MANAGEMENT POLICY

In 1990, the Alberta Water Resources Commission (AWRC), requested by the provincial government to develop a management policy for wetlands, published *Wetlands: Values and Options: A Draft Policy for the Management of Wetlands in the Settled Area of Alberta*. Public open houses and workshops were held to discuss the draft. The revised policy was adopted by Cabinet in 1993 as an Interim Policy pending development of policy recommendations for wetlands in the non-settled area of the province.

TABLE 5.1 COMPARISON OF THE *WATER RESOURCES ACT* AND THE NEW *WATER ACT*

Water Resources Act	**New *Water Act***
Does not include a legislative basis for water resources planning.	Requires a provincial water management planning framework to be completed within three years of proclamation.
Does not recognize the importance of protecting the aquatic environment.	Requires that a strategy for protecting the aquatic environment be developed as part of the provincial water management planning framework.
Does not recognize the importance of integrating water quantity and water quality.	Includes provisions that promote water conservation and protect water quality.
Does not provide a way for new water users to acquire water rights in basins already fully allocated.	Allows for flexible water management in areas where available water is already fully allocated by allowing transfer of water licences.
Does not encourage licensees to share water in time of shortage.	Allows water sharing among licensees in time of shortage.
Does not deal with the export or interbasin transfer of water.	Prohibits the export and interbasin transfer of Alberta's water.

The Interim Policy sets out the Government of Alberta's goal "to sustain the social, economic and environmental benefits that functioning wetlands provide, now and in the future" (AWRC 1993). The intent is to conserve slough/marsh wetlands in a natural state, mitigate degradation or loss of wetlands, and enhance, restore, or create wetlands in areas where they have been depleted.

Alberta Environmental Protection is responsible for implementing the Interim Policy. This involves:

- Establishing an interdepartmental Wetlands Management Implementation Committee.

- Review by member agencies of ways in which the policy can be implemented within member departments.

- Identification of priority wetland areas for future study (*Characterization of Wetlands in the Settled Areas of Alberta* by Strong et al. 1993).

- Promoting public awareness of wetland benefits through the development of education material.

The interim policy is applied in the approval process involving activities affecting wetlands. For example, where road grades through wetlands are proposed, those responsible for the project may be required to build moats and islands to compensate for wetland areas affected. At the regional level, policy implementation is coordinated through Environmental Resource Committees. These committees include representatives from different divisions in Alberta Environmental Protection and from other departments. They regularly coordinate actions and address issues for the region.

During the development of the settled area wetlands policy, the need for a policy for the non-settled area became apparent. Work on this new policy began in 1992 and led to publication the following year of *Beyond Prairie Potholes: A Draft Policy for Managing Alberta's Peatlands and Non-settled Area Wetlands.* Following public consultation in the fall of 1993, the Alberta Water Resources Commission drafted a comprehensive policy for managing peatlands and slough/marsh wetlands in Alberta. The objectives for peatlands are to formally designate representative, rare and unique peatland ecosystems for preservation, to allow development of peat resources where appropriate, and to minimize and mitigate effects of peatland developments on surrounding land and water. For slough/marsh wetlands, the intent is to conserve them in a natural state, mitigate degradation and restore depleted or degraded wetlands.

5.1.4 Municipal Land Use Policies

The Land Use Policies of Alberta Municipal Affairs supplement the provisions of the *Municipal Government Act*. These policies provide direction to municipalities to plan land use in a manner that embodies the principles of sustainable development and minimizes environmental impact. Municipalities are encouraged to identify areas such as significant fish, wildlife and plant habitat; wetlands; and riparian areas and to establish land use patterns that minimize the loss of these areas or the negative impacts of development on them.

5.2 WATER QUALITY GUIDELINES, STANDARDS AND APPROVALS

5.2.1 Water Quality Guidelines

To protect the various uses of water, the federal and provincial governments have defined maximum limits for many substances. The Canadian Water Quality Guidelines (CWQG) provide specific maximum or minimum concentration limits or other critical levels for a variety of substances. These limits ensure that water quality is adequate for specific uses, including water for drinking, aquatic life, recreation, and agriculture. If a measured concentration of a specific substance does not meet the guideline, the use in question may be impaired. The guidelines are set to provide ample protection, and an occasional exceedance is viewed as a warning sign rather than a cause for alarm.

Water quality guidelines for Alberta's rivers and lakes were first developed in 1970 and updated in 1977 and 1993. Although similar to the Canadian Water Quality Guidelines, Alberta's guidelines were established for the most sensitive use of water. The 1993 Alberta Ambient Surface Water Quality Interim Guidelines

(AWQG) apply to surface waters except in zones close to effluent outfalls, where effluent has not yet mixed with the receiving water (mixing zones). As with any guidelines, the AWQG also may not apply in instances where natural water quality does not meet the guidelines. New Alberta guidelines for the protection of aquatic life are being developed according to a protocol developed in 1996. These new guidelines will replace the 1993 AWQG after extensive review by the public and experts. Using these guidelines will allow better management and evaluation of water quality, including water in mixing zones. The 1996 protocol for developing these guidelines contains instructions on how to use them. The protocol also incorporates scientifically defensible procedures for adjusting provincial guidelines at specific sites, where conditions (biological, physical, or chemical) may be unique.

5.2.2 Effluent Standards and Project Approvals

Alberta's *Environmental Protection and Enhancement Act* contains a number of provisions to protect water resources from impacts of industrial and other activities:

- Subjecting certain sizes and types of proposed projects to an environmental assessment process.
- Requiring approvals for certain construction, operation, and reclamation activities.
- Effluents discharged into water bodies must be approved and meet specific effluent limits at their point of discharge.

The Act establishes a wide range of administrative and legal measures for ensuring compliance with its requirements.

Unlike the obvious "point sources" of pollution, like industrial sites, some land-based activities which produce pollution are not specifically regulated under the Act. If non-point pollution sources cause significant adverse environmental effects, the Act can be used to intervene. Runoff from farmland and urban landscapes are examples of non-point sources of water pollution. Research is underway to determine the mode, extent, and distribution of pollution from these sources
(see Section 5.7).

5.2.2.1 Industrial Effluents

Alberta Environmental Protection sets limits for contaminants released by industrial facilities. The two main methods used to calculate these limits are described below. These limits may be dependent on site-specific circumstances and occasionally, best professional judgement.

(1) Determining discharge limits that minimize contaminant releases within existing technical and financial constraints. These limits are often based on best available technology and for most substances, provide a high level of water quality protection.

(2) Determining discharge limits necessary to protect water quality in the receiving water body. This approach takes water quality conditions at the site into account, as well as other uses of the water body. Effluents containing a single regulated substance are restricted in concentration to meet Alberta's Surface Water Quality Interim Guidelines. Effluents that are a mixture of regulated substances must be non-toxic in the receiving water, as determined by toxicity tests. These tests measure the whole effluent's acute and chronic toxicity to aquatic organisms. As shown in **Table 5.2**, several different species of plants and animals can be used as test organisms. These species are sensitive representatives of the categories to which they belong, and the range of their responses, when considered together, should ensure protection of most aquatic ecosystems.

TABLE 5.2 WHOLE EFFLUENT TOXICITY TESTS

Category/Species	Test	Effects examined
Vertebrate: rainbow trout	acute – 96 hrs	survival
Invertebrate: zooplankton (*Daphnia magna*)	acute	survival
Invertebrate: zooplankton (*Ceriodaphnia dubia*)	chronic	survival and reproduction
Vertebrate: fathead minnow larva	sublethal – 7 days	growth and survival
Plant: freshwater alga *(Selenastrum capricornutum)*	chronic – 4 days	growth

A *Water Quality Based Effluent Limits Procedures Manual* has been developed by Alberta Environmental Protection to guide industry with regard to water quality limits for discharges to lakes, rivers, and streams. A computerized modelling tool has also been developed to enable licensed dischargers to calculate the potential for any effluent to meet or exceed water quality guidelines.

For the past 25 years, industries have been required to monitor certain water quality or flow characteristics as part of their operating approvals. Alberta Environmental Protection reviews the monitoring data and spot checks water samples. Approvals are reviewed on an ongoing basis and in more detail every ten years when they are being considered for renewal. If deemed necessary, more restrictive limits or additional monitoring requirements may be imposed. Beginning in the early 1990s, as industrial approvals have come up for renewal, some companies have been asked to determine the impact of their discharge on the receiving water body.

There are also provisions under the federal *Fisheries Act* requiring pulp mill operators to monitor, on a three-year cycle, environmental effects on rivers into which they discharge effluent. Alberta Environmental Protection also conducts independent effluent monitoring at each mill, twice per year.

5.2.2.2 MUNICIPAL WASTEWATER

Sewage treatment plants must meet standard and design specifications set out in *Standards and Guidelines for Municipal Water Supply, Wastewater, and Storm Drainage Facilities* (Alberta Environment 1988). Treatment options under these standards and guidelines include mechanical treatment facilities (such as activated sludge plants, extended aeration plants, and rotating biological contactors) and lagoon systems **(Section 4.2.2)**.

Mechanical treatment facilities discharge continuously into a receiving stream or river under a licence that specifies effluent standards to be maintained. The discharge allowed is based on the volume of flow in the receiving stream or river. A minimum dilution of 10:1 (receiving:discharge water) is required for mechanical plants with continuous discharges. Where receiving streams are unable to dilute to this extent, effluent is stored, usually over the winter, and released during high flows in spring. Effluent standards for mechanical treatment plants are shown in **Table 5.3**.

Daily or weekly monitoring and monthly reporting of these parameters is required. To monitor compliance with these standards, some effluent samples are split and tested by both the treatment plant laboratory and Alberta Environmental Protection.

Tertiary treatment has been installed in some larger municipalities, and others will be required to install this advanced level of treatment by the year 2005. Allowable effluent nutrient levels at present are: phosphorus 1 mg/L, nitrogen from ammonia 5 mg/L in summer and 10 mg/L in winter, and faecal coliform 200/100 mg/L.

Lagoons must also meet design standards and configurations specified in the *Standards and Guidelines for Municipal Water Supply, Wastewater, and Storm Drainage Facilities.* Based on average daily flow, these standards are the strictest in Canada, requiring wastewater detention in multiple cells for treatment and 12 months storage before discharge into a watercourse. A study of lagoon effluent quality commissioned by Alberta Environmental Protection in 1994 found that lagoons throughout the province have effluent quality similar to, or better than, effluent from mechanical treatment plants. Because of their high effluent quality and low operational needs, lagoons are not required to report on a monthly basis.

Some municipalities dispose of treated effluent using methods that do not involve discharge into surface water. In southern and central Alberta, effluent from lagoons is being used to irrigate certain agricultural crops. In some small lagoons, the water is simply allowed to evaporate.

Sewage treatment produces a residue called sludge. A number of sludge treatment and disposal options exist and are used in the province. Most sludge residue is applied to land in various forms for fertilizing and soil conditioning, subject to environmental requirements. Since 1995, sludge from municipal wastewater treatment plants in the Edmonton and Calgary area - accounting for almost 95 percent of all wastewater sludge in the province - has been disposed of by spreading it on about 3000 hectares of land.

5.2.2.3 Surface Water Project Approvals

Projects that may affect water management or alter bed or shoreline (such as stream crossings, sand and gravel removal, or shoreline erosion protection) require permits or licences **(see also Section 4.3.1)**. Conditions to protect the aquatic environment may be specified in the approval. For example, a project's timing may be restricted in order to protect spawning fish.

Table 5.3
Limits for Municipal Wastewater Treatment Effluent

Parameter	Mechanical plants serving over 20 000 population	Mechanical plants serving less than 20 000 population
Total suspended solids	20 mg/L*	25 mg/L
Biochemical oxygen demand	20 mg/L*	25 mg/L

*some older plants are allowed 25 mg/L until upgrading

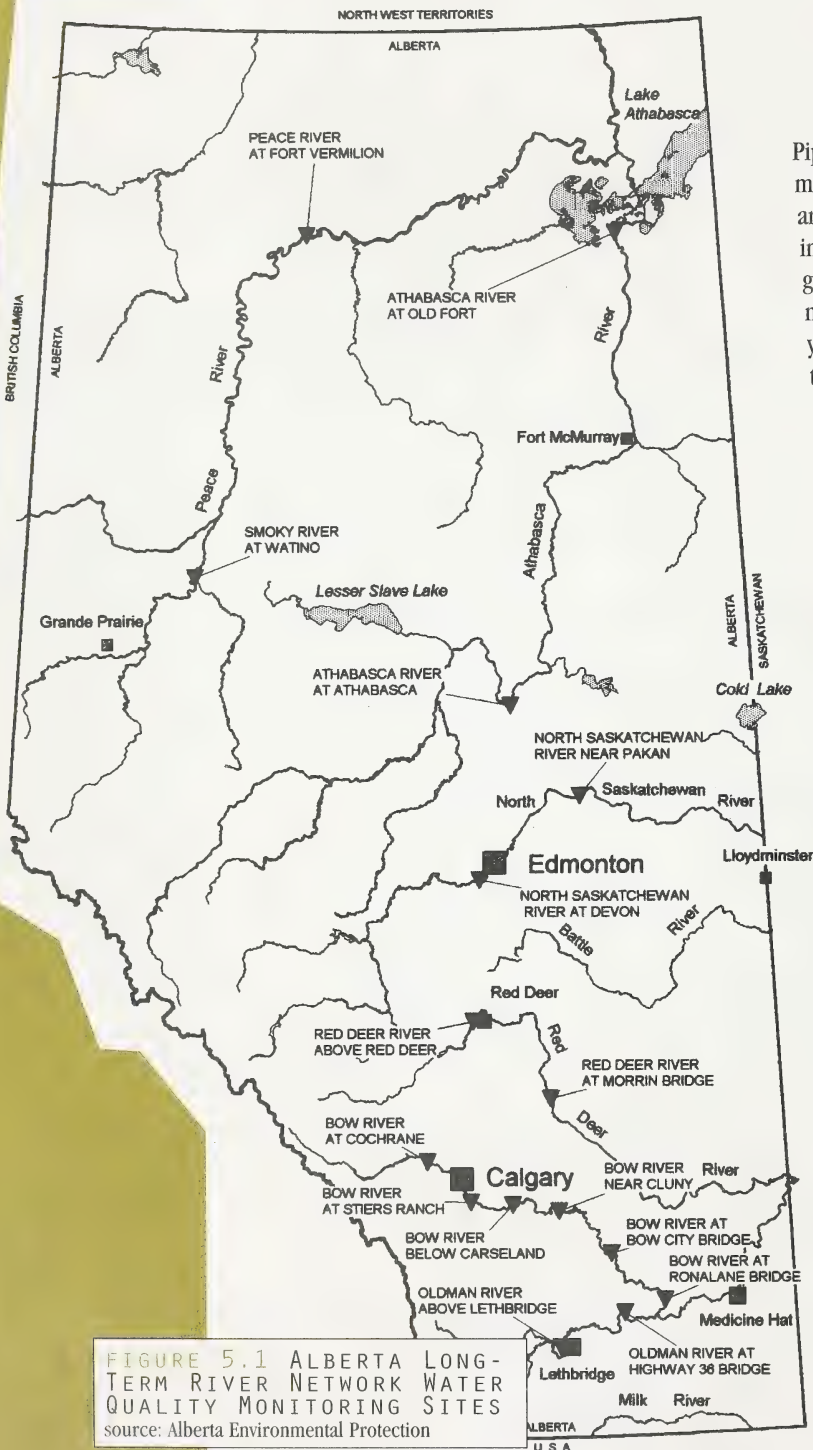


FIGURE 5.1 ALBERTA LONG-TERM RIVER NETWORK WATER QUALITY MONITORING SITES
source: Alberta Environmental Protection

Pipelines must be buried in such a manner that scouring from floods and ice will not rupture them. For instance, pipelines carrying sweet gas or non-polluting materials must be placed below the 1:50 year bed-scour depth, whereas those carrying sour gas, oil, or other chemicals must be placed deeper, below the 1:100 year bed-scour depth. Operational guidelines for industry are found in *Stream Crossing and Design Guidelines* (1985) and *Application Procedures for Buried Pipeline(s) Crossing a Watercourse or Waterbody* (1993).

5.3 WATER QUALITY MONITORING

5.3.1 WATER QUALITY MONITORING BY ALBERTA ENVIRONMENTAL PROTECTION

Alberta Environmental Protection monitors an array of chemical and physical parameters on a monthly basis upstream and downstream from cities and other significant discharge sources on the mainstems of major rivers. This long-term program to detect water quality trends involves 16 sites **(Figure 5.1)**.

Substances and conditions monitored at these river network sites and guidelines for these parameters are listed in **Appendix C**. Other parameters that reflect water quality are monitored, although there may be no associated guidelines. Examples include alkalinity, hardness (amount of dissolved calcium and magnesium), major ions (sodium, carbonate, sulphate, chloride, calcium, magnesium, potassium), turbidity, organic carbon, and chlorophyll *a*. Pesticides are also monitored at these sites. In 1995 the list of pesticides monitored was changed to reflect recent trends in pesticide use.

In some river studies, trace organics are also monitored. These include polychlorinated biphenyls (PCBs) and 90 "priority pollutants" identified by the U.S. Environmental Protection Agency. Biomonitoring with benthic invertebrates, benthic algae, and macrophytes has also been used to complement chemical evaluation of water quality.

Shorter-term, site-specific water quality evaluations are also carried out on rivers, lakes, and reservoirs to support regulatory, water management, and assessment functions. **Figures 5.2** and **5.3** show the sites monitored for these purposes between 1970 and 1995. Monitoring stations have also been established on the Peace and Athabasca rivers for monitoring of potential pulp mill effects on water quality.

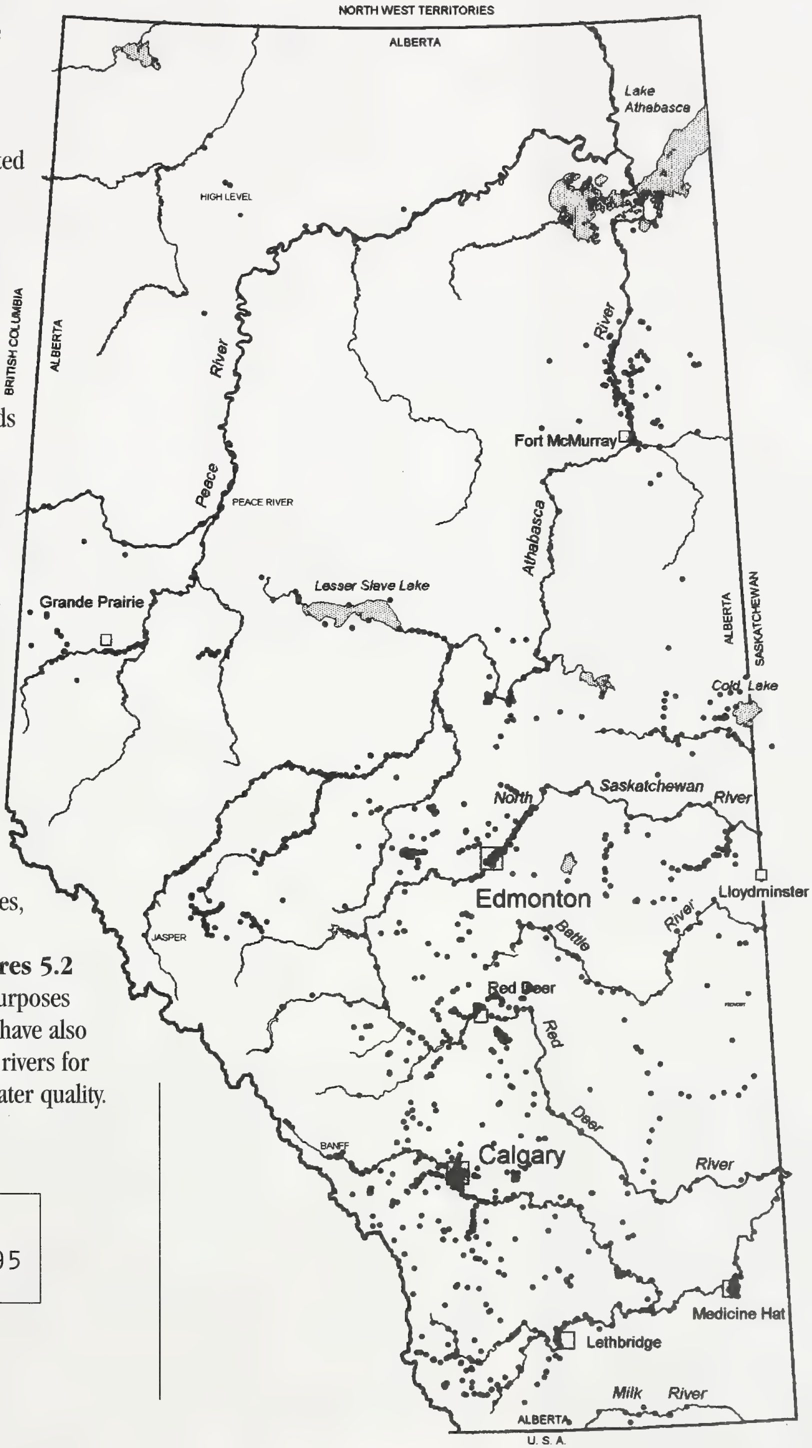


FIGURE 5.2 ALBERTA RIVERS AND STREAMS WATER QUALITY MONITORING SITES, 1970-1995
source: Alberta Environmental Protection

Natural Flows

The amount of water a province or country must pass on to downstream jurisdictions is based on a percentage of the yearly natural flow. The natural flow in a stream or river is the amount of water a stream or river would have without interference from human activity. To calculate natural flows, streamflow measurements are taken at some 50 sites within the province and adjusted to account for the amounts of water used.

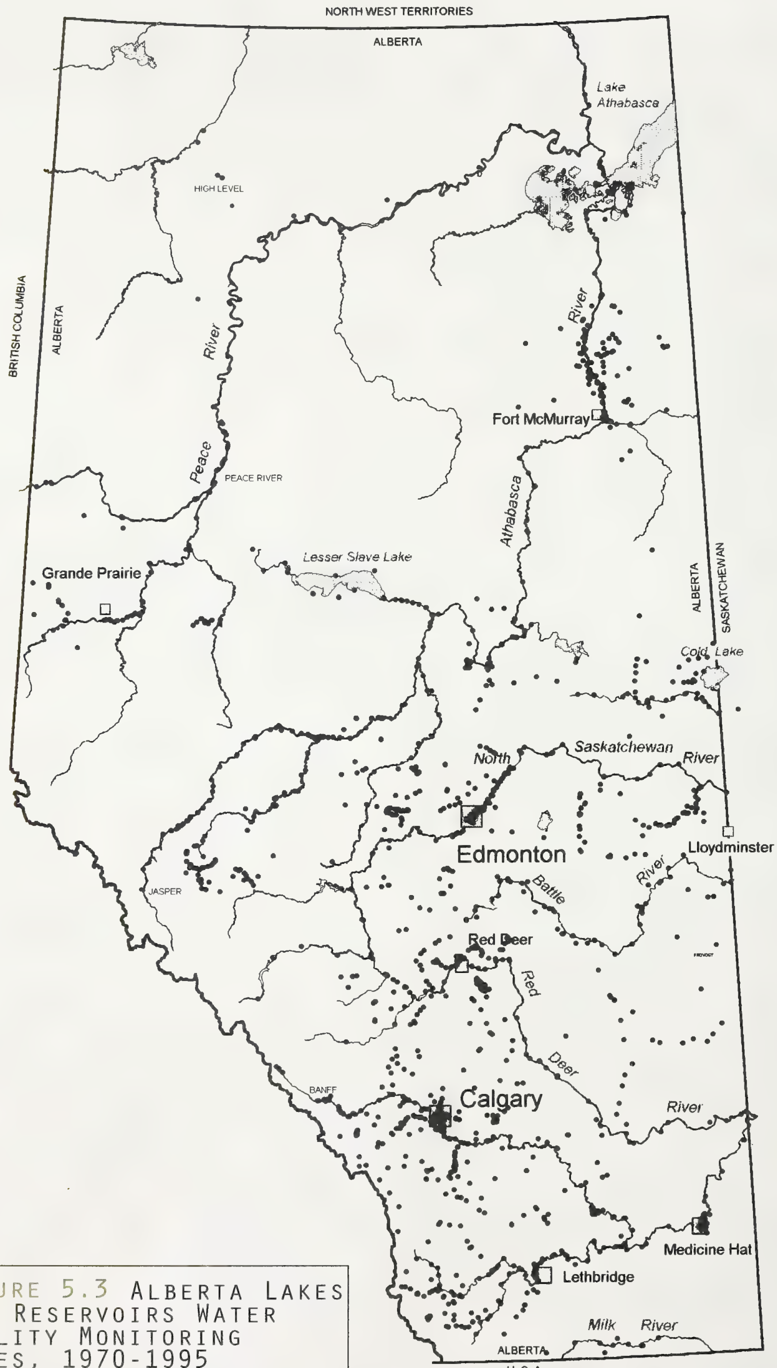


FIGURE 5.3 ALBERTA LAKES AND RESERVOIRS WATER QUALITY MONITORING SITES, 1970-1995
Source: Alberta Environmental Protection

5.3.2 Interprovincial Monitoring

To ensure that water flowing from one province into another is shared fairly, Canada and the provinces of Alberta, Saskatchewan, and Manitoba established the Prairie Provinces Water Board (PPWB). Under the 1969 Master Agreement on Apportionment administered by the PPWB, Alberta is entitled to 50 percent of the natural flow of an interprovincial river before it enters Saskatchewan. Apportionment agreements are also in place between the U.S. and Canada and Alberta and Saskatchewan for the Milk River Basin **(Section 6.5)**.

Under the Prairie Provinces Water Board Water Quality Agreement in 1992, water quality objectives are also specified for the eastward-flowing Beaver, North Saskatchewan, Battle, Red Deer, and South Saskatchewan rivers at the Alberta-Saskatchewan border. Like the Canadian and Alberta water quality guidelines, the PPWB objectives are numerical concentrations or statements of limits to chemical, physical or biological variables to protect water users, including aquatic life. However, unlike the other two water quality guidelines, they are specific to each river, reflecting the rivers' individual characteristics and uses. Environment Canada monitors the water quality on each river reach. If an objective for a river is not met, the PPWB reviews the situation and makes recommendations on how to resolve the problem.

Under a PPWB contingency plan, downstream provinces and member agencies are informed of any unusual water quality condition, including surface spills, that might harm the water quality of eastward-flowing interprovincial streams or interprovincial aquifers, or cause public concern. All agencies are alerted so that they can take appropriate action to minimize public health hazards and environmental effects.

Environment Canada has also collected pesticide data since 1971, mostly in national parks where the influence of atmospheric transport can be assessed, and at the provincial boundaries for the PPWB.

5.4 RIVER BASIN PLANNING AND MANAGEMENT

5.4.1 Approach

Water management in Alberta focuses on the province's five major drainage basins and many sub-basins, although many programs and strategies apply throughout the province. This river basin framework is consistent with an ecosystem approach to water management, since lakes, rivers, and wetlands within a drainage area are interconnected.

Integrated land and water use planning for some basins and sub-basins is also underway. Examples include the Red Deer River Integrated Management Plan **(Section 6.4)** and the Lesser Slave Lake Integrated Management Plan.

5.4.2 Instream Needs and Objectives

As demand for water from Alberta's rivers increases, water managers need to know the amount of water required to support the aquatic life and human instream uses of the river, such as boating and other forms of recreation. Water management planning includes the assessment of these instream uses for individual rivers or river reaches.

The range of instream uses that may be assessed has broadened over the past decade. These vary from the streamflow requirements of a few sportfish species to considerations such as:

- Flow requirements for riparian vegetation.
- Water quality and flow requirements for ecosystem health and diversity.
- Water quality and flow requirements for recreational uses and aesthetics.

Our ability to assess instream needs has improved over the course of these studies, as has our understanding of the characteristics of individual rivers and the aquatic life they support.

Rivers for which instream flow needs studies have been initiated are shown in **Table 5.4**. An example of instream guidelines is shown in **Figure 5.4**. These guidelines were developed to support trout stocked in the Oldman River after construction of the Oldman Dam **(see Section 6.4)**.

After an instream flow needs study has been conducted, instream objectives or recommendations for managing river flow and water quality are made with participation of stakeholders. These objectives must consider not only the instream flow needs assessment but also existing effluent and water licences, other uses of the river, and other water management planning considerations. It is not always possible to meet all of these demands on the river. In such cases, alternative scenarios may be assessed and compromise solutions worked out. When dam or other water control structures are involved, operating plans to achieve the recommended flows are developed.

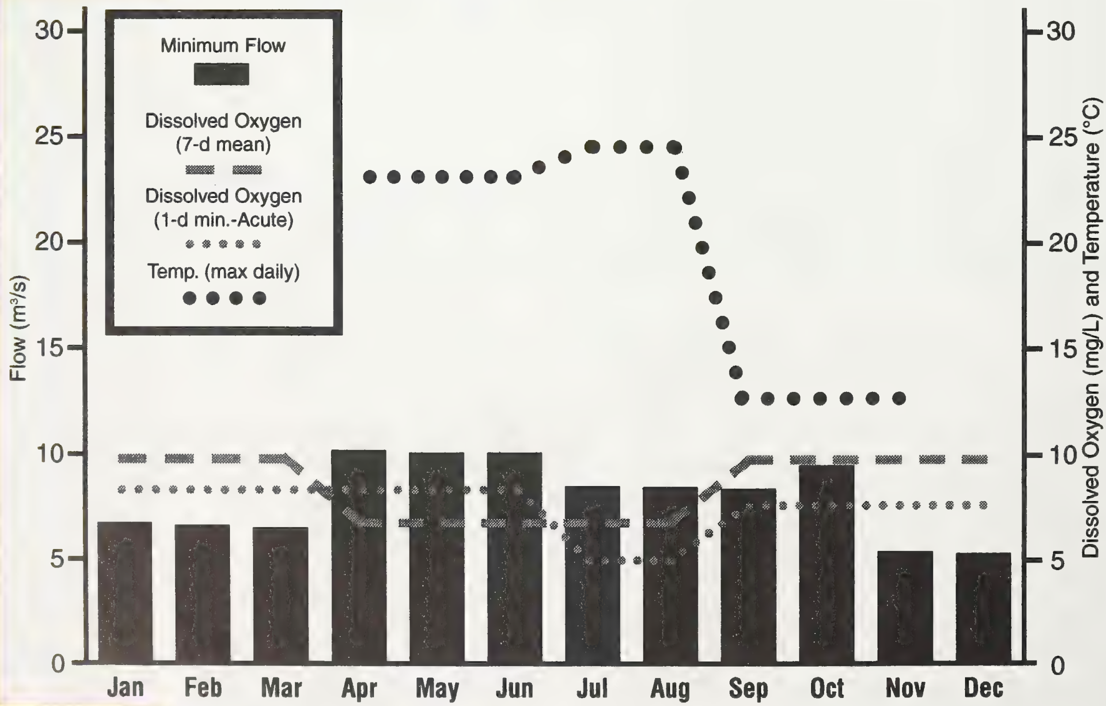


FIGURE 5.4 INSTREAM FLOW GUIDELINES TO PROTECT FISH AND FISH HABITAT IN THE OLDMAN RIVER UPSTREAM OF FORT MACLEOD
source: Alberta Environmental Protection

River	Instream needs evaluated	Fish species evaluated	Status of evaluations
South Saskatchewan River Basin			
Bow River Sub-basin			
Bow River	Fisheries, riparian vegetation and wildlife, water quality, recreation.	Rainbow trout, brown trout, mountain whitefish.	In progress.
Sheep River	Fisheries, water quality.	Rainbow trout, mountain whitefish.	In progress.
Elbow River	Fisheries, water quality, recreation.	Being determined.	To begin in 1997.
Kananaskis River	Fisheries, recreation.	Brown trout, mountain whitefish.	In progress.
Highwood River	Fisheries, riparian vegetation, water quality, aesthetics.	Rainbow trout, mountain whitefish.	Completed (part of EIA).
Pekisko Creek	Fisheries, stock watering, aesthetics.	Rainbow trout (all life stages).	Completed.
Oldman River Sub-basin			
Oldman River	Fisheries, water quality (river and reservoir), water quantity, riparian vegetation, recreation (river and reservoir).	Rainbow trout, brown trout, walleye, sauger.	Completed; ongoing monitoring.
Waterton River	Fisheries, water quality, water quantity.	Rainbow trout, cutthrout trout, brown trout, mountain whitefish, walleye.	Completed.
St. Mary River	Fisheries, water quality, water quantity.	Rainbow trout, cutthrout trout, brown trout, mountain whitefish, walleye.	Completed.
Belly River	Fisheries, water quality, water quantity.	Rainbow trout, cutthrout trout, brown trout, mountain whitefish, walleye.	Completed.
Willow Creek	Fisheries, riparian vegetation.	Rainbow trout, brown trout, bull trout.	Completed.
Red Deer River Sub-basin			
Red Deer River	Fisheries, riparian vegetation, water quality, recreation.	Brown trout, mountain whitefish, walleye, goldeye.	Completed.
South Saskatchewan River Sub-basin			
South Saskatchewan River	Fisheries, riparian vegetation, water quality.	Being determined.	In progress.
North Saskatchewan River Basin			
Sturgeon River	Fisheries.	Northern pike.	Completed.
Vermilion River	Fisheries.	Walleye, northern pike.	Completed.

TABLE 5.5 PRIORITY RIVER CLASSIFICATION FOR CHRS NOMINATION

Unless otherwise noted, the entire river has been classified.

River	Classification AA	A
Athabasca (Three sections)		X
Battle (One section)		X
Beaver		X
Belly		X
Bow (One section)	X	
Castle	X	
Clearwater (Athabasca River Basin)	X	
Clearwater (North Saskatchewan River Basin)		X
Crowsnest		X
Highwood	X	
Little Smoky		X
Milk	X	
North Saskatchewan (Three sections)	X	X
Oldman (Two sections)	X	
Peace (Two sections)	X	
Red Deer (Two sections)	X	X
Sheep		X
Slave		X
Smoky		X
South Saskatchewan	X	

5.4.3 PRESERVING ALBERTA'S RIVER HERITAGE

The Canadian Heritage Rivers System (CHRS) has been established by the federal, provincial and territorial governments to recognize outstanding Canadian rivers and to ensure future management to protect their heritage value. Rivers or river reaches deemed to be outstanding representatives of natural heritage, human heritage, or recreational values are nominated for inclusion in the CHRS by the government following approval by local authorities and stakeholders.

At the request of local authorities, a background study is initiated to identify the values for which the river may be nominated and the relevant management issues.

The Canadian Heritage River Board reviews each nomination and determines the river's suitability for inclusion. Suitability is based on criteria related to the integrity of the values for which the river was nominated and the ability t maintain these values in the future. Once a rive has been nominated, a river management planning study is undertaken. The river is then officially designated a Canadian Heritage River.

Determining Instream Flow Needs for Fish

Calculating instream flow needs for fish involves scientific analysis of both the streamflow and the water quality needs of the particular species.

Once species have been selected on which to base flow management, information is gathered about the presence of all life stages of the species (fry, juvenile, adult, spawning), and their use of the river's habitat. In clear streams, such studies involve observing fish in the river during open water season. Hydraulic measurements are taken at the same time.

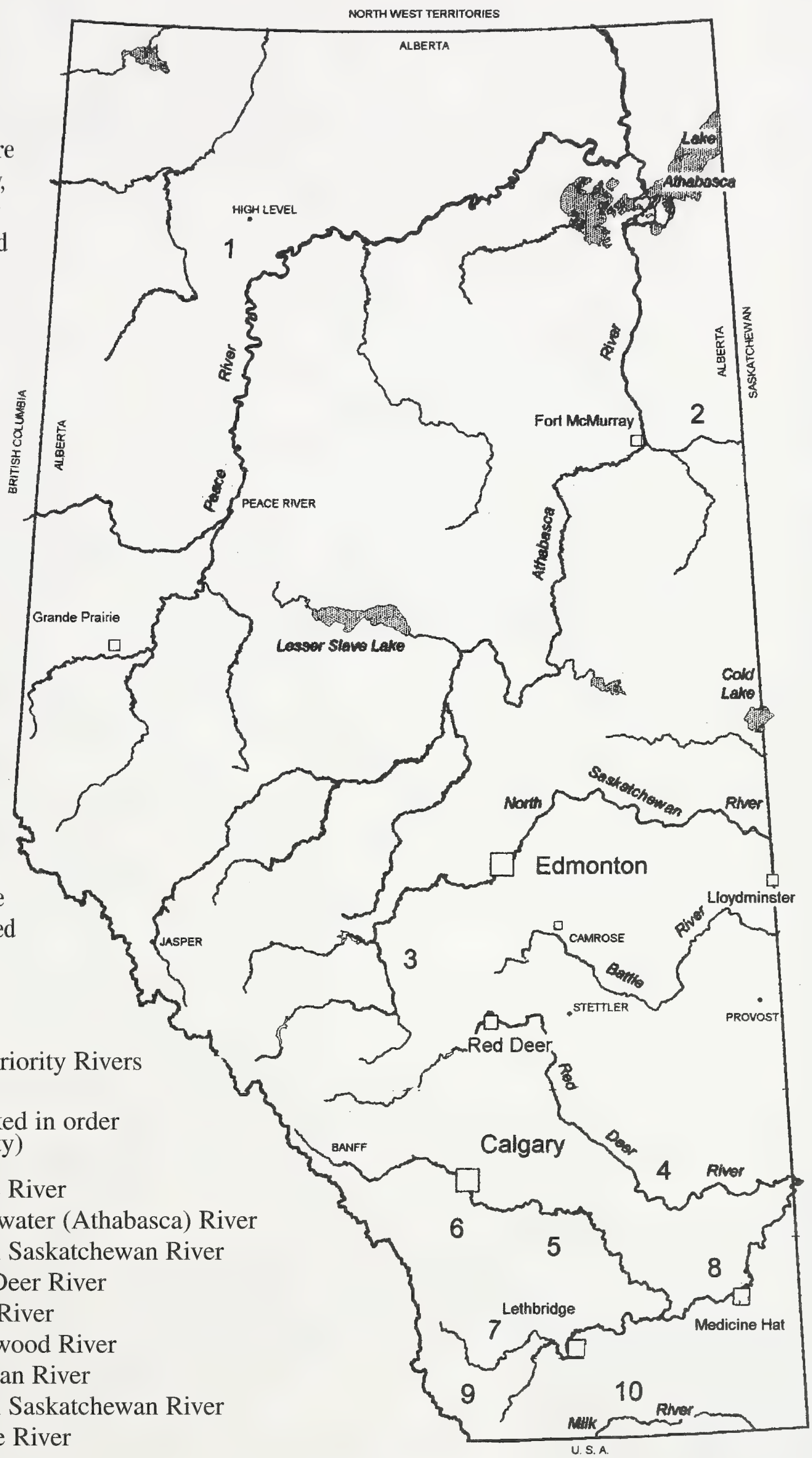
Next, critical water quality needs of each life stage are identified (such as, water temperature for incubation and the dissolved oxygen levels required by embryos or adults). In nature, fish have adapted to survive some periods of poorer water quality brought on by drought or other natural occurrences. To see how often critical water quality objectives have not been met, historical streamflow records are used in a computer simulation model of streamflow/water quality relationships. This information is used to determine minimum necessary water quality levels. Minimum flows required to meet these water quality needs can then be calculated.

Based on the information gathered about the river's use by the species' various life stages, a flow regime is recommended for each river reach for each week of the year. Alternative water management scenarios can then be evaluated based on streamflows that closely approximate these recommendations. Decisions may then be made as to whether these recommendations can be fully implemented in order to meet other licensed users' needs. Public input is obtained and considered in making these decisions.

FIGURE 5.5 CANADIAN HERITAGE RIVERS SYSTEM PRIORITY RIVERS

eritage Rivers are monitored annually for ianges in the conditions for which they were esignated, and for changes in river integrity, articularly water quality. At least once every) years, the Canadian Heritage Rivers Board eviews each designated river.

berta is a full participant in the CHRS rogram. The headwaters of the Athabasca iver in Jasper National Park and those of e North Saskatchewan River in Banff ational Park are now designated as eritage Rivers. Begun in 1994, the rovincial government's Alberta Rivers udy has evaluated 72 rivers on the basis unique features, number of natural ones through which the river passes, and her data. From this, 39 rivers have been lected for further evaluation according a series of evaluation criteria within the HRS theme categories of natural eritage, human heritage, and recreation lues. A short list of 22 rivers has since een developed on the basis of how well ich river met general and specific tegrity guidelines, and how well it could be anaged. The highest scoring rivers are listed Table 5.5. Rivers in category "A" have a imber of outstanding features (historical, ivironmental and/or creational) that recommend em for further study. The ghest status (AA) indicates no iparent serious management incerns. Rivers in these tegories are shown in **Figure 5**. It is expected that some or of these rivers will be ominated. However, ominations are not limited to ese rivers. In addition, if ore information becomes



CHRS Priority Rivers

(not ranked in order of priority)

1. Peace River
2. Clearwater (Athabasca) River
3. North Saskatchewan River
4. Red Deer River
5. Bow River
6. Highwood River
7. Oldman River
8. South Saskatchewan River
9. Castle River
10. Milk River

LEGEND

1. Airdrie
2. Athabasca
3. Black Diamond/Turner Valley
4. Bragg Creek
5. Calgary
6. Camrose
7. Canmore
8. Cardston
9. Cochrane
10. Crowsnest
11. Drumheller
12. Edmonton
13. Fort MacLeod
14. Fort McMurray
15. Fort Vermilion
16. High River
17. Hinton
18. Lacombe
19. Lamont
20. Lethbridge
21. Manning
22. M.D. of Big Horn
23. M.D. of Rocky View
24. Medicine Hat
25. Nose Creek
26. Okotoks
27. Peace River
28. Pincher Creek
29. Ponoka
30. Red Deer
31. Rochester
32. St. Albert
33. Sangudo
34. Slave Lake
35. Sundre
36. Vegreville
37. Watino
38. Whitecourt

✻ Floodplains Designated to December 31, 1995

▲ Technical Work in Progress 1994-1995

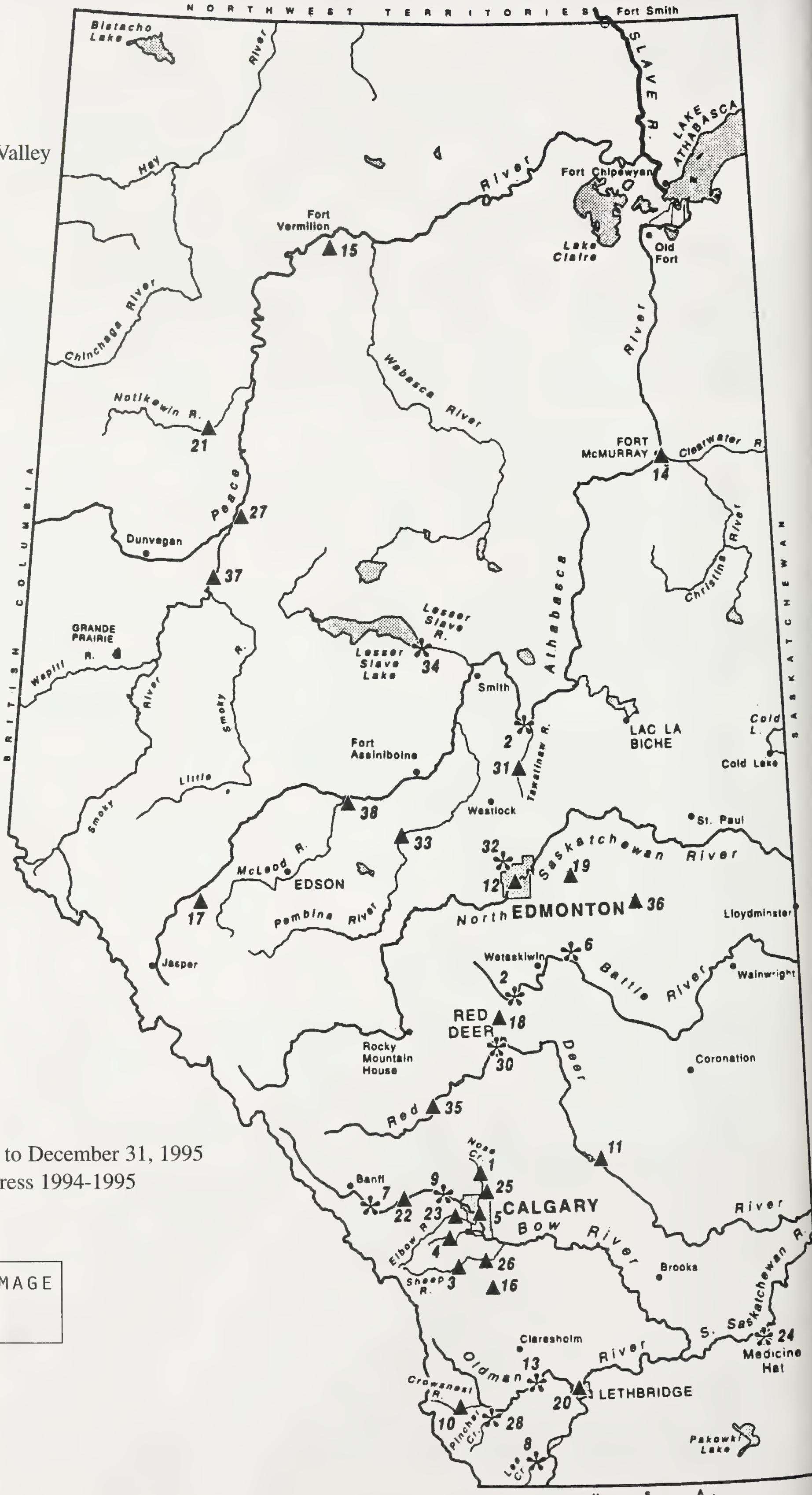


FIGURE 5.6 FLOOD DAMAGE REDUCTION PROGRAM - COMMUNITY LOCATIONS

available on a river not presently in the highest categories, its classification may change. Of these rivers, the Clearwater/Christina was nominated as a Canadian Heritage River in 1996.

5.4.4 Preventing and Reducing Flood Damage

Major floods sometimes result in significant property damage. For many years, structures such as dykes and dams were used to minimize such damage. However, restricting development in flood-prone areas is now seen as a more effective way to reduce and prevent flood damage in urban areas. A mapping program conducted under the Canada-Alberta Flood Damage Reduction Program is identifying flood risk areas in towns and cities throughout Alberta. The mapping uses a multi-zone approach enabling local governments to manage development in floodplains. **Figure 5.6** shows communities for which flood-risk areas have been mapped and designated and the communities for which mapping is in progress as of December 1995.

Rural areas are also subject to flooding, but mapping these areas would not be cost-effective. Furthermore, local residents often have the most knowledge about the location of flooding limits. One example of efforts to reduce rural flood damage is the Pembina River Valley Floodplain Management Study. The Public Advisory Committee for the study reviewed many options for limiting flood damage, including a flood control reservoir and dam, crop insurance, floodproofing, shoreline protection, and channel alteration.

5.4.5 Monitoring Water Levels

High water levels can endanger communities and farms, and low levels can cause problems for industry, irrigation, and aquatic life. To avoid this, Alberta Environmental Protection monitors river flow conditions, mountain snow conditions, ice cover, status of reservoir storage, and lake levels throughout the province. Over 480 river flow and water level stations are operated through a federal-provincial cost-sharing agreement. Data from these and from automated weather stations are transmitted by satellite and telephone to Edmonton. There it is analysed and used to prepare weekly river reports, river and lake flood warnings, and information about water supply conditions to local authorities, irrigation districts, hydroelectric power companies, and the general public. An automated river report telephone service provides recorded messages summarizing current river conditions. Information is also provided on the Alberta Environmental Protection Internet home page.

Alberta Environmental Protection staff watch for predictions of heavy rainfall in river headwaters and identify areas at risk of flooding. During emergencies, field staff check instrument readings in flood risk areas and take manual measurements when necessary.

5.5 LAKE MANAGEMENT

5.5.1 Lake Studies and Lake Management Planning

Alberta Environmental Protection conducts several types of lake studies. These include:

- Regional lake water quality assessments, especially for nutrients and algae.
- Long-term studies to monitor change, including changes influenced by climate.
- Assessments of effects of activities, such as water level manipulation or watershed development.

The department also helps develop water quality management plans for recreational lakes. **Figure 5.7** shows the general procedure followed in developing a management plan. The first step, taken by stakeholders,

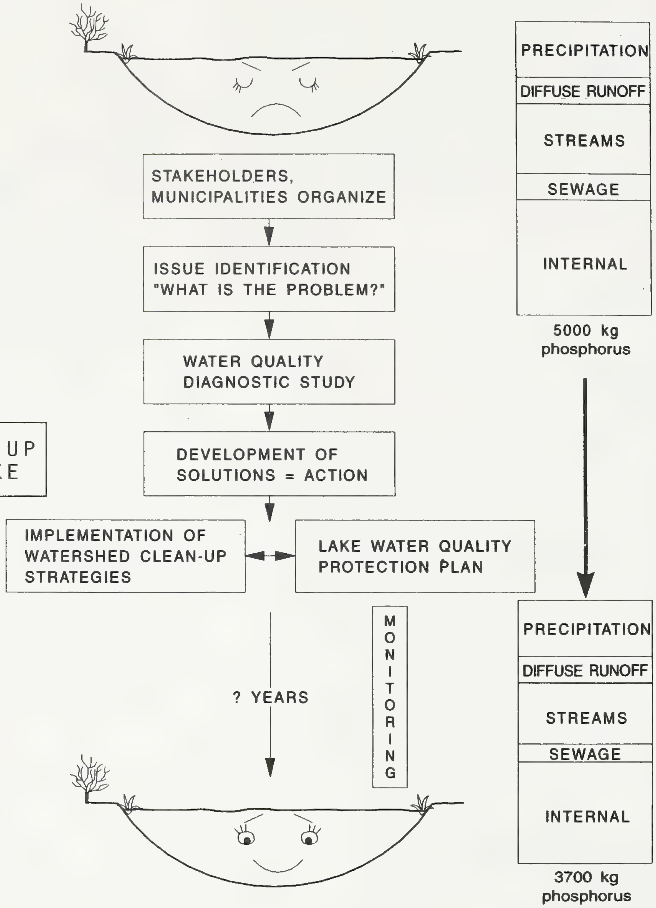


FIGURE 5.7 THE CLEAN-UP OF A HYPOTHETICAL LAKE

is to define the problem clearly. A diagnostic study is then done to determine relevant conditions in the lake. Among other things, this usually involves a detailed assessment of nutrient loading (particularly phosphorus) from all sources. Stakeholders then focus on the sources easiest to control and develop a clean-up plan, if necessary, with technical advice from Alberta Environmental Protection. Implementing any plan requires considerable effort on the part of lake users in order to raise support and funding for clean-up actions. Water quality sampling is conducted over several years to obtain as much information as possible about lake functions and the response to actions taken.

Lake Advisory Committees have been established by the Minister of Environmental Protection for certain lakes in Alberta. The committees' purpose is to make recommendations or provide advice on particular local water management concerns. There have been nine lake advisory committees: Buffalo Bay-Horse Lake, Mann Lake, Sylvan Lake, Chestermere Lake, Wabamun Lake, Lac la Nonne, Pigeon Lake, Buffalo Lake, and Pine Lake.

Case Study: Pine Lake

Pine Lake is a small lake situated in the rolling parkland some 35 km southeast of Red Deer. Formed from two basins in a glacial meltwater channel, the lake is long and narrow (about 8 km by 0.8 km maximum width). Its watershed is large in relation to the area of the lake - approximately 36:1. The lake is also fairly shallow, averaging 5 m in depth. Several intermittent streams enter the lake, and a creek drains it. The water residence time for the lake is about nine years. Approximately half the lake's watershed has been cleared for agriculture, especially livestock operations, and the other half remains forested. The area adjacent to the lake contains approximately 130 summer cottages and homes, five campgrounds, and several church camps.

Pine Lake has always been a relatively productive lake, although sediment core analyses suggest the lake was mesotrophic prior to European settlement. The lake is high in phosphorus and supports abundant aquatic vegetation that is used by waterfowl. Nine species of fish are present, including walleye, northern pike, and yellow perch. The walleye population, derived from a stocking of fingerlings, is classed as "collapsed" **(see Section 5.6.3.2)**. Algal blooms and excessive plant growth sometimes deplete oxygen levels, causing occasional summer fish kills.

Following expressions of concern by local residents about these and other lake issues, the provincial government undertook preliminary studies of these problems in 1989. These studies indicated that the lake might be a good candidate for restoration. In 1991, the Minister of Environmental Protection appointed the Pine Lake Advisory Committee to represent interested parties, including local farmers and residents. Diagnostic studies were begun to evaluate the phosphorus budget in the lake, identify the sources of nutrients in stream sub-basins, evaluate present conditions, and establish baseline data. This work, a combined action of Alberta Environmental Protection and the Advisory Committee, included the following:

- A new bathymetric survey of the lake, mapping the depth contours.
- Monitoring wind speed and direction, air temperature and precipitation.
- Surface hydrology.
- Sampling to obtain depth profiles of temperature, dissolved oxygen, redox, pH and specific conductance.
- Water sampling for nutrient content, algal productivity, and standard chemical analyses.
- Groundwater hydrology sampling using test wells to determine volume and characteristics of groundwater flowing into the lake.
- Sampling to detect leachate from septic systems.
- Bioassay to determine biologically available phosphorus.
- Spectral imaging to determine macrophyte distribution.
- Stream sampling to measure nutrient loadings and identify pollution sources.

Pine Lake was unusually productive in 1992, partly due to warm spring weather. Most phytoplankton present that summer were potentially toxic blue-green algae, and spectral imaging revealed abundant macrophytes. Large amounts of phosphorus were entering the lake during spring via inflowing streams. Lake sediments were found to be a significant phosphorus source, contributing some 60 percent of the lake's total phosphorus. Other contributing factors were streams (33 percent), atmospheric deposition (three percent) and diffuse runoff (three percent). The contribution from sewage was calculated, but not measured directly.

The Pine Lake Restoration Society, which replaced the Advisory Committee, has adopted the goal of "returning to 1900 by 2000" and embarked on a watershed restoration plan in cooperation with the local community, Alberta Environmental Protection, and Alberta Agriculture, Food and Rural Development. This plan focuses on reducing or preventing agricultural runoff, correcting sewage leakage into the lake, and reducing internal phosphorus loading. Agricultural projects completed to date under the plan include moving a livestock wintering area, containing and managing runoff from livestock confinement areas, and providing alternative livestock watering areas. Residential and resort projects have included a survey of private sewage systems, replacing a faulty sewage system, and constructing a new sewage lagoon system by a golf and country club resort. An experimental system for withdrawing water from the deepest zone of the lake has been proposed to reduce the amount of phosphorus escaping from the lake bottom (internal loading).

Current research into the potential effects of agricultural and forestry activities on lakes is described in **Section 5.7**. Other lake research activities are being pursued through Alberta universities and the Alberta Research Council. Various other projects, funded and managed by Ducks Unlimited Canada, Environment Canada, and Alberta Environmental Protection, are also underway.

5.5.2 Identification of Acid-sensitive Lakes

To determine whether acidic deposition **(see Section 4.3.5)** poses a threat to Alberta's lakes, the buffering capacity (as measured by alkalinity levels) of more than 1100 lakes in the province was evaluated between 1983 and 1993. This work used government and university data supplemented by Alberta Environmental Protection field surveys.

As a result of these evaluations, five percent of Alberta lakes are now classified as highly sensitive to acidic deposition. These lakes occur in three different regions **(Figure 5.8)**:

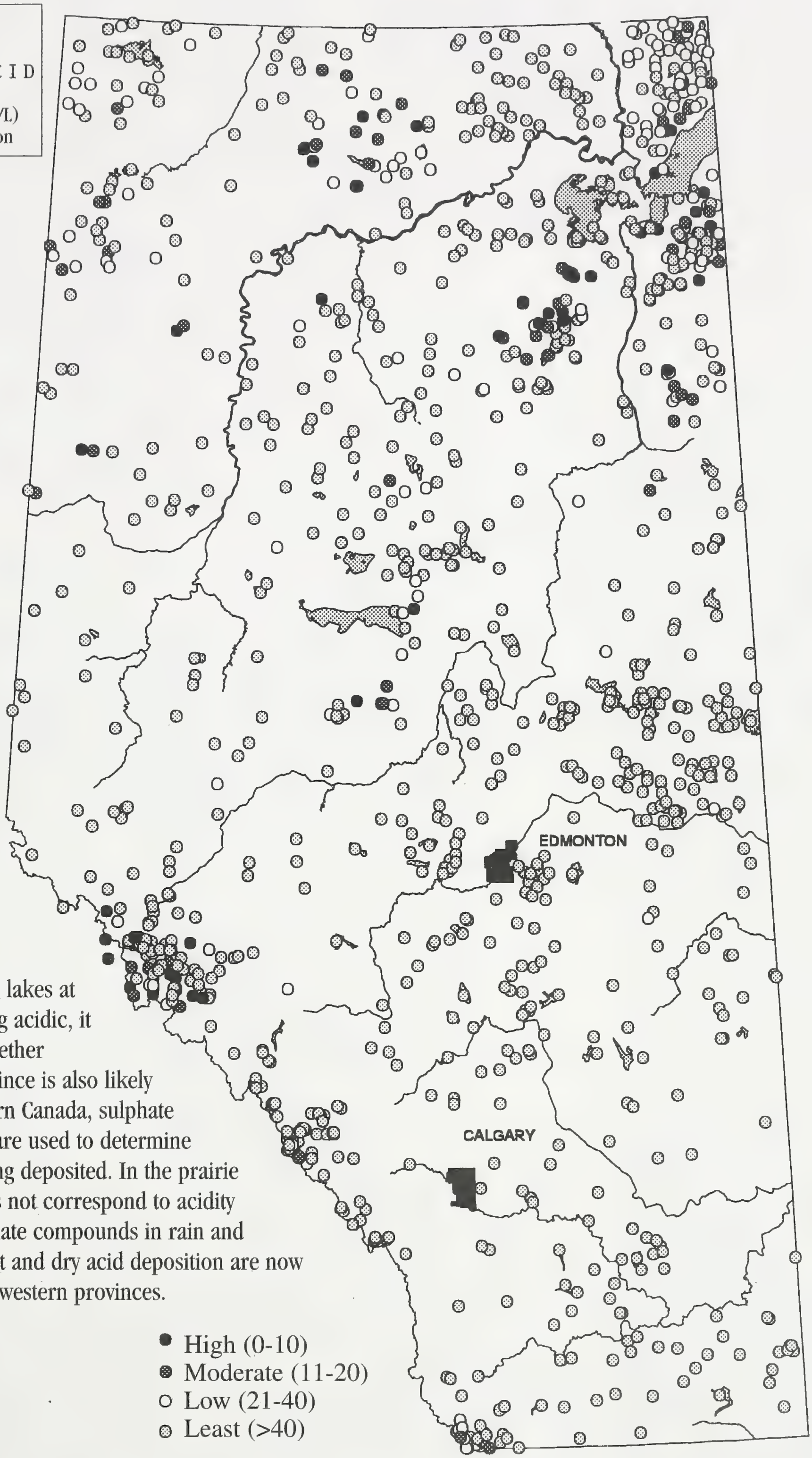
- The Rocky Mountain Natural Region (primarily at high altitudes in Jasper and Waterton Lakes National Parks).

- The Canadian Shield (both the Kazan Upland and Athabasca Plains).

- The northern part of the Boreal Forest Natural Region (upland areas such as the Muskeg, Caribou, Birch Mountains, Clear Hills and Swan Hills).

FIGURE 5.8
SENSITIVITY OF ALBERTA LAKES TO ACID DEPOSITION

Lake sensitivity based on alkalinity (mg/L)
soucre: Alberta Environmental Protection



In the northern Boreal Forest, 11 percent of 109 lakes sampled since 1987 were found to be sensitive to acidification. Many of these are in peatland areas and appear to be naturally acidic with poor buffering capacity. Some northern boreal lakes sampled 10–20 years ago were re-sampled in 1993. No trend toward further acidification was observed.

In addition to identifying lakes at greatest risk of becoming acidic, it is necessary to know whether precipitation in the province is also likely to acidify lakes. In eastern Canada, sulphate levels in rain and snow are used to determine how much acidity is being deposited. In the prairie provinces, sulphate does not correspond to acidity because of neutral sulphate compounds in rain and snow. New models of wet and dry acid deposition are now being developed for the western provinces.

5.6 ECOLOGICAL AND SPECIES MANAGEMENT

5.6.1 Ecological Management

Several programs under Alberta Environmental Protection help to preserve riparian and wetland areas. The Natural Areas Program protects areas for public appreciation and enjoyment that contain important biological or landscape features. The Environmentally Significant Areas Program identifies and maps habitats containing rare species or highly diverse communities of plants and/or animals. Many of these areas are wetlands or riparian areas adjacent to rivers, streams, or lakes. **Figure 5.9** shows Alberta's environmentally significant areas.

5.6.2 Evaluation of the Status of Wildlife Species

In Alberta, evaluation of the status of wildlife and aquatic species began with the publication of the Government of Alberta's *Status of the Fish and Wildlife Resource in Alberta* (1985) and *A Policy for the Management of Threatened Wildlife in Alberta* (1989). In 1991, the government's first *Status of Alberta Wildlife* report established an objective evaluation system for monitoring population trends in Alberta species. The system also set priorities for managing at-risk and other species, and has helped the development of special restoration plans for at-risk species.

The Government of Alberta is committed to publishing the *Status of Alberta Wildlife* report every five years. The 1996 edition contains information on 483 mammal, bird, reptile, and amphibian species. This includes 104 species either not listed or designated as "status" unknown in 1991, but since assigned a status. The report also shows that 65 species have been upgraded in status, in part due to better information and refinements in the evaluation process.

The refined ranking system assigns species to one of five lists:

- Red
- Blue
- Yellow
- Green
- Status Undetermined

The Red and Blue lists include species that are or may be at-risk, respectively. Alberta Environmental Protection will complete detailed status reports on all Red and Blue list species identified in the 1996 report. **(A more complete explanation of the ranking system is found in Appendix B.)**

In the late 1980s, threatened and endangered plant species in Alberta were also identified and selected for further study. As a result, populations of high priority plant species are now being monitored. In addition, a 1996 amendment to Alberta's Wildlife Act includes plants and invertebrates in the definition of "wildlife", allowing for better protection and management of these often neglected species. Alberta is one of only four jurisdictions to extend legislative protection to plants and invertebrates.

To better monitor wildlife populations, Alberta Environmental Protection established a comprehensive Biodiversity Species Observation Database in 1995. This electronic data storage and retrieval system helps the collection and use of detailed information on the distribution and abundance of all Alberta wildlife species. The database will also be shared with other jurisdictions to aid cross-boundary conservation efforts.

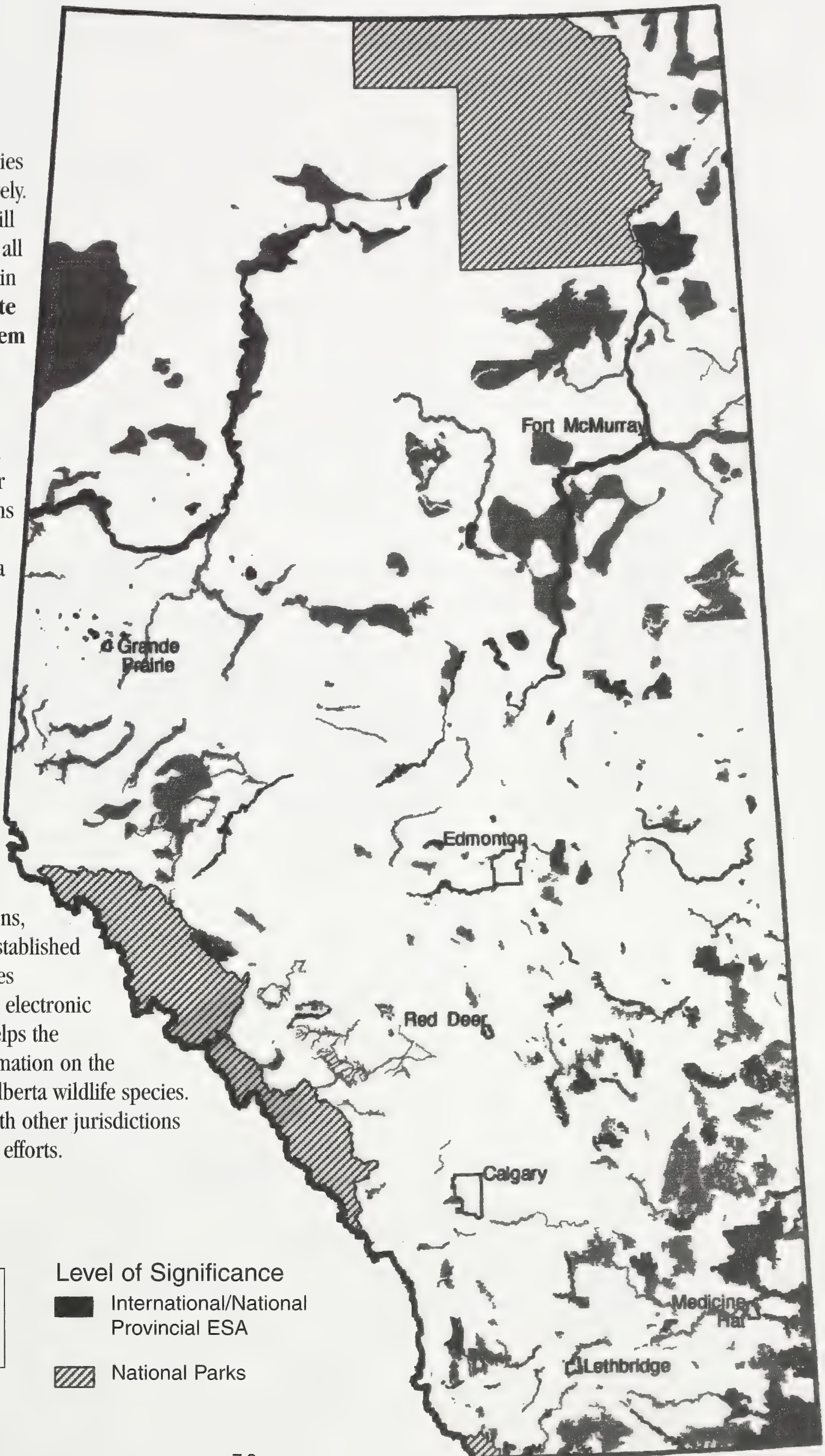


FIGURE 5.9
ENVIRONMENTALLY SIGNIFICANT AREAS
source: Alberta Environmental Protection

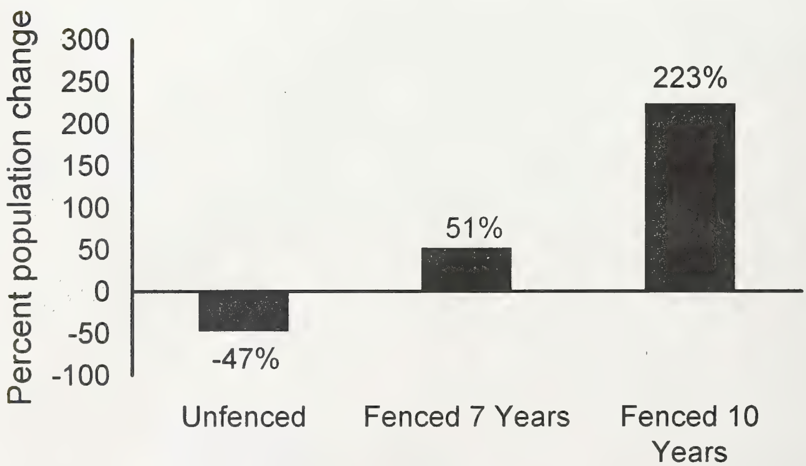
5.6.3 Fisheries Management

5.6.3.1 Management and Habitat Development Programs

To meet the increasing demand for recreational fishing, the Fisheries Management Enhancement Program (FMEP) supports projects that enhance fish production and protection. This program is funded through sportfishing licence fees and includes fish populations assessments, habitat evaluation, fish hatcheries, user surveys, education, and enforcement. Fisheries habitat enhancement is conducted under the Fisheries Habitat Development Program (FHDP), and includes projects such as lake aeration to raise dissolved oxygen levels. This program is also financed from sportfishing licence fees.

Fencing stream corridors to prevent livestock damage to riparian areas has been an ongoing activity under the FHDP for many years. In 1975 two sections of the North Raven River, a spring-fed tributary of the Red Deer River, were fenced to exclude cattle. In addition, livestock watering stations were installed, vegetation was planted along damaged parts of the streambank, and rocks were placed to stabilize the bank where necessary. Soon overhanging streamside vegetation returned, the stream became narrower and deeper, and the number of trout increased. After 10 years, trout numbers in the fenced portion had increased by 223 percent **(Figure 5.10)**. Today the stream is one of Alberta's top brown trout streams.

FIGURE 5.10 Trout Population Changes in Three Sections of the North Raven River, 1973-1985
source: Alberta Environmental Protection



Lake stocking is another activity conducted under FMEP and FHDP. To make fishing more accessible to anglers in urban areas, many small lakes near urban areas are stocked with fast-growing strains of rainbow trout. These lakes often contain aquatic life that can support trout, and trout growth rates can be rapid (up to 2 kg in 2 years). However, many of the lakes are susceptible to winter-kill and lack suitable spawning sites, making repeated stocking necessary.

5.6.3.2 Species Management Plans

Of Alberta's 51 native fish species, two are at serious risk (threatened), four are vulnerable, and none are endangered **(see Tables 3.1 and 3.3 for species' names)**. Over the next five years, management and recovery plans will be prepared and implemented for the threatened and vulnerable species. Species management plans are also prepared for important game fish under heavy sportfishing pressure, such as walleye and bull trout, as described below.

- **Walleye** - The walleye is a popular sportfish present in 177 lakes and reservoirs and 64 river systems in the province. A typical pristine lake in Alberta produces about one walleye per hectare of surface area. However, there are often five or more anglers per hectare on many Alberta lakes in summer. As a result, walleye populations in many lakes are declining, because too few fish survive to spawning age (9–10 years) to maintain stable populations.

  Traditional sampling methods for determining the status of the walleye population in Alberta's lakes are too time and labour-consuming. A more effective method, developed by Alberta Environmental Protection and the Walleye Task Force, uses fish sampling to place a lake's walleye population in one of the following categories:

  - *Trophy* - slow-growing population with many older fish and relatively few young.
  - Stable - highly productive condition in which there are few older fish - these have been harvested, reducing predation on younger fish - and fish grow quickly, spawning at a relatively early age.
  - Vulnerable - declining population with low numbers of fish and few fish over the age of 10 years.
  - Collapsed – very low walleye density and few mature fish.

  After a lake has been categorized, pre-determined regulations for that category are applied to the lake. These regulations, developed through extensive consultation with the fishing public and other stakeholders, are designed to sustain "stable" and "trophy" populations, stabilize "vulnerable" populations, and, where possible, restore "collapsed" populations. They allow for moderate harvest on "stable" walleye lakes, low harvest on "vulnerable" and "trophy" lakes, and no harvest on "collapsed" lakes. Approximately 35 percent of Alberta's walleye populations are in the "collapsed" category.

- **Bull Trout** - The bull trout, under pressure for many years **(see Section 3)**, is now being helped back to recovery by the Bull Trout Management and Recovery Plan. Under this plan to restore healthy, self-sustaining bull trout populations, regulations have been established prohibiting harvest of the species. The plan also calls for correcting stream blockages affecting populations, reducing competition from introduced species, and improving public awareness of the situation.

  In 1994, inventories of bull trout spawning beds (called "redds") in headwater streams of the Oldman River sub-basin were undertaken with funding from the Fisheries Management Enhancement Fund. These inventories are ongoing. They supply information on the spawning habitat of bull trout and help establish indices that can be used to monitor population changes. In 1995, 176 bull trout redds were found during the stream surveys.

Research to assist with bull trout management is being conducted at the universities of Lethbridge and Calgary with funding from the FMEP. The studies include (a) determining the degree to which bull trout in major river basins have hybridized with other trout, and (b) population modelling to determine sustainable harvest levels.

5.6.4 Waterfowl and Wetland Habitat Management

Since 1986 the waterfowl preservation efforts of federal and provincial wildlife agencies and Ducks Unlimited Canada have been combined under the North American Waterfowl Management Plan (NAWMP), a 15-year agreement between the governments of Canada, the United States, and (as of 1994) Mexico. The purpose of this combined effort is to restore declining waterfowl populations through wetland management and restoration, conserve biological diversity, integrate wildlife conservation with sustainable economic development, and promote partnerships of agencies and individuals for conservation. NAWMP aims to conserve 1.1 million hectares of priority wetland and upland habitat in Alberta. Alberta NAWMP partners include Alberta Environmental Protection, Environment Canada, Ducks Unlimited Canada, Wildlife Habitat Canada, and Alberta Agriculture, Food and Rural Development.

NAWMP has taken an ecosystem approach since 1994, building benefits for non-waterfowl species into its waterfowl management programs. For example, amphibian surveys have been carried out in conjunction with habitat restoration work. In addition, March 1996 statistics indicate that NAWMP's land-use conservation program, Alberta Prairie CARE, has secured about 198 000 hectares in the province through lease, purchase, and long-term stewardship agreements. Growth in the number of participating landowners is shown in **Figure 5.11.**

FIGURE 5.11 Number of Land owners Under Agreement to the North American Waterfowl Management Plan
source: Ducks Unlimited Canada

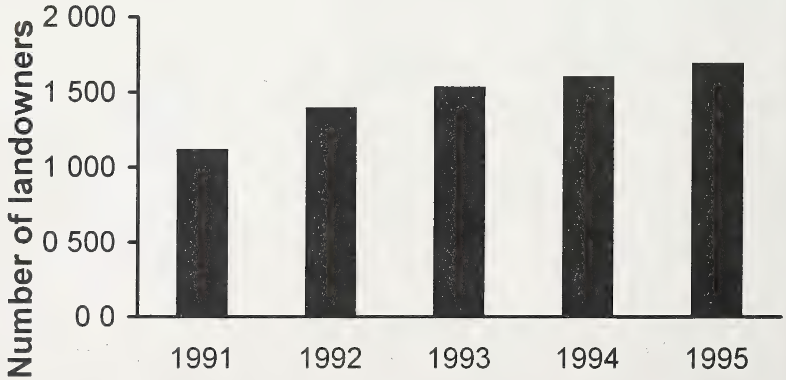
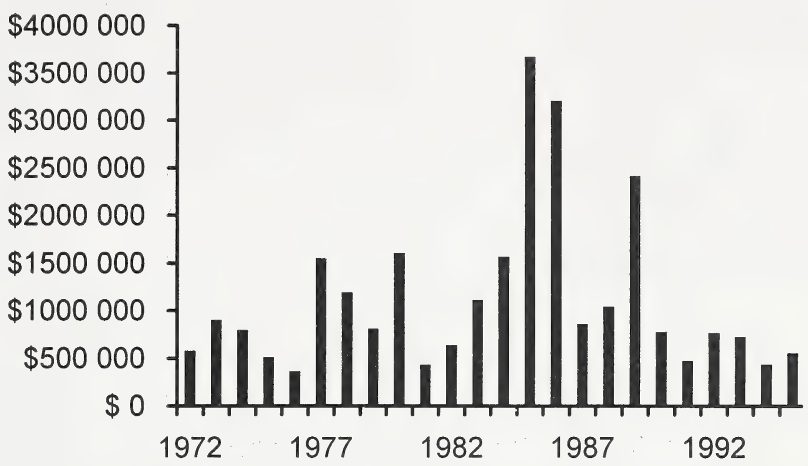


FIGURE 5.12 TOTAL COMPENSATION FOR WATERFOWL DAMAGE CLAIMS PAID IN ALBERTA, 1972-1995
source: Agricultural Financial Services Corporation

Costs for programs preventing waterfowl damage to unharvested crops and compensating farmers for waterfowl-inflicted damage have been shared by the federal and provincial governments for many years. In recognition of the fact that waterfowl damage can deter the maintenance or enhancement of waterfowl habitat, the compensation rate was changed in 1990 to a payable amount equal to 80 percent of actual crop loss. Total amounts paid out under this program are shown in **Figure 5.12**.



5.6.5 AMPHIBIAN AND REPTILE MONITORING

Amphibian monitoring programs are being conducted in cooperation with Alberta representatives of the Task Force on Declining Amphibian Populations in Canada. In 1996, Alberta Environmental Protection initiated a province-wide, volunteer Amphibian Monitoring Program to collect information on species distribution and to raise public awareness. Field identification aids and training for volunteers are provided. Public participation and interest in the program have been strong: more than 250 Albertans are presently involved. As well, intensive monitoring of specific populations is being conducted by scientists from the universities of Alberta and Calgary.

Snakes are the most common reptiles found in Alberta. In this cold climate, good overwintering sites are very important for these cold-blooded animals. Snakes gather in large numbers to hibernate in communal caverns or underground dens, called "hibernacula". Protection of these sites is important for the conservation of snake populations. A province-wide volunteer survey to identify all major snake hibernacula is being undertaken.

5.7 COOPERATIVE RESEARCH PROGRAMS

5.7.1 FORESTRY

The effects of timber harvesting on aquatic ecosystems in the mixed wood Boreal Forest **(Section 4.3)** are being addressed by research under the Terrestrial and Riparian Organisms, Lakes and Streams (TROLS) Program at the University of Alberta.

The research's basic objectives are to:

- Determine the effects removal of riparian forest has on lake and stream ecology in western boreal regions.
- Determine the effects of a newly created forest edge on vegetation, insects, and small vertebrates.
- Evaluate community and population responses to varying buffer strip widths.
- As a contribution to sustainable forestry, provide recommendations on the minimum buffer width required to prevent major changes in aquatic and riparian terrestrial communities (TROLS 1995).

Field studies are being conducted on 12 experimental lakes in three general areas: South Calling Lake, Lac La Biche, and Pelican Hills. With the cooperation of Alberta-Pacific Forest Industries Ltd. and Weyerhaeuser Canada Ltd., forest stands ("buffer strips") of four different widths are being left in patches around the lakes. Measurements will be taken over several years to determine the effects of different buffer strip widths on the water table, water flow, nutrient concentrations in runoff, water quality, and aquatic vertebrate and invertebrate communities.

(Ducks Unlimited Canada, Tye Gregg)

5.7.2 Agriculture

A program to monitor existing and potential effects of farm and ranch operations on Alberta's surface and ground water resources was part of the Canada-Alberta Environmentally Sustainable Agriculture (CAESA) Agreement. Signed in 1992 under Canada's Green Plan, CAESA was a five-year initiative to sustain and enhance the agri-food sector and protect natural resources by facilitating the adoption of effective resource management practices. One of CAESA's five component programs was a Resource Monitoring Program focused on soil and water resources. Water quality investigations under this program were directed by Alberta Agriculture, Food and Rural Development, Alberta Environmental Protection, Alberta Health, Agriculture and Agri-Food Canada, and Environment Canada.

Following extensive data reviews and the development of a site selection process, three water quality studies were undertaken. Each study has specific objectives:

- The Haynes Creek Study will define direct effects of specific agricultural practices on water quality. The Haynes Creek watershed is representative of land with intensive mixed farming on soils that have a high erosion potential. Effects of runoff from fields and from intensive, mixed agriculture are being assessed. It may be possible to extrapolate results to watersheds with similar characteristics and agricultural intensity.

- A stream water quality survey will examine the effect of agricultural intensity on water quality. This survey includes 27 streams that drain land with soil and landscape characteristics similar to Haynes Creek, but where agricultural intensity ranges from high to low. If agricultural intensity influences stream water quality, streams in high intensity areas should differ in water quality from streams in low intensity areas.

- A standing water survey will assess the effects of current pesticide use on the water quality of small lakes across Alberta. Small lakes were selected in areas with different intensities of pesticide use. If agricultural pesticide use influences the level of pesticide contamination in lakes, then the number of detections should be higher in the high-use areas as opposed to the low-use areas.

Several other studies under CAESA examined other water quality issues, such as surface runoff quality from feedlots.

In addition to work conducted under CAESA, several other initiatives are aimed at reducing the impact of certain agricultural practices on water:

- In 1995, an updated *Code of Practice for the Safe and Economic Handling of Animal Manures* was prepared by the Intensive Livestock Operations Committee, composed of provincial livestock producers' associations, rural municipalities, and the provincial departments of Agriculture, Food and Rural Development, Health, Municipal Affairs, Environmental Protection, and the Farmers' Advocate. This code of practice describes ways for producers to minimize the potential for surface and groundwater contamination from feedlots and seasonal feeding facilities, liquid and solid manure storage facilities, and application of manure to land.

- Livestock grazing management strategies to protect streams and riparian areas are being developed and field-tested under the Riparian Habitat Management Program, a collaborative effort of Alberta Environmental Protection, Alberta Agriculture, Food and Rural Development, the Alberta Cattle Commission, and Trout Unlimited Canada. A document resulting from this work, *Caring for the Green Zone*, helps ranchers protect and manage riparian areas for their own benefit as well as that of the environment.

- Studies on the water quality of irrigation return flows are being conducted in the Strathmore area by Alberta Agriculture, Food and Rural Development.

5.7.3 Peatlands

The Alberta peat harvesting industry has established a Peat Management Task Force, with membership from government, industry and the University of Alberta. The Task Force will review peatland management issues and make recommendations on the management of peat resources in Alberta. To ensure the orderly development and conservation of peatlands, an assessment of Alberta's peatland resources was conducted in 1995/96. The assessment consisted of:

- A peatland inventory and mapping.
- Assessment of peatland conservation and development values in Alberta.
- Development of a system to classify, evaluate, and rank peatlands for protection purposes.

The inventory was conducted within an ecosystem framework to consolidate previous regional peatland inventories and ensure that provincial coverage is complete. In addition, peatland conservation and development issues are being examined by natural region and subregion, and more-detailed peatland inventories are being conducted in specific areas. The information obtained will assist in peatland management decisions.

The assessment of peatland areas for protection followed a methodology developed by Nicholson and Turchenek (1995). As with Alberta's Natural Areas Program, site protection criteria are based on educational, recreational, and natural heritage values. Important considerations include the presence of rare species or features, biophysical diversity, size of the peatland unit, and amount of human disturbance.

The Peat Management Task Force is also supporting research related to environmental effects of peat harvesting. Research programs are investigating effects of harvesting on water quality and the re-establishment of conditions favouring peat formation.

5.8 MANAGEMENT OF DISEASE AND INVADING NON-NATIVE AQUATIC SPECIES

5.8.1 Waterfowl Disease Contingency Plan

Waterfowl die-offs from disease have occurred on at least 33 lakes and wetlands in the Parkland and Grassland natural regions since 1924. In addition, repeated losses have occurred over the past 15 years on several wetlands and lakes in these regions (Beaverhill, Grantham, San Francisco, Pakowki, and Whitford lakes) as well as on Utikuma Lake in the Boreal Forest Natural Region. At least some of these die-offs have involved avian botulism, caused by a toxin produced by the bacterium *Clostridium botulinum*. It is thought that the toxin develops in decaying material, such as dead invertebrates, in warm water. Ducks feeding on these invertebrates become poisoned and die. Botulism spores, present in the digestive tracts of all marsh creatures, proliferate in the carcasses, producing toxins that are then absorbed by developing fly maggots. These maggots are the agent for the rapid spread of the disease among the rest of the waterfowl population (Clark 1987).

A Waterfowl Disease Contingency Plan for Alberta was first developed in 1992 and updated following outbreaks of botulism at Pakowki Lake in 1994 and 1995. This very large, shallow lake in the southeastern corner of the province is used by thousands of waterfowl and shorebirds, including species not common to Alberta, such as the white-faced ibis. The 1995 botulism outbreak was triggered by a hot, dry summer that led to declining water levels, blue-green algal blooms, and exposed mudflats. Dead birds were first found on July 10, and by summer's end, over 100 000 dead birds had been collected, and total mortality was estimated at 200 000 (Pybus and Eslinger 1996). Field action, a co-operative effort by Alberta Environmental Protection, Ducks Unlimited Canada, and the Canadian Wildlife Service, included carcass collection and burial. A multi-agency Pakowki Lake Working Group is examining ways to limit future avian mortality on the lake.

Under the provincial Waterfowl Disease Contingency Plan, all wetlands at risk for disease outbreaks are monitored throughout spring and summer, and cases of diseased waterfowl are reported promptly. In the event of an outbreak, cooperative action taken by the above agencies may include (depending on the individual case) diagnosis, clean-up, carcass disposal, clean-up of the water body (for example, flushing and disinfecting), rehabilitation or treatment of birds, and reduction of potential for disease.

5.8.2 Whirling Disease

A disease of trout and salmon known as "whirling disease" has been implicated in the recent decline of wild trout populations in Montana, Colorado and Utah. This disease, long known to fish hatcheries, has not yet been found in Canada.

The agent causing the disease is a microscopic parasite that infects the cartilage of fish. Symptoms include skeletal deformities and an abnormal "whirling" behaviour in young fish. Adult fish carrying the disease may not show any signs of it.

The parasite spreads by means of a bottom-dwelling invertebrate, the tubifex worm, that serves as an intermediate host. Spores released by the parasite from an infected (usually dead) fish enter bottom sediments and are taken up by the worm, in which they develop. Fish become infected by ingesting the worm or contacting mature spores in the water. Spores can live in bottom sediments for many years.

Strategies in Alberta are being developed to prevent transmission of this disease. Anglers, boaters, and guides who have been fishing out-of-province are being asked to take precautions, such as avoiding any transfer of water

FIGURE 5.13 DISTRIBUTION OF PURPLE LOOSESTRIFE IN ALBERTA, 1996
source: Survey Purple Loosestrife Infestation

or fish from one water body to another, washing mud from boots, waders, boats and trailers, and disposing fish remains in sanitary landfills. Fish hatcheries, already required to import stock certified free of whirling disease, are being encouraged to take extra precautions. Whether trout or salmon imported from the U.S. as food products pose a risk to Alberta's rivers (for example, by flushing fish remains into the sewer system) is also under evaluation.

5.8.3 Project Purple Loosestrife

Purple loosestrife is a fast-growing perennial plant introduced into North America from Eurasia. It crowds out native wetland species, forming dense stands that choke out native plants and invade new areas by means of copious seed production. Eventually the invaded wetland's entire food web diminishes, as has occurred over large areas in the United States. In many cases the sources of infestations have been traced to cultivars growing in gardens.

Project Purple Loosestrife is a three-year program to eradicate all outbreaks of this weed in Alberta by increasing public awareness of the problem and how to prevent and control outbreaks. The project is coordinated by Alberta Agriculture, Food and Rural Development with assistance from Alberta Environmental Protection, Ducks Unlimited Canada, the Canadian Wildlife Service, Alberta Native Plant Council, Devonian Botanic Garden, Alberta Tree Nursery and Horticulture Centre, Alberta Nursery Trades Association, and Alberta Irrigation Projects Association.

Since the project's commencement in 1993, many local volunteer groups have been formed to control and monitor infestations. Purple loosestrife has been designated a noxious weed under Alberta's Weed Control Act, making it the mandatory responsibility of every landowner to control its growth on his/her property.

Figure 5.13 shows the location of infestations in the province in 1996. Ongoing studies suggest that all infestations in the province to date have been found and a level of control achieved.

5.9 EDUCATION AND PUBLIC AWARENESS

Public understanding of the many functions and uses of water resources is essential if we are to preserve aquatic ecosystems. Videos, brochures and teaching materials have been produced for school and public use, including the following:

- *The Vital Edge* (general public) - video showing the ecological value of lakeshores and how to preserve them.
- *Water in Alberta, The Living Flow* (targeted to school grades 7 - 10) - a teaching kit examining sources of water, uses of water, water conservation and water management.
- *Water Literacy Program* (grades 4 -12) - individual modules exploring all aspects of water use Wetlands.
- *Webbed Feet Not Required* (targeted to grades 4 - 6) - teaching kit examining wetlands ecosystems, functions, and issues.
- *Focus On* (general public) - short articles on topics such as wetlands, water conservation, and water quality.
- *Threatened Species Education Program* (kindergarten to grade 9) - general and species-specific guides focusing on threats to particular species and on broader environmental issues.
- *Alberta's Threatened Wildlife* (general public) - set of 12 brochures describing status and distribution, habitat, limiting factors, management, and outlook for individual species.

- *Alberta Fishing Education Program* (general public) - program focusing on fisheries management concerns, fish identification, and fishing regulations.

- *Atlas of Alberta Lakes* (Mitchell and Prepas 1990) - (general public) - Produced cooperatively by Alberta Environmental Protection, the University of Alberta and the former Alberta Water Resources Commission, this comprehensive document summarizes scientific information related to various aspects of many of Alberta's lakes, including lake characteristics, water quality, hydrology, and biology.

- *Guidelines for Lakeshore Use* (lakeshore users) - brochure providing information on the government approvals needed before development on public lakebeds and shores can be carried out.

Many non-governmental organizations also publish educational material, hold workshops, and/or conduct research on water and related subjects (for example, the Alberta Lake Management Society, Ducks Unlimited Canada, and Trout Unlimited Canada).

(Ducks Unlimited Canada, Barry Bishop)

6.0 THE MAJOR RIVER BASINS

6.1 THE PEACE-ATHABASCA-SLAVE RIVER BASIN (Figure 6.1)

The Peace, Athabasca and Slave Rivers are the largest rivers in the province in terms of volume **(Figure 2.4)** and together drain the largest river basin in the province. Along with the Liard, Hay and Buffalo Rivers[1], they drain into the Mackenzie River system leading to the Arctic Ocean. This basin contains Alberta's two largest lakes, Lake Athabasca and Lake Claire, and the world's largest boreal freshwater delta, the Peace-Athabasca delta.

This basin includes portions of several natural regions. Extensive areas of boreal forest and wetlands cover the northern part of the basin, and the Canadian Shield occupies the far northeastern corner. The western part of the basin extends into the Rocky Mountain and Foothills regions. Parkland areas occur in the west and south.

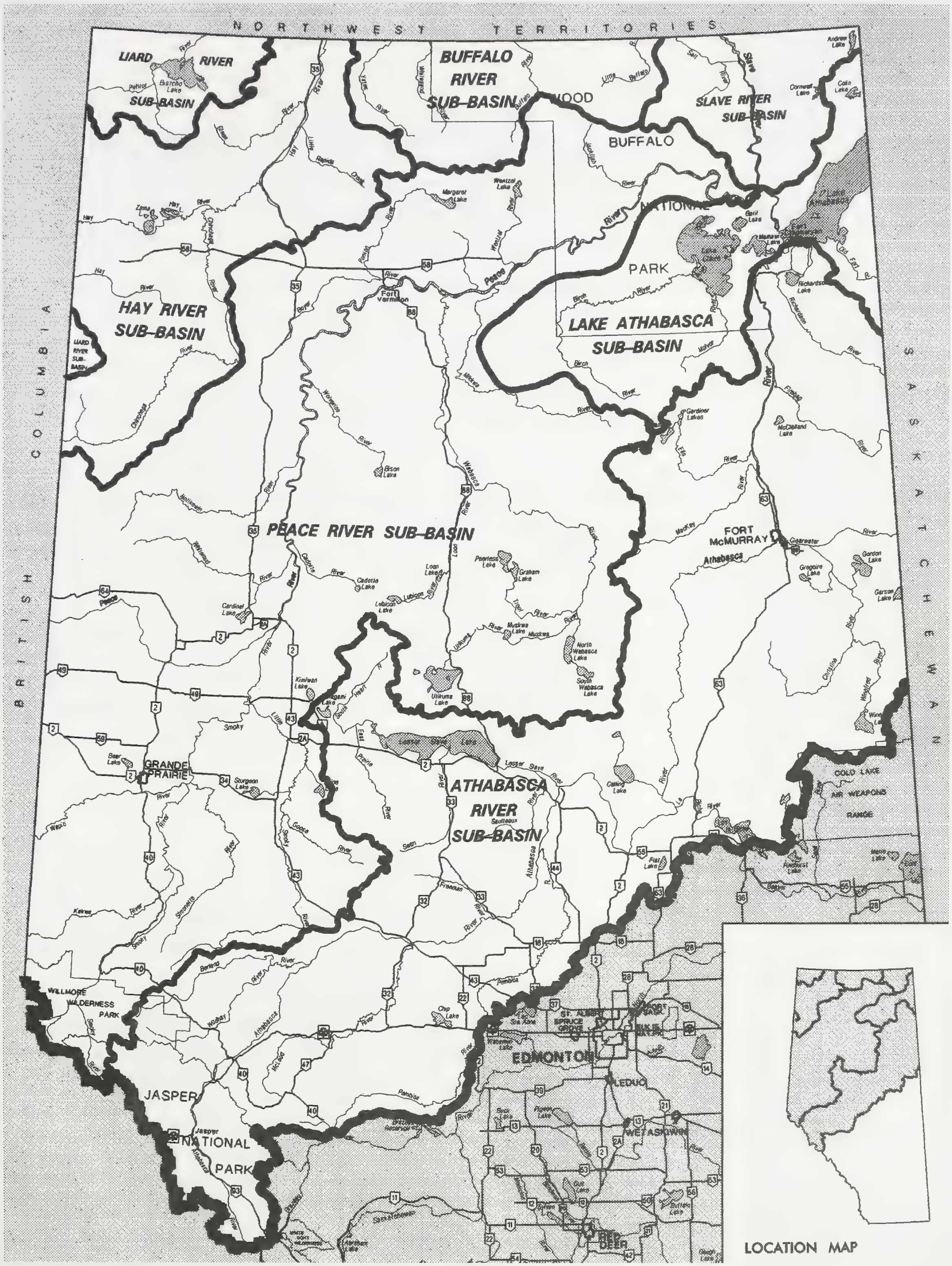
The Peace-Athabasca-Slave River basin is one of the least populated in the province, with some 266 000 residents, most of whom live in agricultural areas or its two cities, Grande Prairie and Fort McMurray. Major land uses are forestry, mining, exploration and development of petroleum reserves, and agriculture.

6.1.1 Rivers, Lakes, and Wetlands

Originating in the mountains of British Columbia, the Peace River enters Alberta through the Peace River Parkland, the northernmost economically important agricultural land in Canada. The Smoky, Wapiti, and Little Smoky rivers join the Peace River from the Rocky Mountains, and the Wabasca River joins it further to the northeast. The Athabasca River begins in the Rocky Mountains of Alberta and is joined along its northeastern course by many tributaries, including the McLeod, Pembina, Lesser Slave, and Clearwater rivers. Where the Peace and Athabasca rivers approach each other at Lake Athabasca, the Peace-Athabasca Delta has formed. The Slave River begins at the confluence of the Peace River and the main outflow channel from Lake Athabasca, and flows northward, draining the Canadian Shield on the east and the Peace River Lowlands on the west.

[1] Although the Laird, Hay and Buffalo Rivers are actually not part of the Peace-Athabasca-Slave river basin, they are included as part of this basin for the purpose of this report.

FIGURE 6.1 PEACE-ATHABASCA-SLAVE RIVER BASIN



A broad range of lake types occurs in the basin. The numerous small lakes that dot the Canadian Shield uplands are clear, low in nutrients (oligotrophic or mesotrophic), and among the most dilute (low salinity) in the world. Lake Athabasca, the fourth largest lake entirely within Canada, occupies the southern edge of the Shield. It receives water from the Athabasca River through channels traversing the Peace-Athabasca Delta. Rivers in Saskatchewan also contribute to the lake. The lake's deepest portion, and 70 percent of its area, lie within Saskatchewan. The Alberta portion is fairly shallow and biologically productive (as measured by chlorophyll content). Other large lakes within the basin include Lesser Slave Lake (a fairly shallow lake that is the eighth largest in Canada), and a number of deeper, mesotrophic lakes such as Winefred Lake, with its trophy-class sport fishery.

Many of the small lakes present in the Boreal Forest Natural Region are shallow and eutrophic with lush summer growths of macrophytes and blue-green algae. "Brown-water lakes" in the northern part of the basin are rich in organic matter from peatlands in their watersheds. Some of these lakes are acidic and may have poor buffering capacity **(Section 5.5.2)**.

Peatlands cover much of the northern part of the basin. Floating peat bogs and open, hummocky black spruce bogs underlain with permafrost and with lichen and peatmoss carpets are often interspersed with open, wet, non-permafrost fens. Many large marshes are also present, found primarily in the southern part of the basin but also in the north.

Several of the province's largest and most significant wetlands occur in the basin:

- **The Peace-Athabasca Delta** is a complex mixture of low-lying marshes, lakes, streams, mudflats, and shrub lands. It results from a flow of water that changes direction depending on water levels in different parts of the system. Three main channels drain the delta, usually flowing north to the Peace River and then to the Slave River. However, spring flooding on the Peace River, sometimes combined with ice jams, causes water in these channels to reverse its direction toward Lake Athabasca. This causes flooding which refills the marshlands and perched basin lakes essential to the delta's ecosystem.

Since 1968, the W.A.C. Bennett Dam on the Peace River in British Columbia has greatly affected the delta's ecosystem by reducing peak flows on the river. As a result, back flooding of channels occurs much less frequently, and marshes and lakes are drying out. Drought during this period may have worsened the impact. Weirs constructed in the 1970s to retain water in the marshes did not succeed in restoring perched basin water levels. An ecosystem management plan has been developed for the delta **(see Section 6.1.3.3)**.

- The 11 000-hectare **Hay-Zama Lakes Complex**, about 110 km northwest of High Level, is one of North America's largest and important staging areas for migratory waterfowl. During spring and fall as many as 30 000 migrating geese and 100 000 ducks may use lakes in the complex.

- The **summer territory of the whooping crane** is a remote area in Wood Buffalo National Park where the North American population of whooping cranes nest and raise their young. The area consists of marshes and soft-bottomed pothole wetlands intertwined with low-lying islands and spits covered with spruce and willow.

6.1.2 Factors Influencing Aquatic Ecosystems

Reflecting the historical importance of water transportation in the north, the majority of urban centres in the basin are situated on rivers and lakes: Jasper, Hinton, Whitecourt, Athabasca, Fort McMurray, and Fort McKay on the Athabasca River, the towns of Peace River and Fort Vermilion on the Peace River, the town of Slave Lake on Lesser Slave Lake, the town of Lac La Biche on Lac La Biche, and Fort Chipewyan on Lake Athabasca.

Today, aquatic resources are still highly important to residents of the basin:

- Surface water bodies provide drinking water for three-quarters of the local jurisdictions supplying treated water, and for another 10 percent of households obtaining their own drinking water.

- Subsistence fishing, hunting, and trapping is carried on by many residents throughout the basin, including First Nations' people and Métis. Data on this subsistence harvest are lacking.

- About two-thirds of the province's commercial fish harvest is caught in this basin by about 400 fishermen. Lakes with commercial fisheries include Utikuma, Lesser Slave, Lac La Biche, North Buck, Bistcho, South and North Wabasca, and Fawcett lakes. In 1994/95 approximately 635 000 kg of fish were harvested from Lesser Slave Lake.

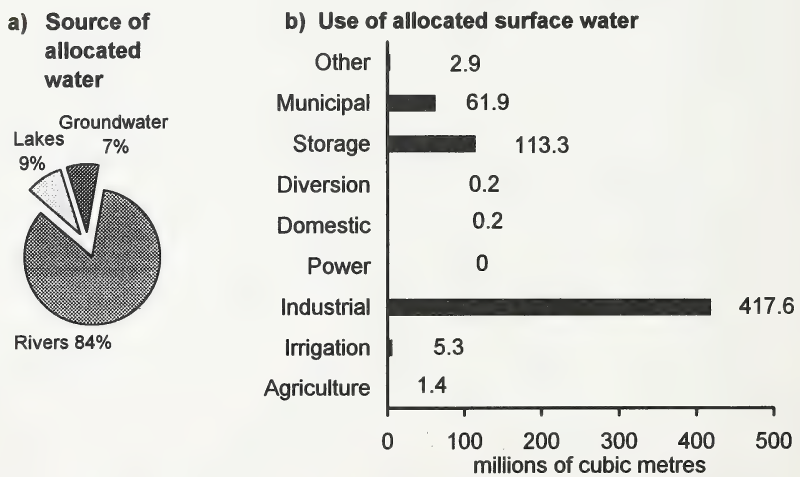
- More than two-thirds of the total provincial harvest of beaver, muskrat, mink and river otter comes from the basin. At present, approximately 3470 trappers (registered and resident) hold licences in the basin. In any given year, about half of these people are actively engaged in trapping.

- Basin residents use water for recreation more frequently than the provincial average: 72 percent of households participate in some type of water-based recreation, as compared to 61 percent provincially. Fully 54 percent of basin residents engage in fishing, whereas 42 percent participate in swimming, 35 percent in boating, and 17 percent in canoeing. Anglers take on average 23 kg of fish annually, primarily northern pike and walleye. The total sportfish harvest, 354 000 kg, equals roughly one-quarter of the commercial fish harvest in the basin.

• Approximately 50 commercial recreation businesses operate in the basin, providing guided fishing, boat and canoe touring, waterfowl hunting, and other services. Fly-in fishing lodges or tent-camps are located on a number of lakes, including 15 lakes in the Canadian Shield region.

The amount of water allocated for all purposes in the basin (656 million cubic metres) accounts for only 7.7 percent of provincial water allocation. Industrial activity in the basin has increased greatly since the early 1980s and is the largest single use of surface water **(Figure 6.2)**. Most of the water allocated for industry (63 percent) is used for processing in pulp mills, the rest going mainly to oilfield injection and cooling water for thermal power plants. Rivers supply 84 percent of the basin's water demand, with about three-quarters supplied by the Athabasca River system and one-quarter by the Peace River.

FIGURE 6.2 WATER ALLOCATION IN THE PEACE-ATHABASCA-SLAVE* RIVER BASIN
*includes the Mackenzie River Basin portion in Alberta
source: Alberta Environmental Protection



Licenced industrial effluents discharged to the rivers are primarily from the mining of coal and oil sands, and from pulp mills. Regulated parameters for each type of facility are shown in **Table 6.1**.

The effect of pulp and paper mills on water quality in the basin has been an issue for many years. The first kraft pulp mill in Alberta began operation in 1957 on the Athabasca River at Hinton. In 1973 a second kraft mill was built on the Wapiti River near Grande Prairie. Between 1988 and 1993, three chemi-thermo-mechanical pulp mills and one kraft mill were constructed within the Athabasca River Basin. Another kraft mill was built on the Peace River during this period. Today, these mills produce a combined total of over 6000 tonnes per day of pulp.

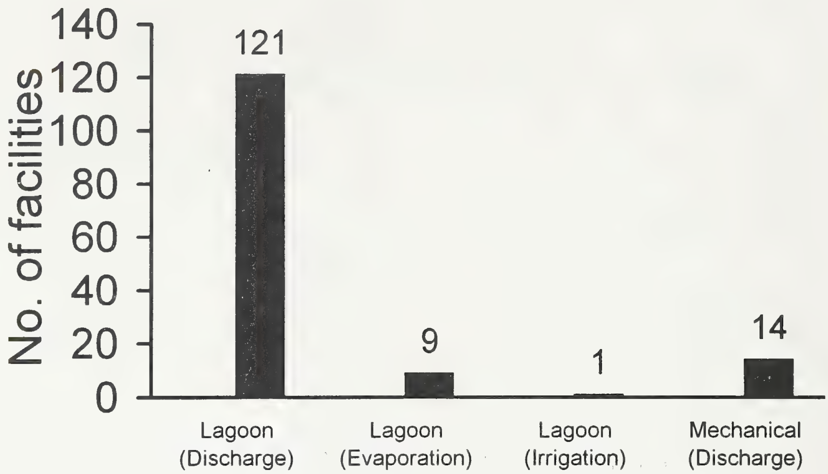
TABLE 6.1 INDUSTRIAL FACILITIES DISCHARGING INTO THE PEACE-ATHABASCA-SLAVE RIVER BASIN

Athabasca River Basin		
Facility Type	**No. of Facilities**	**Regulated Parameters**
Power Plant	1	Oil and grease, temperature, total suspended solids (TSS), pH, fish bioassay[1]
Pulp Mills	5	Adsorbable organic halides (AOX)[2], biochemical oxygen demand (BOD), colour, resin acids[3], TSS, pH, dioxins and furans (where applicable), fish bioassay
Oil Sands	1	Ammonia, chemical oxygen demand[4], oil and grease, phenols, pH, fish bioassay
Coal Mines	4	TSS, pH, oil and grease, settleable solids (where applicable)
Peace River Basin		
Pulp Mill	1	AOX, BOD, colour, resin acids, pH, fish bioassay
Oil Sands	1	Oil and grease, pH, chlorides
Smoky River Basin		
Power Plant	1	Iron, oil and grease, total phosphorus, TSS, pH
Pulp Mill	1	Dioxins and furans, AOX, BOD, chromium, colour, resin acids, pH, TSS, fish bioassay
Coal Mine	1	TSS, pH

[1] bioassay must be passed
[2] a measure of total chlorinated organic matter
[3] type of organic acid derived from plants
[4] test of the amount of organic matter in water or effluent as determined by a strong chemical oxidant

The potential for depletion of dissolved oxygen in the Athabasca River was an issue of concern during the period of rapid industrial expansion. Other concerns have centred on the potential formation of dioxins and furans arising from the use of chlorine in kraft pulp bleaching, and their effects on downstream drinking water quality and safety.

FIGURE 6.3
MUNICIPAL WASTEWATER DISPOSAL SYSTEMS IN THE PEACE-ATHABASCA-SLAVE RIVER BASIN
source: Alberta Environmental Protection



Municipal wastewater discharges to the basin are relatively small **(Figure 6.3)**. However, the Wapiti/Smoky river system, on which the City of Grande Prairie is located, is relatively small in volume and is therefore more limited in its ability to assimilate discharges from the city's wastewater treatment system and nearby pulp mill.

Concerns that large-scale timber harvesting in the basin may affect aquatic or riparian ecosystems **(as described in Section 4.3)** are being addressed by university researchers under the Terrestrial and Riparian Organisms, Lakes and Streams Program **(Section 5.7)**.

The potential for commercial peat harvesting is being considered. Such harvesting would affect peatland ecosystems in the basin **(Section 4.3)**. The prospect for expansion of this industry, along with other industrial activities in the basin that might affect peatlands, has led industry and government to sponsor an inventory of the ecologically significant peatland areas within Alberta **(see Section 5.7)**.

6.1.3 Management Actions Specific to the Basin

6.1.3.1 Regulation of Industry in the Basin

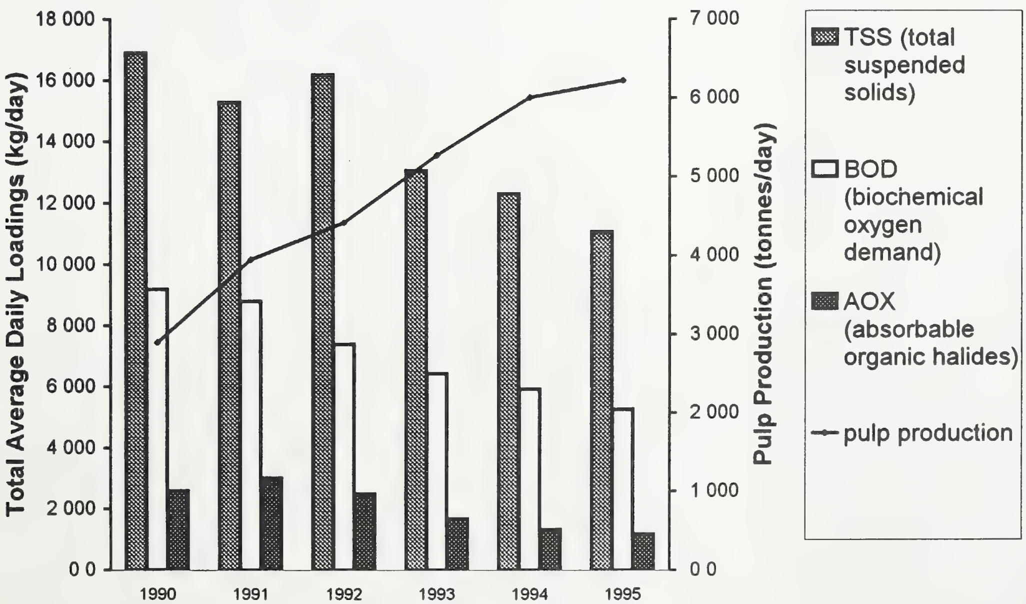
The Pulp and Paper Industry

The pulp and paper industry in Alberta is regulated by both federal and provincial governments. To avoid regulatory overlap and duplication by both levels of government, the province administers or takes a lead role in administering federal requirements. Federal regulations require the monitoring of pulp mill environmental effects to determine the impact of mill effluent on receiving waters. Monitoring focuses on water quality, fish habitat, and adult fish conditions in the receiving waters, including (where relevant) dioxins and tainting. This assessment is reported every three years, beginning in 1996.

The industry is also regulated by the *Environmental Protection and Enhancement Act* and associated regulations. Under this Alberta legislation, all new pulp, paper, newsprint, and recycled fibre mills with a capacity of more than 100 tonnes per day must prepare an environmental impact assessment. In addition, all pulp and pulp and paper manufacturing plants must obtain an approval for construction, operation and/or reclamation. The legislation also provides for the setting, application, and enforcement of effluent limits by Alberta Environmental Protection **(see Section 5.2)**. Both technology and water quality-based limits are set and periodically revised to keep pace with changing technologies. Mills must monitor their effluents for many substances daily and must also monitor effects in receiving rivers.

Since 1989, continuous dissolved-oxygen monitoring during ice cover periods at points upstream of the town of Smith (upstream of the town of Athabasca) and Grand Rapids (upstream of Fort McMurray) shows that oxygen levels remain above 6.5 mg/L at all points along the river's route in this reach. In spite of a 12-fold increase in pulp production by 1993, discharges have been declining for all substances. The actual discharge by all mills is shown in **Figure 6.4**.

FIGURE 6.4 Summary of Alberta Pulp Mill Performance, 1990-1995
source: Alberta Environmental Protection



Oil Sands Mines

Of the two oil sands plants, Suncor and Syncrude, only Suncor is permitted to discharge process-affected water to the river. (This discharge does not include wastewater from the oil extraction process.) The process-affected water is treated before its release and must comply with limits specified in the company's licence. Because small amounts of seepage from tailings ponds escape the collection systems, both groundwater and surface water are monitored. Suncor is moving the fine tailings behind Tar Island Dyke into ponds in the mine pit. Both companies are developing tailings disposal methods that will produce dry landscapes.

6.1.3.2 The Northern River Basins Study

The Northern River Basins Study (NRBS) began in 1991 as a response to concerns expressed by northern residents following the 1991 approval of the Alberta-Pacific Pulp Mill near Athabasca. The NRBS conducted scientific research and gathered traditional knowledge and other public input to determine the current conditions of the Peace, Athabasca and Slave rivers. During the course of this work approximately 150 projects were commissioned, and final reports of each project were made available to the public. A few of the findings are summarized below.

One NRBS study surveyed water users in the basin. About one-sixth of the local governments in the basin indicated problems with water quality. These problems included increased siltation and turbidity, the presence of methane in the water, and contamination from agricultural runoff. Availability of trained persons with the expertise to operate water treatment plants was also cited as a problem for some small communities. The survey also found that three percent of basin households obtain drinking water directly from a river, whereas two percent obtain it from a lake. Over 45 percent of households that used river water for drinking and 29 percent of those that used lake water reported problems with water quality, particularly the water's taste and smell (MacLock and Thompson 1996). Separate NRBS field studies found compounds influencing taste and odour throughout the Athabasca River.

The Northern River Basins Study also found that phosphorus and nitrogen from pulp mills and municipalities affect concentrations of these nutrients in the Athabasca and Wapiti rivers, particularly during periods of low flow.

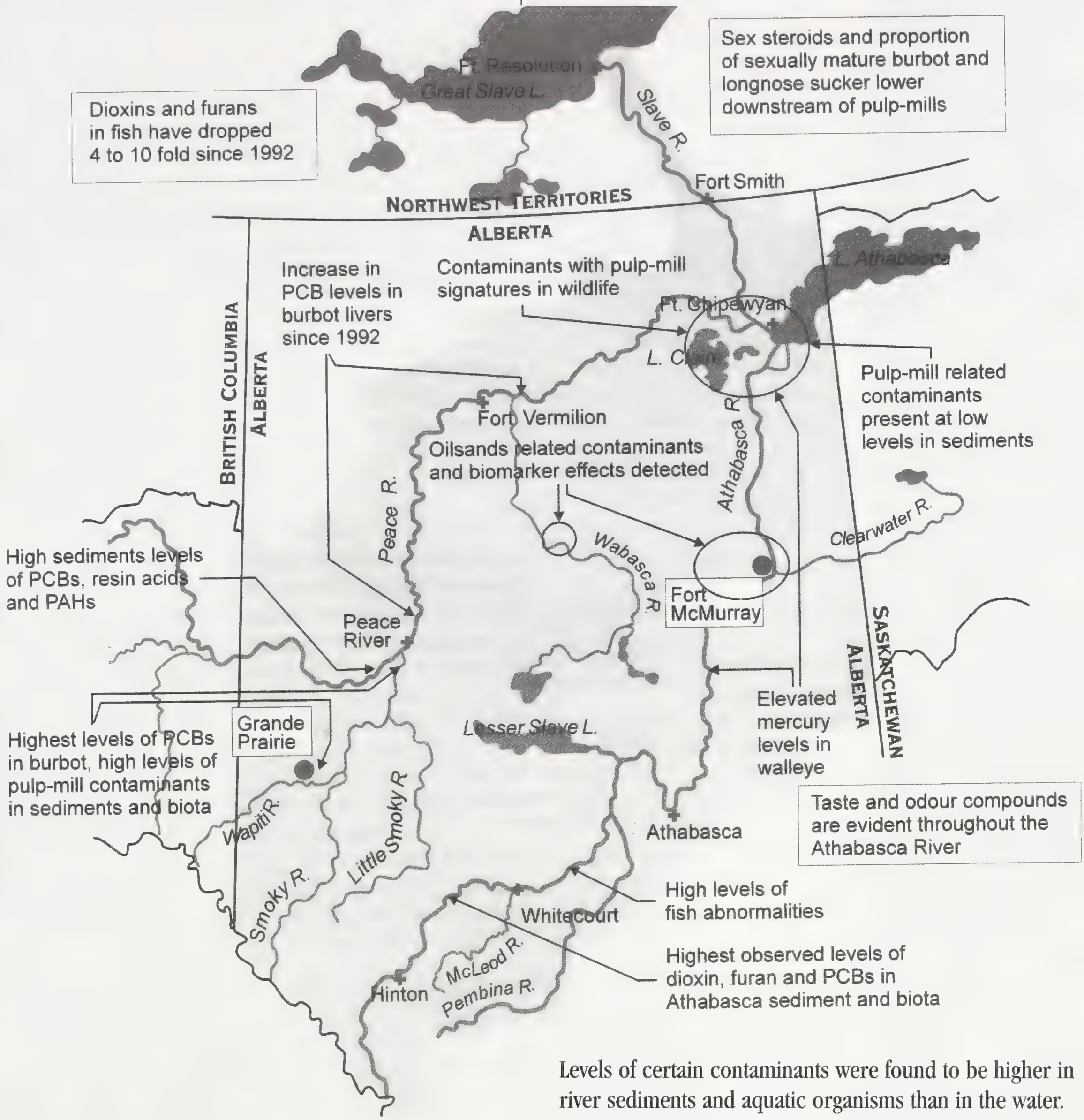


FIGURE 6.5 WATER CONTAMINANT ISSUES AND FINDINGS OF THE NORTHERN RIVER BASINS STUDY
source: Northern River Basins Study

Levels of certain contaminants were found to be higher in river sediments and aquatic organisms than in the water. In general, contamination was low compared to other river systems in Canada or the world. Persistent organochlorides including dioxins, furans, and chlorinated resin acids were found in the tissues of some fish species (for example, burbot liver) and in some sediment samples **(see Figure 6.5)**. However, tissue concentration levels declined significantly between 1991 and 1994. Fish sex hormone levels in fish were found to be below normal near pulp mill effluent sources. (The long-term ecological implications of this finding are unknown.) Of almost 23 000 fish from the basin examined by the NRBS, less than one percent exhibited abnormalities indicative of contaminants, and then only in specific locations.

In its summary *Report to the Ministers* 1996, the NRBS made recommendations aimed at preserving the aquatic resources of the basins. Separate recommendations were also made by the First Nations Committee of the Northern River Basins Study Board. These recommendations are currently being reviewed by the sponsoring governments (Alberta, Northwest Territories, Canada).

6.1.3.3 Peace-Athabasca Delta Technical Studies

In 1992 and 1993 scientists met to address the problems facing the Peace-Athabasca Delta. From their meetings came an ecosystem management plan and a program of technical studies to address the major environmental questions needing answers before the plan could be implemented. Technical studies were conducted from 1993 through 1996 and involved Environment Canada, Alberta Environmental Protection, B.C. Hydro, the Mikisew Cree First Nation, the Athabasca-Chipewyan First Nation, and the Fort Chipewyan Métis Nation. Information was gathered on a range of topics, including the following:

a) Ecosystem investigations
- topographic database establishment
- flood history description using traditional knowledge and written historical records
- vegetation mapping and monitoring
- flow monitoring network
- ice studies digital elevation model

b) Water management options studies
- artificial ice dam or ice jam construction on the Quatres Fouches channel
- structural alternatives (e.g. Riviere des Rochers weir)
- small-scale remediation (e.g. Claire River restoration)

6.1.3.4 North American Waterfowl Management Plan

The boreal forest and agricultural areas of the Peace-Athabasca-Slave River basin are important breeding areas for ducks in North America **(Figure 3.8).** Securing wetlands and adjacent upland areas in the Peace Parkland Natural Subregion is an important focus of the North American Waterfowl Management Plan **(see Section 5.6)**.

6.1.3.5 Northern Lakes Fisheries

Remote fishing camps on lakes of the Canadian Shield rely on the presence of large sportfish to attract anglers. However, an Alberta Environmental Protection assessment has shown that these cold lakes have low productivity for fish. For example, Charles Lake on the Shield produces only about 0.2 kg of lake trout per hectare per year. Thus the sustainability of the fishery depends on the willingness of visitors to practice catch-and-release fishing. Some camp operators have put catch-and-release rules in place. So far, client cooperation and catch rates have been good.

6.1.3.6 Mackenzie River Basin Transboundary Waters Master Agreement

Encompassing portions of Alberta, British Columbia, Saskatchewan, and the Northwest Territories, the Peace-Athabasca-Slave River Basin comprises a large part of the Mackenzie River Basin. Efforts are underway by Canada, British Columbia, Alberta, Saskatchewan, the Yukon Territory, and Northwest Territories to reach an agreement to apportion river flows and preserve river water quality in the Mackenzie River Basin.

6.1.3.7 Hay-Zama Lakes Environmental Considerations

Because of its environmental value, the Hay-Zama Lake area was set aside for wildlife by Order-in-Council in 1958, and resource extraction in the area has been controlled since then. A joint committee of industry, government, and the public provides advice to government and operators in the area regarding environmental considerations. Recently, new boundaries have been drawn up based on biological and hydrological criteria, and new special requirements for oil and gas operators have been issued to encourage the rapid and safe extraction of oil and gas reserves in the area. Surface development on new mineral leases in part of the area is not permitted, and requests for surface access in other parts of the area are reviewed by Alberta Environmental Protection.

In 1996, the Energy and Utilities Board published special requirements for oil and gas companies operating in the Zama Lake Area. Each year during a five-week spring period (beginning in mid-April) and an eight-week fall period (beginning in mid-August), companies must either suspend well production and helicopter operations or employ a person to monitor wildlife migration. In consultation with Alberta Environmental Protection, the companies determine which well operations will be suspended. Furthermore, construction of stream crossings for roads and pipelines is suspended annually between mid-April and mid-July to accommodate fish spawning and migration.

6.1.3.8 Management Strategy for Exposed Bed and Shore on Public Lands in Northern Alberta

A management strategy responding to drought conditions in northern Alberta was developed in 1994 by Alberta Environmental Protection and Agriculture, Food and Rural Development. The strategy provides for agricultural use of newly exposed bed and shore land in a manner that maintains the benefits of these lands for waterfowl, other wildlife, and plant species. The strategy permits haying on newly exposed lands, but delays the first hay cut until after July 15 in order to protect nesting and brood habitat for wetland bird species. The strategy clearly states that ownership of the exposed bed and shore is held by the Crown, and that Crown permission is required for an adjacent landowner to conduct agricultural activities on the exposed area.

6.2 THE BEAVER RIVER BASIN (Figure 6.6)

The Beaver River Basin is a relatively small river basin, encompassing 15,500 km^2 in east central Alberta. The basin becomes larger as it extends eastward across Saskatchewan and Manitoba, eventually emptying into Hudson Bay **(Figure 2.3)**.

Situated in the Boreal Forest Natural Region, the Beaver River Basin is underlain with sandstone and shales covered with rolling glacial moraine and clay and sand deposits. Thick forests of poplar and white spruce are present, with jack pine on sandy locations.

The large Cold Lake Air Weapons Range occupies the northern part of the basin, and the largest centres of population are in the eastern portion. Oil and gas exploration and development occur throughout. The large Cold Lake oil sands deposit and petroleum extraction installations such as Fort Kent (Suncor Pilot Plant) and Esso (Leming Lake/Mehikan) are located in the eastern part. Most of the urban centres in the basin, including the towns of Bonnyville, Cold Lake, and Grande Centre, are also situated in the eastern portion near the lower reaches of the Beaver River. Agricultural activity occurs mainly in the southern part of the basin.

6.2.1 Rivers, Lakes, and Wetlands

The basin is named after its major river, the Beaver, that rises in Beaver Lake near Lac La Biche and flows into Saskatchewan. Low topography throughout the basin results in many meandering streams and small rivers. These watercourses drain numerous lakes of all sizes, including Cold Lake, Moose Lake, Muriel Lake, Ethel Lake, Wolf Lake, and most of the lakes within Lakeland Provincial Park and Provincial Recreation Area.

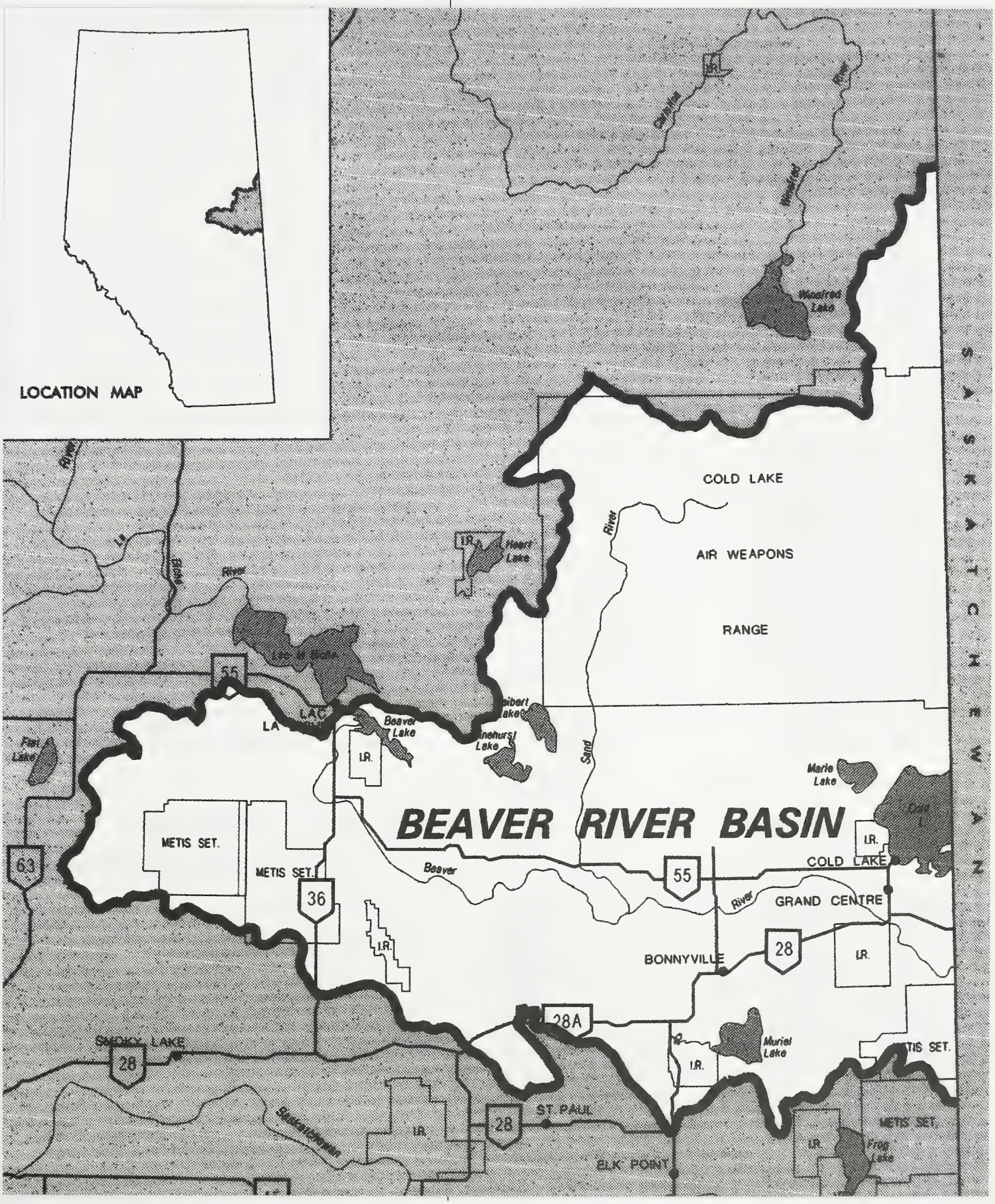
Wetlands, both marshes and peatlands, are also present in great number. A moderate amount of peatland is present, primarily in the form of fens, although some bogs are also present. Extensive peatland complexes exist around Lac La Biche.

The River Otter

The river otter, a member of the weasel family, inhabits lakeshores, streams, and beaver ponds in Alberta. The highest density of river otters in the province occurs near the northern edge of the Beaver River Basin. Otters in this area forage chiefly on small fish such as minnows and suckers, but larger fish, insects, crustaceans, molluscs, waterfowl and (rarely) young beavers are also food items (Reid et al. 1994). Otters rely heavily on beaver habitat for denning, foraging, and overwintering.

In the last decade Alberta's otter populations appeared to be declining. However, in the past several years, otters have been seen outside of their usual range. Results from the annual trappers' survey also indicate growth in otter populations.

FIGURE 6.6 Beaver River Basin



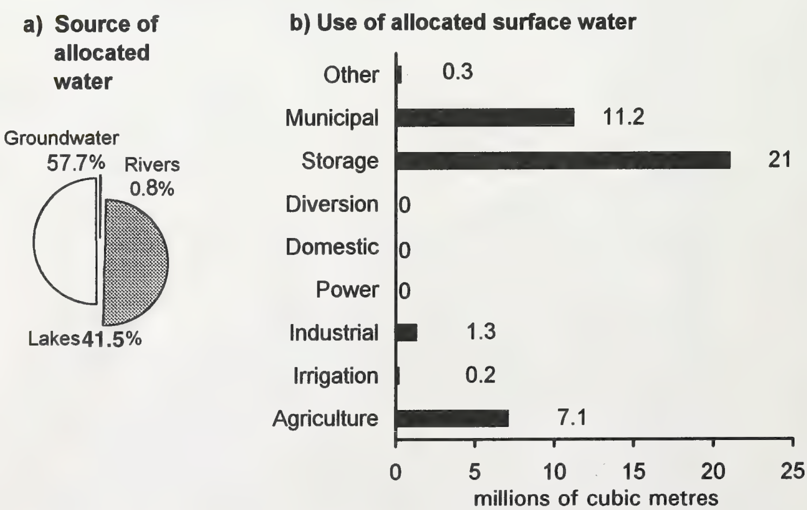
Case Study: The Beaver River

The Beaver River is a relatively small river that originates on and flows through forested plains. It has a low gradient and meanders over a sandy river bed. Fed mainly by spring runoff and summer storms, its flow is highly variable both seasonally and annually. In recent years, flows have been considerably below average, as shown in **Figure 3.3**. Under the Master Agreement on Apportionment, one-half of the river's natural flow must be passed on to Saskatchewan.

The river is fairly pristine, particularly in its upper reaches. However, because the river is ice-covered for much of the year and often has low flows, its dissolved oxygen levels are naturally low. The Beaver's major tributary, the Sand River, contributes 50 percent of the water in the Beaver River (as measured at the Saskatchewan border). Groundwater also contributes significantly to the river's flow. The source of this water, the Durlingville Aquifer, occurs in the area where a large pre-glacial channel passes beneath the river. Concentrations of certain substances are unusually high at this site, probably reflecting the quality of inflowing groundwater.

In its downstream reaches the Beaver River is affected by municipal and industrial wastewater. In the spring and fall of 1991 and 1993, the river was sampled below each of the municipal and Canadian Forces Base (CFB) wastewater effluent discharge points (outfalls), the CFB storm sewer outfall, and in four other places on the river. The sites below both wastewater effluent outfalls had higher concentrations of phosphorus than upstream sites, with

FIGURE 6.7 WATER ALLOCATION IN THE BEAVER RIVER BASIN
source: Alberta Environmental Protection



levels of biologically available phosphorus 40 to 60 times higher than background levels in the river. Other substances that did not meet surface water quality guidelines included cadmium and iron (probably reflecting naturally high levels in the river), copper, chromium, phosphorus and nitrogen (higher downstream of the CFB discharge outlet), manganese, total nitrogen and total coliform bacteria (higher downstream of the municipal lagoon outfall). However, streamflows at the time of sampling and for a number of years were below average. It is therefore thought that more normal flows would likely have resulted in fewer exceedances of the guidelines.

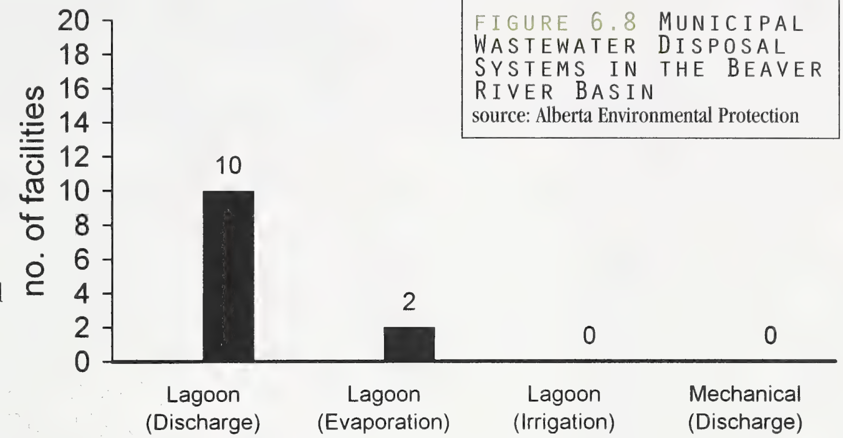


FIGURE 6.8 MUNICIPAL WASTEWATER DISPOSAL SYSTEMS IN THE BEAVER RIVER BASIN
source: Alberta Environmental Protection

Benthic invertebrates in the Beaver River near the Saskatchewan border were sampled between 1983 and 1987. The low diversity and numbers of organisms found were thought to be a consequence of the sandy river bottom. Nevertheless, the Beaver River system contains several species uncommon to Alberta, including the crayfish *Orconectes virilis*, whose distribution is apparently limited to this basin, and a species of clam that inhabits sandy areas within the Sand River.

6.2.2 HUMAN FACTORS INFLUENCING AQUATIC ECOSYSTEMS

This basin contains one of the province's major tourist and recreational areas, the "Lakeland area" (Cold Lake and the numerous lakes surrounding it). Many of Alberta's high-capability recreational lake shorelands for swimming, boating, fishing, canoeing, and camping are located here. Sportfishing is very popular on a number of lakes such as Seibert Lake, which has a trophy northern pike fishery. Until the past decade or so, access to most of these lakes was fairly limited. However, increasing numbers of resource development roads and off-highway vehicles have changed this situation dramatically, putting heavy fishing pressure on several lakes.

A total of 97 million cubic metres of water (equal to 1.1 percent of the total provincial allocation) was allocated from this basin in 1996. Unlike the practice in other river basins, most of the water allocated is groundwater (57.7 percent). Lakes supply 41.5 percent of the allocation and rivers and streams less than one percent. Allocated surface water is used mostly for water storage ponds for purposes such as wildlife habitat enhancement or conservation. The amount allocated is based on potential surface evaporation from the stored area and is thus not actually consumed. Municipalities are the next highest users, followed by agriculture **(Figure 6.7)**. In the future, additional water may be required by the petroleum industry **(see below)**.

Municipal wastewater facilities in the basin are shown in **Figure 6.8.** Treated wastewater from CFB Cold Lake and also storm sewer drainage from the base enters the Beaver River via Marie Creek. A lagoon system for Cold Lake and Grand Centre also discharges into the river, as do smaller lagoons upstream.

Many lakes, such as Beaver Lake, Moose Lake, Pinehurst Lake, Helena Lake and Cold Lake, are also used by First Nations' peoples for domestic fishing. Commercial fishing is conducted on several lakes in the basin, including Cold Lake, Spencer Lake, and Wolf Lake. The trapping of beaver, mink and muskrat is an important activity in the river basin, with the trapping rate for muskrat second only to that of the Peace-Athabasca Delta.

6.2.3 Management Actions Specific to the Basin

6.2.3.1 Beaver River Water Resources Study

Proposed industrial projects involving *in situ* recovery of heavy oil in the Beaver River Basin led to a study in the early 1980s of basin water supply and the ability of basin water resources to meet potential industrial demand. Following this study, the Cold Lake-Beaver River Water Management Plan was developed with extensive public participation. This plan, now mostly implemented, limits water withdrawal from various water bodies in the basin and sets guidelines for water recycling and effluent discharge.

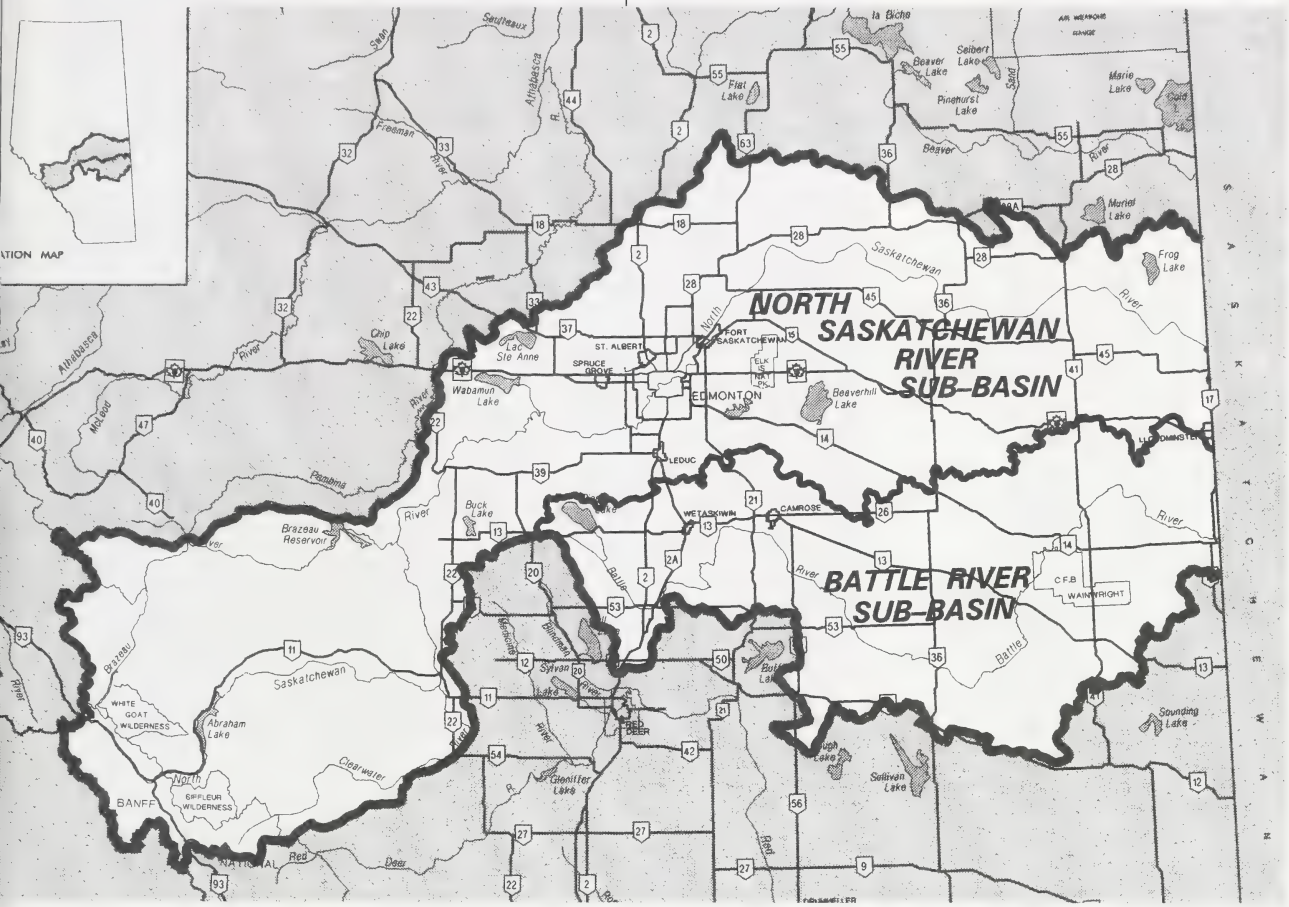
6.2.3.2 Lakeland Provincial Park and Provincial Recreation Area

In recognition of the recreational potential and environmental importance of an area with a high density of lakes, the Lakeland Provincial Park and Provincial Recreation Area was established in 1992 in the boreal mixed wood forest east of Lac La Biche. A panel has been appointed by the Minister of Environmental Protection to conduct public hearings and receive public input for a draft management plan for the area.

6.3 The North Saskatchewan River Basin **(Figure 6.9)**

The North Saskatchewan River Basin, considered here together with the Battle River sub-basin to its south, spans the central part of Alberta from the icefields of Banff and Jasper national parks to the Parkland and Boreal Forest natural regions at the Alberta-Saskatchewan border. The combined basins drain some 80 000 km^2 and form the third largest basin in the province. The major river, the North Saskatchewan, has six major tributaries: four originating in the mountains - the Brazeau, Nordegg, Ram, and Clearwater rivers - and two that rise in the parkland - the Sturgeon and Vermilion rivers. The Battle River, which begins in the central Alberta parkland near Ponoka, joins the North Saskatchewan River in Saskatchewan. Although much smaller than the North Saskatchewan River, the Battle River drains about 44 percent of the combined basin area.

GURE 6.9 NORTH
SKATCHEWAN RIVER BASIN



Approximately one million people live in the North Saskatchewan River Basin, most of them in the Edmonton vicinity, and the largest number of industries in any Alberta river basin are located here. Much of the parkland in the basin has been cleared for agriculture. Timber is harvested mainly in the foothills and oil and gas exploration and development occur throughout the basin. Coal deposits on the plains are mined and the coal burned to generate electric power.

6.3.1 Rivers, Lakes and Wetlands

The North Saskatchewan River is a typical mountain-origin river. It originates in the Columbia Icefields as a cold, well-oxygenated mountain stream supporting trout and mountain whitefish. The river is impounded in the mountains by the Bighorn Dam. From there to Edmonton, mountain tributaries triple the river's volume. Below Edmonton, the river's volume increases little.

The Lake Sturgeon

The lake sturgeon, a species dating back 300 million years to the Devonian period, is present in the North and South Saskatchewan river systems. Sturgeons lack scales and have a cartilaginous skeleton - they are not directly related to other present-day fishes. At one time the species was distributed throughout Alberta and Canada. Today, dams isolate surviving populations in the North and South Saskatchewan river systems from each other and from sturgeons in the province of Saskatchewan.

Sturgeon are long-lived and slow to mature, first breeding at about 20 years of age. Females spawn only once every four to six years. In Alberta, the age record is 55 years (male) and 80 years (female), and the weight record is 48 kg (105 lbs). A 62-year-old sturgeon measuring 178 cm (5.9 ft) was recorded in 1991.

The sturgeon fishery in Alberta collapsed in the 1940s from overfishing and was closed until 1968. In recent years, some sportfishing has been permitted under special licence with size and harvest limitations. Populations in the North Saskatchewan River presently number less than 1000, most of which are immature fish. There are not yet sufficient numbers of mature fish for full recovery of the population. The South Saskatchewan River population, occurring in the Oldman, Bow and lower Red Deer rivers, numbers about 5000 and is also mostly immature. Whether populations in the North and South Saskatchewan river systems can survive over the long term, despite their genetic isolation, is unknown.

Sturgeon are bottom feeders, consuming a variety of invertebrates, molluscs, vegetation, detritus, and small fish. During the time of spawning in the spring, sturgeon migrate upstream. It is believed that adequate spawning locations are available, although habitat conditions are not fully understood. Whether regulated flows on both river systems have helped or hindered the species is also unknown.

Because of their slow maturation, sturgeon cannot adapt rapidly to changing conditions resulting from human activity. They are therefore more sensitive to negative environmental changes than many other species.

As the river flows eastward, it picks up naturally occurring dissolved substances, including heavy metals and trace elements such as iron and aluminum, from surrounding soils and rocks. Inflowing groundwater and tributaries also influence its water quality, as do human activities **(see below)**.

Below Edmonton higher water temperatures prevail, along with warmwater fish species and aquatic shoreline vegetation. Lake sturgeon are present downstream from Devon. Here the river is home to waterfowl, gulls, and other birds, and beaver and muskrat inhabit its banks. The river valley serves as an important wildlife corridor.

The Battle River is supplied by local runoff, groundwater, lakes, and reservoirs. Driedmeat Lake is a part of the river occupying a glacial meltwater channel. The water level here has been stabilized by a weir to augment downstream flows during drought.

Lakes in the North Saskatchewan River basin vary greatly in size and water quality, from clear mountain and foothill lakes to the fairly shallow and productive parkland lakes. A few smaller lakes, such as Crimson Lake and Lake Eden, are mesotrophic. Some of the larger popular lakes include Wabamun Lake, Lac Ste. Anne, Pigeon Lake and Miquelon Lake.

With its rolling "knob and kettle" topography, the parkland portion of the basin contains many small, shallow "pothole" sloughs (most under 0.8 hectares in area, ranging in density from 5.5 to 11.0 per km^2). These wetlands provide some of the best waterfowl breeding areas in Alberta, with waterfowl densities as high as 125 breeding ducks per km^2. Beaverhill Lake, a large shallow lake/wetland east of Edmonton, is of international significance **(see sidebar)**.

Beaverhill Lake

Beaverhill Lake, a vast wetland near Tofield, is internationally famous for its large concentrations of waterfowl and shorebirds in spring and fall. Groups of 50 000 shorebirds and 200 000 staging waterfowl have been counted here. Water levels fluctuate widely in the shallow expanse of the lake, surrounding marshes, and nearby sloughs in response to changes in precipitation and evapotranspiration. Parts of the lake and adjoining wetlands have been stabilized by weirs and other structures by Ducks Unlimited Canada. Shoreline fencing and nesting islands have been constructed under the Buck for Wildlife program.

Shorebirds found in large concentrations at the lake include the red-necked phalarope, pectoral sandpiper, white-rumped sandpiper, buff-breasted sandpiper, dowitcher, red knot, ruddy turnstone and black-bellied plover. Endangered species that use the lake include nesting pairs of piping plover, migrating peregrine falcons, and, occasionally, migrating trumpeter swans and whooping cranes.

Beaverhill Lake holds many distinctions :

- *One of Canada's four designated Western Hemisphere Shorebird Reserves*
- *A designated Ramsar site (wetland of international significance)*
- *Wetlands for Tomorrow Program - recognized as one of the most important lakes in the Parkland Natural Region*
- *A Watchable Wildlife Site under the Alberta Watchable Wildlife Program of Alberta Environmental Protection*
- *A National Nature Viewpoint (Canadian Nature Federation)*
- *Portions of the lake have been designated as a Natural Area under the Natural Areas Program of Alberta Environmental Protection*

The Beaverhill Bird Observatory operates a research and bird-banding station at the lake. The annual Beaverhill Lake Snow Goose Festival, first held in 1993, attracted over 6000 visitors in 1996 to view staging snow geese and other waterfowl.

The southern limit of peatlands is also found in the North Saskatchewan River Basin. Although only small numbers of peatlands are present, they include rich fens with a great diversity of life. One such fen is the misnamed "Wagner Bog" **(see sidebar)**.

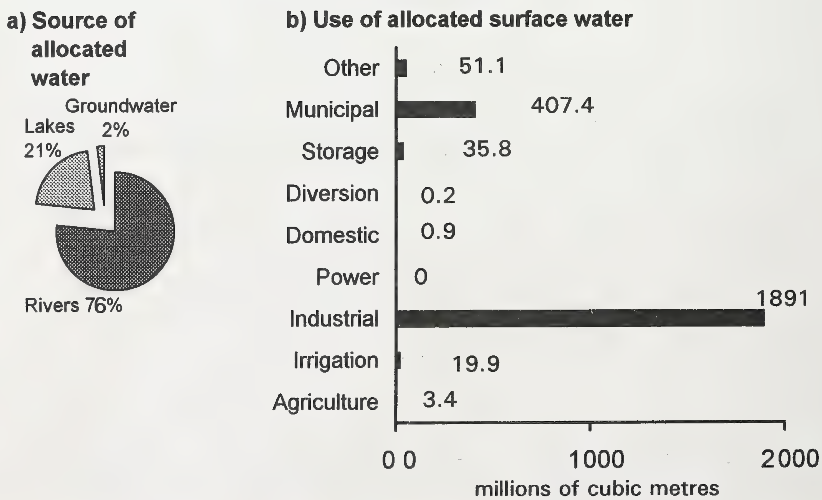
Wagner Natural Area

A small peatland area known as "Wagner Bog" in the Parkland Region near Edmonton is a designated Natural Area due to its unique features. This area is, in fact, not a bog but a mosaic of peatland types from rich fens to nutrient-poor Sphagnum hummocks. The peat's age, based on its depth, is estimated to be 4700 years (Johnson 1982).

Springs flowing into the area contribute a variety of dissolved minerals. Although most of the springs contain calcium carbonate, others have high concentrations of sulphate or sodium. The spring water, at 4°C year-round, supports a number of unusual plants. Marl flats, containing calcium carbonate precipitated from the spring water, support rare plant species including the bog adder's-mouth orchid. Fifteen of Alberta's 26 orchid species have been found here. Other rich-fen species and wet-sedge-fen species are present, and this wetland features larch trees over 300 years old. Wildlife species include red-sided and wandering garter snakes, Canada lynx, mink, long-tailed weasel, northern flying squirrel, northern long-eared bat, big brown bat, silver-haired bat, and hoary bat (Kaiser and Hendy 1982).

The water basin for the wetland extends outside of its boundaries, and so is vulnerable to developments such as increased human residence and water well use, or road construction that alters water flow patterns. Wagner Natural Area is one of the few areas in Alberta that has been licensed under the Water Resources Act to "use water in its natural state for the purpose of conservation, recreation or the propagation of fish and wildlife." The licence was acquired by the Wagner Natural Area Society, which manages the area.

FIGURE 6.10 WATER ALLOCATION IN THE NORTH SASKATCHEWAN RIVER BASIN
source: Alberta Environmental Protection



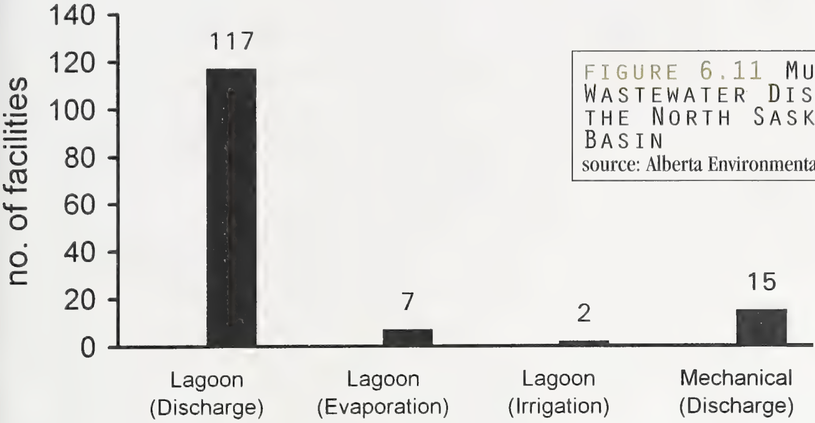


FIGURE 6.11 MUNICIPAL WASTEWATER DISPOSAL SYSTEMS IN THE NORTH SASKATCHEWAN RIVER BASIN
source: Alberta Environmental Protection

6.3.2 Human Factors Influencing Aquatic Ecosystems

The Bighorn dam, built in 1973, and the Brazeau dam, built in 1961 on the tributary Brazeau River, stabilize the North Saskatchewan's flows, increasing them in winter and reducing peak flows in summer. Water supply in the Battle River is naturally limited and variable. A reservoir at Forestburg allows a steady supply of cooling water for a coal-fired power plant.

Summer water demands on the Sturgeon River from horticultural operations and golf courses in the Edmonton area are not always met due to low mid-summer flows in some years **(see Section 6.3.3)**.

Under the Master Agreement on Apportionment, 50 percent of the natural flows of the North Saskatchewan and Battle rivers must be passed to the province of Saskatchewan.

Within the basin, about six billion cubic metres of water are used for cooling coal-fired power plants west of Edmonton. Ninety-nine percent of this water is returned to the river. In addition, 2.5 billion cubic metres of water were allocated in the basin in 1996, making it the second most allocated basin in the province. Of the water allocated, 76 percent is obtained from rivers, 21 percent from lakes, and two percent from groundwater **(Figure 6.10)**. The river supplies drinking water to Edmonton and the surrounding region **(Figure 4.5)** and water for many industries in the Edmonton-Fort Saskatchewan area.

About 15 of these industries discharge effluents to the North Saskatchewan River between Edmonton and Fort Saskatchewan. The Battle River receives effluent from two coal mine settling ponds and a power plant **(Table 6.2)**.

Seven of the basin's 141 municipal wastewater systems discharge continuously to the river **(Figure 6.11)**. The largest of these systems, one belonging to the City of Edmonton and another to surrounding communities, are located in the Edmonton vicinity. During rainstorms and spring runoff, storm sewers discharge runoff from city streets into the river, whereas older sewers in part of the city discharge combined stormwater and untreated sewage **(see Section 6.3.3)**.

Although advanced treatment technologies and flow regulation have improved water quality in the North Saskatchewan River since the 1950s, the water quality from Edmonton to the provincial boundary is influenced by the Edmonton area. Toxic levels of ammonia are present in the immediate area of wastewater discharges, and high nutrient levels below Edmonton stimulate growth of aquatic plants, causing daily swings in dissolved oxygen levels. Storm and combined storm-sanitary sewers add coliform bacteria, chromium, lead, nickel, and suspended solids to the river. Edmonton's effect on the river can be detected at least 100 km downstream **(Figure 4.7)**.

TABLE 6.2 INDUSTRIAL FACILITIES DISCHARGING INTO THE NORTH SASKATCHEWAN RIVER BASIN
source: Alberta Environmental Protection

North Saskatchewan River Basin		
Facility Type	**No. of Facilities**	**Regulated Parameters[1]**
Insulation	1	Ammonia-N (NH_3-N), chemical oxygen demand (COD), oil and grease, phenolics, total suspende solids (TSS), pH
Power Plants	3	Free chlorine available, oil and grease, total iron total P, total N, TSS, COD, dissolved oxygen, total dissolved solids (TDS), flow, temperature
Refineries	3	NH_3-N, COD, fish bioassay[2], oil and grease, phenols, sulphide, TSS, pH
Fertilizer Plants	2	NH_3-N, nitrate-N, organic N, fish bioassay[2], oil and grease, copper, nickel, cyanide, phosphate, TSS, pH
Food Processing	1	Fish bioassay[2], non-filterable residue, total chloride, pH
Foundry	1	COD, oil and grease, total iron, TSS, pH
Chemical Plants	8	Range includes: COD, oil and grease, TSS, pH max, pH min, total organic carbon, sulphides, fis bioassay[2], NH_3-N, total Kjeldahl N (TKN), vinyl chloride, phosphate
Battle River Sub-basin		
Coal Processing	2	Oil and grease, settleable solids, pH, iron, non-filterable residue
Power Plant	1	Fish bioassay[2], oil and grease, total iron, TSS, p

[1] List inclusive for the facilities present in the basin. For each individual facility, som or all of the listed parameters may be regulated.
[2] Bioassay must be passed.

Levels of phenols, aluminum (bound to soil and clay particles), and copper occasionally exceed Canadian Water Quality Guidelines upstream of Edmonton and frequently exceed them downstream. The upstream levels are mainly from natural sources, whereas downstream levels also include substances from municipal and industrial sources.

Land-based activities upstream of Edmonton also affect the river. For many years, Edmontonians complained about the taste and odour of tap water during spring runoff. Studies by the City of Edmonton suggest that this problem originates (at least in part) from certain tributary creeks upstream. (Peaks in levels of colour and organics in the city's raw water coincide with runoff events in these creeks.) In addition, livestock waste accumulated over the winter may enter these creeks during spring runoff.

In addition to agriculture, forestry operations and resource development also influence water quality in the river. Although the overall effect of these activities on the river is not well documented, it has been shown that at certain times of year, particularly during spring runoff, levels of suspended solids, bacteria, nutrients, and organic materials increase upstream of Edmonton. Studies during spring runoff found increases in total phosphorus (53 percent), nitrogen (44 percent), faecal coliform bacteria (48 percent), copper (31 percent), and dissolved organic carbon (50 percent) in the river at Devon (upstream of Edmonton). These increases were due to contributions from runoff, streams (excluding major tributary rivers), and atmospheric deposition.

Water resources in the North Saskatchewan River Basin are also used for recreation. Major focal points of this activity are rivers and streams in the upper reaches and the larger lakes near Edmonton. The mountain and foothills streams are of significant recreational importance for sportfishing, canoeing, and kayaking. Larger lakes near Edmonton are used extensively for boating, angling, and other water-based activities, and have high-density cottage developments and heavily used campgrounds. In some lakes intensive use may be affecting water quality.

Research is being conducted to examine whether agriculture is affecting water quality in small lakes in the parkland that might be vulnerable to runoff containing nutrients and agro-chemicals **(Section 5.7)**.

Wetlands in the Parkland Natural Region have been greatly affected by agriculture and development. Some of the highest rates of wetland loss in Alberta between 1970 and 1990 occurred in this area **(Section 4.3)**.

6.3.3 Management Actions Specific to the Basin

6.3.3.1 Water Quality Monitoring and Studies

Alberta Environmental Protection has two long-term monitoring stations on the river upstream and downstream of Edmonton and has conducted water quality studies along the entire river between 1985 and 1989 and in the Edmonton area in 1991, 1994, and 1995. Environment Canada has a water quality monitoring site near the Saskatchewan border.

Fish from four sites on the river between Rocky Mountain House and Devon were sampled for mercury content in 1985. Goldeye, sauger, walleye, and northern pike in the lower river reaches had residues above the Canadian guideline of 0.5 ppm (mg/kg) for commercially marketed fish. The mercury is considered to be of natural origin. Fish consumption guidelines are in place for these species.

A North Saskatchewan River Basin Study was completed in 1994 with the participation of eight major industries and two municipalities (City of Edmonton and Capital Region Sewage Treatment Plant). The study concluded that measurable effects were present from the two municipal discharges and one company discharge (Sherritt in Fort Saskatchewan). All three of these facilities are being required to reduce their impact on the river.

Levels of certain metals including chromium, cadmium, and copper in the Battle River occasionally exceed Canadian Water Quality Guidelines for the protection of aquatic life, and the Prairie Provinces Water Board objectives. Levels of metals in the water, sediments, and biota of the Battle River were examined jointly by the governments of Canada, Alberta, and Saskatchewan in 1989 and 1990. This study found that the high levels are mainly from natural sources.

6.3.3.2 Municipal Drinking Water and Wastewater Treatment

In recent years the City of Edmonton has addressed drinking water quality problems by using activated carbon to remove impurities. The city has also installed an early warning system for spring runoff on certain creeks, and is monitoring colour changes in raw water.

Edmonton's wastewater treatment plant will include ultraviolet radiation for killing bacteria, including pathogens, by 1998. Tertiary treatment facilities to further remove ammonia, phosphorus, and nitrogen will be installed in both the Edmonton and the Capital Region sewage treatment plants by 2005. The city is also in the process of modifying its combined stormwater-sewer system.

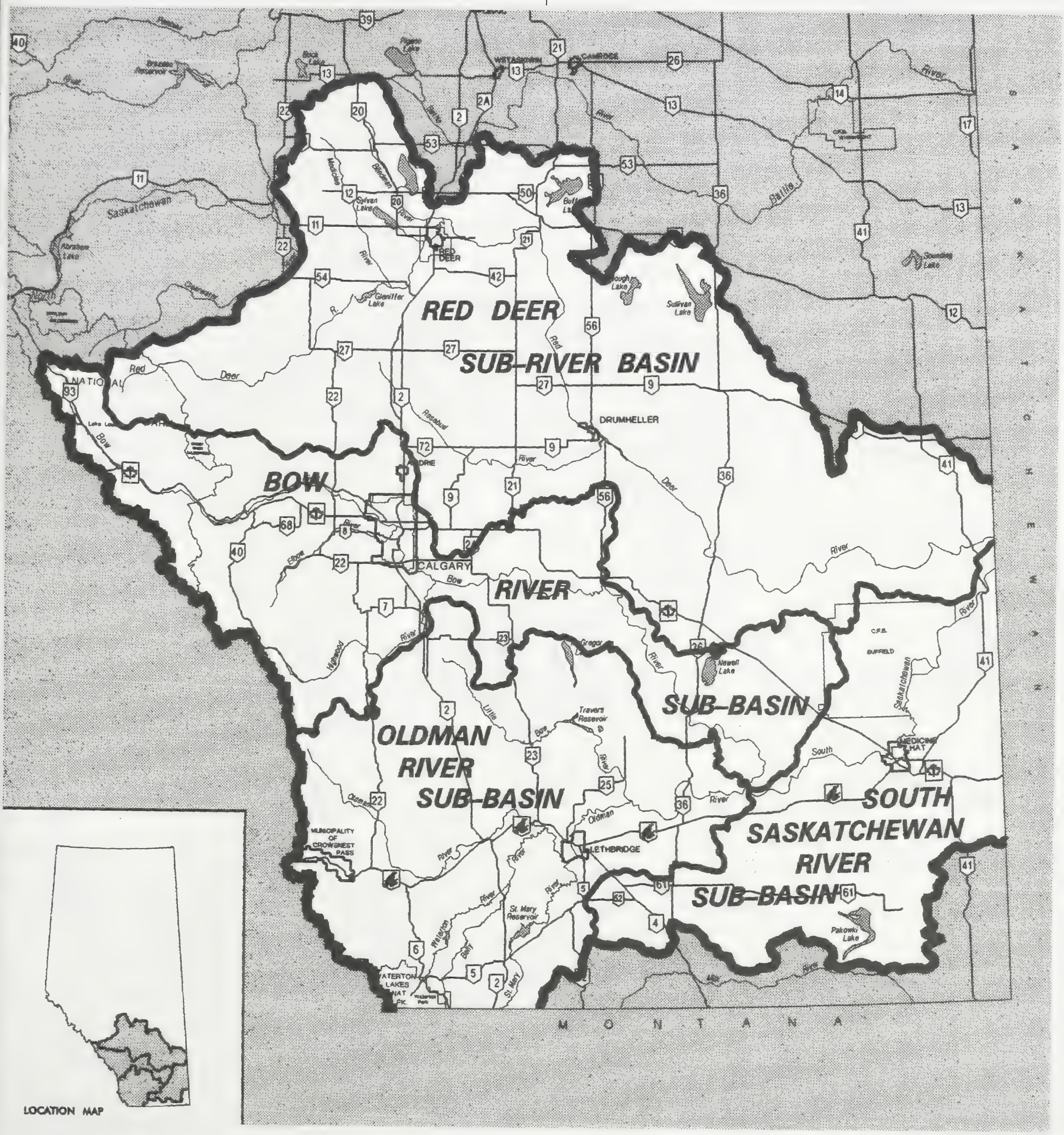
6.3.3.3 Instream Flow Needs Studies

In 1996, a study of the Sturgeon and Vermilion River sub-basins examined their natural flows, instream flow needs, and water allocation, and developed guidelines for the amount of water that can be withdrawn in the future.

6.3.3.4 North American Waterfowl Management Plan

As well as striving to maintain, secure and enhance wetlands in this and other areas, the North American Waterfowl Management Plan is working with the agricultural community in the region to modify agricultural practices to benefit wildlife habitat while maintaining agricultural production. A major aim is to improve the amount and/or quality of upland nesting cover around remaining wetlands.

FIGURE 6.12 SOUTH SASKATCHEWAN RIVER BASIN

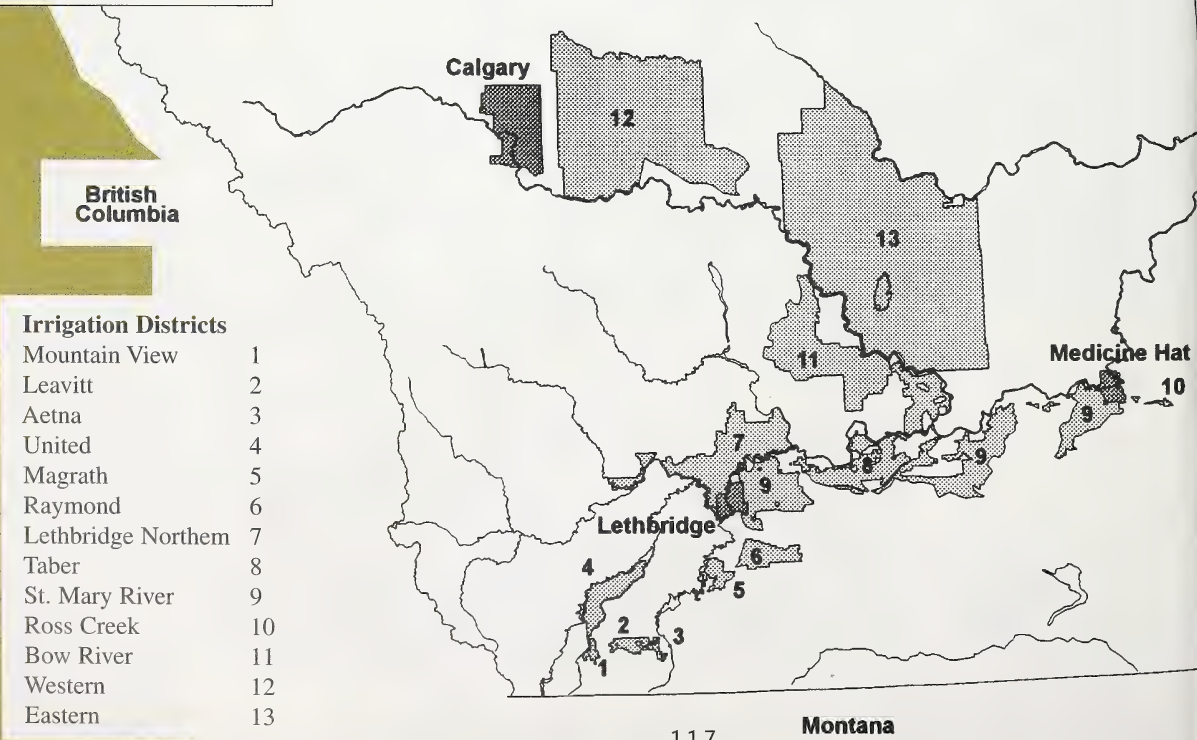


6.4 THE SOUTH SASKATCHEWAN RIVER BASIN

The South Saskatchewan River Basin **(Figure 6.12)** includes the watersheds of the Red Deer, Bow, and Oldman rivers, all of which begin in the Rocky Mountains and flow east across the foothills and prairie. The Bow and Oldman rivers merge between Lethbridge and Medicine Hat to become the South Saskatchewan River, which is joined by the Red Deer River just east of the Alberta-Saskatchewan border. The combined watershed area of these rivers is 121,095 km^2, of which 41 percent belongs to the Red Deer River sub-basin, 22 percent to the Oldman, 21 percent to the Bow and 16 percent to the South Saskatchewan.

This large basin is diverse, including part of the Rocky Mountain, Foothills, Boreal Forest, Parkland and Grassland natural regions. Coal deposits are mined in the northern foothills and oil and gas is located throughout the basin. The combination of fertile soils and dry climate in the southern part of the basin have favoured irrigation farming. All of the province's 13 irrigation districts are located in this basin **(Figure 6.13)**. Livestock are also raised throughout the region. Major cities of the basin include Calgary, Red Deer, Lethbridge, and Medicine Hat.

FIGURE 6.13
IRRIGATION DISTRICTS
source: Alberta Agriculture, Food and Rural Development



6.4.1 Rivers, Lakes, Reservoirs and Wetlands

Melting snow in the mountains supplies 75 percent of the flow in the basin's three major rivers. Their mountainous watersheds stretch from the northern tip of Banff National Park to Glacier National Park in Montana. Between mid-May and mid-July in most years, a great surge of meltwater courses down the rivers' steep river beds through the mountains and foothills and out onto the prairie. When heavy rain occurs at the same time, flooding may result. Over the rest of the year, flows are frequently low. Low flows in August combined with high temperatures sometimes result in difficult habitat conditions for freshwater aquatic life.

The upper coldwater reaches of the South Saskatchewan river system contain mountain and lake whitefish and many kinds of trout-bull, brook, brown, cutthroat, golden, lake, and rainbow. Downstream reaches contain northern pike, goldeye, mooneye, yellow perch, walleye, sauger, and lake sturgeon. Some of the best stream angling opportunities in the province are found in this basin, both in headwaters and further downstream.

In the Grassland Natural Region, river valley floodplains are the only areas with enough soil moisture to support the natural establishment and growth of trees. Three species that can grow in these conditions are present in the South Saskatchewan River Basin **(Figure 6.14)**: the plains cottonwood (*Populus deltoides*), the narrowleaf cottonwood (*P. angustifolia*), and the balsam poplar (*P. balsamifera*) (Rood and Mahoney 1991).

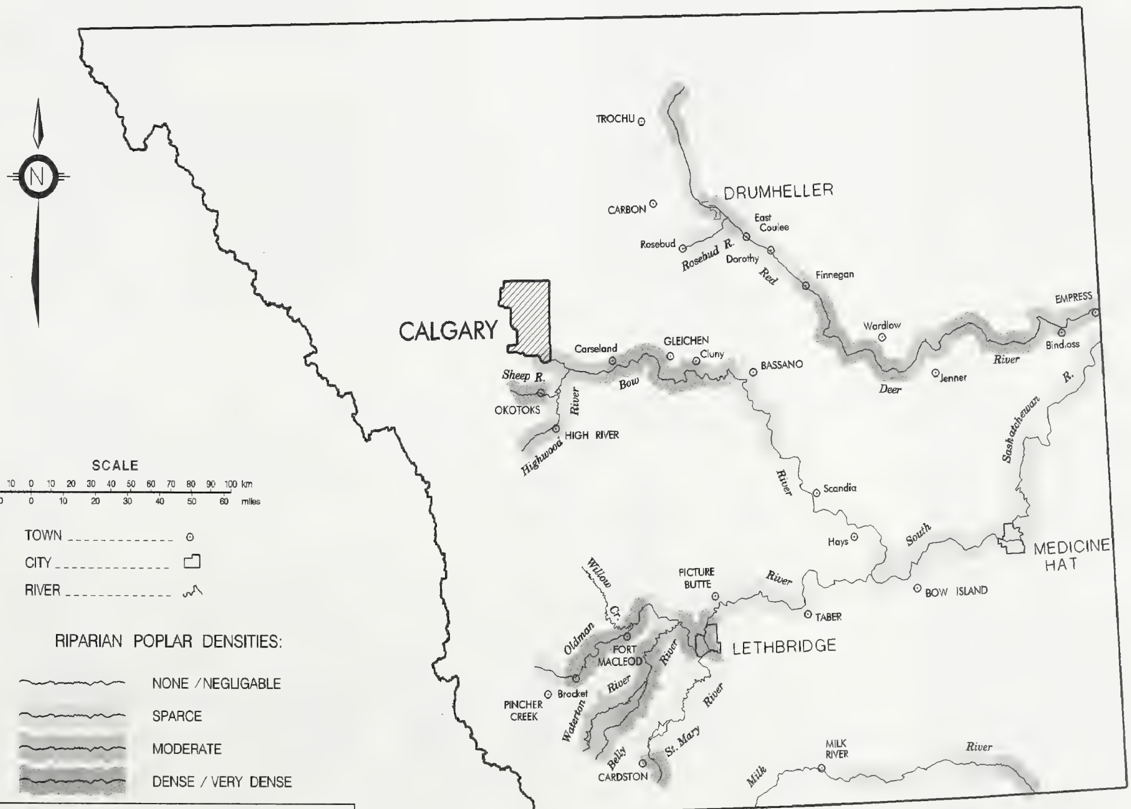


FIGURE 6.14 Distribution of Riparian Poplars in Southern Alberta
source: World Wildlife Fund Canada and Alberta Forestry, Lands and Wildlife, 1982

Cottonwoods and River Flows

Cottonwoods on river floodplains in southern Alberta are highly dependent on hydrological conditions for their establishment and growth. In spring, the trees release their seed near the time when rivers are receding after peak spring flows. These peak flows scour away or bury competing vegetation on the floodplain and deposit sand and silt on which the seeds can germinate. The new seedlings need gradually receding river water levels so that their roots can maintain contact with the receding water table as they grow. Successful conditions for seedling establishment in the Oldman River Basin likely occur only once in every ten years (Mahoney and Rood 1993).

The June 1995 flood on the Oldman River ***(see Section 3.0)*** *occurred shortly before the natural release of cottonwood seeds and gave biologists an opportunity to observe the effects of water levels on cottonwood seedling germination and establishment. Measurements taken in the fall of 1995 at sites along the Oldman and South Saskatchewan rivers found high densities of new seedlings for all three cottonwood species. Seedlings furthest downstream (at lowest elevations), the plains cottonwoods, showed the most growth* ***(Figure 6.15)****. This species is the most reliant on seed germination for spreading (Rood et al. 1996). Seed germination and growth was aided by the flood and by a gradual decline in river flow over the summer.*

Riparian areas in the Parkland and Grassland Natural Regions are important wildlife habitat areas. About three-quarters of the birds inhabiting the Grassland Natural Region use riparian habitats during some part of their life cycle. River valley canyons and coulees are home to some plant and animal species that are rare or uncommon in the province.

The Red Deer River sub-basin, which includes portions of Foothills, Boreal Forest, Parkland and Grassland natural regions, contains the most lakes and wetlands. Several large lakes including Sylvan Lake, Gull Lake, Buffalo Lake, and Pine Lake occur in this sub-basin. The other sub-basins, situated primarily in the Grassland Natural Region (apart from their headwaters), contain few natural lakes. Examples include Tyrrell Lake near Lethbridge and Eagle Lake near Strathmore which are both shallow, saline, and high in nutrients.

The Bow and Oldman river basins contain an extensive network of diversions, canals, dams, and water storage reservoirs. There are 89 reservoirs within this system. Some of the larger reservoirs include Lake Newell, the St. Mary River, Oldman River, Chin, Waterton River, Milk River Ridge, Keho Lake, Travers, and McGregor Lake reservoirs.

Non-peat wetlands occur within the mountains, foothills, and grassland areas. Within the settled area they cover 12 percent of the land area of the Red Deer sub-basin, 7.1 percent of the Bow, 14.1 percent of the South Saskatchewan, and 5.1 percent of the Oldman sub-basins. Many wetlands in this region have been lost due to drought, drainage, and rehabilitation of the irrigation canal system **(Section 4.0)**.

6.4.2 Human Factors Influencing Aquatic Ecosystems

The rivers of the South Saskatchewan River Basin have less than 10 percent of the total average annual streamflow of the province but support approximately one-half of Alberta's population. These rivers and their tributaries are the only water supply for most water needs in the Grassland Natural Region. Groundwater is in insufficient supply and often of poor quality.

The upper Red Deer River sub-basin is used for forestry, agricultural and industrial purposes. Industrial uses downstream from Red Deer are concentrated near Joffre and Finnegan. Heavy agricultural uses exist along the southerly flowing tributaries downstream from Finnegan. The northerly flowing tributaries are used as return flow channels for the irrigation districts. Towns and cities such as Sundre, Red Deer, Drumheller, and Bindloss also use the river. The Dickson Dam on the Red Deer River, completed in 1983, provides a reliable year-round water supply for industry and municipalities in the Red Deer River Basin, improves water quality, and improves Alberta's ability to meet its apportionment agreement with Saskatchewan.

The Sheerness and Deadfish Diversions

The Sheerness and Deadfish Diversions are examples of government and industry working together to use water efficiently. Two pumping diversion systems on the Red Deer River supply water to a portion of Special Area No. 2 in eastern Alberta. The Sheerness Diversion, a cooperative project between the Alberta Government and Alberta Power Limited (APL), supplies water from the Red Deer River via pipeline to APL's coal-fired power plant at Sheerness, where it is used for cooling. A diversion from this pipeline supplies the Henry Kroeger Regional Water Services Commission, which distributes treated water to the communities of Hanna, Richdale, Cereal, Youngstown, Oyen, Delia, and many individuals along the distribution routes. From May to September, APL releases water from its cooling pond into a 14-mile long concrete-lined canal that conveys it to Carolside Reservoir where the water is stored and then released into Berry Creek. Water from the canal, reservoir, and Berry Creek is used by area ranchers for irrigation and to water livestock.

The Deadfish Diversion is an irrigation and stock-watering supply project operated by Alberta Environmental Protection. A pump facility downstream from Sheerness on the Red Deer River diverts water into the Deadfish Reservoir. From there, the water is released into lower Berry Creek, further increasing the water supply available to downstream farms.

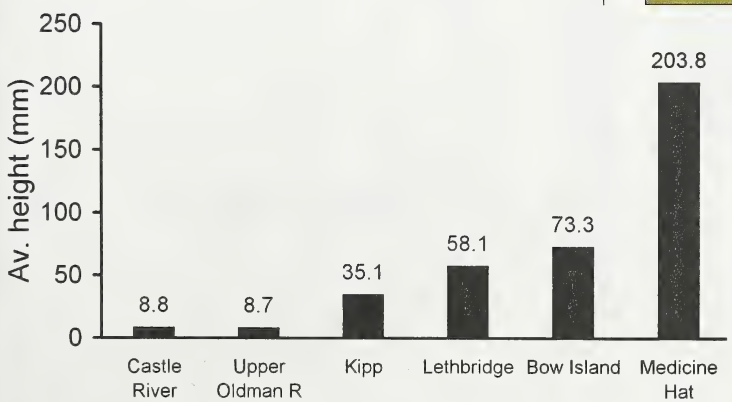


FIGURE 6.15 COTTONWOOD SEEDLING HEIGHTS, OLDMAN RIVER, AUTUMN, 1995
source: modified from Rood *et al.* 1996

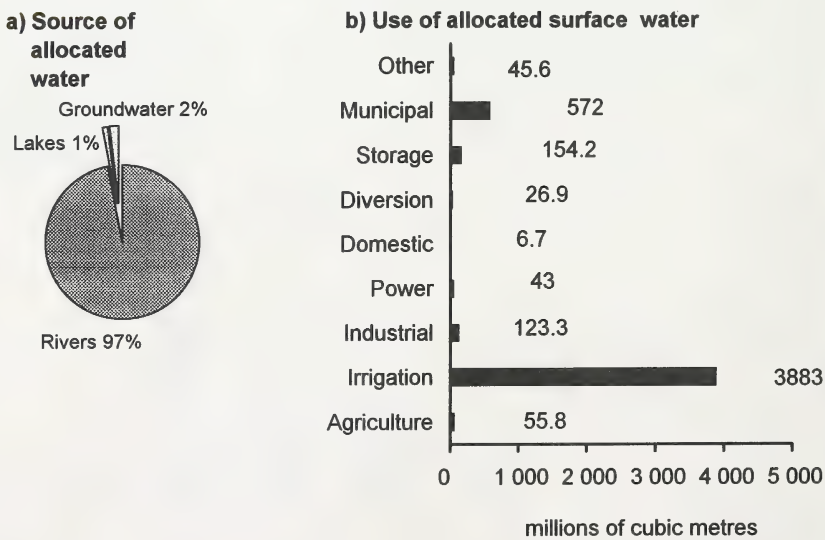
Lakes in the northern part of the Red Deer River sub-basin receive extensive recreational use. Lakes in the basin's lower reaches are also used for recreation and as storage reservoirs.

Water uses in the Bow River sub-basin are municipal, recreational, and industrial. The Bow River and its tributaries are harnessed by 11 hydro-electric dams and six reservoirs, producing about three percent of the total power generated in Alberta. Three irrigation districts draw water from the Bow, as do municipalities and industries at Calgary, Strathmore, Gleichen, Bassano, Brooks, and elsewhere along the river. The river is widely used for fishing and boating, and many parks and trails exist alongside it.

The Oldman River sub-basin supports irrigation, agricultural, and municipal uses. The Oldman, Belly, Waterton, and St. Mary rivers support nine irrigation districts. Lethbridge is the major municipal water user within this sub-basin. The Oldman River Dam and storage reservoir, built for multiple use, became operational in 1991.

Sixty-one percent of the total water allocated in the province is in the South Saskatchewan River Basin. Of this amount, 97 percent is from rivers, two percent from groundwater sources, and less than one percent from lakes. Irrigation is by far the largest use of water in the basin, followed by municipal use **(Figure 6.16)**.

FIGURE 6.16 WATER ALLOCATION IN THE SOUTH SASKATCHEWAN RIVER BASIN
source: Alberta Environmental Protection



Because of its location in the semi-arid part of Alberta, the South Saskatchewan River Basin has a history of competing demands for water, and economic development is further increasing demand. In addition, Alberta's apportionment commitment to Saskatchewan requires one-half of the natural flow of water in the South Saskatchewan River Basin to be passed to Saskatchewan each year. **Figure 6.17** shows how well this commitment is being met. Since the total flow of all three major river systems in the basin is used to calculate the natural and required amounts of water at the border, water consumption in one sub-basin affects the amount of water available for consumption in the others.

Many municipal treatment systems discharge into the basin's rivers **(Figure 6.18)**. Industrial discharges to the basin are shown in **Table 6.3**. These effluents stimulate the growth of weeds and algae downstream of major cities and some towns.

FIGURE 6.17 ANNUAL FLOWS OF THE SOUTH SASKATCHEWAN RIVER* NEAR THE ALBERTA-SASKATCHEWAN BOUNDARY
source: Alberta Environmental Protection
*includes flow of the Red Deer River

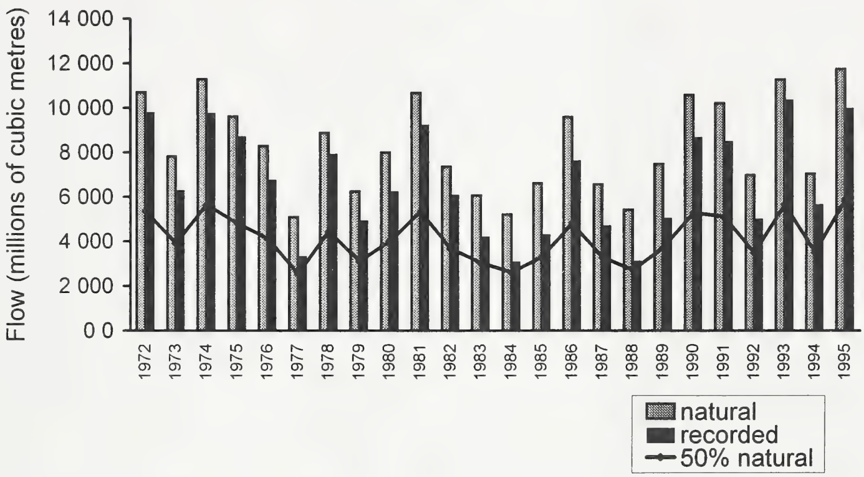


FIGURE 6.18 MUNICIPAL WASTEWATER DISPOSAL SYSTEMS IN THE SOUTH SASKATCHEWAN RIVER BASIN
source: Alberta Environmental Protection

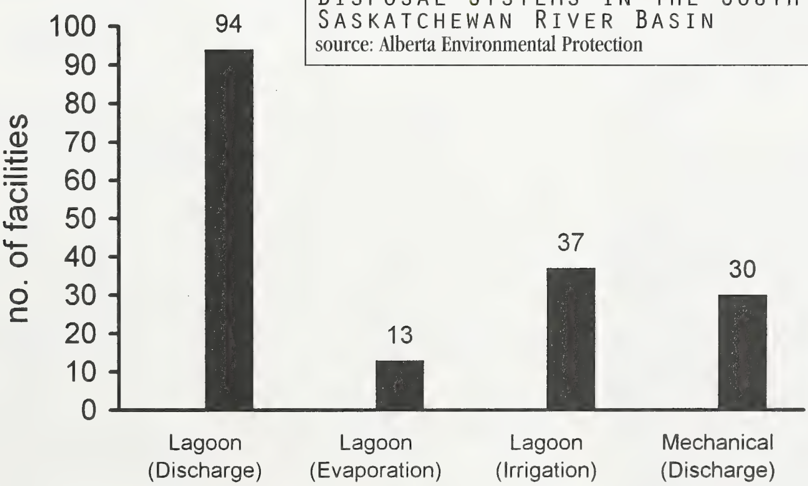


TABLE 6.3 INDUSTRIAL FACILITIES DISCHARGING INTO THE SOUTH SASKATCHEWAN RIVER BASIN
source: Alberta Environmental Protection

Bow River Sub-basin		
Facility Type	**No. of Facilities**	**Regulated Parameters**
Concrete and Cement	1	Chemical oxygen demand (COD), oil and grease, total suspended solids (TSS), pH
Fertilizer	1	
Gas Plants	3	Ammonia-N (NH_3-N), COD, chlorine residual, pH, oil and grease, TSS
Meat Processing	1	NH_3-N, biological oxygen demand (BOD), oil and grease, chlorine residual, TSS, pH
Refinery	1	Oil and grease, phenols, TSS, pH
Oldman River Sub-basin		
Gas Plant	1	NH_3-N, COD, chloride, oil and grease, TSS, pH
Sugar Plant	1	BOD_5, TSS, NH_3-N
Red Deer River Sub-basin		
Chemical Plants	2	Fish bioassay[1], total organic carbon, TSS, pH
Coal Mines	2	Oil and grease, TSS, pH
Power Plant	1	Oil and grease, total iron, total N, TSS, pH
South Saskatchewan River Sub-basin		
Chemical Plant	1	Total P, pH
Fertilizer Plant	1	NH_3-N, oil and grease, organic N, phosphate, TSS, pH
Food Processing	1	NH_3-N, BOD, oil and grease, chlorine residual, TSS, pH
Gas Plants	1	NH_3-N, COD, fish bioassay[1], chlorine residual, TSS, pH
Power Plant	1	

[1] bioassay must be passed

6.4.3 Management Actions Specific to the Basin

6.4.3.1 Water Allocation in the South Saskatchewan River Basin

The extensive planning process used for the South Saskatchewan River Basin in the mid-1980s initiated a basin-wide approach to water management. The process examined various scenarios for water use and management in the basin and included public hearings to determine and discuss policy options. Based on these deliberations, the Alberta Water Resources Commission presented recommendations for water management in the basin to the provincial government. Subsequently, in 1990, the province announced its water management policy for the basin.

The policy states that the principle of multiple use will continue to govern use and management of basin water. The policy recognizes the need to determine the maximum amount of irrigation water that each major river can supply without affecting the river's instream needs. The amount and location of irrigation expansion in the basin have been set by the South Saskatchewan River Basin Water Allocation Regulation. The policy recommends reviewing and, if necessary, updating these irrigation expansion guidelines by the year 2000.

A review of expansion guidelines is underway. The Year 2000 Review of Irrigation Expansion Guidelines is examining present and potential use of the basin's major rivers to determine any necessary guideline modifications. Although the review's main focus is irrigation, the instream flow objectives established for each major river by its public advisory committee will also be considered. To date, the review has assessed instream needs for the Oldman, Bow, Red Deer, and South Saskatchewan rivers, as well as some of their major tributaries **(Section 5.4)**.

Scientific analysis and public involvement are key to the review's success. Public involvement is being channelled through a stakeholder public advisory committee. Scientific analysis will rely on the best available technology to ensure that the information base is able to meet the task of assessing alternative water allocations. Computer models are being developed or updated to better estimate the water requirements of irrigation districts, TransAlta Utilities hydro operations, and in general by Alberta Environmental Protection. (The water balance calculations are based on average weekly natural flows, consumption, and instream needs.)

6.4.3.2 Municipal Wastewater

The stresses municipalities place on the ability of the basin's rivers and streams to assimilate contaminants have been reduced in recent years:

Some communities now irrigate with lagoon wastewater **(Figure 6.18)** and dispose of sludge on land. The City of Lethbridge on the Oldman River has upgraded its wastewater treatment. Municipal effluent from the town of High River is being diverted to Frank Lake, a large wetland near the town, to protect the Highwood River **(see next sidebar)**. Calgary's two wastewater treatment plants are improving phosphorus removal and disinfection using ultraviolet irradiation. The City of Calgary is conducting a pilot project involving an experimental wetland to improve stormwater quality before its discharge to the Bow River. The artificial wetland will retain stormwater long enough for sediments to settle out and for vegetation to remove some of the water's nutrients. The effects of various flow conditions on stormwater quality will also be tested.

Frank Lake

Frank Lake, a 1200-ha marsh near High River, for decades has been a highly important nesting, moulting, and staging area for waterfowl and shorebirds as well as home to many species of songbirds, amphibians, reptiles, mammals, and plants. In the early 1980s, water in the marsh dropped to very low levels. An opportunity to restore water levels arose when Cargill Foods Ltd. proposed a meat packing plant near High River. Alberta Environmental Protection (AEP) reached an agreement with Ducks Unlimited Canada (DU), the marsh's water-licence holder, to use Frank Lake to dispose of Cargill's treated effluent. Alberta Environmental Protection and DU also agreed to further supplement the marsh's water supply by diverting some of the Highwood River's natural flow to the marsh at a time when there would be no effect on the Highwood's downstream fisheries. In addition, AEP arranged with the Town of High River to redirect town wastewater to the marsh rather than to the Highwood River, once the town's wastewater treatment plant was upgraded.

In 1989, a water pipeline was constructed to Frank Lake, and cross-dykes and water control structures were built in the marsh. Flood-prone lands and uplands surrounding the marsh were acquired and are being managed for many species under the North American Waterfowl Management Plan/DU multi-species program. Thanks to these efforts, Frank Lake is again being used by thousands of nesting and migrating birds, including several threatened or endangered species.

Recent monitoring data indicate that occasional outflows from the lake are adding nutrients to the Little Bow River. Alberta Environmental Protection will be reviewing wastewater licence limits for the marsh and working with stakeholders involved in the operation of the wetland complex to mitigate any environmental concerns.

6.4.3.3 Bow River Water Quality Initiatives

In 1990 the Bow River Water Quality Task Force was appointed by the Minister of the Environment in response to concerns about the Bow's deteriorating water quality. Task Force members represented users of the river: urban and rural municipalities, agriculture, industry, First Nations peoples, and recreational interests. In 1991, the task force published a report, *The Bow River: Preserving Our Lifeline*, which contained 33 recommendations to improve the river's quality. These included identifying the amount of pollution the river could receive without ecological harm, and improving sewage treatment and regulation of the river's flow. The report also recommended creating an advisory council on Bow River water quality.

The Minister of Environmental Protection appointed the advisory council the following year. The council's mandate was to promote awareness, improvement, and protection of water quality in the Bow River, foster cooperation among agencies with water quality responsibilities for the Bow, and provide communication links among governments, interest groups and the public. In

1994 the council published a state-of-the-river assessment, *Preserving Our Lifeline: A Report on the State of the Bow River*. In 1996, the council reorganized and became the Bow River Basin Water Council, with an expanded mandate for groundwater as well as surface water, riparian zones, and tributaries of the river.

Some original task force members and provincial government representatives continue to serve on the council, which continues to implement many of the task force's recommendations. At present, Alberta Environmental Protection is working with the Council and Alberta Agriculture, Food and Rural Development to prepare a plan to help with environmental management decision-making for the Bow River Basin. Council responsibilities now include development of instream flow objectives and water conservation guidelines, and contributing to the Year 2000 Review of Irrigation Expansion Guidelines.

Canada Creosote Containment Management Strategy

The former site of a wood-preserving plant on the south bank of the Bow River in Calgary is one of the largest "orphan" contaminated sites in Canada. From the mid-1920s until the mid-1960s, the plant, operated by Canada Creosote Ltd., treated lumber with a variety of preservatives, including tars, creosote, petroleum oils, and pentachlorophenol. Investigations during the late 1980s confirmed the presence of creosote contamination in soils and groundwater under the site, and in adjacent riverbed gravel under the Bow River. Monitoring wells installed along the south bank of the river indicated a zone of contaminated water approximately 250 metres wide discharging into the river.

An Alberta Research Council (ARC) computer model predicted that 15 m^3 of liquid creosote and 650 kg of other dissolved contaminants would enter the river each year unless corrective action was taken. ARC undertook a further assessment, evaluating risks to humans or wildlife exposed to the chemicals through inhalation, fish consumption, and recreational use of the river. The assessment focused on seven compounds representing the range of chemicals present, and used worst-case scenarios. It concluded that no measurable effects on human health were likely, and that fish and wildlife ingesting river water or contaminated aquatic invertebrates downstream of the site were not at risk (although random contamination could occur in fish and invertebrates that directly ingest creosote droplets.)

In 1989, creosote seepage into the river triggered an emergency response from Alberta Environmental Protection. A cofferdam was constructed to isolate the seepage area, and visible heavy creosote was vacuumed from the riverbed. Longer term action has also been taken to physically isolate the creosote beneath the site from the river. A 640-m barrier, consisting of a secant pile wall and slurry trench, was built around the site. Extraction wells within the contaminated area were also installed. The wells remove groundwater, which is then treated to reduce contaminants to levels acceptable for discharge to Calgary's sanitary sewer system. One extraction well has been used to recover creosote for use as a fuel-blend product. Interceptor wells have also been installed on higher ground around the site to reduce the flow of groundwater into the site.

The City of Calgary is scheduled to take over responsibility for the site's containment system in 1997. Alberta Environmental Protection will continue to monitor the river water for contamination.

Fish Habitat Enhancement Structures

• Groynes deflectors - deflect the main current and provide shelter areas and bank protection

•V-weirs (on Crowsnest River) - create self-maintaining pools with feeding, resting, and overwintering areas. Rocks in the pool provide cover and isolation from other fish. Rocks at the end of the pool provide additional cover and feeding spots.

• Scattered rock clusters - placed downstream of dams to provide shelter from currents and predators

6.4.3.4 Red Deer River Corridor Integrated Management Plan

In 1994 scientific studies began on the Red Deer River to determine the water quality and flow conditions necessary to protect the aquatic and riparian environment and meet demands such as water-based recreation. These studies were combined with regional land use planning in the Red Deer River Corridor. The resulting Red Deer River Corridor Integrated Management Plan focuses on the mainstem Red Deer River and the land and resources within five kilometres of the river valley's top edge. Land, water and air resources within this area are managed in an integrated manner to avoid conflicts and encourage sustainable use of resources.

The integrated plan calls for development of instream flow objectives for the Red Deer River. Included will be recommendations for the operation of the Dickson Dam. The plan also calls for the development of management objectives for land use activities affecting water quality or riparian habitats.

6.4.3.5 Oldman River: Fisheries Mitigation and Instream Flow Needs and Objectives

Fisheries Mitigation

The Oldman River Dam's impoundment of the Oldman River meant the loss of approximately 43 km in total of high quality fish habitat on the Crowsnest, Castle and Oldman rivers. The impoundment also blocked fish access to upstream spawning grounds.

In response to this impact, the Government of Alberta undertook a mitigation program for the Oldman River. The program's goal was to have no net loss of recreational fishing opportunity in the area. Following cooperative discussions between Alberta Environmental Protection; Alberta Public Works, Supply and Services (APWSS); and the Oldman River Dam Local Advisory Committee, a decision was made to replace the high quality fish habitat lost to reservoir flooding and to develop self-sustaining populations of priority species below the dam. Species and habitat replacement priorities were as follows:

- Upstream areas were higher priority than downstream areas, which in turn were higher priority than newly created reservoir habitat.

- Trout were higher priority than mountain whitefish in all three upstream rivers. Brown trout were preferred over rainbow trout on the Crowsnest River, and on the Oldman below the dam. Bull trout were added as a third priority species at a later planning stage. (The possibility of establishing bull trout populations in downstream tributary streams is being investigated.)

Using fish population and habitat inventories conducted before the dam's construction, a habitat replacement plan was developed. The plan, designed to replace 225 000 m^2 of high quality habitat by improving lower-quality habitat in reaches above the reservoir, is ongoing. APWSS developed the required habitat enhancement techniques and enacted them in stages **(see sidebar)**. Measurement of the habitat structures' and techniques' effectiveness is ongoing and will be incorporated into future plans.

Flows sufficient to maintain water temperatures and adequate dissolved oxygen for brown trout were calculated and incorporated as part of the operating strategy for the dam **(Figure 5.4)**. It was assumed that these flows would also suffice for mountain whitefish. Operating rules for the dams on two downstream tributaries, the Waterton and St. Mary rivers, were also planned to ensure that flow needs on the Oldman River were met. Brown trout were stocked for three years in the Oldman between Fort Macleod and Monarch to establish a self-sustaining population. A final stocking will take place in 1997.

Measurements taken in the Oldman River Reservoir since the first year after filling show the reservoir to be oligotrophic, with a low phytoplankton biomass and clear water. Water temperatures in the reservoir and up to 100 km downstream lag behind upstream river temperatures during spring warming and fall cooling. Water temperatures, monitored along the river each year, have been suitable for brown trout as far as Fort Macleod, although fall spawning may be delayed due to high water temperatures. Dissolved oxygen levels downstream of the dam meet calculated requirements except, occasionally, below Lethbridge.

Elevated levels of mercury have occasionally been found in newly created reservoirs. Mountain whitefish, rainbow trout, bull trout, and white and longnose suckers from the reservoir and sites upstream and downstream have been sampled annually since 1992 for mercury residue in muscle tissue. The levels found, regardless of species or site, have remained safely below the Canadian fish consumption guideline of 0.5 mg/kg. This may be attributable in part to the deliberate removal of topsoil and woody vegetation from the reservoir basin prior to filling.

Ongoing fish population and creel studies assess whether habitat enhancement has increased fish populations. Evaluating fisheries habitat enhancement works have been ongoing since 1987. The program experienced a setback when the flood of June 1995 **(described in Section 3)** damaged some of the artificial habitat structures. Most enhancement works on the Crowsnest River experienced only minor damage, whereas those on the upper Castle River suffered more damage due to severe bank erosion. On the Oldman River, shifting gravel buried many of the fish habitat structures. A reconstruction program was implemented following inspection of the damage.

Other Instream Flow Needs and Objectives

In addition to fisheries mitigation and enhancement, other purposes can also be achieved by regulating flows downstream of the Oldman River Dam. Work to determine the flows necessary to protect various components of the aquatic and riparian environments, and other instream uses, began prior to the dam's construction. In addition to the fisheries work described above, this work included water quality and quantity modelling for the river and reservoir, inventories of the extent and condition of cottonwood forests downstream of the dam, and evaluation of river and reservoir recreation needs. In 1993 the Oldman River Reservoir Environmental Advisory Committee, a public committee composed of interest groups within the Oldman River

Basin and a federal government representative, was established to advise the Minister of Environmental Protection on the effect of the Oldman River Dam strategy on aquatic and riparian environments within the South Saskatchewan River Basin. Their review considered the water needs for interprovincial apportionment, instream uses, and the frequency of water shortages for offstream users. The Committee will also be involved in assessing offstream water needs beyond the year 2000.

6.4.3.6 Restoration and Enhancement of Lakes and Wetlands

Cooperative projects to stabilize and improve water levels for fish, wildlife, and recreational purposes while at the same time providing drainage and flood control continue to be undertaken on lakes and wetlands in southern Alberta. The Tyrrell-Rush lakes project is one example. Runoff from farmland is conveyed to Tyrrell Lake and nearby marshes for the benefit of fish, waterfowl, upland birds, furbearers, and other species. This "Wetlands for Tomorrow" project involves Alberta Environmental Protection, Ducks Unlimited Canada, the St. Mary River Irrigation District, and the County of Warner. The Eastern Irrigation District, along with Ducks Unlimited Canada and Alberta Environmental Protection (Buck for Wildlife Program), is engaged in similar work to restore productive wetlands.

The primary focus of the North American Waterfowl Management Plan in the South Saskatchewan River Basin is "drought-proofing the prairies" by establishing and securing wetlands. In addition, NAWMP staff work with ranchers and irrigation districts to develop grazing systems that will provide better upland nesting cover.

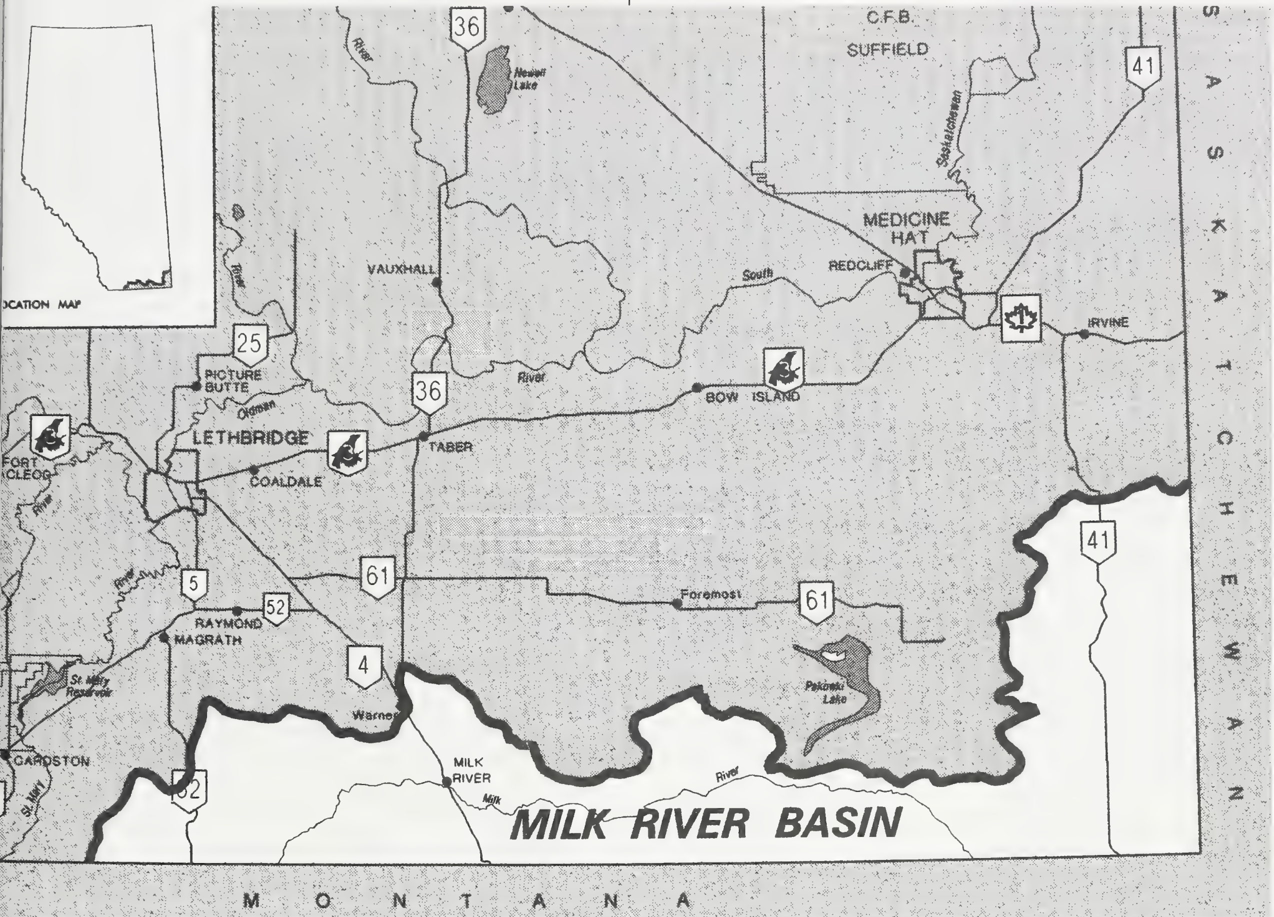
6.5 THE MILK RIVER BASIN

The Milk River Basin **(Figure 6.19)** is the smallest major river basin in the province, occupying about 6500 km^2 in the arid Grassland Natural Region of southeastern Alberta. This river basin is the most northerly part of the vast Missouri-Mississippi River basin of the United States and is formed by the Milk River, which enters Alberta from Montana, flows eastward, and then loops back into Montana.

The westernmost portion of the basin is extensively cultivated. Further east, cattle ranching is the major land use and cattle feedlots are common. Dryland crops predominate, with some irrigated crops also grown. The Cypress Hills occupy the northeastern corner of the basin.

With no cities and few towns, the basin has a population of under 2500. The town of Milk River is located near the mainstem of the Milk River.

FIGURE 6.19 Milk River Basin



6.5.1 Rivers, Lakes and Wetlands

The Milk River and its tributary, the North Milk River, are the only major rivers of the basin. Several tributary creeks, including Lodge Creek, originate in the Cypress Hills of Alberta, flow southeastward through Saskatchewan, and join the Milk River in Montana. Other small tributaries flow northward into Alberta from the Sweetgrass Hills of Montana.

Because of its arid climate and relatively flat terrain, the basin has few natural lakes. Small wetlands occupy 7.5 percent of the basin's area. Some occur along the river floodplain and at the bottom of coulees.

Case Study: The Milk River

The Milk River and its main tributary, the North Milk River (also called the "North Fork"), originate in the foothills of the Rocky Mountains in Montana and enter Alberta separately, merging about 20 km west of the town of Milk River. The resulting Milk River mainstem meanders eastward across the Mixedgrass and Dry Mixedgrass subregions in a large canyon carved by glacial meltwaters before turning south and re-entering Montana.

The State of Montana has used the Milk River for many years to convey extra water from the state's mountainous western region to its dry eastern part of the state for irrigation purposes. The transfer is accomplished by

The St. Mary Sculpin

Sculpins (Cottus species) are small bottom-dwelling fish that live among stones and eat aquatic insect larvae. Several species occur in the Milk River and a few other locations within the province.

There has been some uncertainty regarding the taxonomy of the species. The species referred to here as "the St. Mary sculpin" was not known in Alberta until 1988. The species is classified by the Committee on the Status of Endangered Wildlife in Canada as threatened. The largest specimen found in the province so far measured 10.8 cm long.

To date, the St. Mary sculpin has been found in two river reaches in Alberta: some 220 km of the upper and middle reaches of the Milk River, and approximately 80 km of the upper St. Mary River. A population in the Milk River upstream of the confluence with the North Milk River has apparently disappeared, probably due to low or absent flows in some years. However, the sculpin's range has extended eastward in the mainstem. The population therefore appears stable, but vulnerable to low flows.

Baseline data for future population monitoring have been obtained. A provincial management plan is being developed to ensure that current habitat is maintained and that the population can be self-sustaining.

means of a canal constructed in 1917 between the St. Mary and North Milk rivers in Montana. During the irrigation season, water is diverted from the St. Mary to the North Milk River. As a result, flows in the North Milk in Alberta are approximately twice their natural volume between April and October. In the Milk River, flows in the mainstem are from 1.3 to 12 times higher than natural, as illustrated in **Figure 6.20**. This figure also shows that the river can experience low flows from July to March.

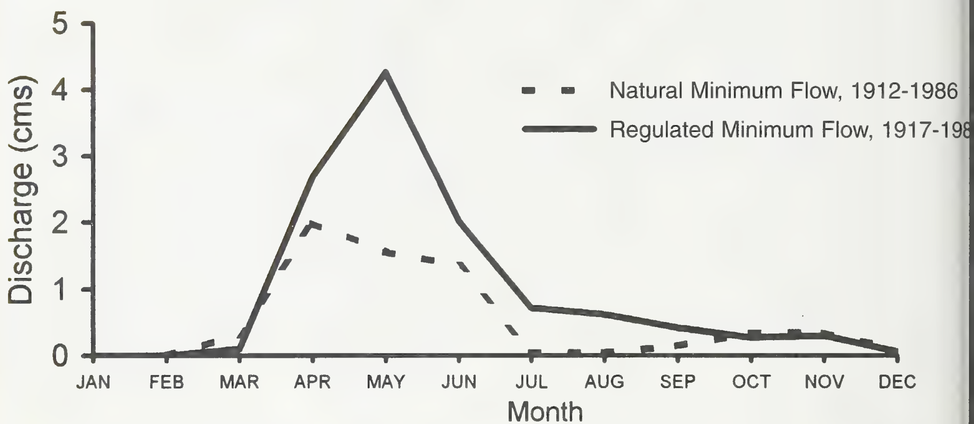


FIGURE 6.20 HYDROGRAPH OF THE MILK RIVER AT THE TOWN OF MILK RIVER
source: Alberta Environmental Protection

Apportionment agreements between Canada and the United States (the Boundary Waters Treaty of 1909 and the Order of the International Joint Commission in 1921) entitle Canada to 50 percent of the natural flow of the Milk River during the winter. From April to October, Canada is entitled to 25 percent, except when the natural flow exceeds 18.6 m^3/s, in which case the excess is divided equally between the two countries. Natural flows of the Milk's tributary creeks originating in the Cypress Hills are shared equally between Canada and the United States. Alberta and Saskatchewan share Canada's portion of these flows.

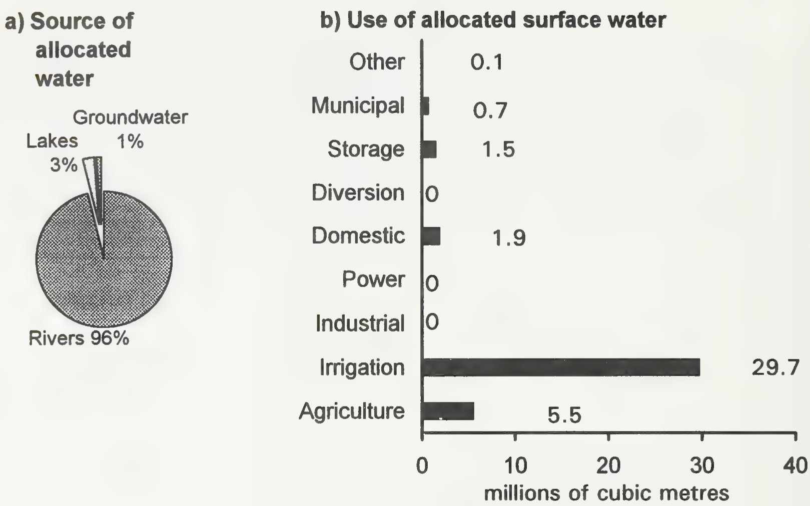
The Milk River is a relatively warm, slow-moving, alkaline river, with water temperatures as high as 28°C in the summer and an average pH of 8.5. Several of the sandstone formations through which the river flows in Alberta give it the heavy silt load responsible for its milky appearance. The sediment load of the water increases downstream. The river carries a high load of dissolved calcium causing excessive hardness. Some naturally occurring metals are occasionally present at levels exceeding water quality guidelines for aquatic life. Total phosphorus, nitrogen, sulphate and faecal coliform bacterial levels occasionally exceed the most stringent water quality guidelines for irrigation of certain crops. In general, however, when the river's flow is augmented during the irrigation season, its water quality is good.

The river's water is well-oxygenated during the ice-free season, but during long cold spells under ice cover, oxygen levels can become low in the mainstem. This condition, combined with low flows and high levels of dissolved solids, probably limits the number of fish wintering in the mainstem. However, despite these limitations, the river supports several rare or uncommon fish species by virtue of its connection to the Missouri-Mississippi River system. These are all non-sport species, including the stonecat (a type of catfish), finescale dace, northern redbelly dace, brassy minnow, and three species of sculpin. Common sportfish species in the mainstem include sauger, pike, and burbot. The North Milk River, which has a greater variety of clean-water invertebrates such as stoneflies and mayflies, also has mountain whitefish and trout.

The river valley with its floodplains, oxbows, gravel bars, braided channels, cliffs, and tributary coulees supports a wide diversity of species in the area. Stands of plains cottonwoods along the river **(Figure 6.14)** and lush shrubs and grasses supply food and shelter for many wildlife species. Rare plant species in the river valley include prickly milk vetch, crested Whitlow-grass, and tufted hymenopappus. Some provincially rare and uncommon fauna in the river valley and adjoining coulees include the western painted turtle, northern leopard frog, yellow-bellied marmot, eastern short-horned lizard (on the canyon rim), and Weidemeyer's admiral butterfly. Uncommon bird species found here include the loggerhead shrike, black-headed grosbeak, violet-green swallow, yellow-breasted chat, prairie falcon, golden eagle, and ferruginous hawk. The peregrine falcon has also been successfully reintroduced.

Recreational use of the river includes canoeing, rafting, and swimming, the latter being popular at Writing-On-Stone Provincial Park. The river is not heavily used for fishing.

FIGURE 6.21 WATER ALLOCATION IN THE MILK RIVER BASIN
source: Alberta Environmental Protection



6.5.2 HUMAN FACTORS INFLUENCING AQUATIC ECOSYSTEMS

The amount of water allocated in the basin, 41 million cubic metres, is less than one percent of the total water allocation in the province. Over 95 percent of the basin's allocation is obtained from rivers (primarily the Milk River, but also Lodge Creek). This water is used mostly for irrigation and to a lesser extent other agricultural uses **(Figure 6.21)**. The towns of Coutts and Milk River also obtain their water supply from the Milk River.

Point-source effluents to the Milk River are few and include wastewater from one municipality and irrigation return flows. Surface runoff from diffuse agricultural sources increases below Writing-on-Stone Provincial Park.

6.5.3 MANAGEMENT ACTIONS SPECIFIC TO THE BASIN

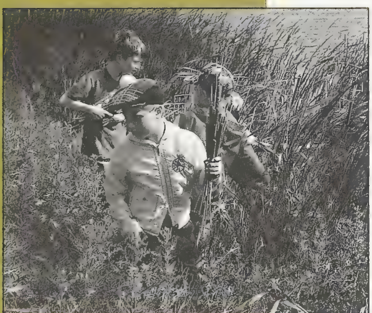
In 1985, detailed site-specific studies related to water storage were carried out in this area, including studies of water quality, soil, benthic invertebrates, fish, rare flora and fauna, and cottonwood stands along the river. These studies provided valuable information for water management.

Protection of some riparian habitat has been achieved by establishing the Milk River Natural Area and adjacent Kennedy Coulee Ecological Reserve. The Milk River Management Advisory Committee, established in 1990 with representatives from non-governmental organizations, the ranching community, and government, directs the management of the area. Research on rare or vulnerable species in the area is ongoing.

7.0 CONCLUSIONS AND FUTURE DIRECTIONS

7.1 CONCLUSIONS

What are the current conditions of Alberta's aquatic ecosystems? How have human activities affected them and what is being done about it? Much remains to be learned about aquatic ecosystems and the interactions of their living and non-living components before we can fully answer these questions. In the meantime, human activities affecting the aquatic environment continue. Managing provincial water resources involves not only having protective measures in place based on present knowledge, but also monitoring the aquatic environment and continually refining strategies in the light of new information. Some key points from this report are summarized below.



(Ducks Unlimited Canada, Tye Gregg)

Alberta's Aquatic Ecosystems - Alberta is blessed with a wide variety of rivers, lakes and wetlands. They are more common in northern Alberta with its large rivers (Peace and Athabasca), large lakes (Athabasca, Lesser Slave, Cold Lake, Lac La Biche) and vast peatlands. In southern Alberta, water supplies are more limited but demand for water is high.

Aquatic ecosystems provide a reliable supply of water for many uses. They also assimilate waste discharges from many sources and provide key habitat for Alberta's flora and fauna. Management of this resource focuses on allocating water for different uses, monitoring water quality and flow, regulating discharges to water bodies, and researching aquatic ecosystems to better understand them.

Aquatic Ecosystem Management in General

- Aquatic ecosystems are influenced by activities within the entire drainage basin, a fact increasingly reflected in management approaches.

- Aquatic ecosystems include natural as well as human components. The government is working with stakeholders to mitigate the adverse effects of human activities. Many water-related projects are being carried out through partnerships among landowners, local communities, industry, academia, and/or governments. Examples include the North American Waterfowl Management Plan and programs under the Canada-Alberta Environmentally Sustainable Agriculture Agreement.

- Management of point sources of pollution, such as effluent from industry or wastewater treatment plants, has improved. Studies are underway to better understand and manage non-point sources of pollution, like runoff from urban landscapes or agricultural lands.

- A major revision of the *Water Act* has "modernized" Alberta's approach to water management.

- The flow and water quality needs of aquatic ecosystems are now better understood and considered when allocating water for human use.

- The effects of past overfishing in some of Alberta's lakes and streams are now being addressed. Although this approach has increased current restrictions on fishing, it ensures that fish stocks will recover.

- No fish species in Alberta are considered endangered. Two species are "threatened" and four are considered "vulnerable," but management steps are underway to ensure these populations recover. The target for the next five years is to have less than five percent of species categorized as at serious risk.

Rivers

- In Alberta, rivers are the primary source of water for human use. As well, most waste discharged to water bodies is discharged into rivers.

- Overall water quality in Alberta's rivers is good. However, in some reaches, natural water quality does not always meet provincial guidelines. Often this lower quality is due to the presence of naturally occurring substances, such as riverbed metals or high seasonal silt loads. In other instances, guidelines are not met as a result of human activity, particularly downstream from major urban centres. Bringing water quality downstream of urban areas closer to upstream conditions is an ongoing goal of Alberta Environmental Protection.

- In spite of urban growth, the water quality downstream of Alberta's cities has not changed significantly over the past several years. This is probably the result of improvements to wastewater treatment. Improved production technology has decreased concentrations of several contaminants and oxygen-demanding substances from pulp mill wastewater in the Peace-Athabasca river system.

- Due to the presence of natural pathogens, such as *Giardia*, untreated river and lake water in the province is not considered safe to drink.

Table 7.1 rates Alberta's six major river systems on their water's suitability for recreation, aquatic life, and agricultural use. Ratings are based on relevant water quality variables specified by the Canadian Council of Ministers of the Environment. Measurements were taken once per month throughout 1994 at two long-term monitoring sites on each river and compared to the Alberta Ambient Surface Water Quality Interim Guidelines. In general, the table demonstrates that upstream water quality is better than downstream water quality. Recreation involving direct contact with the water is the activity most seriously affected by water quality. Municipal wastewater and stormwater and non-point (diffuse) sources are the most common pollution sources.

Lakes

- Alberta has many eutrophic lakes due to the fertility of the watersheds in which they are located.

- Alberta's lakes are in high demand for recreation. Human preferences regarding lake levels and water quality sometimes differ from natural lake conditions. For instance, oligotrophic lakes are preferred for many recreational activities, whereas eutrophic lakes are more productive ecosystems. Likewise, people usually want lake levels to remain stable, whereas changing lake levels may be beneficial to the aquatic ecosystem.

- The quality of water in some eutrophic lakes has declined as a result of human activity. Concerns exist about certain individual lakes, particularly in central and southern parts of the province. Blue-green algal blooms occur in some eutrophic lakes and are potentially toxic to animals and humans.

TABLE 7.1 1994 WATER QUALITY INDEX: SUITABILITY OF ALBERTA'S MAJOR RIVERS FOR VARIOUS USES
source: Alberta Environmental Protection

Alberta's Major Rivers	Recreation	Aquatic Life	Agriculture
SMOKY / PEACE RIVERS			
at Watino	0	+	++
at Fort Vermilion	0	+	++
Issues – pulp mills and municipal wastewater effluents			
ATHABASCA RIVER			
at Athabasca	0	+	++
at Old Fort	0	+	++
Issues – pulp mills and municipal wastewater effluents			
NORTH SASKATCHEWAN RIVER			
upstream of Edmonton	++	++	++
downstream of Edmonton	---	+	++
Issues – municipal and non-point pollution sources			
RED DEER RIVER			
upstream of Red Deer	+	++	++
downstream of Red Deer	0	+	++
Issues – municipal and non-point pollution sources			
BOW RIVER			
upstream of Calgary	++	++	++
downstream of Calgary	---	0	++
Issues – municipal and non-point pollution sources; reduced flows due to water withdrawal			
OLDMAN RIVER			
upstream of Lethbridge	++	++	++
downstream of Lethbridge	0	+	++
Issues – municipal and non-point pollution sources			

++ good water quality – very few tests do not meet guidelines (100 – 96 percent compliance)
+ fair water quality – guidelines occasionally not met (95 – 86 percent compliance)
0 poor water quality – guidelines often not met (85 – 71 percent compliance)
--- not acceptable for use – guidelines frequently not met (70 percent compliance or lower)

Wetlands

- Although we seldom use them directly as a water source, wetlands are important components of the hydrological cycle, interacting with adjacent rivers, lakes, and groundwater. Alberta's marshes, sloughs, and peatlands support a wide diversity of plants and animals, many of which are entirely dependent on healthy wetlands and the land immediately surrounding them. Our province's wetlands provide economic and recreational opportunities, and their ability to purify water is an important part of several wastewater treatment projects.

- Many of Alberta's sloughs and marshes have been lost in the settled area of the province since European settlement began here. The principal causes of this loss are drought, drainage, and intensive cultivation for agricultural production. An increasing number of cooperative programs involve landowners in the protection and management of wetlands and adjacent uplands.

7.2 FUTURE DIRECTIONS

As Alberta continues to grow and develop, the demands we place on our aquatic resources will increase. Some changes likely to occur in the near future are discussed below.

Municipal - As Alberta cities and towns continue to grow, demand for dependable supplies of clean water will increase. Water conservation by urban households, institutions, and industries will be needed to reduce this demand. Municipal wastewater treatment will continue to improve as treatment plants are updated and treatment technology improves. The use of alternative and more advanced technologies for handling wastewater will also increase. Technologies and management strategies to improve the quality of urban stormwater releases will become more commonplace in order to further reduce the impact of urban centres on aquatic environments.

Agriculture - Growing world markets are expected to lead to an increase in Alberta's agricultural production. This growth may include more intensive livestock operations and expansion of the agri-food processing industry. Alberta Agriculture, Food and Rural Development is working both to minimize the amount of water that the agri-food industry will require and to ensure good effluent management. Work begun on watershed protection under the Canada-Alberta Environmentally Sustainable Agriculture Agreement will continue, and the feasibility of a joint stream monitoring network will be evaluated by Alberta Environmental Protection and Alberta Agriculture, Food and Rural Development.

Irrigation efficiency is expected to improve both in terms of more efficient water management by irrigation districts and better timing and application by individual farmers. A changing climate, whether from global warming or from normal climatic cycles, will be an important determinant of future irrigation demand. The Year 2000 Review of Irrigation Expansion Guidelines in the South Saskatchewan River Basin will provide a reassessment of irrigation and instream needs.

Forestry - In northern Alberta, the potential impact of a growing forest industry will increase as harvesting proceeds. Many Alberta forestry companies are adopting ecosystem management as their management strategy and recognize that their activities can affect aquatic ecosystems. A Forest Conservation Strategy is being prepared by a partnership of government, industry, environmentalists, and other forest users to clarify goals, principles, and strategies for forest management. The industrial processing of timber into pulp, paper, lumber, and other products is also changing, with improvements in water use efficiency and effluent quality. The rivers of the Peace-Athabasca-Slave River Basin, in which the majority of forest industry activity occurs, also bear the impact of other human activities and climate variation.

The Northern River Basins Study has found evidence of cumulative effects of development in the sediments, water, and biota throughout the rivers, particularly in certain reaches (NRBS 1996). Management of forestry impacts will be done in the context of all human activities affecting the rivers.

Other Industries - Industrial expansion will add to the demand for water. Some industries have shown that water recycling and re-use can reduce this demand. Further improvements in effluent treatment are also possible.

A potential increase in acid-forming emissions from expanded production from oil sands in northeastern Alberta may be offset by improved emission controls in individual plants. Acid-sensitive lakes in this region will be monitored for impacts.

Although there is potential for significant expansion of hydroelectric power generation within Alberta, at present it is unlikely that any projects will proceed. Small generating facilities will continue to be added to existing dams when economically justified.

Recreational and "Natural" Values - Public awareness of the importance of healthy aquatic ecosystems is increasing. As well, public interest in the state of Alberta's lakes is growing as cottage and residential developments expand. Current practices in lake management planning and the implementation of lake clean-up and protection plans by stakeholders are expected to continue.

The aesthetic value of rivers and small lakes is increasingly important to urban planning and development. At the same time, the use of rivers for recreational pursuits such as pleasure boat cruising, canoeing, and rafting is increasing. These trends will place added importance on river water quality.

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Personal Communications

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GLOSSARY

aerobic - requiring oxygen (opposite: *anaerobic*).

alkalinity - a measure of the ability of a water body to neutralize acid.

assimilative capacity - the ability of a natural water body to process organic and inorganic materials over a period of time.

bedrock - layer of rock that lies beneath surface deposits of soil and unconsolidated materials.

benthic - bottom-dwelling.

biochemical oxygen demand (BOD) - A measure of the concentration of biologically degradable material present in wastes. BOD_5 is a test performed on water or effluent to determine the level of pollution from organic matter. The test measures the amount of oxygen consumed by biological processes breaking down organic waste at 20°C over a five-day period.

bioassay - a test of the effect of a contaminant on one or more living organisms.

coliform - type of bacteria present in the digestive tracts of animals and also present in other sources such as soil. Faecal coliform bacteria are present in the intestines of warmblooded animals including, humans.

drainage basin - watershed.

ecosystem - interacting community of plants and animals and their physical environment.

effluent - wastewater, treated or untreated, flowing from a treatment plant, sewer, or industrial outfall.

eutrophic - highly fertile surface water.

eutrophication - gradual enrichment of surface water.

evapotranspiration - process by which plants lose water to the atmosphere through evaporation and transpiration.

floodplain -low land and relatively flat areas adjacent to a river onto which the river may flood.

groundwater - the fresh water found beneath the earth's surface, usually in aquifers, that supplies wells and springs.

ion - an electrically charged atom.

leachate - water that has percolated through soil and picked up soluble or suspended materials.

acrophyte - large, rooted aquatic plant.

ainstem - the primary channel of a river.

icroorganisms - living organisms too small to be seen with the naked eye.

itrification - process by which bacteria convert ammonia nitrogen to nitrite and then to nitrate under aerobic conditions.

ligotrophic - low in nutrient content and biological productivity.

rganic soil - soil that has developed from deposits of organic matter.

athogenic - disease-causing.

eat - organic material from vegetation that has partially decomposed under certain conditions, including the presence of water and absence of oxygen.

erched basin - a water-filled basin lying above the water table.

ermafrost - permanently frozen ground.

lankton - tiny plants and animals that inhabit the water column (free-swimming or floating).

hytoplankton - portion of the plankton community composed of plants, such as algae.

productive - high in concentrations of essential plant nutrients, which in turn promote growth of plants and animals.

reach (of a river) - a relatively uniform segment of a river.

redd - site where fish have spawned.

riffle - shallow area in a river that has a broken water surface due to presence of rocks or other materials on the streambed.

riparian - influenced by the presence of adjacent channeled or ponded water.

riverine - pertaining to rivers.

runoff - portion of precipitation landing on an area that flows into surface streams.

silt - sedimentary materials composed of fine or intermediate-size mineral particles.

spawn - process in which fish eggs are laid and subsequently fertilized.

sphagnum peat - peat that consists primarily of moss of the genus *Sphagnum.*

staging - gathering of birds prior to migration in spring or fall.

till - glacial deposit of unstratified material consisting of a mixture of clay, gravel, sand, and rocks in any proportion.

total dissolved solids (TDS) - inorganic and organic material dissolved in water, as determined from dried residue.

total suspended solids (TSS) - small particles of solid material that are suspended in, or floating on, the water.

toxic - capable of causing disease, death, or birth defects in organisms when ingested or absorbed.

trophic status - degree of biological productivity, e.g. eutrophic, mesotrophic, oligotrophic.

turbidity - water cloudiness caused by the presence of suspended particles.

wastewater - used water from a house, community, or industry that contains dissolved or suspended matter.

watershed - area of land that drains rainfall and snowmelt runoff into a body of water.

water table - upper surface of the groundwater, or the level below which the soil is saturated.

zooplankton - portion of the plankton community composed of animals.

APPENDIX A: FISH SPECIES IN ALBERTA

Common Family and Species	Scientific Family and Species
LAMPREYS	Family Petromyzontidae
Arctic lamprey	*Lampetra japonica*
STURGEON	Family Acipenseridae
*lake sturgeon	*Acipenser fulvescens*
MOONEYES	Family Hiodontidae
*goldeye	*Hiodon alosoides*
*mooneye	*Hiodon tergisus*
MINNOWS	Family Cyprinidae
lake chub	*Couesius plumbeus*
brassy minnow	*Hybognathus hankinsoni*
western silvery minnow	*Hybognathus argyritis*
emerald shiner	*Notropis atherinoides*
river shiner	*Notropis blennius*
spottail shiner	*Notropis hudsonius*
northern redbelly dace	*Phoxinus eos*
finescale dace	*Phoxinus neogaeus*
fathead minnow	*Pimephales promelas*
northern squawfish	*Ptychocheilus oregonensis*
flathead chub	*Platygobio gracilis*
longnose dace	*Rhinichthys cataractae*
redside shiner	*Richardsonius balteatus*
pearl dace	*Margariscus margarita*
SUCKERS	Family Catostomidae
longnose sucker	*Catostomus catostomus*
white sucker	*Catostomus commersoni*
largescale sucker	*Catostomus macrocheilus*
mountain sucker	*Catostomus platyrhynchus*
quillback	*Carpiodes cyprinus*
silver redhorse	*Moxostoma anisurum*
shorthead redhorse	*Moxostoma macrolepidotum*
BULLHEAD CATFISH	Family Ictaluridae
stonecat	*Noturus flavus*
PIKE	Family Esocidae
*northern pike	*Esox lucius*

TROUT, CHAR, GRAYLING AND WHITEFISH	Family Salmonidae
*cutthroat trout	*Oncorhynchus clarki*
*rainbow trout	*Oncorhynchus mykiss*
*golden trout[1]	*Oncorhynchus aguabonita*
*brown trout[2]	*Salmo trutta*
*lake trout (char)	*Salvelinus namaycush*
*brook trout (char)[3]	*Salvelinus fontinalis*
*bull trout (char)	*Salvelinus confluentus*
Dolly varden (char)[4]	*Salvelinus malma*
*Arctic grayling	*Thymallus arcticus*
*lake whitefish	*Coregonus clupeaformis*
*tullibee (cisco)	*Coregonus artedii*
shortjaw cisco	*Coregonus zenithicus*
*mountain whitefish	*Prosopium willamsoni*
round whitefish	*Prosopium cylindraceum*
pygmy whitefish	*Prosopium coutleri*
TROUT-PERCH	Family Percopsidae
trout-perch	*Percopsis omiscomaycus*
COD	Family Gadidae
*burbot (ling)	*Lota lota*
STICKLEBACKS	Family Gasterosteidae
brook stickleback	*Culaea inconstans*
ninespine stickleback	*Pungitius pungitius*
threespine stickleback[5]	*Gasterosteus aculeatus*
SCULPINS	Family Cottidae
slimy sculpin	*Cottus cognatus*
St. Mary sculpin[6]	*Cottus sp.*
spoonhead sculpin	*Cottus ricei*
deepwater sculpin	*Myoxocephalus thompsoni*
PERCH	Family Percidae
*yellow perch	*Perca flavescens*
*walleye	*Stizostedion vitreum*
*sauger	*Stizostedion canadense*
Iowa darter	*Etheostoma exile*
logperch	*Percina caprodes*
CICHLID	Family Cichlidae
South African jewelfish[7]	*Hemichromis bimaculatus*
LIVEBEARERS	Family Poeciliidae
mosquitofish[7]	*Gambusia affinis*
sailfin molly[7]	*Poecilia latipinna*

* Game fish species of importance in the domestic, recreational and commercial fisheries

[1] Species introduced into Alberta in 1959

[2] Species introduced into Alberta in 1924

[3] Species first introduced into Alberta in 1910

[4] Species introduced in 1974 (only to Chester Lake); originally believed to be Arctic char

[5] Unauthorized introduction into Hasse Lake circa 1970

[6] Formerly known as shorthead sculpin (Cottus confusus); species status currently under review

[7] Introduced circa 1920s and present only in the Cave and Basin Hot Springs at Banff

APPENDIX B: ALBERTA'S SYSTEM FOR EVALUATING THE STATUS OF WILDLIFE

The status of Alberta's wildlife populations was evaluated and assigned to various categories for management in 1991. Reassessments based on current knowledge of the scientific and natural history communities are made every five years, with the most recent being conducted in 1996. The status categories used **(see below)** do not indicate the degree of endangerment of the species, but rather the priority for research and management. Placement of a species on the red or blue list is followed by the gathering of information needed to protect the species.

Red list - Current knowledge suggests these species are at risk. Their populations have declined to nonviable levels in Alberta, or show a rate of decrease indicating that they are at immediate risk of declining to nonviable levels. More detailed work on their status and/or management of their populations and habitat is required until they are no longer deemed at risk.

Blue list - Although current knowledge suggests these species may be at risk, the threats they face are less immediate. This category may include species that are particularly vulnerable to non-cyclical declines in population or habitat, or to reductions in provincial distribution. Species that are generally suspected of being vulnerable, but for which information is too limited to clearly define their status, are also placed in this category to indicate the immediate need for more information.

Yellow list - These species are not at risk but may require special management to address concerns related to naturally low populations, limited provincial distributions, or demographic/life history features that make them vulnerable to changes in the environment.

(Ducks Unlimited Canada, Tom Sadler)

APPENDIX C: INORGANIC AND BIOLOGICAL PARAMETERS ROUTINELY MONITORED BY ALBERTA ENVIRONMENTAL PROTECTION AT LONG-TERM RIVER NETWORK SITES

Parameter	Notes	Source(s)	Guidelines*
Water temperature	Influences many chemical and biological processes.	Air temperature has greatest influence; some industrial discharges.	AWQG: not more than 3°C above ambient temp.
Total suspended solids (TSS) (concentration of particles suspended in the water)	High levels can be harmful to fish. Can reduce photosynthesis.	Soil erosion.	AWQG: not >10 mg/L except when background levels exceed 100 mg/L, in which case not >10% of background.
Total dissolved solids (TDS) (concentration of substances dissolved in water)	May affect aquatic organisms. High levels in drinking water consumed in large quantity can be harmful.	Natural sources, irrigation return flows, thermal power plant effluents.	CWQG: treated drinking water: 500 mg/L; livestock watering: 3000 mg/L.
pH (measure of acidity) pH 7– neutral; <7 – acidic; >7 – basic	Aquatic organisms require a pH range near neutral. Affects solubility of metals.	Influenced by basin geology. Can be affected by biological activity, pollution.	AWQG: 6.5–8.5 CWQG: 6.5–9.0
Biochemical Oxygen Demand (BOD) (amount of dissolved oxygen needed by microorganisms in the water to convert organic matter to inorganic matter)	High levels may cause dissolved oxygen to fall below levels essential for aquatic life.	Many organic substances including decaying plants; agricultural runoff; municipal and industrial effluent.	AWQG: not to exceed an amount causing dissolved oxygen to fall below 5.0 mg/L.
Fluoride		Weathering of rocks; municipal wastewater.	AWQG: 1.5 mg/L CWQG: irrigation: 1.0 mg/L.
Cyanide (general term for a diverse group of carbon and nitrogen-containing organic and inorganic compounds)	Some forms are toxic.	Plant decomposition; metabolism of microorganisms; effluent from mining, steel mills, oil refining, electroplating.	AWQG: 0.010 mg/L CWQG: 0.005 mg/L.
Aluminum	Toxicity increases when pH <6.5.	Rocks and clay; some industrial effluents.	CWQG: >pH 6.5 – 0.1 mg/L; <pH 6.5 – 0.005 mg/L.
Arsenic	Some forms are highly toxic.	Rocks; burning of fossil fuels; some industrial and municipal effluents.	AWQG: 0.01 mg/L CWQG: 0.0g mg/L.
Barium		Rocks.	AWQG, CWQG: treated drinking water: 1.0 mg/L.
Boron		Rocks; soil; some municipal and industrial effluents.	AWQG: 0.5 mg/L CWQG: irrigation-0.5–6.0 mg/L.
Cadmium	Concentrations above 0.01 mg/L may be toxic to aquatic life.	Rocks; mining; agriculture; burning of fossil fuels.	AWQG: 0.01 mg/L CWQG: 0.0002–0.0018 mg/L depending on hardness of water.

Chromium	Toxic to some aquatic invertebrates at low concentrations.	Naturally occurring; metal plating; some pulp mill effluents.	CWQG: fish: 0.02mg/L; other aquatic life: 0.002 mg/L.
Cobalt		Weathering of ores; coal burning.	CWQG: irrigation: 0.05 mg/L.
Copper		Weathering of minerals; numerous human sources.	CWQG: 0.002 to 0.004 mg/L depending on hardness.
Iron		Rocks; burning of coal; acid mine drainage; metal processing; landfill leachate.	AWQG, CWQG: 0.3 mg/L.
Lead	Toxic to fish and other organisms, particularly in soft water.	Weathering of sulphide ores; urban runoff; atmospheric deposition; industrial and municipal effluents.	AWQG: 0.05 mg/L. CWQG: 0.001 to 0.007 mg/L depending on hardness.
Manganese	Essential trace element for living things.	Naturally occurring; some industrial discharges.	AWQG: 0.05 mg/L CWQG: irrigation: 0.2 mg/L.
Mercury	Toxic to aquatic organisms and man.	All types of rock; industrial, municipal effluents; atmospheric deposition; industrial emissions; landfill leachate	AWQG, CWQG: 0.0001 mg/L.
Nickel		Naturally occurring; burning of fossil fuels; smelting; electroplating.	CWQG: 0.025–0.15 mg/L depending on hardness.
Selenium		Soil; copper and lead refining; municipal effluent.	AWQG: 0.01 mg/L CWQG: 0.001 mg/L.
Vanadium		Naturally occurring; atmospheric deposition from steel production, burning of oil and gas.	CWQG: irrigation: 0.1 mg/L.
Zinc	Essential mineral.	Naturally occurring; industrial and municipal discharges.	AWQG: 0.05 mg/L CWQG: 0.03 mg/L.
Phosphorus (P)	High levels may result in excessive growth of algae and macrophytes.	Natural; agricultural runoff; irrigation return flows; municipal effluents.	AWQG: inorg+org $P0_4$: 0.15 mg/L; as elemental P: 0.05 mg/L.
Nitrogen (N) (ammonia, nitrites, and nitrates, organic N)	N is an essential plant nutrient. Ammonia can be toxic to fish.	Natural; irrigation return flows; agricultural runoff; effluent from fertilizer and gas plants; municipal effluents.	AWQG: 1.0 mg/L (total N). CWQG: 1.37 mg/L at pH 8 and 10°C. (NH_4– N).
Oil and grease (non-specific; includes many chemicals)		Some naturally occurring; petroleum spills; gas and metal processing effluents.	AWQG: absent CWQG: recreation - not detectable by sight or smell.
Phenols (organic compounds that possess a benzene ring on which one or more hydroxyl groups are attached)	May taint fish; cause taste/ odour problems in drinking water; toxic at high concentrations.	Decomposition of vegetation; some municipal and industrial effluents.	AWQG: 0.005 mg/L CWQG: 0.001 mg/L.
Coliform bacteria, faecal coliform bacteria, E. coli	Presence in water indicates the likely presence of pathogenic species.	*E.coli* and faecal coliform: warm-blooded animals including man; total coliform: all vertebrates.	CWQG: swimming and recreation: 200/100 mL E. coli; irrigation: 100 faecal /100 ml, 1000 total coliform/100 ml.

*CWQG – Canadian Water Quality Guidelines – are for protection of aquatic life unless stated otherwise
AWQG – Alberta Ambient Surface Water Quality Interim Guidelines, AEP 1993

APPENDIX D: SCIENTIFIC NAMES OF SPECIES CITED

Fish

See Appendix A

Birds

American white pelican - *Pelecanus erythrorhynchos*
trumpeter swan - *Cygnus buccinator*
harlequin duck - *Histrionicus histrionicus*
piping plover - *Charadrius melodus*
whooping crane - *Grus americana*
loggerhead shrike - *Lanius ludovicianus*
black-headed grosbeak - *Pheucticus melanocephalus*
violet-green swallow - *Tachycineta thalassina*
yellow-breasted chat - *Icteria virens*
ferruginous hawk - *Buteo regalis*
peregrine falcon - *Falco peregrinus*
prairie falcon - *Falco mexicanus*
golden eagle - *Aquila chrysaetos*
red-necked phalarope - *Phalaropus lobatus*
pectoral sandpiper - *Calidris melanotos*
white-rumped sandpiper - *Calidris fuscicollis*
buff-breasted sandpiper - *Tryngites subruficollis*
dowitcher - *Limnodromus* spp.
red knot - *Calidris canutus*
ruddy turnstone - *Arenaria interpres*
black-bellied plover - *Pluvialis squatarola*
piping plover - *Charadrius melodus*

Mammals

caribou - *Rangifer tarandus*
Canada lynx - *Lynx canadensis*
muskrat - *Ondatra zibethicus*
mink - *Mustela vison*
beaver - *Castor canadensis*
river otter - *Lutra canadensis*
water shrew - *Sorex palustris*
long-tailed weasel - *Mustela frenata*
northern flying squirrel - *Glaucomys sabrinus*
yellow-bellied marmot - *Marmota flaviventris*
northern long-eared bat - *Myotis septentrionalis*
big brown bat - *Eptesicus fuscus*
silver-haired bat - *Lasionycteris noctivagans*
hoary bat - *Lasiurus cinereus*

Amphibians

long-toed salamander - *Ambystoma macrodactylum*
northern leopard frog - *Rana pipiens*
great plains toad - *Bufo cognatus*
Canadian toad - *Bufo hemiophrys*
spotted frog - *Rana pretiosa*
plains spadefoot toad - *Scaphiopus bombifrons*

Reptiles

eastern short-horned lizard - *Phrynosoma douglassi brevirostre*
western hognose snake - *Heterodon nasicus*
prairie rattlesnake - *Crotalus viridis viridis*
plains garter snake - *Thamnophis radix haydeni*
red-sided garter snake - *Thamnophis sirtalis parietalis*
wandering garter snake - *Thamnophis elegans vagrans*
western painted turtle - *Chrysemys picta*

Insects

Weidemeyer's admiral butterfly - *Limenitis weidemeyeri*

Plants

bog adder's-mouth orchid - *Malaxis paludosa*
western blue flag - *Iris missouriensis*
prickly milk vetch - *Astragalus kentrophyta*
crested whitlow-grass - *Draba reptans*
tufted hymenopappus - *Hymenopappus filifolius*
purple loosestrife - *Lythrum salicaria*

READER SURVEY

ALBERTA 1996 STATE OF THE ENVIRONMENT REPORT- AQUATIC ECOSYSTEMS

Your response to this survey will help us improve the quality of future Alberta State of the Environment Reports! Please complete the following Reader Survey and return it to:

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Strategic and Regional Support Division
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1. Your affiliation? Please check (✓) the most appropriate category.

____ Education - Student
____ Education - Teacher/Professor
____ Government
____ Industry (Please specify: ________________)
____ Private business
____ Environmental organization
____ Other organization (Please specify: ___________)
____ Unaffiliated (individual)
____ Other (Please specify: _____________________)

2. For what purpose(s) will you use this report?

____ To learn about aquatic ecosystems in general
____ To learn about Alberta's rivers, lakes and wetlands
____ To assess the state of Alberta's rivers, lakes and wetlands
____ To extract specific environmental data
____ Other (Please specify: _____________________
_______________________________________)

3. Overall, do you find this report to be:

____ Very useful
____ Somewhat useful
____ Not very useful

Comments:

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4. In your opinion, were there any topics that were missing or inadequately covered?

____ Yes ____ No

Please specify:

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5. In your opinion, how well is this report organized and written?

A) This report is:
_____ Very well organized
_____ Fairly well organized
_____ Not well organized

B) The information is:
_____ Very interesting
_____ Fairly interesting
_____ Boring

C) The content is:
_____ Comprehensive
_____ Adequate
_____ Lacking in certain areas

D) The report is:
_____ Very well written
_____ Fairly well written
_____ Not well written

E) The tables and figures in the report are:
_____ Very good _____ Adequate _____ Not very good

Comments:

6. What did you most like and dislike about this report?

Liked

Disliked

7. Any other comments or suggestions for improving future reports?

Thank you for your time and cooperation!

NOTES

ENVIRONMENTAL PROTECTION

NOTES

Alberta
ENVIRONMENTAL PROTECTION