1. Whole Basin overview

Introduction

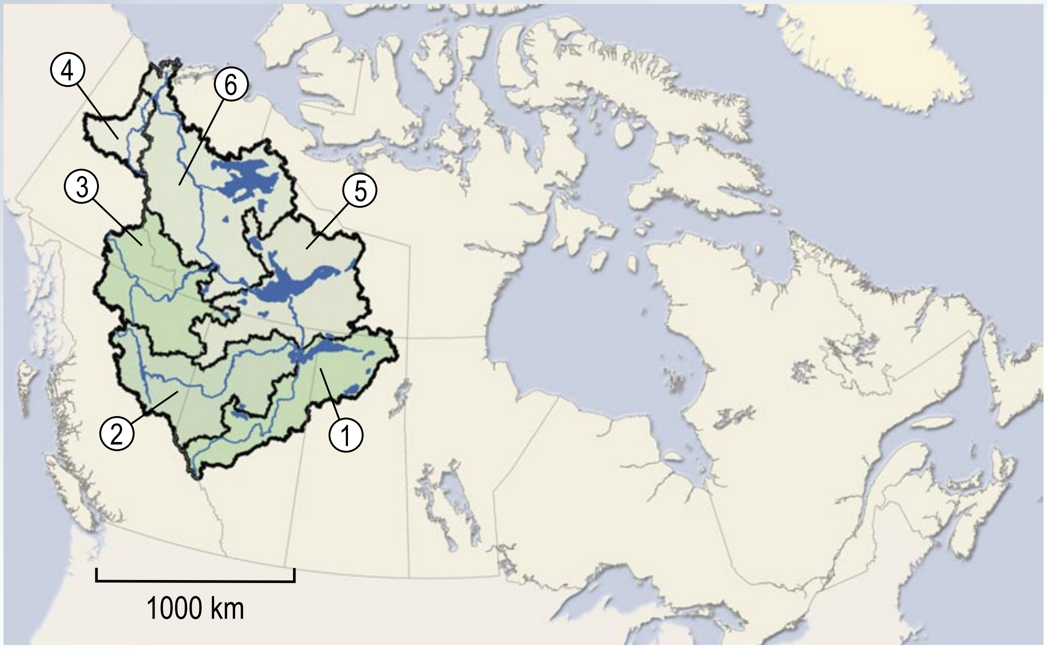
Geography

The Mackenzie River system flows 4,241 kilometres from the Columbia Ice-field in Jasper National Park and the deep snowfields of the upper Peace in northeastern British Columbia to its mouth on the Beaufort Sea of the Arctic Ocean. The Mackenzie River Basin is the tenth largest river basin in the world. It covers about 1.8 million square kilometres or about 20% of the landmass of Canada (Figure 1–1). The average annual discharge of the Mackenzie River is 9,910 cubic meters per second. In Canada, this volume of stream flow is second only to the St. Lawrence River. It accounts for 60% of the freshwater that flows into the Arctic Ocean from Canada and about 9% of the freshwater discharged to all the oceans by all Canadian watersheds.[1] The freshwater and energy (heat) discharged from the Mackenzie River into the Arctic Ocean play a significant role in regulating the circulation of the world's oceans and climate systems.[2]

For the purposes of this report, the Mackenzie River Basin can be sub-divided into six major sub-basins, each with its own major river or lake. The six sub-basins are the Athabasca, the Peace, the Liard, the Peel, the Great Slave, and the Mackenzie-Great Bear (Figure 1–1).

The Basin includes nine lakes over 1,000 square kilometres in area (Table 1–1). Of all the lakes lying entirely within Canada, Great Bear Lake is the largest and Great Slave Lake is the deepest.[3] The basin includes three large deltas; the Peace-Athabasca Delta (which has been designated as a Wetland of International Significance); the Slave River Delta and the Mackenzie Delta.

Permafrost underlies about 75% of the basin. Pingos and patterned ground features associated with continuous permafrost are found in the north, while agriculture and forestry are important economic activities in the southern parts of the



1	Athabasca Sub-basin	3	Liard Sub-basin	5	Great Slave Sub-basin
2	Peace Sub-basin	4	Peel Sub-basin	6	Mackenzie-Great Bear Sub-basin

Rank in Canada*	Lake Name	Area km^2	Depth metres
1	Great Bear Lake, NWT	31,328	413
2	Great Slave Lake, NWT	28,568	614
4	Lake Athabasca, Sask.	7,935	120
21	Lac la Martre, NWT	1,776	––
22	Williston Lake, BC	1,761	––
26	Lake Claire, Alta.	1,436	––
27	Cree Lake, Sask.	1,434	––
34	Lesser Slave Lake, Alta.	1,168	––
38	MacKay Lake, NWT	1,061	––

**Lakes over 1000 km² lying entirely within Canada (excludes Great Lakes which are shared with US).*

Above: Figure 1–1.
The Mackenzie River Basin accounts for about 1/5th of Canada's land mass and consists of six major sub-basins.

Source: Mackenzie River Basin Board Secretariat.

Left: Table 1–1. Large Lakes in the Mackenzie River Basin

Data Source: Human Activity and the Environment 2000 (Statistics Canada).

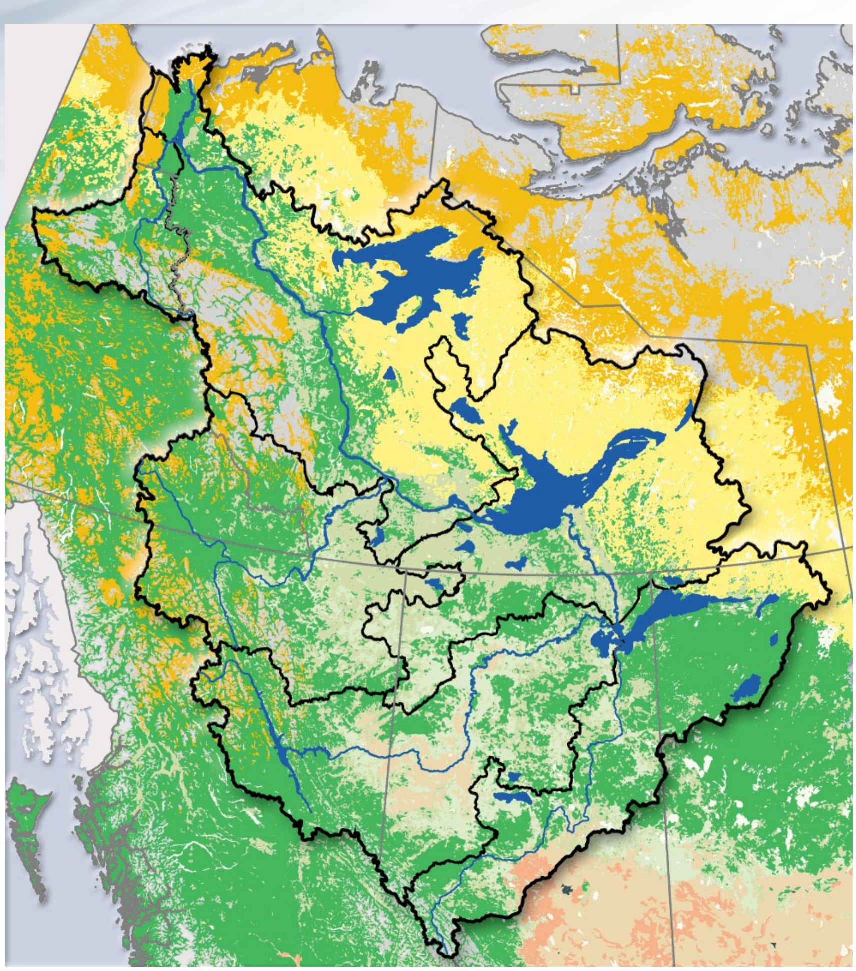


Figure 1–2. Land cover types in the Mackenzie River Basin.

Source: Agriculture Canada.

basin. Vegetation changes from boreal forest in the south to alpine in the mountains and arctic tundra in the north and east (Figure 1–2). The basin extends from the Mackenzie and Rocky Mountains in the west, through the Interior Plains to the Canadian Shield in the east. This range of conditions, in combination with the range of climatic conditions, results in eight of the fifteen major terrestrial ecozones of Canada being represented within the basin.[2]

Human Populations

Approximately 400,000 people live in the Mackenzie River Basin (397,000 in 2001).[1] Between 1971 and 2001 the population increased by 60%. The population of the Mackenzie River Basin represents a little more than one percent of Canada's population, but because of the large area, population density in the Mackenzie River Basin is less than one-tenth of that in Canada as a whole.

In most of the world's major river basins, human populations tend to concentrate along the navigable portions of the river and reach a maximum near the mouth where there is access to ocean shipping routes. In the Mackenzie River Basin, most of the people live in the headwater sub-basins. In 2001 about 50% of the population of the whole Basin lived in the Peace sub-basin and a further 40% lived in the Athabasca sub-basin (Figure 1–3). Most of the people residing in the Mackenzie River Basin (73%) live in Alberta; 17% live in BC, 9% live in the NWT, and less than 1% live in Saskatchewan or the Yukon.[1]

Approximately 15% of the people in the basin

(61,870 in 1996) are Aboriginal, which includes North American Indians, Métis, and Inuit.[4] More than two-thirds of the Aboriginal populations live in the Peace and Athabasca sub-basins, where they account for about 12% of the total population. In the less densely populated portions of the basin, such as the Peel sub-basin and the Saskatchewan portion of the Athabasca sub-basin, more than 90% of the people are Aboriginal. Generally, as the river flows north, the population becomes less dense and the Aboriginal portion of the population increases (Figure 1–3).

Community and Domestic Water Use

The water-use cycle involves withdrawing, using, sometimes cleaning, and then returning water to its source so that others can use it again downstream. There are forty-four community water systems with 1,000 or more customers in the Mackenzie River Basin. Combined, these systems treat and distribute about 110,000 cubic meters of water per day, serving the water needs of about 60% of the basin's population. More than 700 other small water systems serve small communities and rural populations. In addition, some First Nations' reserves and Métis communities have their own water works, while others are served by larger community systems.

The forty-four larger community systems treat and return about 98,000 cubic meters of water per day back to the Mackenzie water cycle. About 10% of treated water is lost from the community distribution systems. The average amount of water used by each person is in the range of 450–500 litres per day in these larger systems. Extrapolated to the entire population of the basin, the estimated municipal and domestic uses of water might total in the range of 175,000 to 200,000 cubic meters per day, equivalent to about twenty seconds of discharge at the mouth of the Mackenzie River.

Source to Tap

Water is used for many purposes in the Mackenzie River Basin, but one of the most important community and domestic uses is for drinking. While most of the people in the Mackenzie River Basin obtain their drinking water from a community drinking supply that is connected to a water treatment facility, a significant number of people obtain their drinking water from other sources such as wells or untreated surface waters. Up to 95% of Aboriginal people living a traditional lifestyle in northern Alberta reported using well water, untreated surface water or other sources of drinking water.[5]

The best way to make sure that drinking water is safe, clean and reliable is to use a multi-barrier

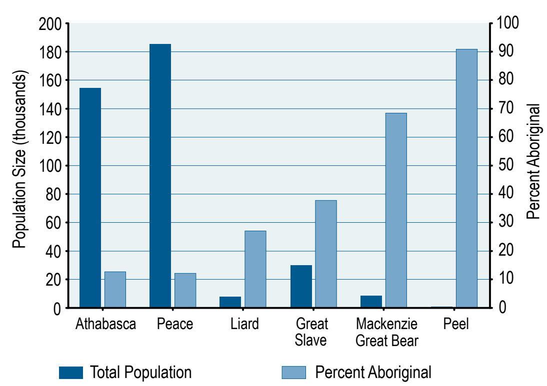


Figure 1–3.
The population density of the Mackenzie River Basin decreases from south to north. About 15% of the people are aboriginal.

Data Source: 2001 Census of Population, Statistics Canada; 1996 Census of Population, Statistics Canada.

approach to protect drinking water from contamination. The four main components of this source to tap approach are source water protection, drinking water treatment, drinking water distribution systems and monitoring and reporting. Provincial, territorial and federal governments have committed to safeguarding the drinking water system through good management, monitoring, reporting, research, guidelines, legislation, and public involvement and awareness. Drinking water that is not treated in conventional water treatment facilities is a major concern. When possible, the best source of drinking water for people living in remote areas away from water treatment facilities is from a protected groundwater well where the surrounding geologic formation serves as a natural filter. The well water should be tested at regular intervals. If the safety of a water supply is unknown or questionable, then the water should be boiled.[5]

Aspects of source water protection are considered in this report on the state of the aquatic ecosystems of the Mackenzie River Basin. Examples of efforts to safeguard drinking water sources include monitoring of water quality, research on environmental contaminants, guidelines for human uses and the aquatic ecosystem, and legislation to reduce the release of contaminants into the environment.

Industry

People use water and discharge wastes for a variety of industrial activities in the Mackenzie River Basin. The most important industries are agriculture, fossil energy, forest products, hydroelectricity and mineral extraction.

Agriculture

Farming is concentrated in the Peace and Athabasca sub-basins. Approximately five million hectares of land, representing about two percent of the Mackenzie River Basin, are used for agriculture.[1] Agricultural practices within the Peace and Athabasca drainages do not use much water since irrigation is not commonly practiced in those basins. Although the amount of land used for farming has been fairly stable, agricultural practices have become increasingly intensive over the past thirty years. During that time, the number of cattle has doubled to nearly one million; the tonnage of fertilizer applied has increased more than 500%; and after accounting for inflation, the amount spent on chemicals has increased more than 1400%.[1] Manure, fertilizer and chemicals can enter aquatic ecosystems with runoff and erosion. Sound farming practices serve to limit the extent to which this occurs.

Fossil Energy

The fossil energy reserves of the Mackenzie River Basin are among the largest in the world. The Peace, Athabasca, Liard and lower Mackenzie drainages overlay large portions of the Western Canadian Sedimentary Basin, the source of much of the conventional oil and gas production in Alberta, British Columbia and the Northwest Territories (Figure 1–4). The oil sand deposits of northern Alberta are the largest deposits of recoverable fossil energy (estimated 300 billion barrels) in the world.

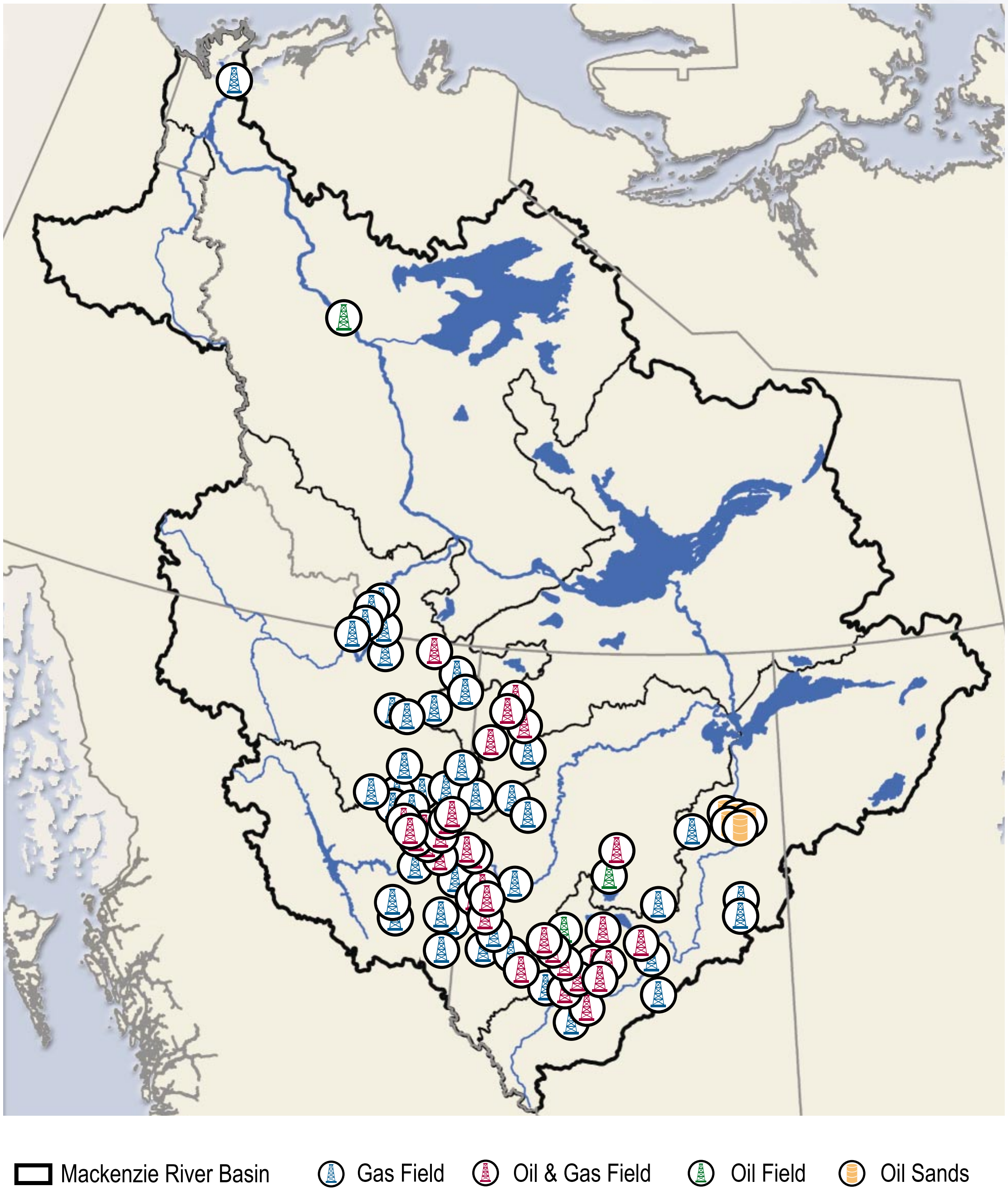


Figure 1–4.
Oil and gas fields and oil sands developments in the Mackenzie River Basin.

Data Source: Geological Survey of Canada.

There are numerous natural gas production facilities, oil production facilities, oil sands production facilities (Figure 1–4), and coal mines (Figure 1–5) within the basin. Petroleum pipelines extend into southeastern Yukon and southwestern Northwest Territories. A proposal to develop pipeline access to the vast natural gas reserves in the Mackenzie Delta is in the environmental assessment stage.[6] Undeveloped fossil energy reserves are known to occur in all of the sub-basins.

Forestry

The forest resources of the Alberta and BC portions of the Peace, Athabasca, and Liard drainages support a variety of forest-products industries. These include pulp mills, newsprint factories, sawmills, and plywood and particleboard factories. There are nine pulp mills and two paper mills in the basin. Ten of the eleven mills discharge treated wastewater to the basin's rivers (Figure 1–5). High value forest resources are also found in the Yukon and NWT portions of the Liard sub-basin, but these are not currently being developed for large-scale production.

Hydroelectricity

Two major power-generating stations have been built in the upper Peace River (Figure 1–5). The G.M. Shrum generating station, which consists of ten generating units that produce 2,730 megawatts (MW) of electrical capacity, is located at Williston Lake, the reservoir created by the construction of the W.A.C. Bennett Dam. Twenty-three kilometres downstream, the Peace Canyon generating station has four units producing 700 MW. These two stations represent approximately 30% of BC Hydro's generating capacity.[7] Operation of these hydroelectric facilities has changed the seasonal pattern of stream flow in the Peace River and there is concern that it may also have affected the ecology of the Peace-Athabasca Delta.

A portion of the Tazin River drainage has been diverted to supply water to three small hydroelectric generating stations on the Charlot River in the Athabasca sub-basin near the northeast end of Lake Athabasca (Figure 1–5). These facilities have a combined capacity of 25 MW.

There are six hydroelectric generating stations in the Great Slave sub-basin (Figure 1–5). Built in the 1960s to supply power to the Pine Point lead /zinc mine, the 21 MW Taltson generating station now supplies power to four communities in the area south of Great Slave Lake. The Bluefish hydroelectric station on the Yellowknife River and four small stations on the Snare River can generate a total of 34 MW to serve the industrial and domestic needs of Yellowknife and surrounding communities.[8]

Mineral Extraction

There are uranium, gold and tungsten mines within the Mackenzie River Basin (Figure 1–5). Gold is mined in BC and NWT and tungsten is mined in the headwaters of the Flat River that drains into the South Nahanni River. Some mines have been closed and are in the process of remediation, while new mines are being proposed. Some areas of the basin are being actively explored for mineral resources, the area northeast of Yellowknife in particular. Canada's third diamond mine has been proposed for Snap Lake in the headwaters of the Lockhart River in the Great Slave Lake sub-basin. Emeralds have been discovered in the headwaters of the Liard River in the Yukon Territory.

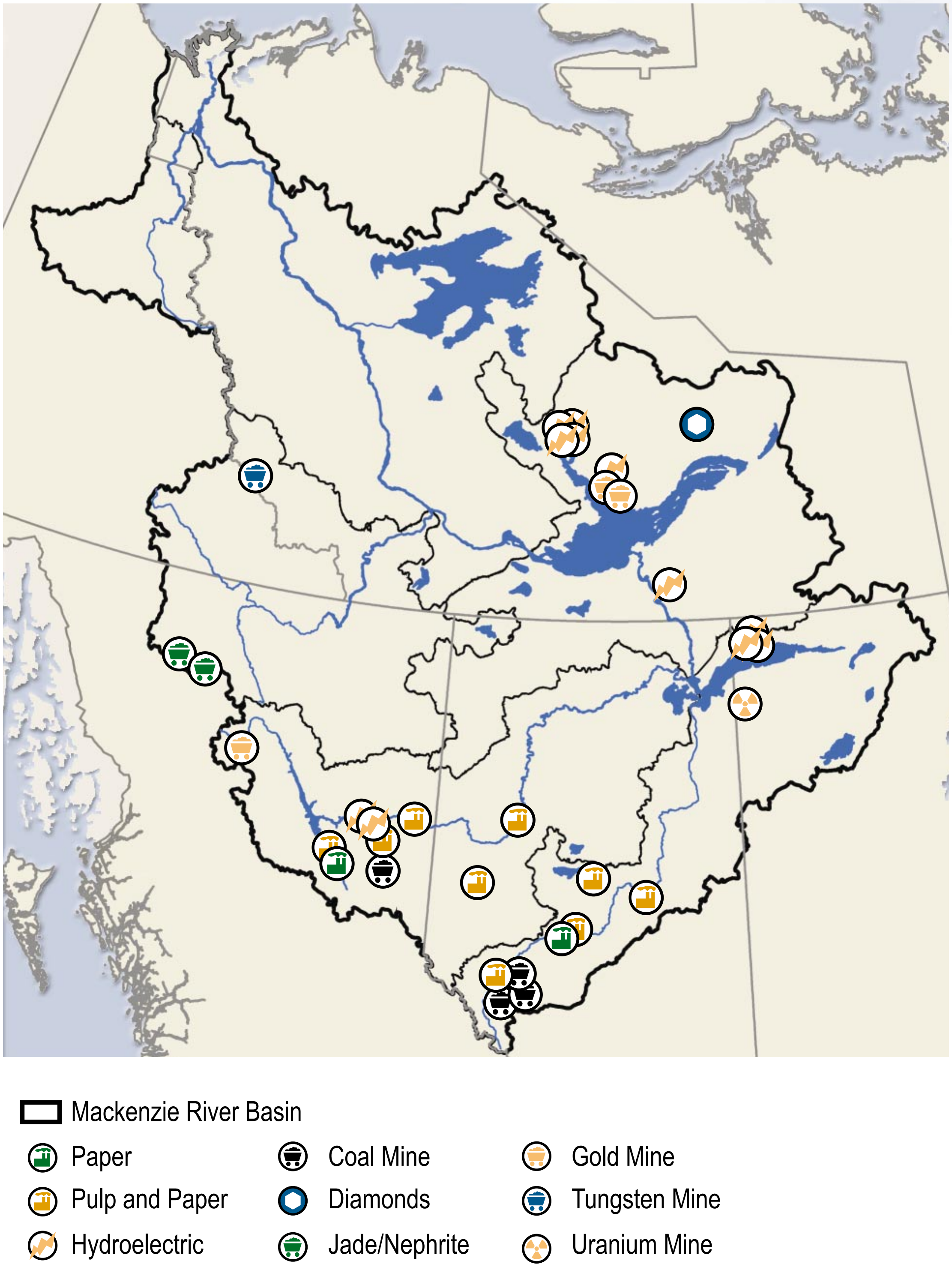


Figure 1–5.

Pulp mills, mines and hydroelectric developments in the Mackenzie River Basin.

Data Source: National Atlas of Canada, Alberta Environment.

The Use of Traditional Environmental Knowledge

The consideration of the long-term, experience-based environmental knowledge systems of Aboriginal people (Traditional Environmental Knowledge or TEK) is increasingly a policy requirement in environmental decision-making in Canada.[9] The use of TEK in decision-making provides a long-term holistic perspective that gives priority to stable ecosystems and sustainable economies.

The requirement to consider TEK in environmental decision-making is based on treaties that were concluded between the government of Canada and various First Nations between 1871 and 1923 with the object of facilitating the settlement of western Canada and securing the right of Aboriginal people to make their living from the land. Of these, Treaties No. 6, 8 and 11 involved the title to portions of the upper Mackenzie River Basin being held by the Crown.

Treaty rights were entrenched with the enactment of the Constitution Act in 1982. The Supreme Court of Canada has established that the government has a duty to consult Aboriginal peoples in decisions made concerning their lands and well-being. TEK is an important aspect of the consultative process between governments, their representatives and Aboriginal peoples.[9]

The duty to consult provides a means by which TEK can influence decision-making. TEK can be broadly categorized in four ways: **knowledge about the environment**; **knowledge about the use of the environment**; **knowledge about values**; and **founding principles of the knowledge system**.[9] Collectively, these types of knowledge can be used to (1) explain how ecosystems work and whether they are healthy; (2) identify the rights and interests of Aboriginal populations; (3) stimulate regulatory and

Subsection 35(1) of Canada's Constitution reads as follows:

"35. (1) The existing aboriginal and treaty rights of the aboriginal peoples of Canada **are hereby recognized and affirmed**."

"From a western scientific perspective, TEK includes empirical facts or associations based on observation and experience, explanations of fact, a culturally specific way of organizing and understanding information, a set of values and in a very broad sense, cultural norms about how to do things. From an Aboriginal perspective, TEK is what people learn from experience, from family and community, and from stories handed down about how to live fully and effectively in their environment. It is thus both knowledge of how things work and a guide to action."

Peter Usher 2000.

policy decisions; and (4) develop long-term goals and objectives.

Several initiatives or processes provide opportunities for Aboriginal residents of the Mackenzie River Basin to be involved in decisions relating to the management of water.

Advisory processes include the development of educational and cultural materials as well as stakeholder advisory processes. *The Northern River Basin Study*[10], the *Mackenzie River Basin Impact Study*[11] and the *West Kitikmeot Slave Study*[12] made significant efforts to include TEK to support numerous regional, national and international initiatives or policies. Agencies and initiatives like the Mackenzie River Basin Board, the NWT Cumulative Effects Assessment and Management Framework Steering Committee, the *NWT Western Biophysical Study* and land use planning boards work with Aboriginal organizations to promote the use of TEK in research, environmental planning and management.

The Alberta government is developing a *Best Practices Handbook for Traditional Use Studies* and has included Aboriginal input on the Northern Alberta Development Council.[13] In the Athabasca oil sands area, the Cumulative Environmental Management Association brings a wide range of stakeholders together to reduce potential long-term environmental impact arising from industrial development in northeastern Alberta. This association includes a Traditional Ecological Knowledge Standing Committee.[14]

The British Columbia Treaty Negotiations Office has recently released a *Provincial Policy for*

"The Arctic Borderlands Knowledge Co-op has a list of about 75 indicators that participants are interested in monitoring. Developed data sets, with explanations, are in place for approximately 40 indicators. Potential indicators were identified at the First Annual Gathering and are reviewed each year."

http://www.taiga.net/coop/index1.html

"Today the geese do not stop in Old Fort because it dried out; there is no food for them to stop and eat; likewise, as a result of flooding and oil spills there are no muskrats either. When we trap animals the meat is spoiled because of oil spills. When they find a muskrats den, they find oil in their homes and the muskrats are sick. They have bleeding noses".

(Daniel Marcel in Coutu and Hoffman-Mercredi. Pg. 79).

Consultation with First Nations and has developed Memoranda of Understanding regarding consultation with several of the Treaty 8 First Nations in northeastern BC.[15]

Yukon has developed *A Framework for First Nations Relations: Consultation Guidelines*.[16]

Quasi-judicial processes include environmental assessment panels and regulatory bodies and boards with legislated decision-making responsibilities and authorities. They incorporate TEK through the appointment of members nominated by Aboriginal communities and by requiring consultation with Aboriginal groups as a pre-requisite to or as part of the regulatory process.

The Yukon Umbrella Final Agreement and the *Yukon Environmental and Socio-Economic Assessment Act* stipulate that environmental impact assessments of new projects must consult with native people and consider traditional knowledge in project assessments. Similar environmental impact assessment and regulatory authorities exist in the NWT through the *Mackenzie Valley Resource Management Act*.

Legislation – Modern Comprehensive Land Claim Agreements between Canada and respective First Nations provide the basis for enacting laws that recognize the importance of TEK. For example, the *Mackenzie Valley Resource Management Act* was passed as a requirement of the Gwich'in and Sahtu settlements in the Northwest Territories and applies throughout most of the NWT. Other modern settlement agreements in the NWT are the *Inuvialuit Settlement Act* and the *Tli Cho Agreement*. Within the Yukon Territory, eight of fourteen land claims have been settled to date under the *Yukon Umbrella Final Agreement*. Several other First Nations within the Mackenzie River Basin are presently negotiating comprehensive land claim agreements with federal and/or provincial governments.

Litigation – The courts have ruled that TEK must be considered in legal and quasi-judicial processes. The Supreme Court of Canada decided that rules of evidence must consider oral history in the proof of Aboriginal rights and titles and has determined that consultation is a key requirement to justify decisions that infringe on Aboriginal rights.

Business – There are many First Nations participating in business ventures in the Mackenzie River Basin. For example, a consortium consisting of petroleum companies and First Nations business groups has proposed the construction of a natural gas pipeline from the Mackenzie Delta to connect with the pipeline grid in northern Alberta. Business ventures such as these provide a first hand opportunity for developers to incorporate TEK into water and aquatic management decisions.

"Dè means the land, and it includes the understanding that all things have life and spirit, and that all things are interconnected."

Definitions: Dogrib Constitution

Climate Change

Climate of the Mackenzie River Basin

Climate is a combination of many features including temperature, precipitation, wind speed, humidity and sunshine. Climatic conditions are governed by complex processes illustrated in Figure 1–6. In the Mackenzie River Basin, the movement of heat and moisture from the North Pacific Ocean into the region is especially important. Processes occurring within the basin are also very important in affecting its climate.

The Mackenzie River Basin is characterized by dramatic seasonal changes in air temperatures. Seasonal monthly averages are about -25° C in winter and +15° C in summer.[17] Average precipitation over the basin is estimated to be 410 millimetres per year, with snow dominating for six to eight months of the year, especially over the mountains on the western side of the basin, where precipitation is greatest. Evaporation from lakes, rivers and wetlands, transpiration from vegetation and sublimation from

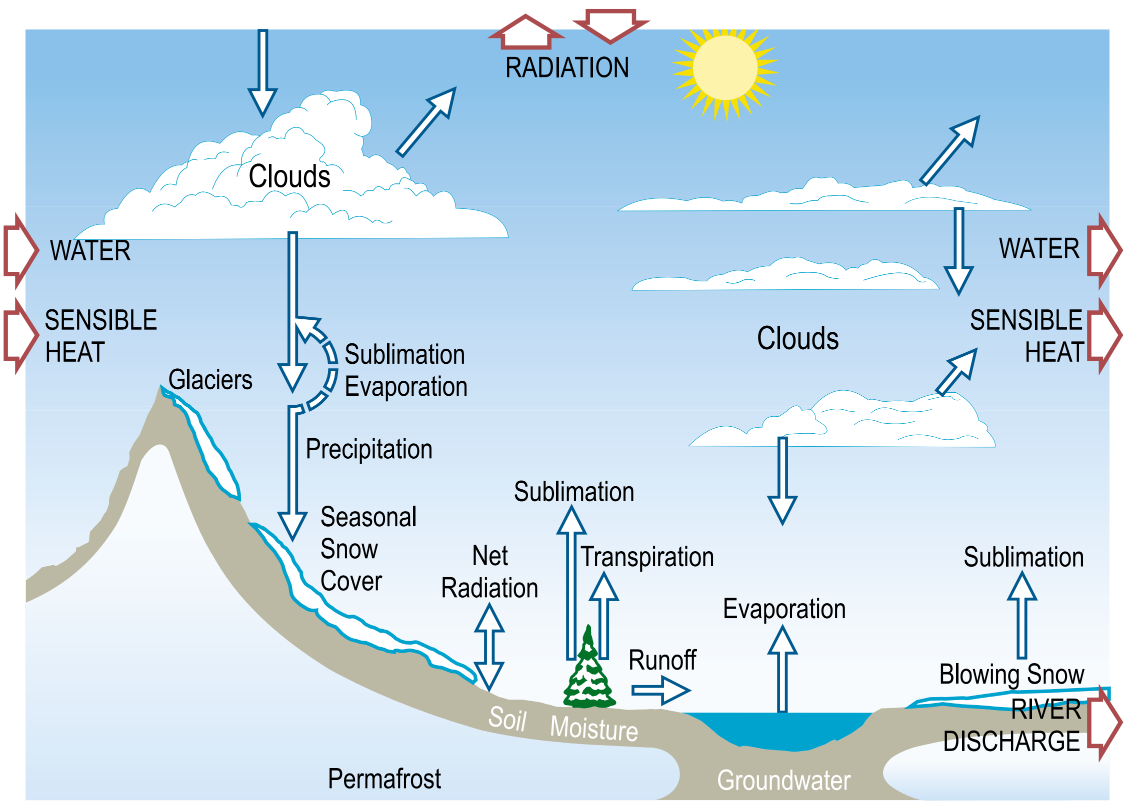


Figure 1–6.

Processes affecting the climate and water cycles of the Mackenzie River Basin. **NOTE:** *Sublimation* is the direct change of snow to water vapour that results in 'winter evaporation'. *Transpiration* refers to the loss of water from plant surfaces to the air. *Sensible heat* refers to the heat energy in an air mass. *Radiation* refers to energy (heat) that enters the basin, predominately as solar radiation, and to energy that leaves the basin.

Source: Stewart *et al.* 1998.

snow and ice total about 230 millimetres per year, on average. Runoff, estimated from the Mackenzie River discharge into the Arctic Ocean, is about 180 millimetres per year. Much of the water that enters the basin is recycled several times before leaving as water vapour or as discharge to the Arctic Ocean. The basin acts like an enormous sponge that can store and release large amounts of moisture in lakes, wetlands and groundwater.

There are four distinct seasons in the Mackenzie River Basin: autumn when snow pack accumulates; winter, a period of light snow and near-constant below-freezing temperatures; spring, when warming and rainstorms enhance runoff; and summer when convective activity dominates. In terms of the water cycle, there are three distinct periods of the year: summer and autumn, when rainfall influences runoff; winter, when rivers and lakes are covered by ice thus reducing runoff; and spring, when sudden melting of ice and snow produces peak runoffs, ice jams and occasional flooding.[17] The spring thaw and early spring ice jam floods are the major hydrological events in the annual cycle and help to shape the physical, chemical and biotic attributes of the basin's aquatic ecosystems.[18]

The Water Cycle

The water cycle refers to the processes by which water is transported through the environment. It relates to the distribution of water on earth and its physical and chemical reactions with other substances.

The Mackenzie River Basin is currently experiencing some of the greatest rise in temperature anywhere in the world, especially during the winter.[17] Average winter temperatures increased between two and three degrees Celsius in the Mackenzie River Basin from 1950–1998 (Figure 1–7). Summer temperatures also increased, but to a lesser degree.[19]

Climate Change and Greenhouse Gases

Recent warming in the Mackenzie River Basin is part of a pattern of climate change. In its broadest sense, "climate change" refers to a change in the "average weather" that a given region experiences.[20] However, the United Nations Framework Convention on Climate Change considers climate change to be a change in climate that is attributable to human activity and is in addition to natural climatic variability.[21]

The sun provides the energy that drives our climate. The earth absorbs about two-thirds of the solar energy that hits our atmosphere. Then, it releases some of this energy back into space. The balance between incoming and outgoing energy is influenced by changes in solar output, changes in the earth's orbit and by the "greenhouse effect". The greenhouse effect refers to the process by which some of the energy emitted from the earth towards space is absorbed or "trapped" by "greenhouse gases" and prevented from escaping the earth's atmosphere (Figure 1–8). The process helps to warm the surface of the earth, keeping it about 33°C warmer than it would otherwise be. This process is vital to life on earth. The major greenhouse gases are water vapour, carbon dioxide, methane and nitrous oxide.[20]

Human activity affects the earth's climate in a number of ways. By draining wetlands and clearing land for forestry, agriculture and cities, humans alter the way the earth's surface reflects sunlight, and reduce the earth's capacity for absorbing carbon dioxide, the main greenhouse gas. The burning of fossil fuels has gained considerable attention because of the large quantities of greenhouse gases released through this activity. Since the industrial revolution in the late 1700's, atmospheric concentrations of

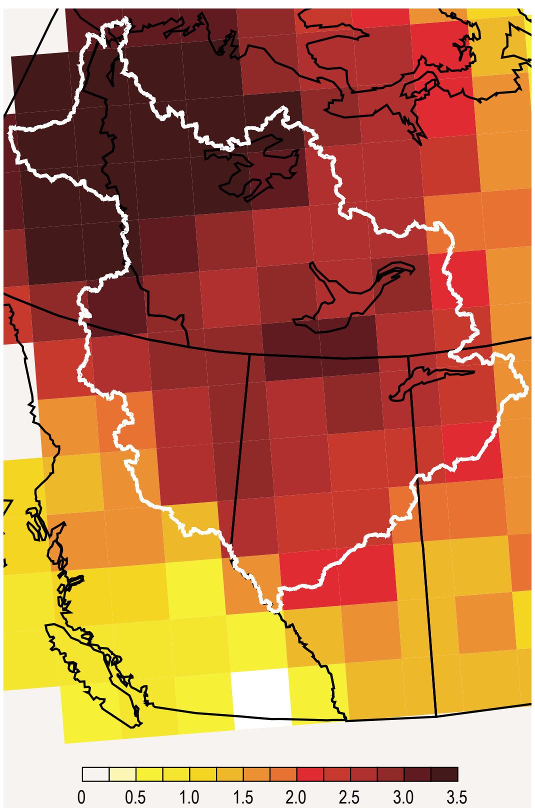


Figure 1–7. Trends in maximum daily temperatures in winter between 1950-1998. Units refer to the change in temperature (°C per 49-year period).

Data Source: Meteorological Service of Canada, Climate Research Branch.

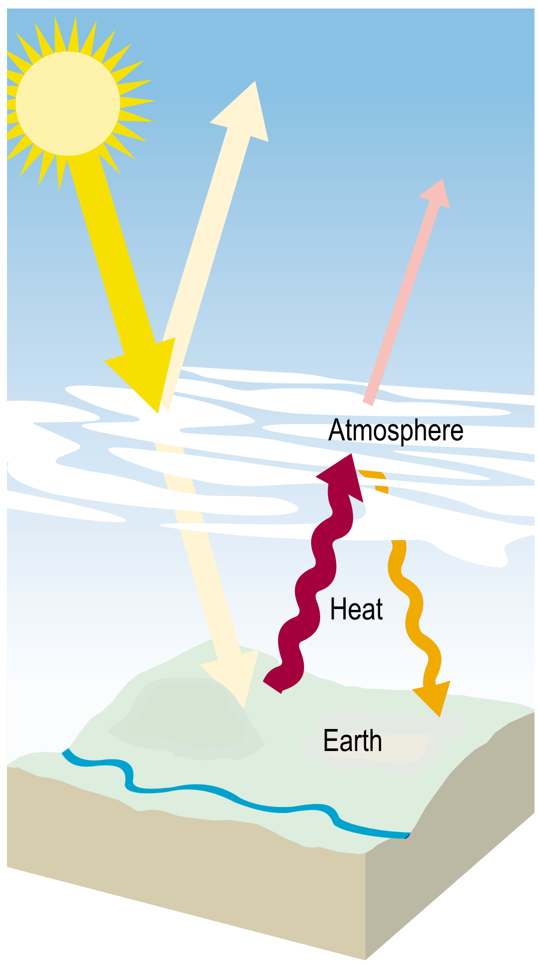


Figure 1–8. The Greenhouse Effect.

Source: Precision Graphics.

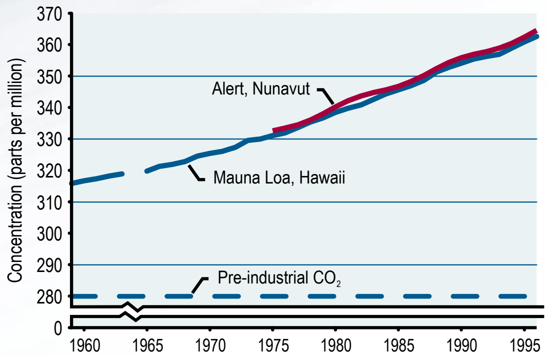


Figure 1–9.

Trends in atmospheric carbon dioxide measured in Hawaii and at Alert, Nunavut, 1959-1996.

Data Sources: Scripps Institute of Oceanography; Environment Canada.

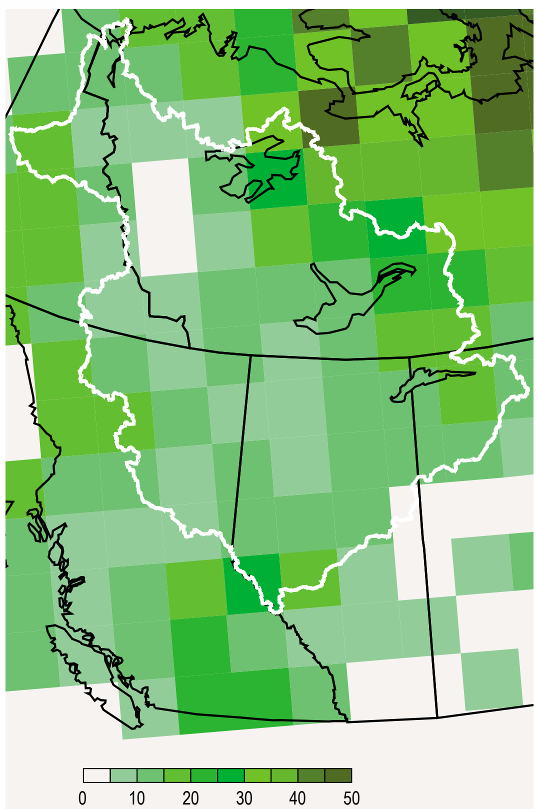


Figure 1–10.

Trends in annual precipitation between 1950 and 1998. Units are percent increase over the forty-nine year period.

Data Source: Meteorological Service of Canada, Climate Research Branch.

carbon dioxide have increased by 31%, methane by 151% and nitrous oxide by 17%.[21] Increases in carbon dioxide have been especially pronounced during the past fifty years (Figure 1–9). These human-made releases of greenhouse gases enhance the greenhouse effect and are considered important factors in climate change.

Climate Change in the Mackenzie River Basin

Because of the recent strong warming trends in the Mackenzie River Basin, there are concerns that climate change may already be affecting the basin's ecosystems and natural resources. These concerns have been further fuelled by changes in total annual precipitation over much of the basin (Figure 1–10). In particular, winter precipitation has increased over much of the northern part of the basin but has decreased in the southwestern part of the basin. In contrast, summer precipitation has increased in the south but has decreased somewhat in the far north.[19] These changes, if extended over a long period of time, could have profound effects on the terrestrial and aquatic ecosystems of the basin.

Glaciers in the headwaters of the Mackenzie River Basin are also affected by a warming climate. The Athabasca Glacier in the Columbia Ice-field has been receding for the last 125 years. It has lost half of its volume and retreated more than 1.5 kilometres.

Since the focus of this report is on the aquatic resources of the basin, the following sections will examine indicators of climate change that are related to the aquatic ecosystems of the basin.

Traditional Knowledge of Climate Change

Knowledge of weather and climate is vital to traditional Aboriginal lifestyles. Although traditional knowledge is sometimes presented as evidence for global climate change caused by human-made increases in atmospheric greenhouse gases, Aboriginal residents from Aklavik point out that weather patterns are continually changing from year to year and that adaptation is a normal part of life.[22] The rate of climate change determines the degree of adaptation required, and if dramatic changes occur within decades, it will be difficult to adapt.[11]

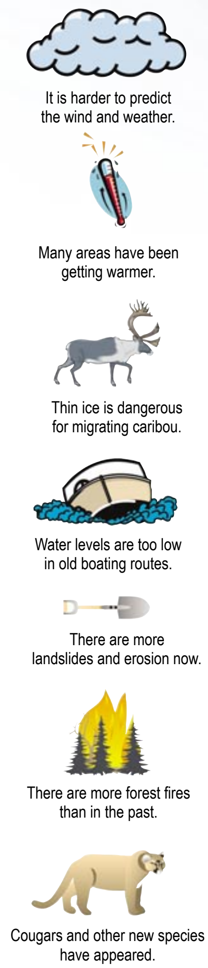
Several communities have noticed an increase in the variability of weather and people are having more difficulty predicting the wind and weather.[22, 23, 24, 25] Most communities in the Mackenzie River Basin reported an overall increase in temperature (Figure 1–11)[22, 24] and some comment that Elders have a difficult time dealing with extreme summer heat.[26] Observations on precipitation vary from community to community, with some reporting more snow or rain than in the past while others report drier conditions.[22, 24, 25, 27] People in the basin have reported thinner ice [25, 28] and have expressed concern for the associated danger to human travellers, migrating caribou, and other wildlife.[24, 26] Moreover, freeze-up occurs later in the fall, break-up occurs earlier in the spring and with less force, and both processes take longer than in the past.[11, 22, 28] During the past one to two decades, water levels have decreased,[25, 26, 28] and small lakes and streams on the barren lands have disappeared.[11] Elders explain that these decreasing water levels result in reduced habitat for aquatic species such as fish, waterfowl and muskrat; populations of these wildlife species have declined in some areas.[28] Low water levels have interfered with fishing and travel because some traditional fishing sites are too shallow to set nets,[29] and important boating routes are no longer navigable.[28]

In addition to the indicators directly related to climate, some of the observed changes to vegetation and wildlife may also be related to climate change.[11, 24, 25] Elders report an increase in erosion and landslides, with more sediment entering the rivers. They also report changes in vegetation diversity and less berry production. There has been an increase in forest fires, resulting in a loss of wildlife habitat as well as a loss of property and trapping areas for the people in the area. In terms of wildlife observations, people have witnessed the appearance of species, such as cougars, that were not traditionally found in the area. There have also been changes in the population size, distribution, and migration of other species, which have implications for people hunting and fishing on the land.

Overall Assessment – Unfavourable

Traditional knowledge has provided a broad perspective on the issue of climate change. Not only has it reported warmer temperatures, a more variable climate and unpredictable weather, but it has also indicated that the environment has changed in response to these changes in climate. Some of the environmental changes could threaten or impose changes upon subsistence lifestyles.

Figure 1–11.
Summary of traditional ecological knowledge indicators of climate change in the Mackenzie
Data Sources: see text



Spring Melt of River and Lake Ice

Spring ice melt and break-up are complex processes that are dependent on numerous factors. One of the major controlling factors is air temperature.[30] Ice melt and break-up also depend on the original ice thickness, which is a function of the severity of the winter and amount of snow on the ice. Snow reflects incoming radiation from the sun and insulates ice from earlier melting.

For many years, Environment Canada has recorded melt dates and ice-free dates at several sites in the Mackenzie River Basin. "Melt date" refers to the beginning of the ice break-up. "Ice-free date" is the earliest date on which the surface water was reported to be completely free of ice.[31]

What is happening?

Melt dates and ice-free dates have been recorded on the Mackenzie River at Fort Good Hope and Fort Simpson and on Great Slave Lake at Back Bay, near Yellowknife. In recent years, melt dates at all three locations have been occurring as many as ten days earlier than they did historically, and ice-free dates have occurred earlier at Fort Simpson (Figure 1–12). In recent years, also, the melting period is lasting longer at Back Bay on Great Slave Lake near Yellowknife.

Why is it happening?

Of the many factors that affect the timing of the spring melt on rivers and lakes, spring air temperature is very important.[30] In recent years, average spring temperatures have increased at each of the locations where earlier melt dates have been observed (Figure 1–13). In addition, the annual snowfall at Yellowknife has increased in recent years, especially when compared to the 1960s and 70s.[31] More snowfall results in a thicker or denser layer of snow accumulating on the ice over the winter, thereby prolonging the melt period.

What does it mean?

Winter roads exist throughout the northern portion of the Mackenzie River Basin, linking remote communities with larger centres. Supplies are often trucked into remote communities and mine sites on winter roads, which cross many lakes and rivers. Travel by snowmobile, either for recreational purposes or in support of subsistence trapping, hunting and fishing, usually occurs over frozen lakes and rivers. As well, wildlife use frozen lakes and rivers to travel between feeding areas. Migrating caribou cross numerous lakes and rivers while travelling from wintering areas to spring calving areas.

If the trend towards earlier melt dates continues, the winter travel season in the north will become shorter. In addition, wildlife that depend on river and lake ice for travelling will have to adapt to the earlier melt dates. To date, there is no evidence that the recent, earlier spring melt dates have been detrimental to wildlife.

Because of the scarcity of bridges, ferries and permanent roads, travel is difficult from the initiation of the melt until lakes and rivers are essentially ice-free, at which time the use of boats makes travel possible again. Longer melt periods will prolong the

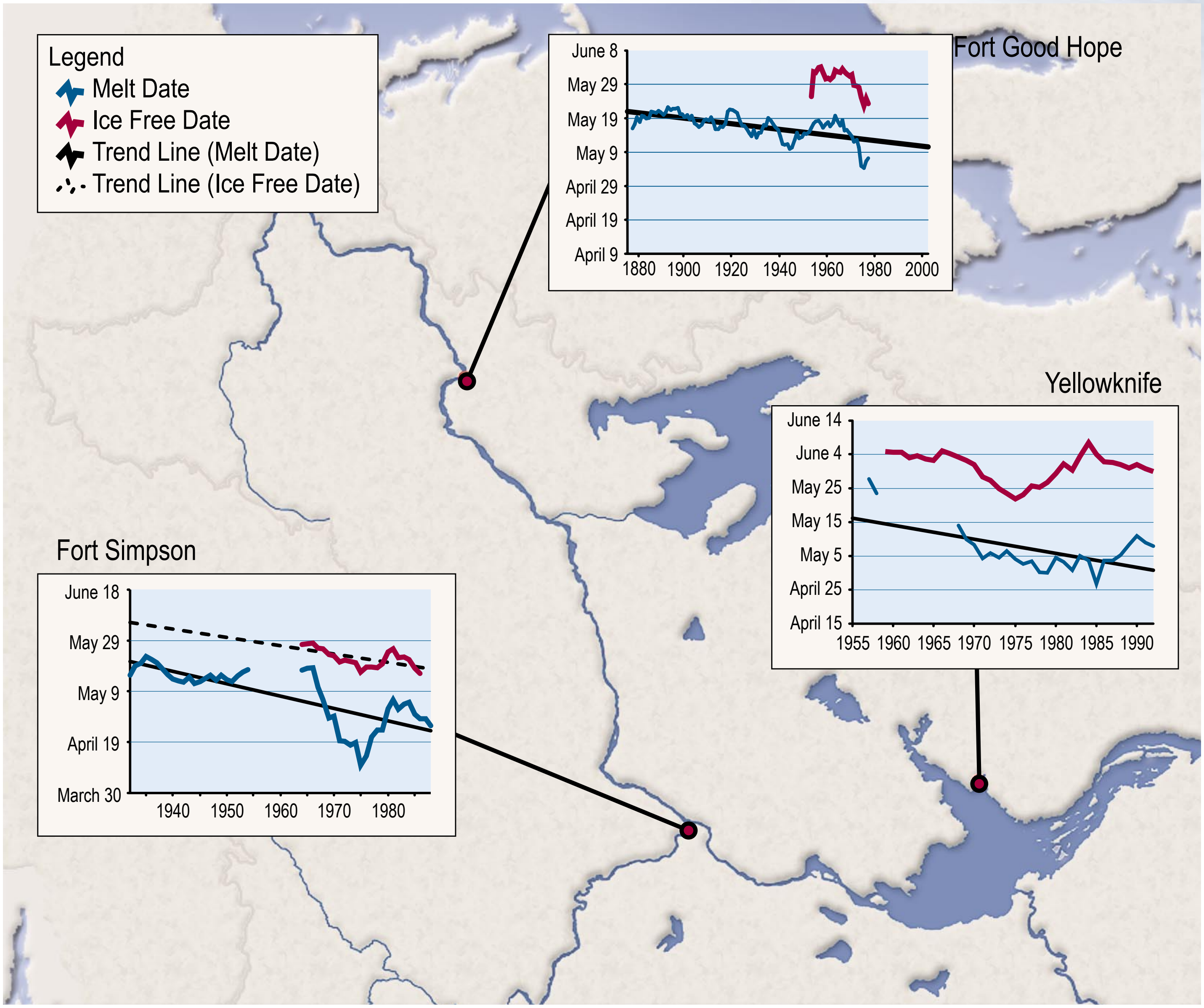


Figure 1–12.

River and lake ice is melting earlier in the Mackenzie River Basin.

Data Source: Atmospheric and Hydrologic Sciences Division, Environment Canada.

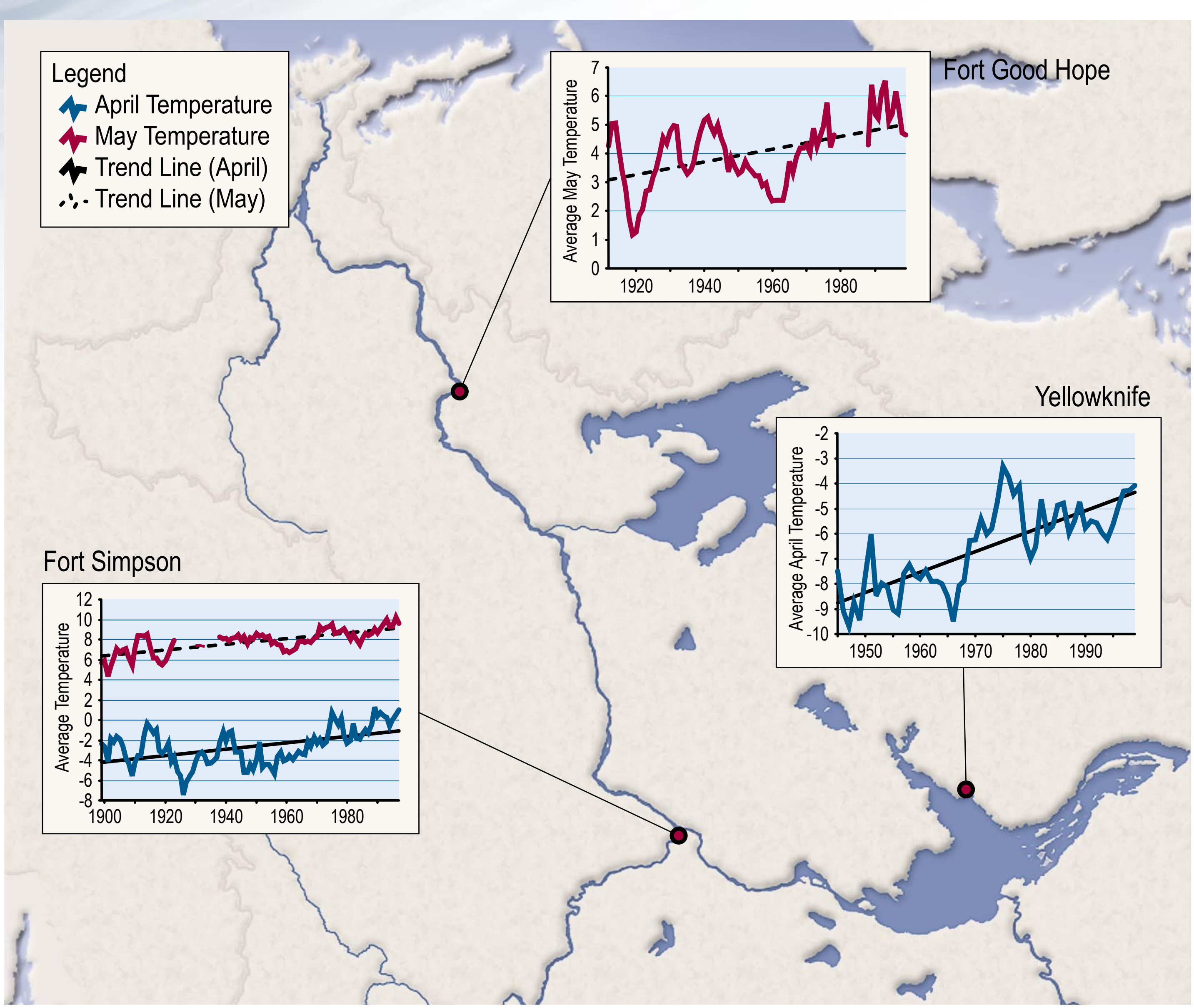


Figure 1–13. In recent years, spring temperatures have been warmer, causing river and lake ice to melt earlier in the year.

Data Source: Atmospheric and Hydrologic Sciences Division, Environment Canada.

period of time when travel in the north is greatly restricted.

Longer ice-free seasons could lead to greater primary productivity in lakes and rivers and to a longer growing season. This could ultimately result in enhanced production of species of fish that are adapted to warmer water. However, these effects could be offset by other conditions that may arise because of climate warming, namely increased erosion and an increased frequency of landslides associated with melting permafrost, which will lead to greater siltation and cause damage to aquatic ecosystems.[32] Furthermore, cold water-adapted species, such as lake trout and arctic char, may be eliminated from the more southerly parts of their ranges. On the plus side, longer ice-free seasons or earlier melt dates could reduce winterkill of fish in lakes subject to oxygen depletion. However, climate change would likely affect aquatic ecosystems in other ways, such as increasing the frequency of mid-winter break-ups and reducing ice thickness, ice scouring and ice jam flooding events. Because these disturbances play a major role in shaping northern aquatic ecosystems, changes in their timing or magnitude could affect the structure and function of aquatic ecosystems.[33]

Overall Assessment – Unfavourable

River and lake ice is beginning to melt earlier in the northern portion of the Mackenzie River Basin. There is some evidence that it is taking longer for rivers and lakes to become ice-free, once the melt has started. If these trends continue into the future, there could be profound implications for winter travel in the north. Aquatic ecosystems could also be affected.

Permafrost

Permafrost is soil or rock that remains below 0°C throughout the year. It forms when the ground cools sufficiently in winter to produce a frozen layer that persists throughout the following summer. A significant portion of the Mackenzie River Basin is underlain by permafrost, a large proportion of which is at temperatures of a few degrees below 0°C.[34] The spatial distribution, thickness and temperature of permafrost are highly dependent on the temperature at the ground surface.

Climate warming causes ground temperatures to increase. As ground temperature increases, the seasonal thaw near the ground surface penetrates deeper into the ground. As ground thaws near the surface, it may settle or sink as a result of thawing of near-surface ground ice, with subsequent re-consolidation of the soil column.

The Geological Survey of Canada (GSC) monitors permafrost at about eighty sites in the Mackenzie River Basin, mainly in the Northwest Territories. The GSC is involved in several other activities related to permafrost, including mapping, modelling the effects of climate change, monitoring landslides and slope stability and conducting studies to understand oil and gas pipeline-permafrost interactions.

What is happening?

Over the past 150 years, the southern boundary of the discontinuous permafrost zone has migrated northward in response to warming after the Little Ice Age, and continues to do so today.[35, 36, 37]

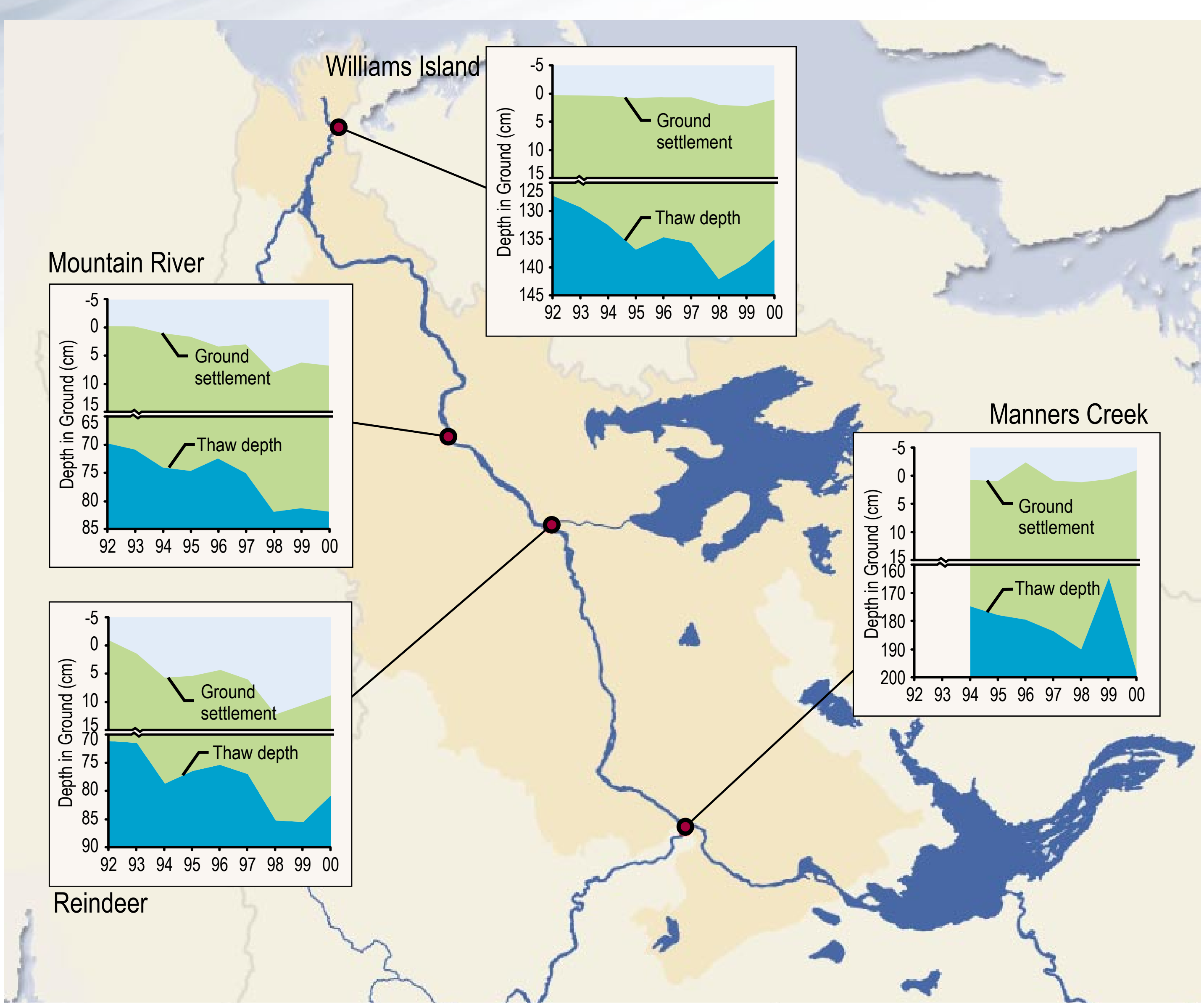


Figure 1–14. Between 1992–1998, maximum summer thaw depths increased and some ground settlement occurred. Cooler temperatures in 1999-2000 interrupted or reversed this trend.

Data Source: Geological Survey of Canada, Terrain Sciences Division.

Maximum annual thaw penetration and ground settlement have been measured at many sites located throughout the western part of the Northwest Territories since 1992. In this report data are presented for four sites representing the boreal forest, tundra, sub-arctic and Mackenzie Delta portions of the basin. Thaw penetration and ground surface settlement increased at most sites up to and including 1998, although increases were small (Figure 1–14). After 1998, relatively cool summers have resulted in an apparent reversal of this trend. The available data, therefore, do not support the identification of a definite, recent trend in permafrost thaw associated with regional climate change. Measurable impacts over a decade appear to be limited to a progressive but subtle settlement of the ground surface.

Why is it happening?

The response of permafrost to changes in air temperature is moderated by several factors such as snow cover, vegetation, surface material, moisture content of the soil and drainage. The moderating influence of these factors may explain, in part, why there was not evidence of a strong time-trend in permafrost thaw during the 1990s. Perhaps more importantly, relatively cool weather in 1999 and 2000 coupled with the fact that data were available for only nine years at most sites, reduced the likelihood of detecting a strong trend in permafrost thaw.

Permafrost temperature determines whether permafrost will thaw, and is itself a sensitive indicator of short- and long-term climatic variability and changes in surface conditions.[38, 39] Permafrost temperatures have increased in the central Mackenzie Valley at the rate of about 0.03°C per year since the mid-1980s (Figure 1–15). In addition, on the tundra where permafrost is colder and thicker, permafrost temperatures at a depth of 28 m increased about 0.1°C per year in the 1990s. However, in the southern Mackenzie Valley near Fort Simpson, permafrost temperatures did not change at a site with sandy soil, closed spruce forest and shallow, relatively warm (-0.3°C) permafrost.

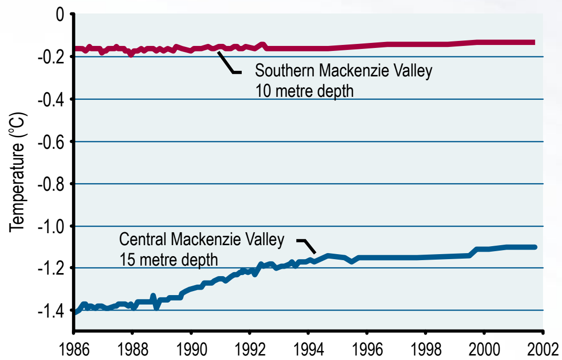


Figure 1–15.
Permafrost temperatures have increased at 15 m depth in the central Mackenzie Valley but have not changed at 10 m depth in the southern Mackenzie Valley.

Data Source: Geological Survey of Canada, Terrain Sciences Division.

What does it mean?

Permafrost and soils

Warming and thaw of ice-rich permafrost can result in a reduction of soil strength, ground instability and settlement. Ground settlement due to the melting of ground ice can damage foundations, roads, pipelines and other infrastructure especially if differential settling occurs. Warming of ice-rich soils and thawing of ground ice on slopes can cause instability resulting in slope failures and landslides.

Permafrost and the water cycle

Permafrost plays an important role in the water cycle through its influence on infiltration, runoff, and groundwater storage and flow.[40] It restricts the movement of water within the ground to the seasonally thawed zone near the surface and to taliks (thawed zones) within the permafrost or the sub permafrost zone. Frozen ground also indirectly influences water movement by affecting rooting zone depth (important for vegetation succession and growth) and the length of the thaw season (important for evaporation). Permafrost plays an important role in moisture balance through its control of water table height. Climate warming causes an increase in active layer thickness, which in turn results in greater groundwater storage and increased infiltration, and leads to lower spring runoff peak and increased base flow.[41] Groundwater flow will play a greater role in stream flow. Furthermore, an increased exchange between surface and subsurface water will affect surface water quality.[42]

Differential settlement may occur in response to thaw of ground ice. This will lead to the development of large depressions in the ground and may change drainage patterns and the distribution of surface water. Permafrost thaw may also cause some northern wetlands and lakes to drain, leading to loss of fish and wildlife habitat.[43]

Slope failures along rivers associated with the thaw of ice-rich permafrost may result in damming of rivers which could cause upstream flooding, and affect river navigation.[44] Aquatic habitats may be affected by increased erosion and by the increased siltation in rivers and streams which may also accompany slope failures .

Permafrost and tailings ponds

Where permafrost occurs near the ground surface, frozen earth-fill dams on permafrost foundations are often used for tailings ponds at mines in the far north. Failure of these dams due to the thawing and differential settlement associated with climate warming could result in contaminants being released from tailing ponds to the surrounding environment. Climate warming and its effects on permafrost have become important considerations in the geotechnical design and environmental impact assessment of tailings management for new mines in the north.

Permafrost and climate change

Permafrost ranges from moderately to highly sensitive to climate warming in much of the Mackenzie River Basin. This is especially true of ice-rich organic terrain with ground temperatures close to 0°C.[45] Complete degradation of permafrost in response to warming may be possible within the next fifty years in the southern, discontinuous zone near Fort Simpson where permafrost is about five to ten meters thick (Figure 1–16).[46] Farther north, where permafrost is thicker, (fifty meters) such as near Norman Wells, permafrost may thin and eventually disappear. Near the Beaufort Sea region where permafrost may be several hundred meters thick, warming would likely result in increases in active layer thickness and thinning of permafrost.

▼ Overall Assessment – Mixed Signals

Permafrost has already started to retreat towards the north in response to warming after the Little Ice Age. Further warming may worsen this trend, although since the mid-1990s surface permafrost has thawed only slightly. Nevertheless, in recent years, permafrost has warmed to temperatures approaching the melting point in much of the Mackenzie Valley, a signal that further melting of large tracts of

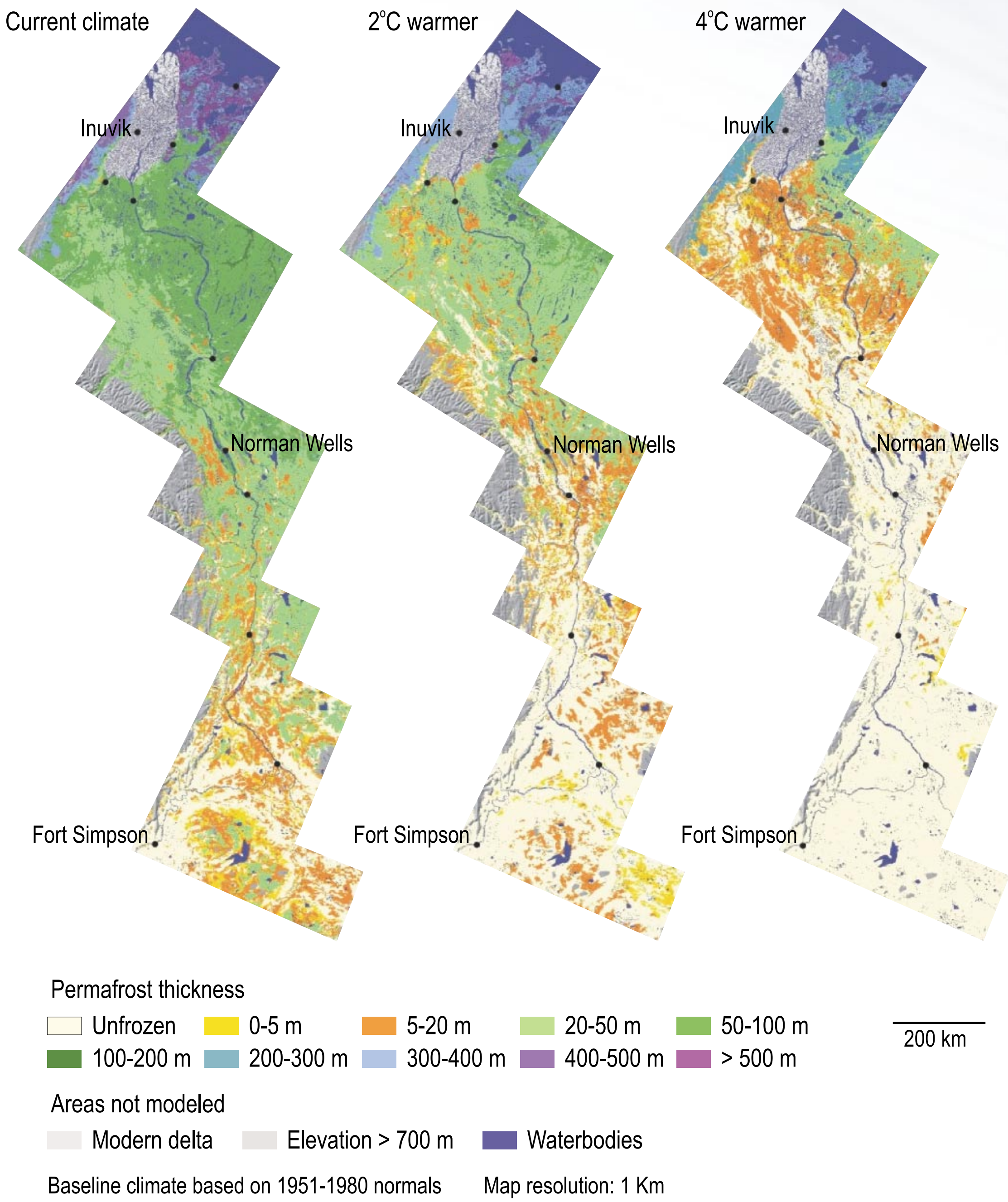


Figure 1–16.

Two climate warming scenarios predict that permafrost will disappear or its depth will decrease in the central Mackenzie Valley of the Northwest Territories.

Source: Wright *et al.* 2001.

The Mackenzie GEWEX Study (MAGS)

The *Global Energy and Water Cycle Experiment* (GEWEX) is an international effort of the World Climate Research Programme aimed at improving our understanding and prediction of the water cycle and its relationship to climate. As a major contribution to GEWEX, the *Mackenzie GEWEX Study* (MAGS) focuses on understanding and modelling the flows of energy and water into and through the atmospheric and hydrological systems of the Mackenzie River Basin. MAGS involves coordinated research into many atmospheric, land surface and hydrological issues associated with cold climate systems.

MAGS has made substantial progress in quantifying and understanding key hydrological processes affecting the water cycle of the Mackenzie River Basin. It is integrating various physical processes into a unified climate-hydrological model to characterize and enhance our understanding of the hydrology of the basin. Modeling is being performed at different scales, from small watersheds and individual events to modeling of the whole Mackenzie River Basin as a unified atmospheric-hydrological entity. Armed with the suite of appropriately tested models, MAGS researchers will analyze the sensitivity of the basin and its components to climatic impacts and will study their effects on the water cycle, including spatial and temporal variability and extremes in climatic and hydrological events. In collaboration with users, the results will be applied for such purposes as improvement of weather prediction, operation of hydroelectric power plants and providing scientific information to improve policy-making decisions.

The *overall goals* of MAGS are: (1) to understand and model the high-latitude water and energy cycles that play roles in the climate system, and (2) to improve our ability to assess the changes to Canada's water resources that arise from climate variability and anthropogenic climate change.

A major accomplishment of MAGS has been to show the importance of the major components of the water cycle of the Mackenzie River Basin at a monthly time scale, and at a resolution of approximately 50 km. Linkages have been made between the amount of rain and snow that falls in the basin and events that occur in their source areas in the Pacific Ocean. The role of clouds in controlling surface energy and water budgets has been described. The importance of processes that occur in winter, such as sublimation during periods of blowing snow and the interception of snow by the forest canopy have been determined. The role played by various processes occurring near the ground surface in controlling evaporation has been described. The amount of water moving to streams and rivers in the basin has been quantified. Through these studies, researchers have obtained an understanding of the internal circulation of moisture and heat within the Mackenzie River Basin, and have started to improve their knowledge of atmospheric and hydrological linkages with areas outside the basin. The region experiences a great deal of heat loss in winter, generating cold air that spreads southward while the upper level cyclones spread towards eastern Canada. Local evaporation is a major moisture source in summer, and convective clouds redistribute this atmospheric moisture. In general, there is strong evidence that climatic anomalies are amplified in the Basin during winter, but are reduced in summer.

Further information on MAGS can be obtained from: MAGS WEB SITE: http://www.usask.ca/geography/MAGS/index_e.htm permafrost may be imminent. Future climate warming will result in the large scale melting of surface permafrost. Permafrost strongly affects the hydrology of the northern portion of the Mackenzie River Basin. One of the important ways in which climate change will affect the hydrology of the Mackenzie River Basin is through its impact on permafrost.

Actions on Climate Change

What is being done about it?

The World Meteorological Organization and the United Nations Environment Programme recognized the importance of climate change and established the Intergovernmental Panel on Climate Change (IPCC) in 1988. The role of the IPCC is to assess scientific, technical, and socio-economic information relevant to understanding the risks associated with climate change.[47]

In 1997, Canada and about 160 other countries agreed to the Kyoto Protocol. The protocol commits thirty-eight industrialized countries to reduce their greenhouse gas emissions to about five percent below 1990 levels between 2008 and 2012. Canada ratified the Kyoto Protocol in December 2002.[48] To meet the Kyoto objective, Canada has developed an action plan which focuses on the five broad areas of transportation, housing and commercial/institutional buildings, large industrial emitters, small and medium-sized enterprises, and the international market. The plan incorporates activities to improve energy efficiency, decrease energy consumption, develop renewable energy sources, reduce industrial emissions, and trade emissions permits.[49]

Numerous programs have been initiated across Canada to study climate change and to develop plans to reduce Canadian emissions of greenhouse gases. The *Mackenzie River Basin Impact Study* was one such program. Its objective was to assess the potential impact of climate change on the land, water, and communities within the Mackenzie River Basin.[11] In 1998, the federal government established the Climate Change Action Fund (CCAF).[50] The CCAF has funded several scientific studies within the Mackenzie River Basin, including the *Mackenzie GEWEX (Global Water and Energy Cycle Experiment) Study*, which includes among its major objectives the development of models to evaluate the impact of both human-induced climate change and natural climate variability on Canada's water resources.

Each of the provincial and territorial governments within the Mackenzie River Basin is developing policies and programs to adapt to climate change and to reduce greenhouse gas emissions. Provincial and territorial plans cover such broad areas as science and technological research; business; individual and government action to improve energy productivity; and communication to achieve improved energy efficiency.[51, 52, 53, 54, 55] Some provincial and territorial governments are providing financial incentives to individuals and businesses to improve their energy-efficiency.[56, 57]

Contaminants

Concerns about pollution, as described by the Gwich'in Renewable Resources Board,[58, 59] are echoed up and down the basin by many of its residents – whether it is residents from Lutselk'e expressing concerns about the effects of mining exploration, or people from the Peace and Athabasca rivers talking about fish consumption advisories, their concerns are much the same: pollutants may be harming fish that are an important part of their traditional diets.

"To ensure chehluk [burbot] survive for the future, the rivers must be kept clean and free from pollution. Chehluk do not taste the way they did 40 years ago. Compared to the past, when fish chehluk was firm and full of flavour, the meat from fish caught today is soft. This change is a result of changes in the water."

Gwich'in Renewable Resources Board. 1997

What is a contaminant?

Another name for "pollutant" is "contaminant". What is a contaminant? In the Canadian Arctic Contaminants Assessment Report, it is described as "a substance that is found in a place where it should not be. This does not necessarily mean that it is harmful, but depending on what it is and the amount that is present, it may be. "[60]

Certain types of contaminants, such as pesticides, are purposely made by human beings. Other contaminants are by-products of industries and other human activities such as the disposal of community wastes. For example, contaminants called dioxins and furans are unwanted by-products formed when pulp mills use chlorine to bleach pulp or when community and domestic garbage is burned. Some contaminants are natural parts of the environment in which we live - that is to say humans do not make them. Heavy metals and radionuclides are examples of these contaminants. Human beings can and do move these substances around, however, through our industries and daily activities, with the result that greater amounts may enter the air we breathe, the water we drink and the food we eat.

Where do contaminants come from?

There are two main sources of contaminants in the Mackenzie River Basin: local sources and global sources. Local sources include mines, municipal sewage, pulp mills and other industries as well as soils, bedrock and forest fires from which naturally occurring contaminants can be released. Some of the contaminants that occur in the Mackenzie River Basin originate in other parts of the world and travel great distances through the atmosphere before being deposited there (Figure 1–17). Persistent organic pollutants such as polychlorinated biphenyls (PCBs) are examples of globally transported contaminants.

Where does information about contaminants in the Mackenzie River Basin come from?

Information about contaminants in the Mackenzie River Basin comes from major programs including the Department of Indian Affairs and Northern Development's Northern Contaminants Program, Slave River Environmental Quality Monitoring Program and Liard River Environmental Quality Monitoring Program. In addition, the *Northern River Basins Study* (http://www3.gov.ab.ca/env/water/nrbs/response/index.html) and its successor, the Northern Rivers Ecosystem Initiative (http://www.mb.ec.gc.ca/nature/ecosystems/nrei-iern/index.en.html), programs, led jointly by Environment Canada and the governments of Alberta and the Northwest Territories, have provided valuable information about contaminants. These programs are good examples of

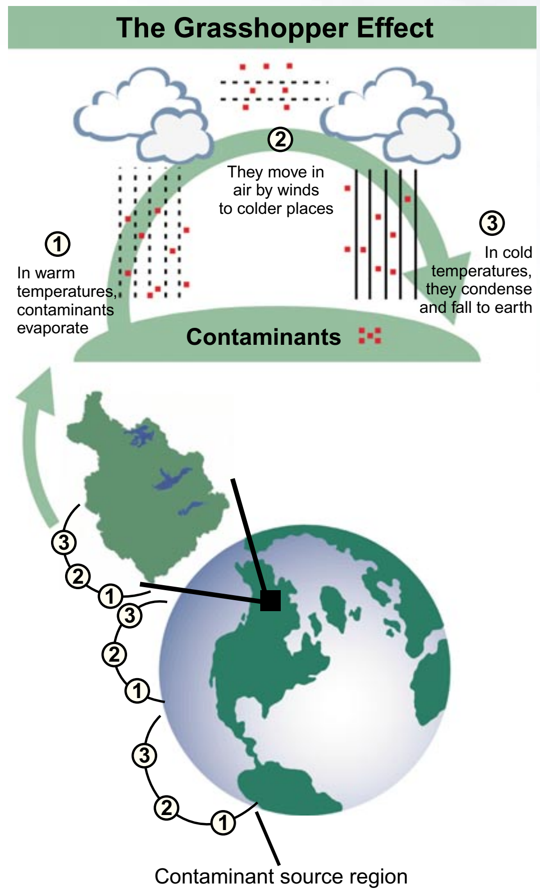


Figure 1–17. Contaminants are transported globally through the atmosphere from southern, warm locations to northern or high elevation, cold locations where they are deposited.

Source: Department of Indian Affairs and Northern Development.

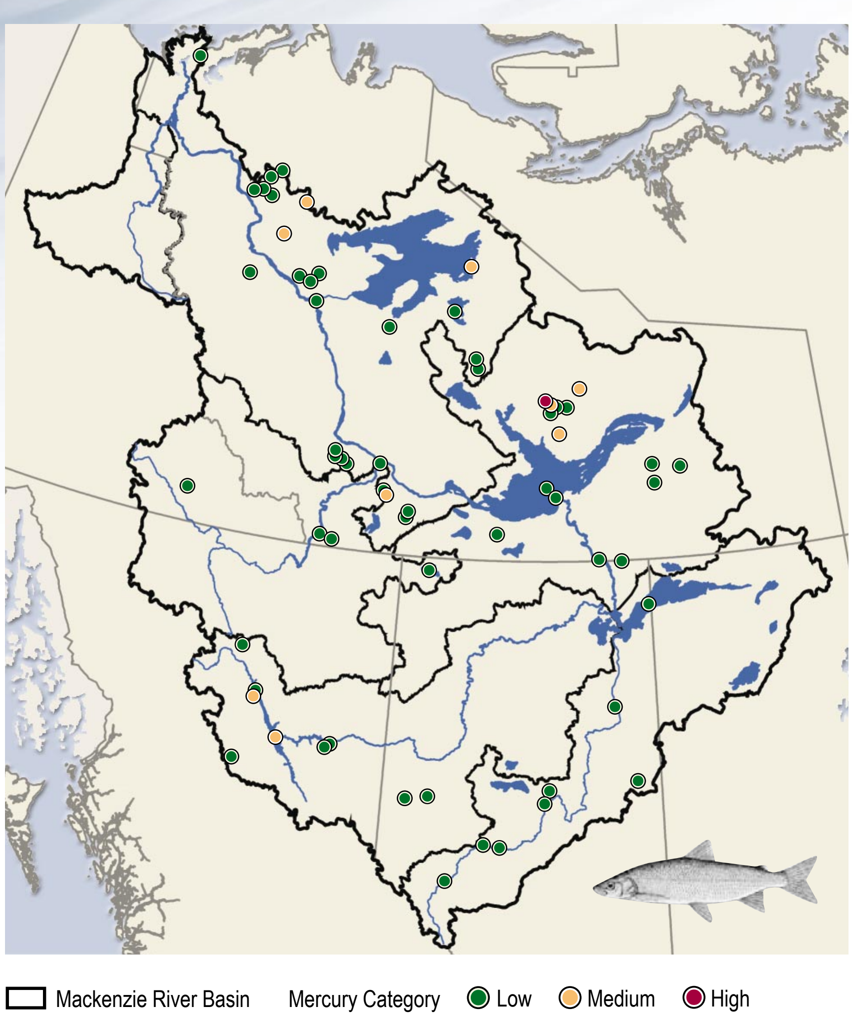


Figure 1–18. Mercury in whitefish at different locations in the Mackenzie River Basin.

Data Sources: Canadian Food Inspection Agency; Department of Indian Affairs and Northern Development; Environment Canada; Fisheries and Oceans Canada; Alberta Environment.

western science and traditional environmental knowledge working together to produce information that is highly relevant to the people in the basin. More information about contaminants in the north can be found at http://www.ainc-inac.gc.ca/ncp/index_e.html.

Attention in this section of the report will be focused on globally transported contaminants and locally produced contaminants that are a concern throughout most of the basin.

Mercury

Mercury is a naturally occurring substance found in varying amounts in soil and bedrock. Its presence in the environment can be influenced by many human activities. Mercury is found in varying amounts in foods that people eat, especially in fish.

What is happening?

Mercury concentrations have been measured in fillets of several species of fish from several lakes and river sites in the Mackenzie River Basin. Concentrations are considered to be high if they are greater than Health Canada's guideline concentration of 0.5 parts per million (ppm) for commercial fisheries. Medium concentrations are those between 0.2 and 0.5 ppm, while low concentrations are those below 0.2 ppm. It has been recommended that people who eat a lot of fish should not eat fish that have mercury levels greater than 0.2 ppm.

Lake whitefish, broad whitefish and mountain whitefish contained low levels of mercury in the vast majority of the sixty-three lake and river sites that were sampled in the Mackenzie River Basin (Figure 1–18). Medium mercury levels in whitefish were found at nine of sixty-three lakes and river sites. Whitefish with high mercury levels were found in only one lake. The average mercury level in whitefish from Giauque Lake in the Northwest Territories was approximately 0.8 ppm. Giauque Lake is the site of the old Discovery gold mine, where mercury was used to separate gold from the ore. This activity resulted in elevated levels of mercury in the mine tailings, some of which entered the adjacent lake through leaching and erosion (see **Chapter 6 – A Legacy of Old Mines**).

The situation with northern pike is different than that of whitefish. Mercury levels were high in northern pike in fourteen of the 122 lakes and river sites sampled in the Mackenzie River Basin. They were medium in sixty-eight of the 122 lakes and low in the remainder (Figure 1–19).

Why is it happening?

Mercury increases through the food chain

Mercury enters lakes and rivers directly from air or precipitation and indirectly from runoff and soil erosion from the surrounding terrestrial environment. Once in the aquatic ecosystem, it undergoes biochemical changes with the result that some of the mercury is transformed to a highly toxic form called methyl mercury. Methyl mercury accumulates

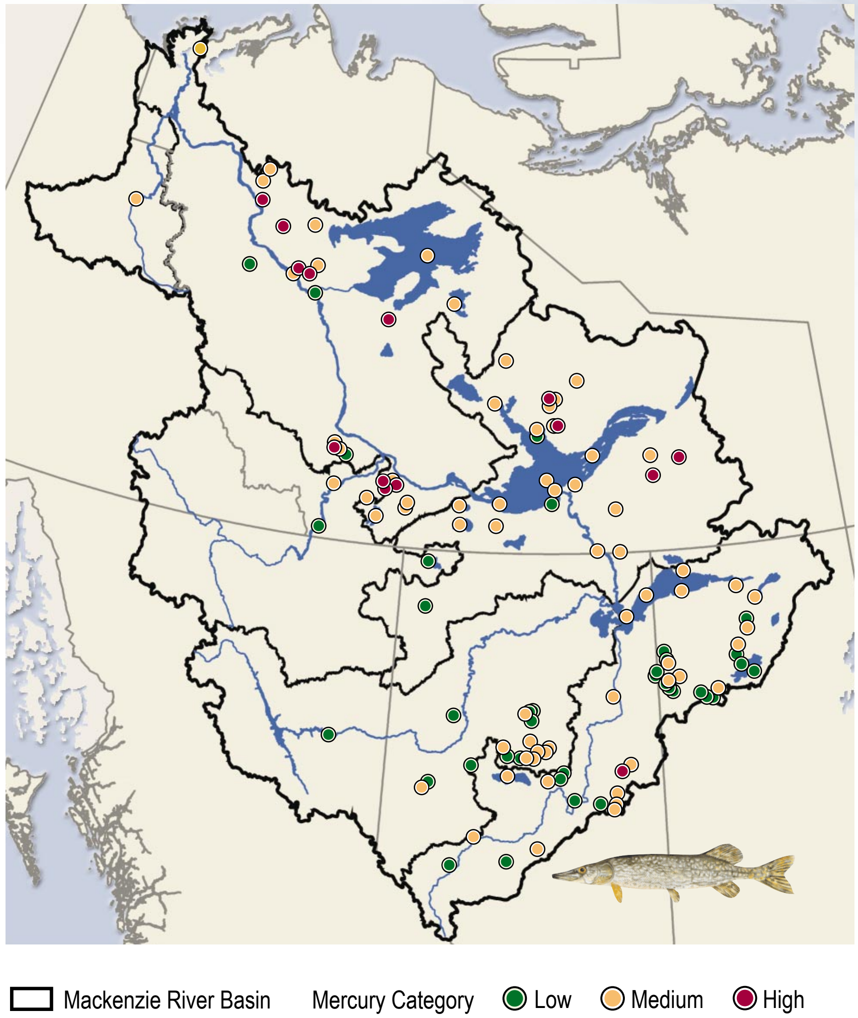


Figure 1–19. Mercury in northern pike at different locations in the Mackenzie River Basin.

Data Sources: Canadian Food Inspection Agency; Department of Indian Affairs and Northern Development; Environment Canada; Fisheries and Oceans Canada; Alberta Environment.

through food chains. The result is that predators in the food web accumulate the highest levels of methyl mercury.

Small insects, snails and crustaceans have the lowest levels of mercury. Whitefish, cisco and other species of fish that eat invertebrates contain slightly higher amounts of mercury. Predatory fish like lake trout, walleye, burbot and northern pike have the highest levels of mercury. These trends are illustrated in Figures 1–20 and 1–21.

Bigger fish have more mercury

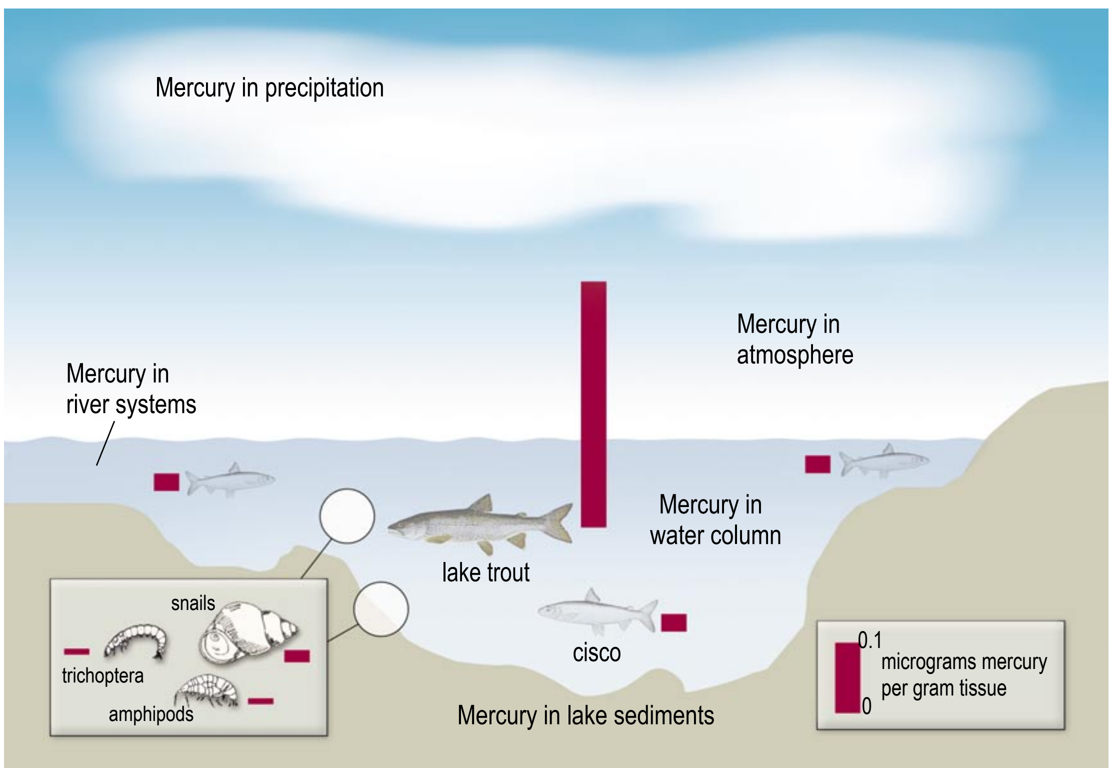
Within a species, larger, older fish usually have greater amounts of mercury in their fillets than their smaller, younger counterparts. This is mainly because mercury builds up in tissues over time. It builds up because fish (and many other living organisms) cannot get rid of mercury as fast as they take it in.

Figure 1–22 shows that mercury levels in large bull trout from the Williston Lake Reservoir at the headwaters of the Peace River tend to be higher than in their smaller counterparts. The graph also clearly shows that the amount of mercury in many of the larger bull trout exceeded the Health Canada guideline of 0.5 parts per million.

Figure 1–20.

Mercury increases through the food chain in Great Bear Lake.

Data Sources: M. Evans, Environment Canada; Evans *et al.* 2002.



Natural versus man-made sources of mercury

Mercury is a natural substance that has always been part of our environment. However, many human activities change the cycling of mercury with the result that there is much more mercury emitted to the atmosphere, globally, now than there used to be. Nowadays, human activities emit just as much mercury to the atmosphere as natural sources do (Figure 1–23). The burning of fossil fuels, including coal, emits more mercury to the atmosphere than any other type of human activity (Figure 1–23). On a worldwide basis, Canada contributes only a tiny percentage of the total amount of anthropogenic mercury emitted to the atmosphere. Most of the mercury emitted by human activities comes from central Europe, southern Africa and Asia, principally China, India and parts of Russia. We don't know exactly how much of the mercury that is deposited in the Mackenzie River Basin is emitted in foreign countries. However, global circulation models indicate that a substantial portion originates in Europe and eastern Asia.[61]

Historical and current trends in mercury deposition in the Mackenzie River Basin

Lake sediments can provide a historical record of contaminant deposition in lakes. It is possible to find out whether mercury deposition has increased, decreased or remained the same over a certain time period by comparing older sediment layers to more recently deposited layers. A measure of the change in mercury deposition, called the "mercury enrichment factor" can be calculated by dividing the amount of mercury in the recently deposited layers by the

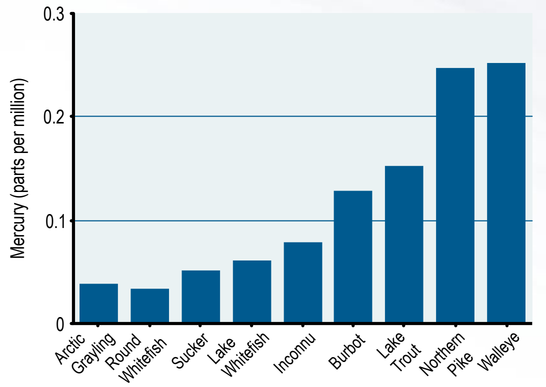


Figure 1–21.
Amounts of mercury are higher in predatory fish than in non-predatory fish in Great Slave Lake.

Data Sources: Canadian Food Inspection Agency.

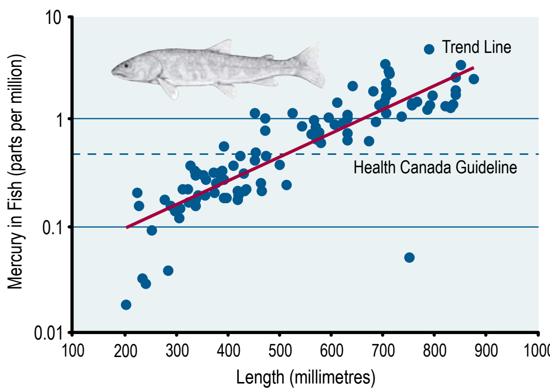


Figure 1–22.
Mercury levels in large bull trout from the Williston Lake reservoir tend to be higher than in their smaller counterparts.

Data Source: Triton Environmental Consultants for BC Hydro.

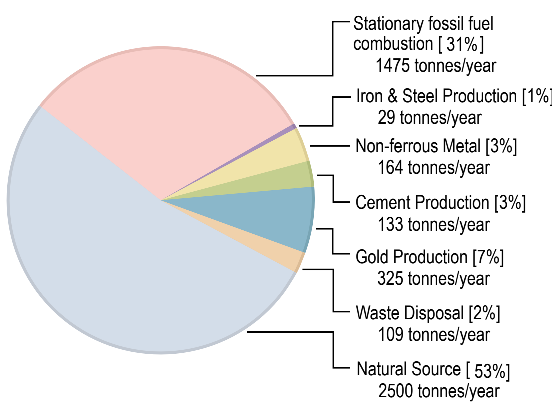


Figure 1–23. Natural and anthropogenic emissions of mercury to the atmosphere

Data Source: Pacyna and Pacyna 2001.

amount in older layers representing deposition of mercury 60 to 120 years ago. Enrichment factors that are much greater than one indicate that mercury deposition in the lake is greater now than it used to be. A value close to one means that mercury deposition is about the same now as it used to be. Values much less than one indicate that mercury deposition is lower than it was historically. Mercury enrichment factors have been determined for thirteen sites in a total of twelve lakes in the basin (two sites were done in Lake Athabasca) (Figure 1–24). Enrichment factors ranged from around 0.4 to 1.5. Taken together, this information indicates that mercury deposition in lakes in the northern part of the Mackenzie River Basin has increased very little in the past 60 to 120 years. This is especially true when compared to enrichment factors in other parts of the world. In the mid-continental USA, for example, enrichment factors are usually between three and four, in Quebec they are generally around two, while in Scandinavia they range widely from as low as 1.2 up to 8.9. The elevated mercury enrichment values in these areas may be caused by the greater amounts of mercury being added to the atmosphere by human activities.[62] The Mackenzie River Basin is so far away from industrial areas where large amounts of mercury are released, that it has thus far been protected from large amounts of mercury being deposited in its lakes, rivers and terrestrial ecosystems.

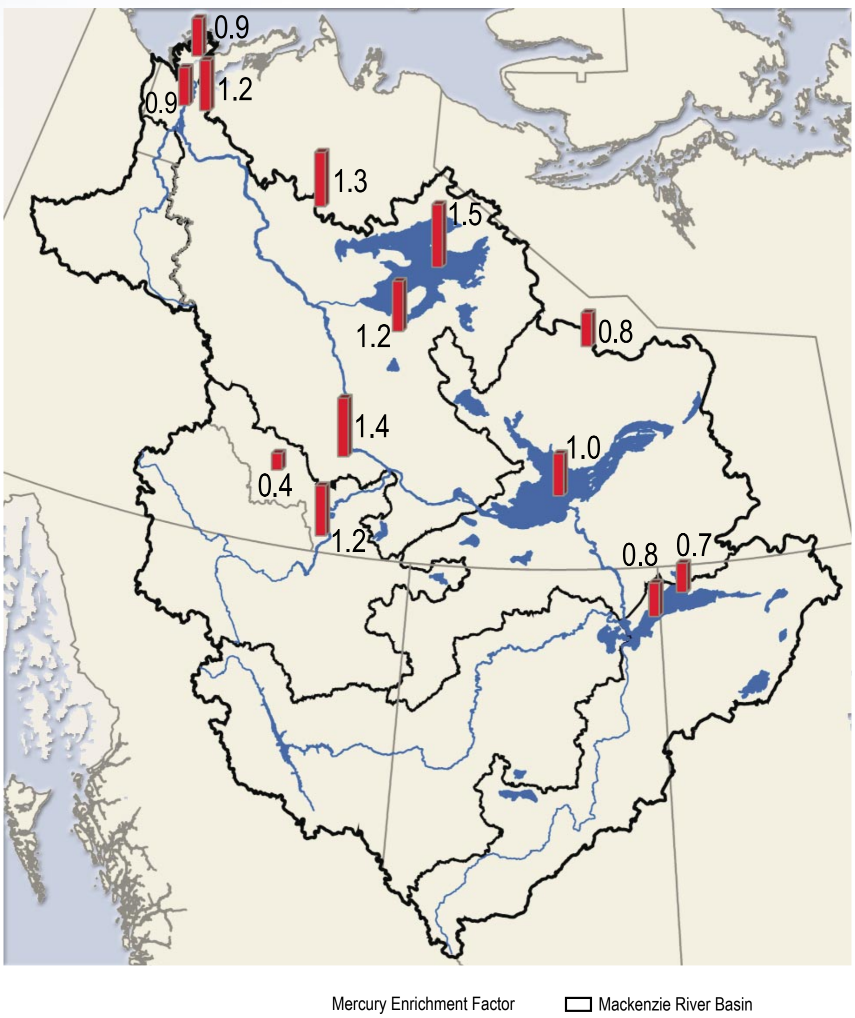


Figure 1–24.
Mercury Enrichment Factors at 13 sites in the Mackenzie River Basin.
Data Sources: Department of Indian Affairs and Northern Development; Lockhart 1997; Graf-Pannatier 1997; R.A. Bourbonniere, M. Evans, D. Muir (Environment Canada).

What does it mean?

First Nations and Métis peoples throughout the basin are clear on the fact that fishing is important not only because it provides a valued source of nutrition, but also because it makes people feel connected to the land. Naturally, then, it is essential to make sure that fish remain an excellent source of nutrition and cultural enhancement for people in the basin.

Whitefish is the most popular species of fish eaten by First Nations and Métis people in the basin.[28, 63, 64, 65, 66, 67, 68] Northern pike is second in importance followed by lake trout, burbot and walleye. The popularity of whitefish is fortunate, since whitefish have among the lowest mercury levels of all the species in the basin. However, the other popular species are more predatory and therefore have higher mercury levels. This could be a concern for people who eat a lot of those fish.

Mercury is a toxic substance that can harm people's health. To minimize the possibility of this occurring, Health Canada has established guidelines for mercury levels in fish. The guideline for commercial fisheries is 0.5 parts per million (ppm). Fish with mercury levels exceeding that level are considered unfit for sale in the marketplace. In addition, Health Canada has recommended that people who eat a lot of fish should not be in the habit of eating fish with more than 0.2 ppm of mercury.

The question on the minds of people who eat a lot of fish is "what do these guidelines in fish mean to me, personally – will my health be affected"? The good news is that a survey of First Nations people in the Northwest Territories reported that less than 1% of over 3,000 people had mercury levels high enough to be considered "at risk", a designation that does not necessarily mean that health has been compromised.[69] Fish is an excellent source of nutrition and the benefits of eating fish will outweigh the risks, provided that the mercury levels are not too high.

What is being done about it?

Mercury is listed as a toxic substance in the *Canadian Environmental Protection Act* (CEPA), meaning that the federal Minister of the Environment can require a company or facility to implement a pollution prevention plan dealing with mercury.[70] The CEPA and the *Fisheries Act*[71] also contain regulations that limit the release of mercury from mercury cell chlor-alkali plants. The Canadian Council of Ministers of the Environment (CCME) has developed Canada-wide standards for mercury emissions from several industries. A standard for mercury emissions from coal-fired electric power generation plants is still under development.[72] In 1998, Canada ratified the United Nations Economic Commission for Europe's Protocol on Heavy Metals as part of the *Convention on Long-Range Transboundary Air Pollution* (1979). This agreement obligates parties to reduce their emissions of mercury, lead and cadmium to below 1990 levels.[73] Government regulations together with industry co-operation and technological advancements in pollution prevention have resulted in a dramatic decrease in mercury emissions from human activities in Canada in the past thirty years (Figure 1–25).

Overall Assessment – Mixed Signals

Except for a small number of water bodies such as Giauque Lake, mercury has increased very little in the Mackenzie River Basin as a result of human activities, especially in comparison to more industrialized regions in the world. Nevertheless, mercury levels in predatory fish in many lakes in the basin are higher

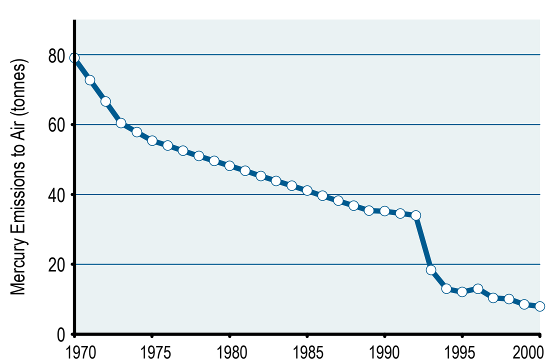


Figure 1–25.
Canadian anthropogenic emissions of mercury from 1970 – 2000.
Data Source: Pollution Data Branch, Environment Canada.

than Health Canada guideline levels. Because mercury is transported globally, international efforts to curtail industrial emissions of mercury must be continued. Monitoring of mercury levels in fish and the publication of fish consumption advisories are required to prevent the occurrence of mercury-related health problems.

Chlorinated Dioxins and Furans

Bleached kraft pulp mills are the major industrial sources of chlorinated dioxins and furans in the aquatic environment of the Mackenzie River Basin. Chlorinated dioxins and furans were first discovered in aquatic ecosystems downstream from bleached kraft pulp mills in the mid- to late-1980s. This discovery sparked governments and industry to adopt measures designed to reduce the production of these industrial by-products and their release into the environment.[74, 75]

Wood chips treated with a preservative called pentachlorophenol are another source of certain types of dioxins and furans. In the past, pulp mills sometimes used pentachlorophenol-treated wood chips to make pulp. This resulted in the additional release of dioxins and furans in their effluent. The *Canadian Environmental Protection Act* now prohibits pulp mills from using pentachlorophenol-treated wood chips, thus eliminating this source of dioxins and furans. Nevertheless, because some of the types of dioxins and furans that are derived from pentachlorophenol persist in the environment for a long time, fish and sediments collected near pulp mills still contain elevated concentrations of these contaminants.

The term "dioxins and furans" refers to a large number of compounds that are quite similar in structure. Amongst the various types of industries that emit dioxins and furans to the environment, bleached kraft pulp mills are unique in that they produce two predominant types of dioxins and furans. These compounds are 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF). For this reason, programs that are intended to monitor the release of dioxins and furans into the environment by bleached kraft pulp mills usually focus on determining concentrations of these two compounds.

There are five bleached kraft pulp mills in the Mackenzie River Basin, three in the Peace sub-basin and two on the Athabasca River. Because of concerns about possible contamination by these mills, many studies have been done over the past several years to determine the extent of contamination of these river systems by these contaminants.

What is happening?

Burbot have been collected intermittently since 1990 at several sites upstream and downstream from four Alberta bleached kraft pulp mills. Concentrations in their livers were highest at sites immediately downstream from pulp mills near Grande Prairie and Hinton (Figure 1–26). They became progressively lower at sites located further downstream. Most importantly, concentrations were highest in 1990 when monitoring began, and declined to much lower levels by 1998 (Figure 1–26).

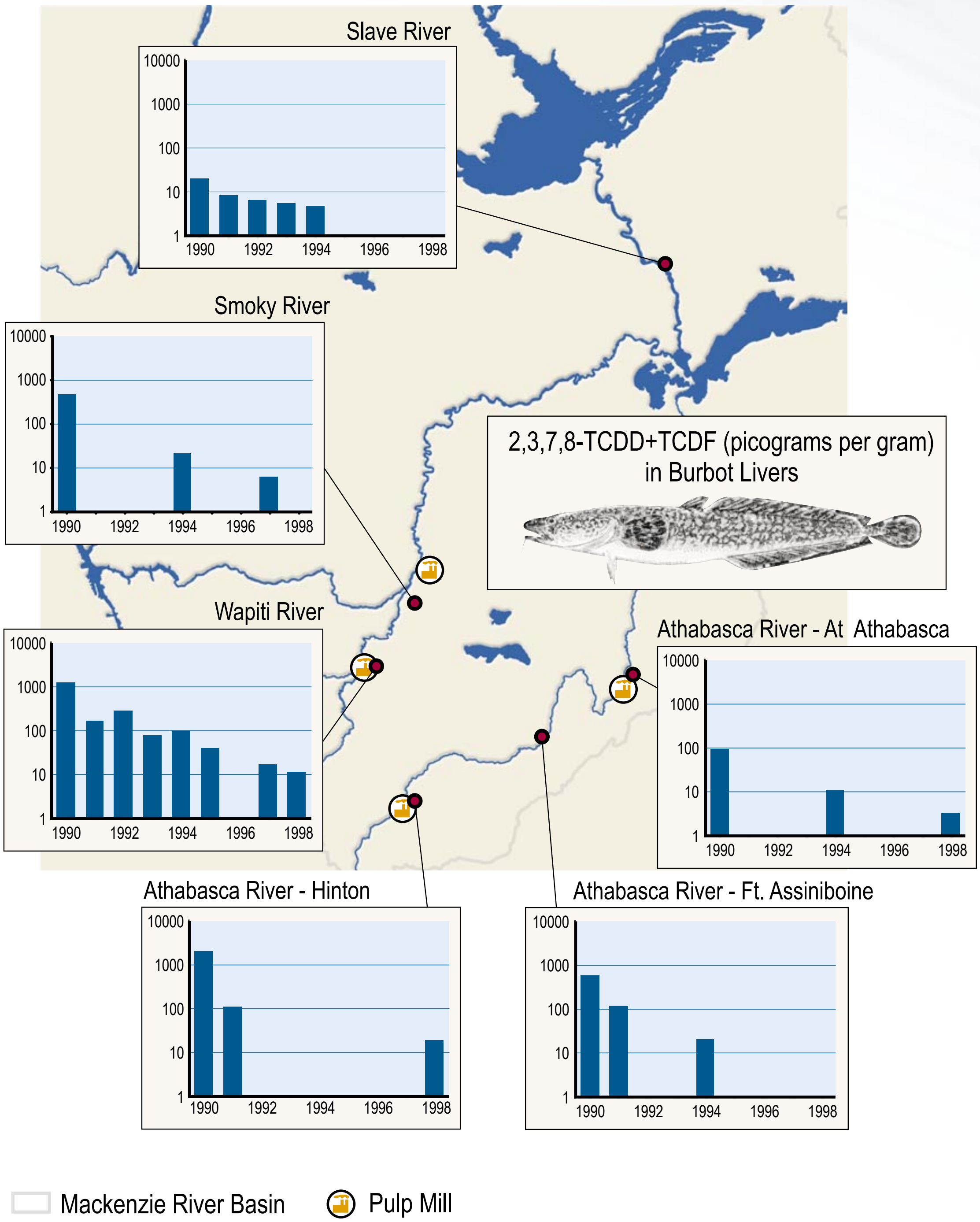


Figure 1–26.

Levels of two dioxin and furan compounds (2,3,7,8-TCDD + 2,3,7,8-TCDF) in burbot livers declined during the 1990s. NOTE: Values are shown on a logarithmic scale.

Data Sources: Sanderson *et al.* 1997; Fraikin *et al.* (Environment Canada and Golder Associates).

Why is it happening?

2,3,7,8-TCDD and 2,3,7,8-TCDF bioaccumulate through food chains. Thus, their concentrations are much higher in fish, especially predatory species like burbot, than they are in prey or the river water itself. Since bleached kraft pulp mills are the major sources of 2,3,7,8-TCDD and 2,3,7,8-TCDF in the Mackenzie River Basin, concentrations of these contaminants are highest in fish living close to the mills and decline rapidly in fish living further away from the mills.

Since 1990, bleached kraft pulp mills have been very successful in reducing concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF in their effluent. This is especially true at the two oldest Alberta bleached kraft mills located at Grande Prairie and Hinton where concentrations in effluent declined to less then 10% of 1990 levels by 2000 (Figure 1–27). The newer mills at Peace River and near Athabasca, Alberta have never released large amounts of dioxins and furans in their effluent (Figure 1–27).

The large reduction in concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF in bleached kraft mill effluent was achieved through major changes in the way that bleached pulp was produced. The most significant of these was the replacement of elemental chlorine by chlorine dioxide. Chlorine is required to "whiten" or bleach the pulp to yield high-quality paper. The use of elemental chlorine resulted in the formation of large amounts of 2,3,7,8-TCDD and 2,3,7,8-TCDF. By switching to chlorine dioxide, the mills have been able to substantially reduce the formation of these contaminants. Furthermore, improvements in the treatment of wastewater prior to its release into the rivers have also contributed to the reductions.

What does it mean?

Dioxins and furans are among the most toxic of the various types of persistent organic pollutants, as they can impact health in many ways. Experimental animals exposed to high concentrations display a wasting syndrome including reduced food consumption, decreased body weight and a loss of fat. Even at low levels of exposure, dioxins and furans can damage the immune system and the liver. They can disrupt the endocrine system and this may lead to developmental problems in foetuses. While not directly carcinogenic, they can promote various types of cancer.[76]

Because of the toxicity of dioxins and furans, it is imperative for pulp mills to reduce to the greatest extent possible the amount of these contaminants released into the environment. To meet the requirements of the *Canadian Environmental Protection Act* (CEPA), dioxins and furans in pulp mill effluent must be below "measurable" levels. Those levels are 15 picograms per litre and 50 picograms per litre for 2,3,7,8-TCDD and 2,3,7,8-TCDF, respectively.[i] Pulp mills must test their effluent monthly, quarterly or annually, depending on their past record of adhering to these guidelines.[77]

What is being done about it?

Dioxins and furans in pulp mill effluent are regulated under CEPA.[77] CEPA regulations limit the amounts of dioxins and furans that pulp mills are

[i] **Note:** There are one trillion picograms in one gram

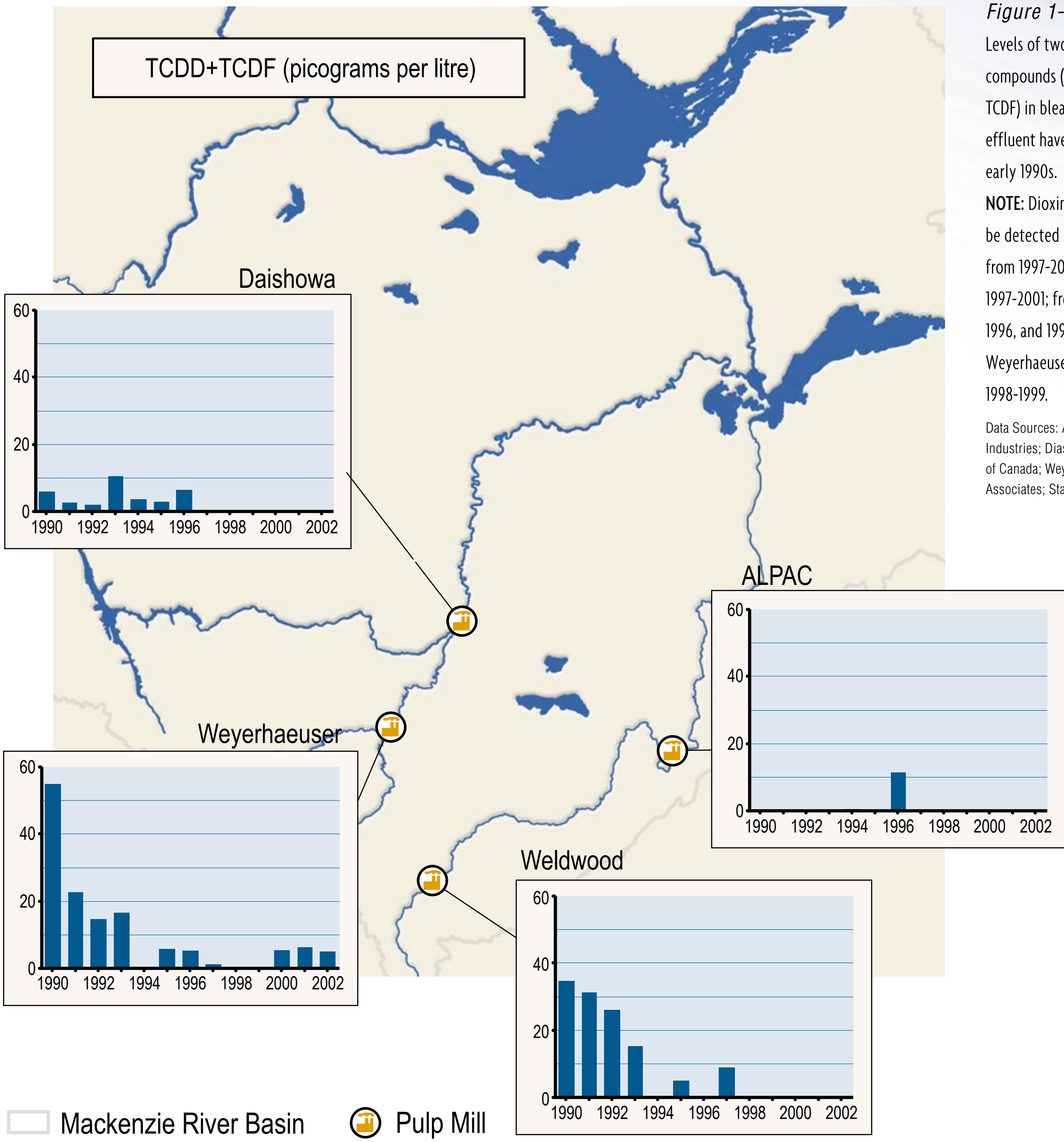


Figure 1–27.
Levels of two dioxin and furan compounds (2,3,7,8-TCDD + 2,3,7,8-TCDF) in bleached kraft pulp mill effluent have declined since the early 1990s.
NOTE: Dioxins and furans could not be detected in effluents from ALPAC from 1997-2002; from Daishowa from 1997-2001; from Weldwood in 1994, 1996, and 1998-2002 and from Weyerhaeuser in 1994 and from 1998-1999.

Data Sources: Alberta-Pacific Forest Industries; Diashowa-Marubeni; Weldwood of Canada; Weyerhaeuser Canada; Golder Associates; Stanley Environmental.

allowed to release into the environment. They also control the use of defoamer agents and treated wood chips in pulp mills to reduce the production of dioxins and furans. In addition, pulp mills are required under the *Fisheries Act* to conduct Environmental Effects Monitoring studies and report the findings of such studies to the federal government.[78] Provincial governments also regulate the release of effluents by pulp mills.

The industry has implemented technological advancements to meet the more stringent regulations that were instituted during the 1990s. The switch from chlorine to chlorine dioxide as a bleaching agent has already been mentioned. Numerous other changes have been instituted at many bleached kraft mills.[79] These include the use of more environmentally-friendly defoaming agents, the adoption of methods that yield cleaner pulp fibres which reduces the amount of chlorine required for bleaching, and finally, the improvement in effluent treatment.

✔ Overall Assessment – Favourable

Concentrations of chlorinated dioxins and furans that are typically associated with bleached kraft pulp mills have declined greatly in livers of burbot since 1990. These reductions have been achieved by more stringent government regulations and by technological advancements by the pulp mill industry aimed at reducing dioxins, furans and other contaminants in their effluent.

Protected Areas

What are Protected Areas?

Protected areas are areas that are considered to be special from a natural, historic or cultural perspective and which, through government legislation, have been afforded a measure of protection from certain types of development.

There are many types of protected areas, ranging from national parks that protect representative areas of national significance to small natural areas that protect sites of local importance. The degree of protection varies widely among them.

In this report, protected areas include

Protected Areas - continued

national parks, migratory bird sanctuaries, national wildlife areas, ecological reserves, provincial parks, territorial parks, wilderness parks, wildland parks, and natural areas, as well as several large tracts of land in the Northwest Territories that have been given interim protection. National historic sites, recreation areas and day use areas are not included in the list of protected areas.

How many Protected Areas are there in the Mackenzie River Basin?

There are approximately 230 protected areas within the Mackenzie River Basin. They account for about twelve percent of the total area of the watershed. During the last decade, the network of protected areas within the Mackenzie River Basin has increased substantially (Figure 1–28). Most of the protected areas occur in the southern part of the basin while there are fewer in the north. Recently, however, several large tracts of land in the Northwest Territories have been granted interim protection. These lands cover approximately 100,000 square kilometres and account for almost half of the land that is protected in the entire Mackenzie River Basin.

Heritage Rivers in the Mackenzie River Basin

The Mackenzie River Basin contains five Canadian Heritage Rivers: the upper Athabasca, the Clearwater, the South Nahanni, the Bonnet Plume and the Arctic Red.[80] The Canadian Heritage Rivers System was established in 1984 to protect the best examples of Canada's river heritage, to give them national

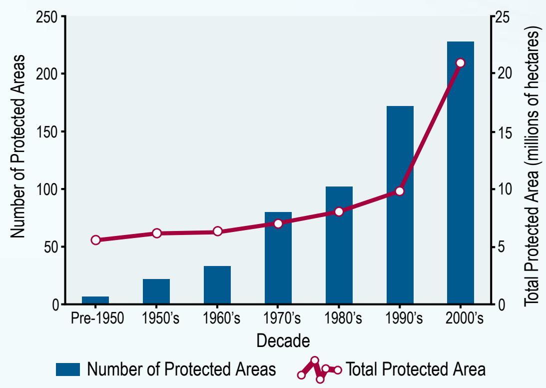


Figure 1-28.

The number of protected areas and the total land mass that is protected in the Mackenzie River Basin have increased substantially.

Data Sources: Environment Canada; Alberta Community Development; B.C. Water, Land and Air Protection; Saskatchewan Environment and Resource Management; Northwest Territories Resources, Wildlife and Economic Development; Yukon Dep't. of the Environment.

Protected Areas - continued

recognition, and to encourage the public to enjoy and appreciate them. There are also three British Columbia Heritage Rivers in the Mackenzie River Basin: the Peace, the Prophet and the Ketchika. An initiative is currently underway to determine the merits of the Mackenzie River as a Canadian Heritage River.

Why are Protected Areas important?

Protected areas are important for maintaining biodiversity and preserving wildlife. They play a role in maintaining our water resources, especially when whole watersheds are protected, as is the case with some of the new protected areas in the Northwest Territories. The ever-increasing extent of human encroachment makes it necessary to protect key habitats that are representative of the wild plants and animals found in each of Canada's major ecozones. Recognizing this need, the Canadian Council of Ministers of the Environment, the Canadian Parks Ministers' Council and the Wildlife Ministers' Council of Canada signed a Statement of Commitment in 1992 to "make every effort to complete Canada's network of protected areas representative of Canada's land-based natural regions by the year 2000".[81] The establishment of protected areas is a key element in the Canadian Biodiversity Strategy, which was developed to conserve Canada's biodiversity and promote the sustainable use of its biological resources.[82]

Wildlife and water resources will be subjected to increasing pressures as human beings continue to expand and intensify their activities in the Mackenzie River Basin. Protected areas will become increasingly important as refuges for wildlife, and will play a role in the protection of watersheds and water resources. It may become necessary to add to the existing protected area network in order to protect wildlife and water resources and to offset future degradation of habitat that may result from industrial expansion. Moreover, as human populations increase within and outside of the basin, the demand for the types of recreational and educational opportunities that protected areas afford will grow.

Protected Areas - continued

What have governments and other agencies been doing to protect key habitats?

Each province and territory within the Mackenzie River Basin developed a strategy during the past several years to fulfil their commitments to extend the network of protected areas. Protected Areas Strategies were developed in the Yukon,[83] the Northwest Territories[84] and British Columbia.[85] The Government of Alberta launched a Special Places Program,[86] and Saskatchewan began work on a Representative Areas Network.[87] These initiatives identified regions where additional protection is required and provided a process to seek this protection. Some jurisdictions embarked on ambitious programs that created new protected areas and substantially increased the network of protected areas within the basin. Their primary goal was to ensure that each ecological region was represented by a protected area capable of maintaining the biodiversity of the region. Some strategies also identified the importance of protecting areas with special natural, cultural, or recreational significance.

New federally protected areas are being planned. The Sahyoue and Edacho National Historic Site is an example of an area in the basin that is in the process of becoming protected. This area covers 5,600 square kilometres of land on two large promontories on the west shore of Great Bear Lake, and was given interim protection in 2001.[88] In another example, land has been withdrawn for a national park in the vicinity of the east arm of Great Slave Lake, while Parks Canada and representatives from Lutselk'e work to negotiate a final agreement.[89] In 2003, approximately 100,000 square kilometres of land in the Northwest Territories were protected from further development on an interim basis. These land areas, located mainly in the vicinity of the Nahanni National Park Reserve and to the northwest of Great Slave Lake in an area known as the Horn Plateau, are protected from further development for a period of five years, pending the completion of negotiations and the development of land use plans.