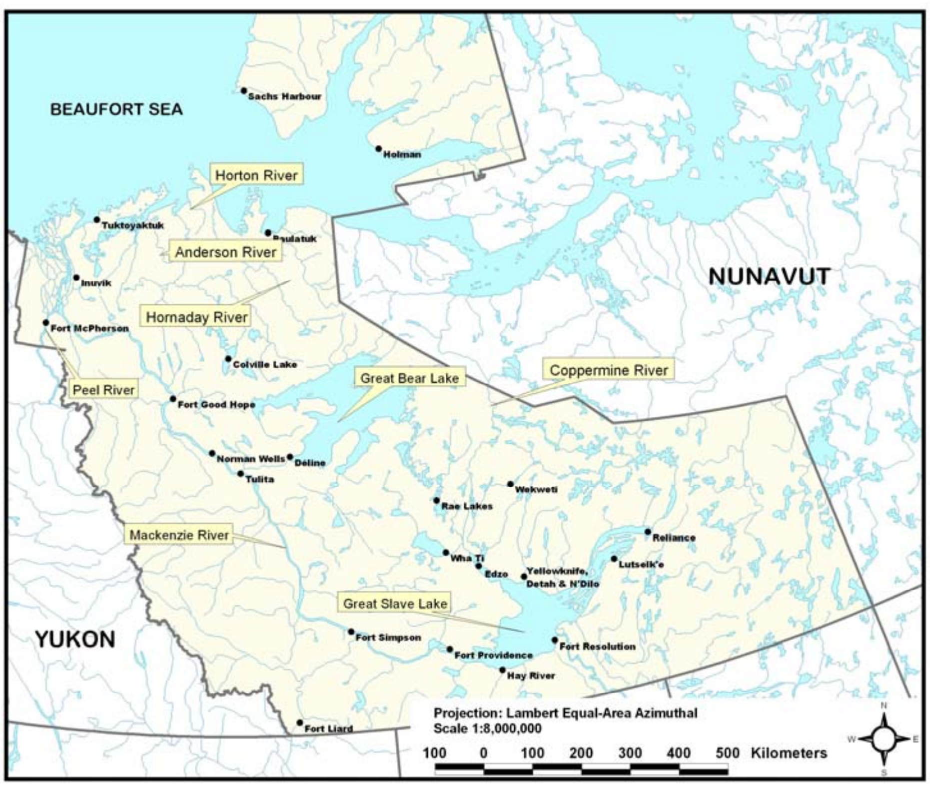
# 3.0 FRESHWATER AQUATIC ENVIRONMENT

## 3.1 FRESHWATER IN THE NORTHWEST TERRITORIES

Canada is a freshwater-rich country with Canadian rivers discharging, on an average annual basis, close to 9% of the world's renewable water supply. Water is also highly visible in Canada with no other country in the world having as much of its surface area covered by freshwater. The Northwest Territories (NWT) covers a total area of 1.34 million square kilometres, or approximately 13.5% of the total area of Canada. Of its area, about 163 thousand square kilometres of the NWT (or 13.5%) is covered by freshwater; an area equivalent to nearly 1/5$^{th}$ of all of Canada’s surface freshwater. The two largest lakes entirely within Canada’s borders are located in the NWT; they are Great Bear Lake (31,328 km$^2$) and Great Slave Lake (28,568 km$^2$). There are also several important river systems; the most notable being the Mackenzie River, the drainage basin of which accounts for about 1/5$^{th}$ of Canada’s land mass (Mackenzie River Basin Board (MRBB), 2004). The principal lakes and rivers in the NWT are shown in Figure 3.1-1.

**FIGURE 3.1-1**
**PRINCIPAL LAKES AND RIVERS IN THE NORTHWEST TERRITORIES**




*Source: Natural Resources Canada; http://www40.statcan.ca/l01/cst01/phys01.htm.*

The predominant freshwater system in the NWT is the Mackenzie River Basin which covers nearly 75% of the territory and drains an area equivalent to about one-fifth of Canada's land mass. Drainage along the eastern border of the NWT is captured in the Coppermine River and Thelon River watersheds that drain into Nunavut. To the north, a portion of the runoff flows directly into the Amundsen Gulf and Beaufort Sea through the West Arctic Basin. There are eight primary watersheds either completely within the NWT or transboundary in nature. Within these watersheds are 26 secondary sub-basins. The main features of these watersheds are described below. In addition, a brief overview of monitoring and research work that has been, or is being carried out, is provided. More detailed information on the findings of monitoring activities is presented in subsequent sections.

The principal drainage basins of the NWT and their respective secondary sub-basins are shown in Figure 3.1-2.

### 3.1.1 Mackenzie Great Bear Sub-Basin

The Mackenzie-Great Bear sub-basin lies almost entirely in the NWT and covers 475,000 square kilometres. Its primary components are the Mackenzie River (Canada's longest river at 1,800 kilometres in length) and Great Bear Lake (the largest lake entirely within Canada at 31,328 square kilometres). The sub-basin also includes Canada's largest delta and second largest wetland, the Mackenzie Delta, covering 13,500 square kilometres. The Mackenzie River transports 60% of Canada's freshwater that drains to the north. In part because of its high water velocities, the Mackenzie River transports more sediment to the Arctic Ocean than any other circumpolar river (MRBB, 2004).

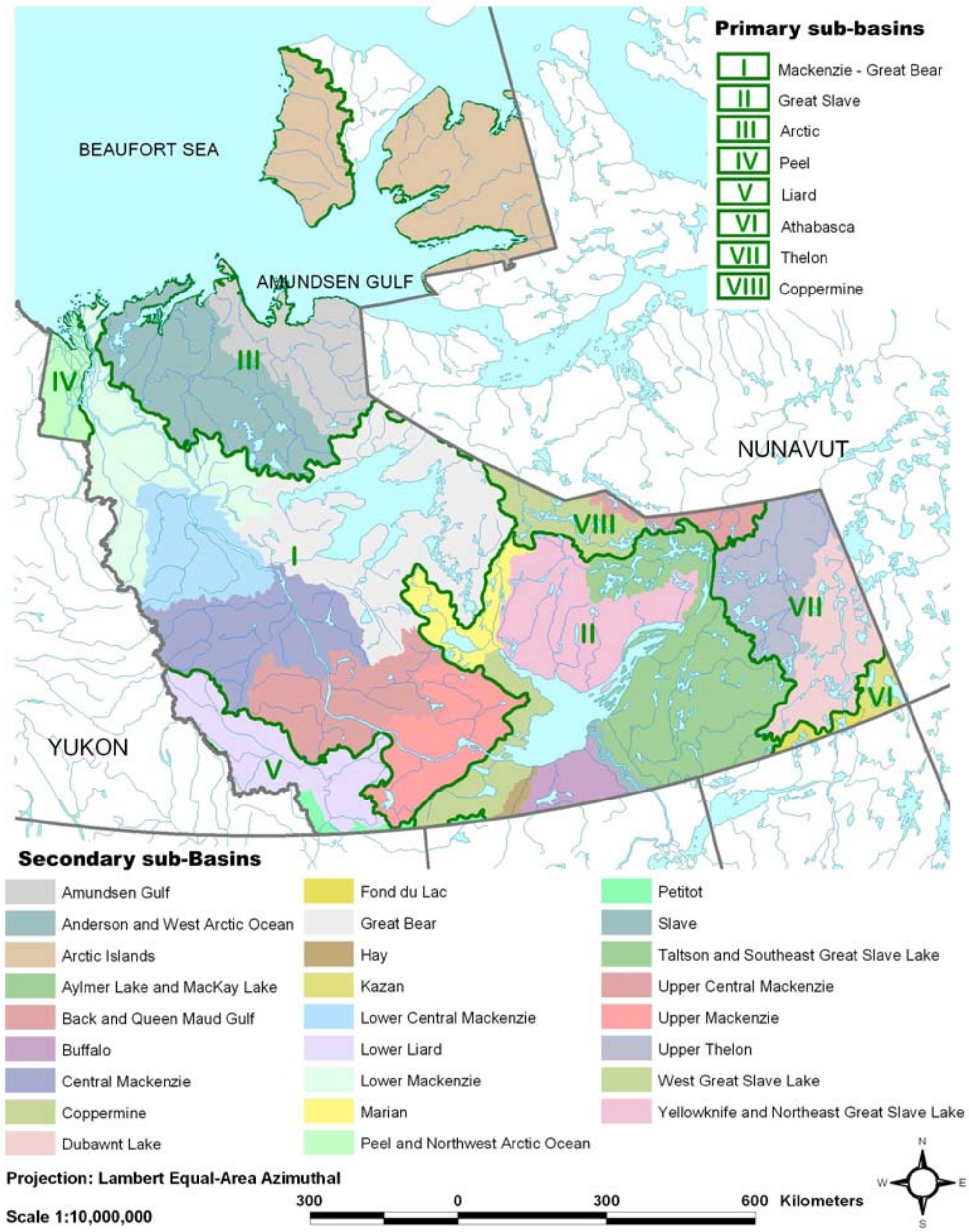
### 3.1.2 Great Slave Sub-Basin

The Great Slave sub-basin includes the Slave River drainage from the Peace-Athabasca Delta and all other tributary inflows into Great Slave Lake. It covers more than 379,000 square kilometres. Approximately 75% of the area is in the southeastern NWT and 20% is in northern Alberta. The remainder extends into northeastern British Columbia and northwestern Saskatchewan. Great Slave Lake is the sub-basin's largest lake and is the fifth largest lake in North America with a surface area of 28,568 square kilometres and a volume of about 2,088 cubic kilometres of water. Great Slave Lake is also the deepest in North America with an average depth of about 73 meters and a maximum depth of 614 meters.

The Great Slave sub-basin consists of fourteen major drainage systems. The largest river, the Slave, contributes about 77% of the inflow to Great Slave Lake. Other major inflows to Great Slave Lake include Taltson, Lockhart, and Hay rivers which, collectively, contribute about 11%

of the flow into Great Slave Lake. Ten other smaller drainage areas in the Great Slave sub-basin provide the remaining 12% of the inflow to Great Slave Lake.

**FIGURE 3.1-2**
**WATERSHEDS IN THE NORTHWEST TERRITORIES**



The Great Slave sub-basin straddles two distinct physiographic regions: the erosion-resistant Precambrian Shield to the east; and the Interior Plains to the west. The Shield features open, stunted taiga forest and hundreds of lakes, while the Plains are characterized by a more dense boreal forest in a landscape that was sculpted and smoothed by continental glaciers. As a result of geological and vegetative differences between these areas, annual runoff is greater in the Shield than in the Interior Plains. The presence of hundreds of small and large lakes in the Precambrian Shield produces more stable flow regimes in its rivers than in rivers of the Interior Plains (MRBB, 2004).

### 3.1.3 Peel Sub-Basin

The Peel River sub-basin encompasses an area of 74,000 square kilometres, from its headwaters in the Yukon to its confluence with the Mackenzie River near Fort McPherson in the NWT (see Figure 3.1-1). The Peel River has a mainstream length of approximately 350 kilometres beginning at the confluence of the Blackstone and Ogilvie rivers. Downstream of this confluence, there are several major tributaries draining the Ogilvie and Selwyn Mountains. These alpine rivers include the Hart, Wind, Bonnet Plume and Snake rivers. Further downstream, the Caribou, Trail, Road and Vittrekwa rivers drain the Peel Plateau. Mountainous terrain and permafrost, both of which cover vast areas of the sub-basin, control the flow of water in most of the rivers of the Peel sub-basin. The Peel sub-basin includes portions of the Taiga Cordillera Ecozone and the Taiga Plains Ecozone (see Chapter 5, Section 5.1.1). Wetlands such as bogs and fens are abundant in the areas of the sub-basin within the Taiga Plains Ecozone (MRBB, 2004).

### 3.1.4 Liard Sub-Basin

The Liard River and its tributaries drain an area of approximately 275,000 square kilometres, making it Canada's ninth largest watershed. The Liard River begins its journey in the Pelly Mountains of southeastern Yukon, flows through northeastern British Columbia and then crosses into the Northwest Territories where it drains into the Mackenzie River. At 1,115 kilometres, the Liard is Canada's eleventh longest river. With an average annual discharge of 1,970 cubic meters per second, it ranks seventh among Canadian rivers in volume of water discharged.

Much of the Liard sub-basin is covered by coniferous and mixed-wood forest. There are extensive mountainous areas, especially in the headwaters along the Yukon-Northwest Territories border and in the western portion. Some of the mountainous areas along the Yukon-Northwest Territories border are prone to massive landslides. Heavy summer precipitation, melting permafrost, deforestation and disturbances to the land caused by the petroleum industry may cause landslides. Landslides can have major effects on local water quality and quantity. (MRBB, 2004)

### 3.1.5 Athabasca Sub-Basin

The Athabasca River and Lake Athabasca together drain an area of about 269,000 square kilometres in Alberta, Saskatchewan and a small portion of the NWT. The Athabasca sub-basin contains several types of ecosystems from the glaciers, alpine meadows and mountain forests in the Rocky Mountains to the boreal forests and muskeg of northeastern Alberta. Forested, Precambrian Shield occurs in the extreme northeastern part of the sub-basin. The Athabasca River flows 1,375 kilometres from the Columbia Ice-field in the Rocky Mountains, across north central Alberta, and through the Peace-Athabasca Delta to Lake Athabasca (MRBB, 2004).

### 3.1.6 Thelon Basin

The drainage basin of the Thelon River encompasses some 142,400 square kilometres. Its source is Eyeberry Lake in the Northwest Territories, and it flows east to Baker Lake in Nunavut. The Thelon ultimately drains into Hudson Bay. From as far apart as 200 km east of Great Slave Lake and the northern Saskatchewan border, waters of the Thelon collect to flow for about 900 km to Baker Lake and Chesterfield Inlet. The Thelon watershed is the largest unaltered drainage basin emptying into Hudson Bay.

The Coppermine River is not "bounded by ... Bathurst Inlet to the east." It could perhaps be stated that to the east of the Coppermine basin is the Contwoyto Lake/Burnside River watershed. The Coppermine River does not begin in the boreal forest 850 km from the coast...

### 3.1.7 Coppermine Basin

The Coppermine River Basin is a coastal watershed of the Arctic Ocean Basin, a zone that is 16.7% of the land area of Canada. In total, the Coppermine River watershed is 50,800 square kilometres, and it is the 8th largest watershed in Nunavut and the NWT. Long and narrow, the southeast/northwest length of the basin is 520 km and the average width is about 100 km. The watershed lies for the most part within the Taiga Shield between Great Slave Lake to the south, Great Bear Lake to the west and the Arctic Ocean to the north and Bathurst Inlet to the east. The headwaters of the Coppermine River are in the Ursula Lake/Lac du Sauvage region.

## 3.2 SURFACE WATER AND SEDIMENTS

### 3.2.1 Monitoring and Research Activities

Several monitoring and research programs related to surface water and sediment quality and water quantity are ongoing in the NWT. Federal, territorial, and municipal agencies have ongoing mandates to conduct research and monitor freshwater issues. As identified in the recent report, *A Preliminary State of Knowledge of Valued Components for the NWT Cumulative Impact Monitoring Program (NWT CIMP) and Audit* (INAC 2005), numerous monitoring programs are currently underway for surface water and sediment quality and surface water quantity. They are listed below. Attachment 3A provides a listing of relevant research articles and reports, as identified in the CIMP report.

#### *3.2.1.1 Current Surface Water and Sediment Quality Monitoring*

**Northern Rivers Ecosystem Initiative (NREI)** (Environment Canada, Government of the Northwest Territories, Government of Alberta. Other key partners are INAC, Health Canada and Alberta Health) **– 1998-2003**

The NREI (1998-2003) is a follow-up to the Northern River Basins Study (NRBS). The Ministers agreed with the direction of the NRBS recommendations and committed to focus their efforts in the areas of pollution prevention, science-based ecological management, resolving contaminant and nutrient issues, endocrine disruption, long-range transport of atmospheric pollutants and continuing environmental research in northern rivers. The NREI works with industry, Aboriginal peoples, academia, communities and others to address the recommendations from the NRBS. NREI completed information reporting on its water, sediment and biota data and that information is stored in and displayed by Eco Atlas CE IMS/GIS.

**Northwest Territories Water Quality Monitoring Program** (Environment Canada**) - since 1960**

**Inter-Jurisdictional Rivers (IJR) Interim Aquatic Quality Monitoring Program** (Environment Canada and Alberta Environment since 1988, and Government of the Northwest Territories) **– 1984-1995**

Water and sediment quality data reports are available for the Hay and Slave River sites

**Nahanni National Park Reserve Aquatic Quality Follow-up Monitoring Program** (Environment Canada and Parks Canada) **– since 1992**

Ongoing monitoring is taking place to fill in gaps found during intensive monitoring between 1992 and 1997, resulting in a 1998 EC-Parks report. Base flow water quality is monitored at all sites each February. Lake and pond limnology and paleolimnology on age-dated slices of sediment are analyzed for chemistry and diatom paleolimnology at several lakes and ponds.

**Spatial and Temporal Trends in Loading and Historical Inputs of Mercury (and other trace metals and organics) from Age-dated Pan-northern Lake/Pond Sediment Cores** (Environment Canada and Parks Canada) **– since 1998**

Transects being sampled in the Northwest Territories include Ft. Liard/Fisherman Lake area, Nahanni NPR, Tuktut Nogait NP, and Aulavik NP.

**Forest Fire Effects on Water Quality and Quantity at Tibbitt Lake** (INAC) **– since 1998**

**Aquatic Effects Monitoring Program** (BHP Diamonds Inc.) **- since 1998**

Lakes and streams near the EKATI mine are monitored to determine potential effects of the mine. A surveillance network program monitors the health of lakes and streams, providing an early warming system. Specific effects monitoring is undertaken where potential adverse effects have been identified. A sewage effects study was conducted at Kodiak Lake. Aquatic baseline and monitoring data was gathered from 1993 to 1997.

**Coppermine Cumulative Effects Monitoring Program** (INAC) **– since 2000**

The Coppermine River Basin is the focus of this monitoring program. An enhanced water quality sampling program is underway which includes monthly sampling at 6 to 8 sites, seasonal sampling at several other sites, and continuous monitoring at the outlet of Lac de Gras. Upcoming studies include snow surveys in a small representative basin to develop snowmelt runoff and basin rainfall-runoff ratios, and monitoring of river-ice breakup using a remote web-cam.

**Slave River Environmental Quality Monitoring Program** (INAC)

Water, suspended sediment and fish tissue quality are monitored on the Slave River at Fort Smith, to address transboundary issues. A five-year follow up program is currently being conducted to determine if any changes in water/sediment quality has occurred.

**Liard River Environmental Quality Monitoring Program** (INAC)

Water, suspended sediment, and fish tissue quality are monitored on the Liard River above the Kotanelee River, to address transboundary issues. A five-year follow up program is currently being conducted to determine if any changes in water/sediment quality has occurred.

**Peel River Water & Sediment Quality Monitoring Program** (INAC)

Water and suspended sediment are monitored on the Peel River above Fort McPherson, to address transboundary issues including community concerns about contaminants. Sampling was conducted in July 2002, June 2003 and August 2004.

**Hay River Water & Sediment Quality Monitoring Program** (INAC and Environment Canada)

Water and suspended sediment are monitored on the Hay River at the NWT/Alberta Border, to address transboundary issues. Sampling was initiated in 2004.

**Ecological Monitoring and Assessment Network (EMAN)** (coordinated by Environment Canada)

Water and sediment quality are monitored at selected EMAN sites in the NWT. See Attachment 3A for a complete description of EMAN.

**Monitoring Related to the Proposed Mackenzie Gas Project** (Environment Canada and Indian and Northern Affairs) **– 2004-2006**

In 2004, lakes near the proposed Mackenzie Gas Project (MGP) Anchor Sites in the Mackenzie Delta/Tuktoyaktuk Peninsula were sampled. Studies involve baseline water, sediment and biota characterization (zooplankton, phytoplankton, benthic invertebrates). In 2005 and 2006, stream and lake studies will be carried out along the MGP pipeline route and near MGP anchor sites. Data collected by government, NGO and industry will be stored in an Eco Atlas CE IMS/GIS, which will link/join with INAC-BGC Engineering Geotechnics IMS/GIS for the MGP development corridor.

**Pre-construction Monitoring for the Yellowknife-Rae Highway** (Environment Canada) **– 1999-2004**

A study was completed to characterize the pre-construction baseline conditions in waterfowl-utilized ponds and borrow pits along the Yellowknife-Rae Highway. Water, sediment, invertebrate and waterfowl data were collected.

#### *3.2.1.2 Current Surface Water Quantity Monitoring*

**Northwest Territories Water Quantity Monitoring** program includes 75 stations operated by the Water Survey of Canada, with funding from Environment Canada, INAC, Northwest Territories Power Corporation, and the Canadian Coast Guard. Monitoring began in 1938 but most stations were established in the 1960s and 1970s. Subsets include:

- **Northwest Territories reference hydrometric basin network** (since 1965) (water flow rates, water quantity, ice phenology)

- **Mackenzie Delta water level, flow and hydrometric data monitoring** (includes a modeling component)

- **Northwest Territories evaporation/water balance** studies were initiated in 1992 for mine site water management. Study sites are located at the Salmita/Tundra mine in the upper Lockhart River basin, the Colomac mine site in the Snare River basin, and Pocket Lake on the Giant mine site near Yellowknife (INAC).

**Global Energy and Water Cycle Experiment (GEWEX)** seeks to understand and model the high latitude water and energy cycles that play roles in the global climate system, and improve the ability to assess the changes to Canada's water resources that arise from climate variability and anthropogenic climate change. Canada is carrying out an investigation of the water and energy cycles of the Mackenzie River, under a program called the Mackenzie GEWEX Study (MAGS). A series of large-scale hydrological and related land-atmosphere studies are being conducted in the Mackenzie Basin to help understand the role of high latitude hydrological and meteorological processes in the global climate system. MAGS is one of 7 regional experiments in different regions of the world. For further details see http://www.msc-smc.ec.gc.ca/GEWEX.

**Water Balance Studies at Lower Carp Lake and in the Snare River Basin** as part of the Mackenzie GEWEX study were established in 1997. Additional GEWEX studies have been initiated for hydrological research in the Baker Creek watershed (Yellowknife area) (Environment Canada), and for ice jam studies at Hay River (Indian Affairs and Northern Development, University of Alberta). MAGS researchers studied lake evaporation from Great Slave Lake from 1997 – 2003 and from 2000 – 2003 on smaller lakes in the Yellowknife area. Investigations studying evaporation from Great Bear Lake began in 2004.

**The Coppermine Cumulative Effects Monitoring Program** is an enhanced program of water quality and water quantity monitoring. Hydrological studies include a snowmelt-runoff study started in 2001 at Daring Lake (INAC) and a small basin hydrologic study that began in 1999 (Wilfrid Laurier University).

**Dendrochronological Sampling and Analysis Project** was initiated in 1999. This project correlates standardized tree ring widths with stream flow and precipitation records. Hydrological records have been extended to the late 1600s with these proxy data methods. Sampling has been done in several locations, including the Yellowknife area, along the Mackenzie Highway, in the South Nahanni Watershed, the East Arm (Great Slave Lake) watershed, the Mackenzie River Delta and the Great Bear Lake watershed (INAC, Environment Canada, and University of Regina).

### 3.2.2 Focus of the Assessment

With the predominant freshwater system in the NWT being the Mackenzie River Basin and its component primary and secondary sub-basins (see Figure 3.1-2), the emphasis of the surface water and sediment quality and surface water quantity assessment in this report is on that basin. The Mackenzie River Basin covers about 75% of the NWT and contains within its area communities that are home to 90% of the resident population. Furthermore, as discussed in Section 3.3.3, the landscape within the Mackenzie River Basin also experiences most of the NWT's industrial development.

This assessment was conducted by reviewing the scientific literature, reports, and scientific and government on-line resources. The objective of the review of background material was to develop a consensus from several perspectives of the status of the indicators.

The valued components and indicators investigated in this assessment are listed in Table 3.2-1 together with the rationale for their selection.

**TABLE 3.2-1**
**WATER QUALITY AND QUANTITY VALUED COMPONENTS AND INDICATORS**

| Valued Component | Indicators | Rationale |
|---|---|---|
| **Surface Water and Sediment Quality** | • Contaminants of primary concern (COPC): turbidity, aluminium, iron, copper, zinc, and mercury | • Water quality in the Mackenzie River and several of its tributaries is affected by a high natural sediment load.<br>• Water quality studies such as the 2003 Mackenzie River Basin State of the Aquatic Ecosystem Report have shown that there are only a limited number of COPCs that frequently exceed water quality guidelines at routinely monitored stations.<br>• Besides the noted COPCs, arsenic is also a concern in the area around Yellowknife due to historic releases from the Giant Mine and Con Mine.<br>• There is only limited data on bacteriological parameters and organic compounds to use in analysis of trends.<br>• There is only limited sediment quality data and mostly what is available is of short duration. |
| **Surface Water Quantity** | • Discharge rates<br>• Ice phenology<br>• Lake levels | • The Mackenzie River Basin, as Canada's largest watershed, has a discharge rate of over 9,900 $m^3/s$.<br>• Flow monitoring on tributary rivers like the Liard River have shown a decreasing trend in the mean annual discharge rate.<br>• Flow in the Mackenzie River has not shown the same trend to date, presumably due to the influence of Great Slave Lake in particular but also Great Bear Lake in moderating the river flow.<br>• Monitoring data on the time of ice over and ice out at river crossings in the southern part of the NWT have shown variability.<br>• Monitoring data on Great Slave Lake suggest a possible lowering of the average lake level although the trend is not conclusive given the large size of the lake. |

### 3.2.3 Stressors on Aquatic Systems

Lacustrine and riverine ecosystems in the NWT are vulnerable to a wide range of anthropogenic and natural stressors, each with the potential to affect their ecology in different ways. Chief among these stressors, but listed in no particular order, are:

- climate change;
- contaminants; and,
- industrial development.

#### *3.2.3.1 Climate Change*

Several comprehensive assessments have been written on the present and future effects of a warming climate on northern regions. Groups such as the Intergovernmental Panel on Climate Change (IPCC)[1] and the Arctic Climate Impact Assessment (ACIA 2004) of the Arctic Monitoring and Assessment Program (AMAP)[2] have considered the evidence of climate change on a global scale and explicitly consider the effects to the northern landscape. International teams of scientists made up of several disciplines, including meteorologists, geologists and biologists, conducted these assessments. The teams used data collected over the last several decades to document ongoing changes and used computer models to predict the extent of changes over the next few decades. Summaries of the assessments are available at their websites. Recent research on the potential impacts of climate change in Canada has revealed that a warming climate could have wide-ranging effects on Canada's environment and the human community. Numerous impact scenarios are presented in the digital atlas of Canada on the website of Natural Resources Canada[3].

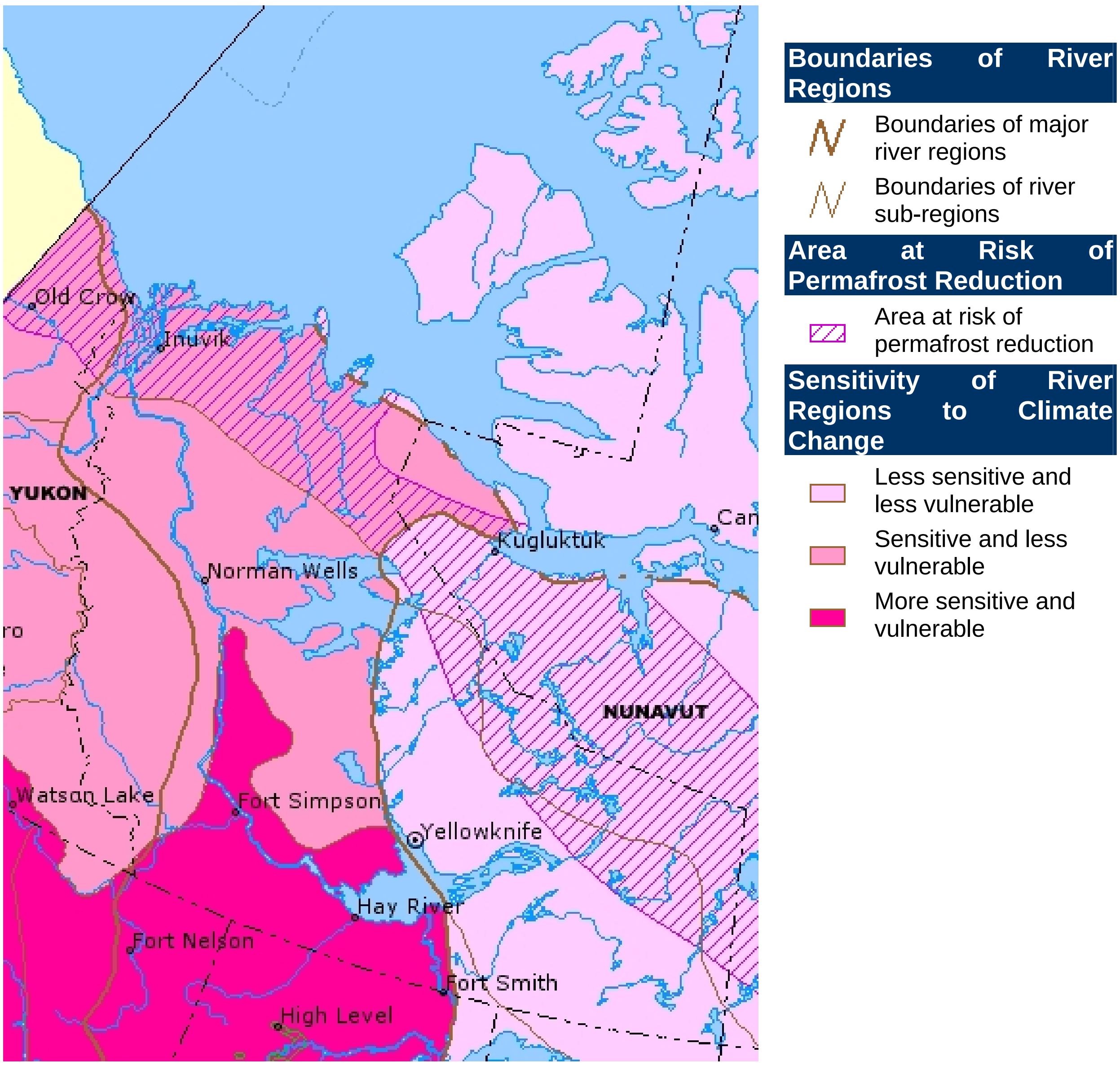
The greatest effects of a changing climate are expected in the higher latitudes, where melting ice and large tracts of drying tundra cause significant changes to the natural hydrologic cycle and carbon exchange. Overall, it has been estimated that the air temperature over the arctic landmass has increased at a rate of 0.40°C per decade since the 1960s. ACIA reports that average winter temperatures in the western Canadian Arctic have increased by 3 to 4°C in the last 50 years, and that precipitation appears to have increased by 8% across the Arctic (ACIA 2004). ACIA predicts that total annual precipitation will increase by 20% in the Arctic by the end of the century. These prolonged changes to the climate are expected to have major effects on northern aquatic regimes. Figure 3.2-1 shows a sensitivity projection for NWT's river regions in response to climate warming. Climate warming has the potential to cause substantial changes to flow in rivers and degradation of permafrost (Ashmore and Church 2000).

The most direct effects of projected climate change on the hydrologic cycle are likely to be an increase in floods and river erosion. In the Northern Shield area, permafrost is at risk of being reduced. The IPCC (IPCC 2001a) concludes that significant erosion of permafrost has already occurred in some areas of the north. This erosion of permafrost will lead to changes in surface water drainage and an increase in the active growth layer (i.e., the layer between permafrost and ground surface). This will likely alter the seasonality of runoff and affect soil instability, which will have implications for the landscape, ecosystems and infrastructure. The direct impact of climate change on permafrost is currently still under study.

[1] http://www.ipcc.ch/
[2] http://www.amap.no/acia/index.html
[3] http://atlas.gc.ca/site/english/index.html

A warming climate would also result in erosion of soils and thermokarst, and the possibility that wetlands and lake levels will be reduced IPCC 2001a. Increases in the melting of snow and ice could cause the ponding of surface waters in some areas, but drying out of wetlands in other areas because of increased evaporation and transpiration. IPCC (2001b) cite studies in which the area of tundra cover is predicted to decrease by as much as 66% of its present size.

**FIGURE 3.2-1**
**SENSITIVITY PROJECTION FOR NWT'S RIVER REGIONS IN RESPONSE TO CLIMATE WARMING**

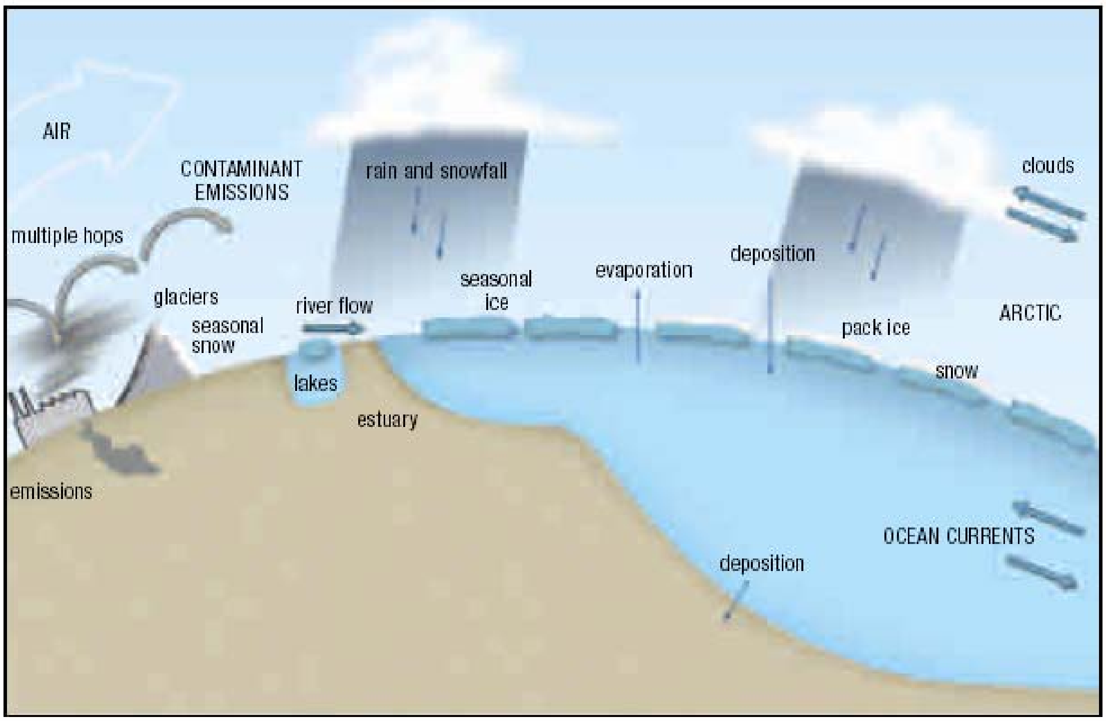



*Source: Digital Atlas of Canada, Natural Resources Canada - http://atlas.gc.ca/site/english/maps/climatechange/potentialimpacts/sensitivityriverregions.*

### *3.2.3.2 Contaminants*

The presence of contaminants in aquatic systems in the NWT can be the result of both natural and anthropogenic activities, and either local or long-range sources. In northern Canada, human activities are responsible for most of the contaminants present in the environment, and most of these chemicals are deposited by long-range atmospheric transport processes; coming from industrialised regions outside of the Canadian North (INAC 2003). Figure 3.2-2 illustrates the various pathways for contaminants in the northern physical environment.

**FIGURE 3.2-2**
**PATHWAYS FOR CONTAMINANTS IN THE NORTHERN PHYSICAL ENVIRONMENT**




*Source: Canadian Arctic Contaminants Assessment Report II (INAC 2003).*

The predominant research conducted on contaminants in the Arctic has been through the Northern Contaminants Program (NCP). NCP was established in 1992 in response to studies that showed the presence of contaminants in the Arctic ecosystem. Many of these contaminants have no Arctic sources and yet some are found at high levels in animals at the top of the Arctic food chain and in humans. The three main contaminant groups of concern are persistent organic pollutants (POPs), heavy metals and radionuclides[4]. Examples of contaminants studied in the NCP are summarized on Table 3.2-2.

[4] http://www.ainc-inac.gc.ca/NCP/abt/des_e.html

## TABLE 3.2-2
## EXAMPLES OF CONTAMINANTS STUDIED IN THE NORTHERN CONTAMINANTS PROGRAM

| Contaminant | Why Does it Exist? What is it Used for> | Where Does it Come From? |
|---|---|---|
| **Persistent Organic Pollutants (POPs)** | | |
| • polychlorinated biphenyls (PCBs) | • used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment;<br>• found in old electrical transformers. | • mostly locally contaminated soils/plants, landfill sites, and also can be created when burning. |
| • dichlorodiphenyltrichloroethane (DDT)<br>• toxaphene<br>• endosulfan<br>• chlordane<br>• hexachlorocyclohexanes (HCHs) including lindane | • pesticides used mainly in agriculture to kill pests (e.g., unwanted animals such as insects) or to prevent human diseases. | • northern hemisphere, particularly mid-latitudes, including North America, Asia, Europe. |
| • chlorinated paraffins (PCAs) | • used in making plastics and in materials to reduce the risk of fire. | • mostly industrial sources in the northern hemisphere. |
| • polychlorinated naphthalenes {PCNs) | • used in electrical insulation fluids and as wood preservatives;<br>• also come from burning metal waste and garbage. | • mostly industrial sources in the northern hemisphere. |
| • polycyclic aromatic hydrocarbons (PAHs) | • produced whenever something is burned, from meat to vehicle exhaust to industrial sources. | • mostly industrial sources in the northern hemisphere. |
| • brominated fire retardants (e.g., polybrominated diphenyl ethers PBDEs) | • used in materials to reduce the risk of fire. | • mostly industrial sources in the northern hemisphere. |
| • butyltins | • used in e.g., special paint to prevent unwanted growth of plants or animals on ship hulls. | • from passing ships. |
| **Heavy Metals** | | |
| • mercury and methylmercury | • are all naturally occurring elements in rocks and soils.<br>• mercury can also be released from flooded lands when reservoirs are created. | • mostly Europe, Asia and North America. |
| • cadmium | • released to the environment from mining and smelting (processing) metals | |
| • lead | • lead is released from coal-burning power stations, incinerators and from burning leaded gasoline | |
| **Radionuclides** | | |
| • cesium | • except for cesium, are naturally occurring radioactive elements in rocks and soils. | • mostly natural sources in the Canadian North |
| • polonium | | • some very limited transport from northern Europe and Russia. |
| • uranium | • can be released to the environment from atmospheric testing of nuclear weapons, dumping of nuclear waste, and nuclear accidents. | |

*Source: Indian and Northern Affairs 2003. Canadian Arctic Contaminants Assessment Report II. Northern Contaminants Program.*

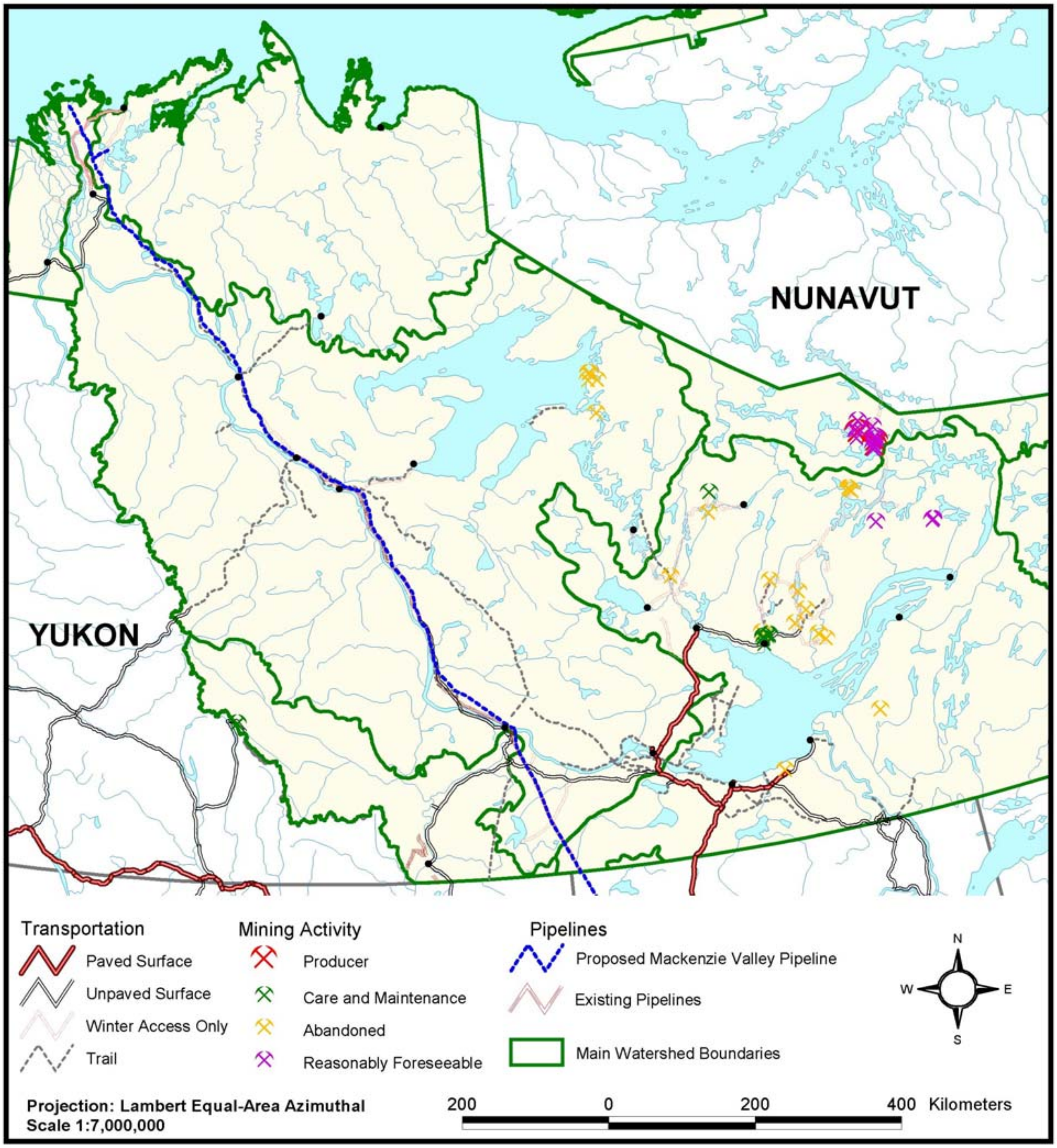
### *3.2.3.3 Industrial Development*

Another significant threat to the freshwater lacustrine and riverine systems in the NWT is the cumulative impact of large-scale development projects that make changes in watersheds. These changes combine to produce stress within the catchment, downstream regions, and can affect aquatic and terrestrial organisms. Past, current, and reasonably foreseeable industrial development in the NWT includes base metal, diamond, gold and uranium mining; oil and gas exploration and production, and hydroelectric generating stations. Development has been an integral part of the northern environment for several decades; however, individual projects have been relatively small and widely dispersed. Historically, mines have affected local environments by building roads and other infrastructure and releasing contaminants to air, soil and water but the physical footprints of the mines were relatively small in nature compared to currently proposed projects. Proposals for extensive oil and gas development, pipelines, permanent roads, hydroelectric projects and several mines within the same watershed will likely make considerable changes to the landscape. A summary of some of these activities in the NWT is presented in Figure 3.2-3.

**i) Hydroelectric Development**

Hydroelectric development has occurred on the Snare, Taltson, and Yellowknife River systems. Potential for additional development has been identified on other rivers, including the Great Bear, Mackenzie, and Lockhart Rivers, as well as expansion of existing hydroelectric development on the Talston River. Hydro development may involve regulation of flow, changes in water level (including flooding), diversion, and construction of barriers. It may also cause changes in the natural regime (e. g., a shift or spread of peak discharge events). Transmission corridors that carry power from generation sites to user sites also create many of the same environmental stresses that are associated with road transportation. Many changes create stress on both terrestrial and aquatic habitats and their effects are long term, and some are more or less permanent. (WKSS 2001)

**FIGURE 3.2-3**
**INDUSTRIAL ACTIVITY IN THE NORTHWEST TERRITORIES**



### ii) Diamond Mining

All producing mines currently in the NWT are diamond mines. Two are currently in full production (BHP Ekati and Diavik), a third is under construction (De Beers Snap Lake), and a fourth is being prepared for an environmental assessment process (De Beers Gachue Kue). Diamond mining in the NWT has significant direct, local impacts on aquatic systems. Lakes are completely or partially drained to allow for open pit access to the kimberlite pipes, water diversion systems are required, and large volumes of waste rock are deposited on the surface. Examples of these components of diamond mining in the NWT are shown in Figure 3.2-4.

**FIGURE 3.2-4**
**EXAMPLES OF COMPONENTS OF DIAMOND MINING IN THE NWT BHP EKATI MINE**

Panda Pit Panda Diversion Channel Waste rock piles

*Source: Independent Environmental Monitoring Agency (http://www.monitoringagency.net/)*

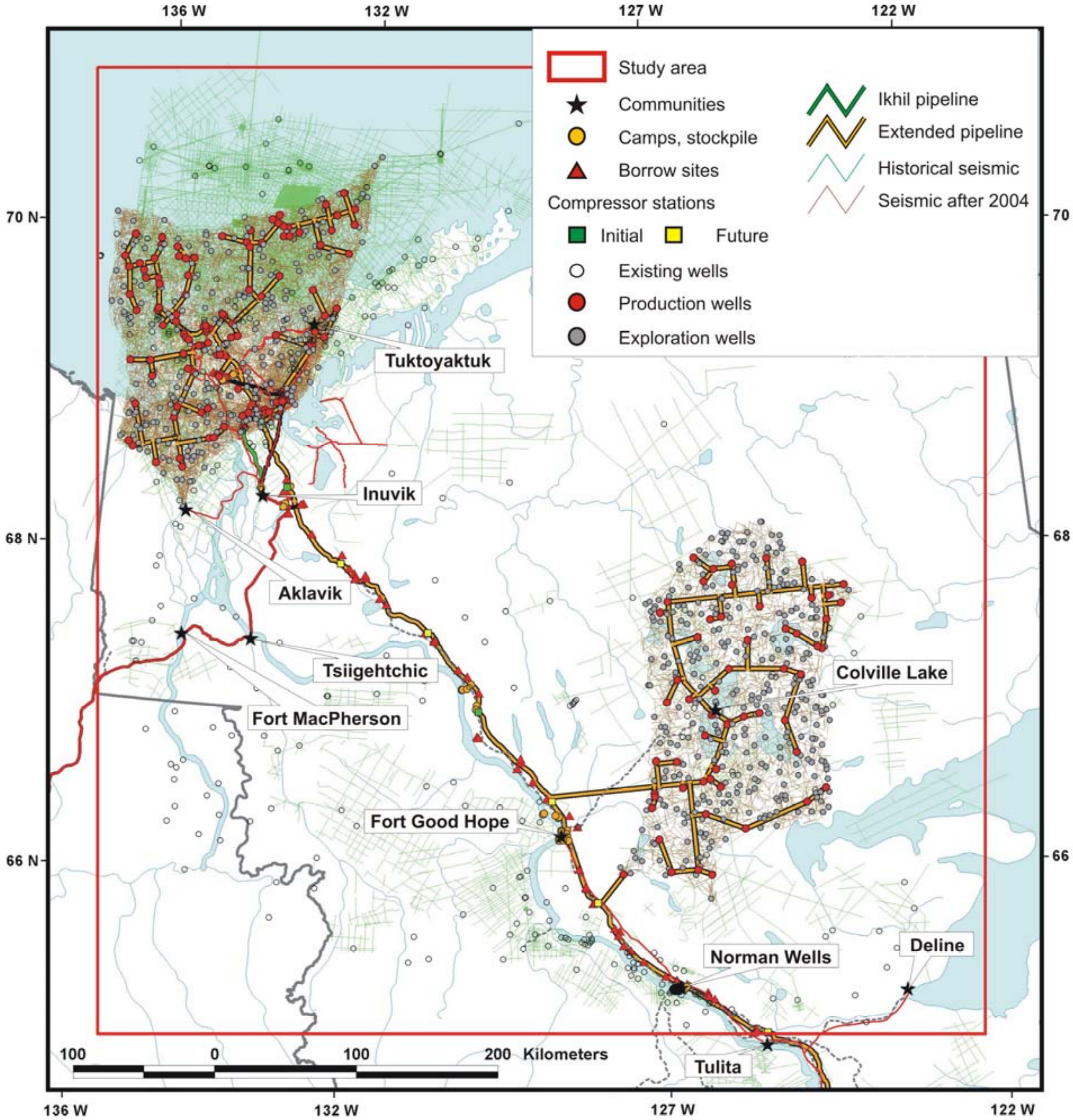
### iii) Oil and Gas Exploration and Production

Oil and gas exploration and production activities can have impacts on ecosystems that far exceed the physical footprints of the development. Exploratory drilling for oil or gas deposits has the potential to impact the environment through product or waste spills, road construction, wastewater discharges, and waste disposal. Development of a production field requires access to, or construction of, infrastructure that includes roads, pipelines, power lines, temporary housing, and drilling facilities. Access roads required by oil and gas development can affect the local landscape by modifying permafrost, the drainage of surface water and by the transport of dust (Walker Everett 1987, Walker *et al*. 1987). Increased infrastructure can lead to increased sedimentation in surface waters from erosion. Spills and contaminated water discharged from drilling operations can cause significant impacts on human health and the environment.

The cumulative impacts of oil and gas development were thoroughly reviewed in the U.S. National Academies National Research Council report, *Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope* (Committee on Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope (CCEEOG) 2003). The report identifies accumulated environmental, social and economic effects of oil and gas leasing, exploration, and production on Alaska's North Slope. In the NWT, the proposed Mackenzie Gas Project (MGP) is currently undergoing an environmental review. If approved, the development will involve the construction of a 1,200 kilometre pipeline to deliver natural gas from three anchor fields in the Mackenzie Delta to northern Alberta. The proposed MGP would also stimulate further natural gas exploration and production in the region. A recent study used industry reports and existing estimates of natural gas reserves in the Mackenzie Valley to derive future development scenarios that could arise as a result of construction of a Mackenzie Valley pipeline (CARC 2005). Figure 3.2-5 is taken from that report and presents a scenario for 2027.

The development of oil reserves in Alaska provides a very good comparison to the type of development that is beginning to occur in the NWT. Walker and Walker (1991) suggest that although the local impacts from the oil industry are small in scale (less than 1 $m^2$ to 1 $km^2$), the cumulative impact from all the development affects the region on a larger scale of 1 $km^2$ to 10,000 $km^2$. Based on the Alaskan experience, it is not unreasonable to expect that a similar level of development in the NWT will result in significant changes to the terrestrial environment.

**FIGURE 3.2-5**
**ESTIMATED CUMULATIVE EXPLORATION AND PRODUCTION RELATED TO THE PROPOSED MACKENZIE GAS PROJECT – 2027 SCENARIO**




*Source: Canadian Arctic Resources Committee 2005. Cumulative Effects Modelling of the Mackenzie Gas Project – Scoping and Development. www.carc.org*

### iv) Export of Bulk Water

Another possible future stress that could be placed on watersheds in the NWT is the exportation of bulk water. The serious problem of water scarcity and poor water quality in many parts of North America could put pressure on Canada's water resources. There is a perception that Canada has plentiful water resources; however, much of the water is tied up in ice and deep lake storage, and is not available through annual river flow (INAC 2003). Removing water in bulk from a drainage basin can have negative impacts within the donor basin. It can compromise existing and future in-stream water uses, alter the ecology of water habitats, and threaten cultural values and cultural activities of residents of the basin.

For the present, the need to protect, conserve and properly use Canadian water resources is recognised by all levels of government. To this end, in December 2003, a federal policy was released that prohibits bulk water removal from major river basins in the Northwest Territories[5]. However, there may be mounting political pressure in the future to ship bulk water south, therefore it will be important to be aware of this eventuality.

### 3.2.4 Surface Water and Sediment Quality

Good water and sediment quality are important to the health of both the natural and cultural environments. The Canadian Council of Ministers of the Environment (CCME) has established Environmental Quality Guidelines (EQG) for protection of aquatic life in water and sediment and for a number of water uses. These guidelines are threshold concentrations of chemical, physical and microbiological substances that are deemed to be safe for most forms of freshwater aquatic life or for various types of uses (e.g., livestock watering, irrigation, recreation and aesthetics, community water supply).

Water and sediments are inextricably linked as a result of biogeochemical processes taking place at the sediment-water interface of lacustrine and riverine environments. Within the NWT the important relationship between water and sediment is of particular note in the Mackenzie River which has the largest sediment load of any river in the Arctic circumpolar world. Its sediments contain very large amounts of non water-soluble organics and metals (up to 20 times greater than larger northern rivers). Many of these contaminants (e.g., POPs and radionuclides) are typically found at very, very low concentrations in surface waters. Hence, only those contaminants which have been found to exceed Environmental Quality Guidelines on a frequent basis are discussed below.

[5] *A Policy Respecting the Prohibition of Bulk Water Removal from Major River Basins in the Northwest Territories* (http://www.ainc-inac.gc.ca/ps/nap/wat/pdf/polprohnwt_e.pdf)

#### *3.2.4.1 Surface Water Quality*

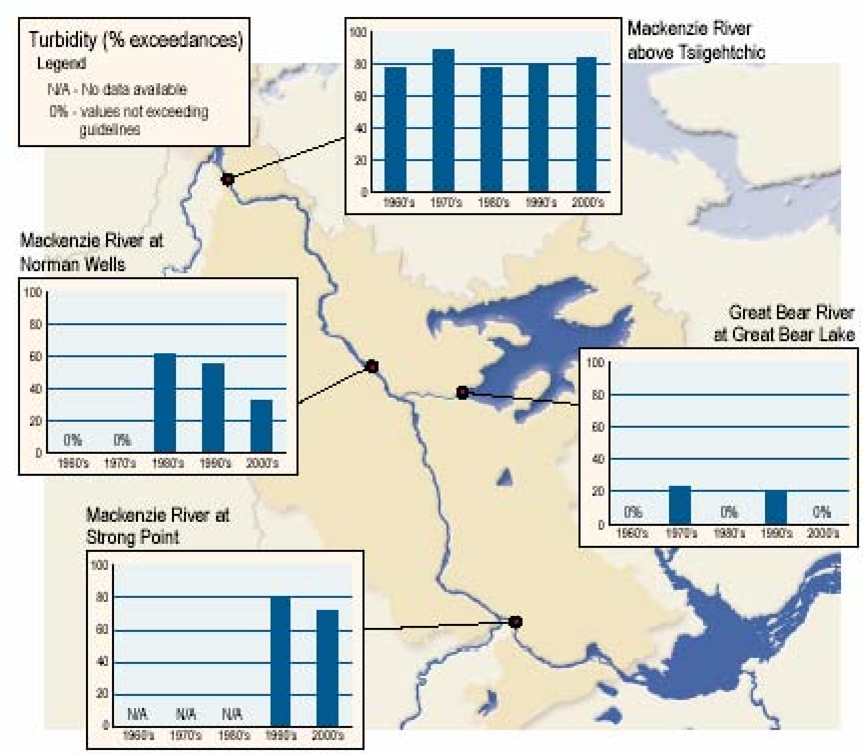
**i) What is being measured?**

Regional surface water quality monitoring is carried out routinely at a number of locations in the Mackenzie River basin, primarily by Environment Canada and INAC. Project specific water quality monitoring is carried out by proponents of mining operations or oil and gas developments and by INAC at several abandoned mine sites and former military sites. Limnological research has been carried out recently on lakes of the Mackenzie Delta/Tuktoyaktuk Peninsula, Mackenzie Valley, Great Bear Lake Area, Fort Simpson-Trout Lake Area, Nahanni NPR, Tuktut Nogait NP and Aulavik NP. A summary of monitoring activities in the NWT is provided in Section 3.2.1.

**ii) What is happening?**

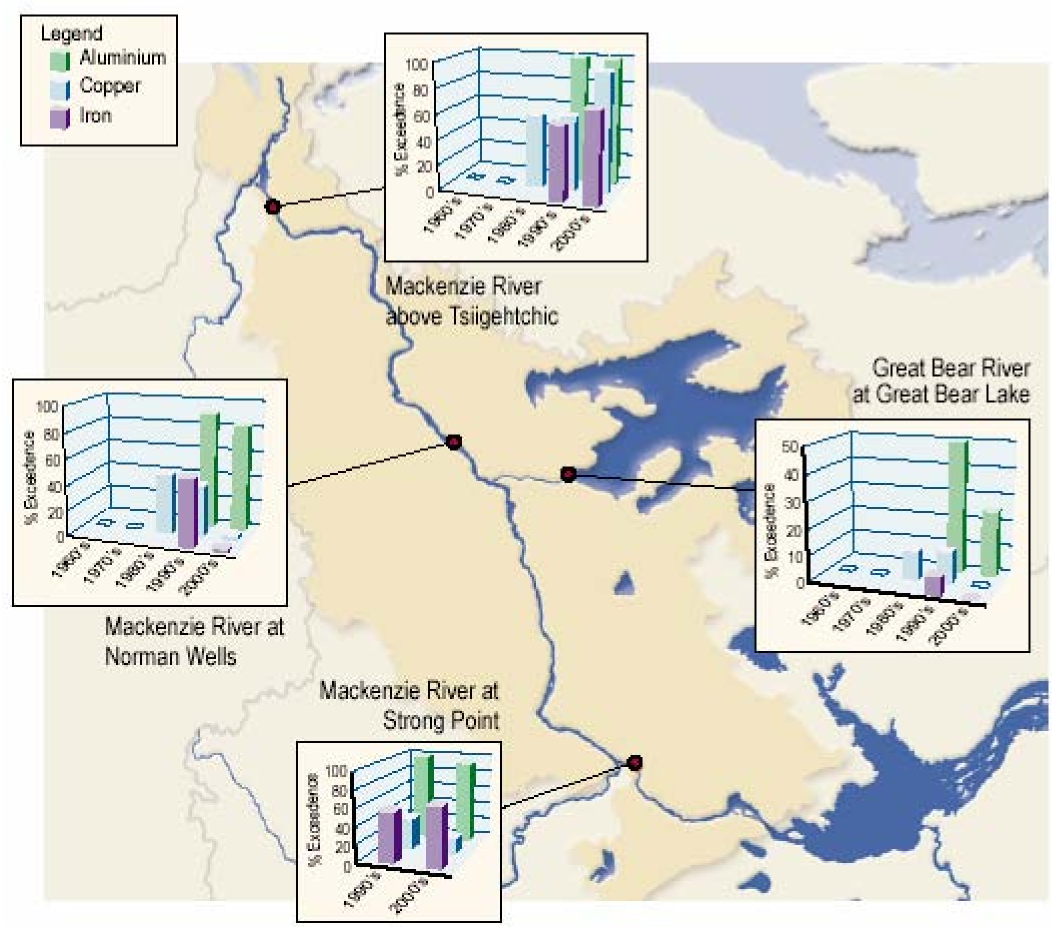
**Mackenzie Great Bear Sub-basin**: Not surprisingly, turbidity levels measured at three locations on the Mackenzie River have fairly consistently exceeded the guideline level for protection of recreation/aesthetics as demonstrated on Figure 3.2-6. Turbidity, a measure of the "cloudiness" of water, is dependent on the suspended sediment and dissolved solids content of water. At the downstream location above Tsiigehtchic, it is seen that the turbidity level has consistently exceeded the guideline on approximately 80% of the samples collected since the 1960s. A consequence of the elevated suspended sediment levels in the Mackenzie River is elevated levels of certain metals (aluminium, copper and iron) as demonstrated on Figure 3.2-7. By contrast, on Great Bear River near the outlet of Great Bear Lake the turbidity level was mostly below the guideline (i.e., there were few exceedances of the guideline) and the frequency of exceedance of the respective guideline values for the metals was lower with the exception of aluminium in the 1990s.

**FIGURE 3.2-6**
**TEMPORAL TURBIDITY MONITORING AND EXCEEDENCES FROM VARIOUS LOCATIONS ALONG THE MACKENZIE RIVER**




*Source: Mackenzie River Basin State of the Aquatic Ecosystem Report 2003. Mackenzie River Basin Board 2004.*

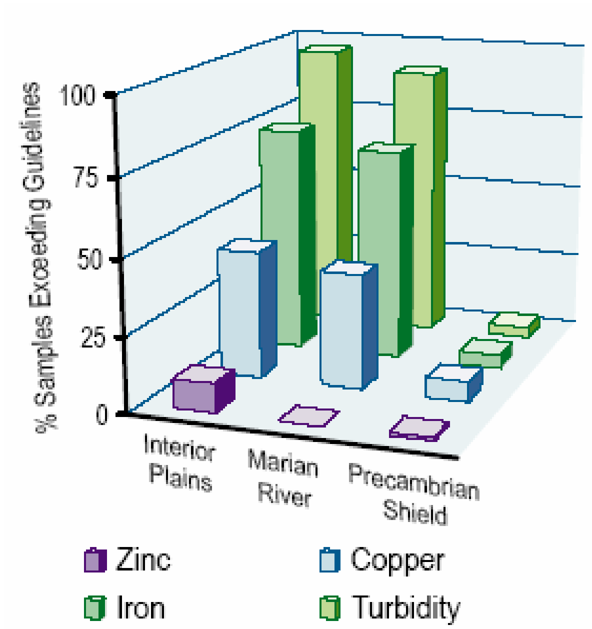
**FIGURE 3.2-7**
**TEMPORAL METAL (ALUMINIUM, IRON, COPPER) MONITORING AND EXCEEDENCES FROM VARIOUS LOCATIONS ALONG THE MACKENZIE RIVER**




*Source: Mackenzie River Basin State of the Aquatic Ecosystem Report 2003. Mackenzie River Basin Board 2004.*

**Great Slave Sub-basin**: The MRBB (MRBB 2004) in its analysis of water quality data on rivers in the Great Slave Sub-basin, separated the rivers according to whether they originated in the Interior Plains, Precambrian Shield or the Marian River watershed. Again the data were evaluated to determine the frequency of exceedance of CEQG. Figure 3.2-8 presents a summary of the analysis of turbidity, copper, iron and zinc data. On the Interior Plains and Marian River, turbidity and iron exceeded the guidelines most of the time and copper was above the guideline on over 25% of the samples. In contrast, turbidity and metals seldom were above the guideline values in rivers on the Precambrian Shield.

**FIGURE 3.2-8**
**ANALYSIS OF TURBIDITY, COPPER, IRON AND ZINC DATA**



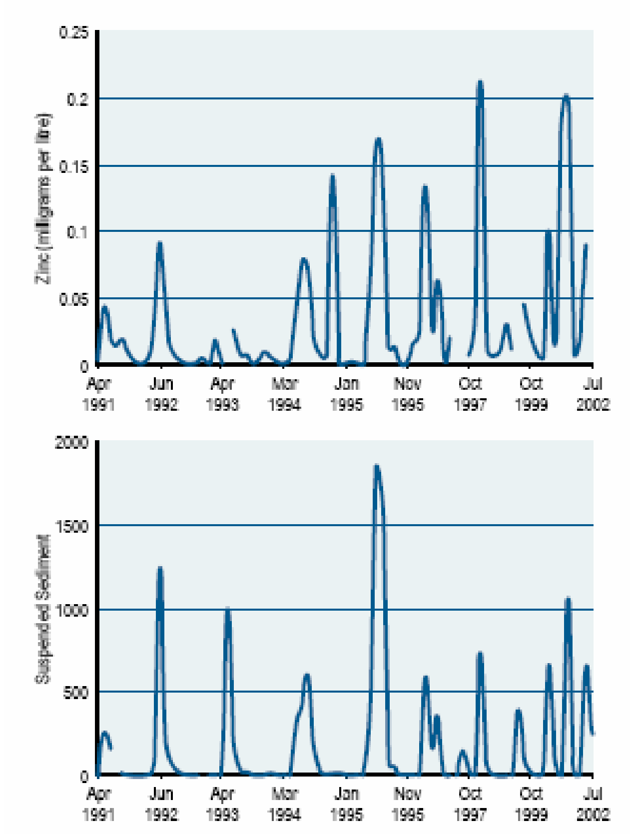

*Source: Mackenzie River Basin Board 2003.*

Besides the metals noted above, arsenic is also elevated in local watersheds draining the Giant Mine and Con Mine sites near the City of Yellowknife. For example, on Baker Creek, which flows through the Giant Mine site, the arsenic concentration upstream of the mine averages approximately 70 µg/L (Steffen Robertson and Kirsten 2002). By comparison, the arsenic concentration in the Yellowknife River, which is the city water supply, averages less than 0.3 µg/L.

**Peel Sub-basin**: Water quality monitoring in the Peel River near Fort McPherson has shown dramatic differences between winter and summer. Figure 3.2-9 prepared by the MRBB (2004) demonstrates the temporal variation in suspended and zinc concentrations in the Peel River between 1991 and 2002. The low levels of suspended solids and zinc observed in the winter contrast sharply with the high levels measured in the summer. Elevated concentrations of suspended solids, zinc (and other metals) in the Peel River are attributable to natural erosion processes occurring in the watershed.

**Liard Sub-basin**: As in the other watersheds, elevated concentrations of suspended solids and metals (notably copper and zinc) have been observed on several occasions at monitoring stations in the Liard River. The overall frequency of exceedance of CCME guidelines is reported to range from 0% to 34%.

**FIGURE 3.2-9**
**TEMPORAL VARIATION IN SUSPENDED AND ZINC CONCENTRATIONS IN THE PEEL RIVER BETWEEN 1991 AND 2002**




*Source: Mackenzie River Basin Board 2003.*

### iii) Why is it happening?

High levels of several metals have been observed to occur mostly in the spring and summer when river flows and turbidity levels are highest. The main factor contributing to elevated turbidity, suspended solids and metal concentrations in the rivers in the Mackenzie River Basin is erosion of soils. River sediment loads are affected by the landscape and underlying geology of a region. For example, the sedimentary rocks and glacial tills of the Interior Plains are more easily eroded than the crystalline bedrock that characterizes the Precambrain Shield.

At the local level, elevated metal concentrations around many of the abandoned mine sites in the NWT are attributable to historic releases and in most cases ongoing discharges of either treated or untreated waters. These waters originate from tailings basins, waste rock piles, mine site contaminated areas, open pits and/or underground mine workings.

**iv) What does it mean?**

The CCME Environmental Quality Guidelines were developed as national reference guidelines. When using the guidelines, the natural environmental conditions and unique aspects of specific water bodies or watersheds must be considered. Therefore, the fact that several exceedances of the guidelines have been observed in the Mackenzie River Basin waters in the NWT does not necessarily mean that plants and animals that are native to these waters are at risk.

Metals, including aluminium, copper, iron and zinc, exist in various chemical forms in water, depending on numerous characteristics of the water. Depending on the metal form, it may or may not be toxic to aquatic life. Because some metals have likely been present at elevated concentrations for thousands of years in rivers on the Interior Plains, it is likely that the plants and animals present in these waters have adapted to these conditions or that the metal of concern is not bioavailable to the organism (MRBB 2004).

**v) What is being done about it?**

Water quality monitoring continues be carried out by federal, territorial and municipal governments at long-term sites and by industrial proponents at new developments. Federal, territorial and regional legislation is in place to regulate the discharge of wastewaters to the natural water bodies in the NWT. Also, water licences are required by communities and industries for the use of water and discharge of wastewater. The licences set limits on the amount of water that can be used and on the quality and quantity of wastewater that can be discharged. When developments are proposed, environmental and health impact assessments must be carried out and submitted to the appropriate authorities for review.

Under the federal contaminated sites action plan (FCSAP) being administered by INAC, corrective action is being taken at a number of priority sites to remediate existing conditions and minimize the future release of untreated mine waters. As part of the process, detailed environmental risk and impact assessments are required to ensure that adequate protection of the environment is incorporated into the remediation design.

**vi) What are the information gaps?**

While turbidity and levels of some metals exceed CCME environmental quality guidelines in all sub-basins, the causes are largely natural in origin. Future monitoring will be useful in determining changes in water quality as they relate to climate change effects. The number of long-term monitoring station is limited however, in comparison to the geographic size of the NWT. Logistical and cost considerations have limited the number of stations and frequency of sampling that has been undertaken in the past. Means of expanding the current regional surface water quality monitoring to include key locations in unmonitored watersheds would be beneficial. Integration of more intensive local research into the long-term monitoring network database would be another means of expanding the water quality database. .

With respect to arsenic in the environment surrounding Yellowknife, both the Giant and Con mines have ceased operations but treatment of contaminated site waters continues. Remediation plans are being developed for both sites which will result in contaminated materials being removed from the surface and disposed in a secure manner and thus eventually eliminate the need for treatment of contaminated mine waters in the long term. Continued monitoring at these sites will be required though to demonstrate the effectiveness of the remediation measures.

Studies on levels of contaminants in lake water and sediments should continue as these are very sensitive to changes in inputs from the atmosphere, runoff and rivers.

Although snow is known to be important for bringing contaminants to the surface (e.g., mercury), more needs to be understood about how this happens, and what happens to the contaminants once they reach the surface

#### *3.2.4.2 Sediment Quality*

**i) What is being measured?**

Measurement of contaminant levels in sediments is important for several reasons. First, even trace levels of contaminants in surface water can be removed and accumulate in river or lake sediments. Second, contaminated sediments have been demonstrated to be toxic to sediment-dwelling organisms and fish. Third, sediment core samples can provide insight to trends in environmental contaminant inventories in the environment. For example, many contaminants make their way in the north via atmospheric dispersion processes. Steps taken to reduce or eliminate the usage of certain contaminants are reflected in the levels measured in sediments. In this regard, a number of sediment core investigations have been undertaken in the NWT.

**ii) What is happening?**

Various types of POPs have been found in sediments in Great Slave Lake and some high Arctic lakes. In Great Slave Lake, POPs are usually found at higher levels in the sediments at the mouth of the Slave River in the West Basin than elsewhere in the lake (INAC 2003). Sediment cores taken close to the mouth of Slave River showed increased trends in PCB concentrations with time and a similar trend in PAHs with most of the increase associated with lightweight

PAHs of probable petrogenic origin. Concentrations of PCDDs were highest in the 1950s and decreased thereafter. No trend was evident for PCDFs, which occurred in substantially lower concentrations than PCFFs (INAC 2003).

Investigations into the fate of POPs and mercury in Amituk Lake on Cornwallis Island have shown that a majority (greater than 95%) of the POPs are not removed to lake sediments but rather either remain in the water column or disappear over time (INAC 2003). For example, half of the HCHs and over 90% of the endosulfan were observed to disappear within a year. For these contaminants, microbial degradation has been identified as an important reason why some POPs have disappeared. In contrast, it was found that approximately 25% of the mercury entering Amituk Lake was removed to the lake sediment. A large portion (approximately 70%) of the mercury input to the lake was attributed to atmospheric deposition on the watershed.

A number of studies of mercury in sediments have been undertaken in the NWT and are summarized in NCP Phase I and II reports. In general mercury levels in sediments were below the CCME Interim Sediment Quality Guideline of 170 nanograms per kilogram. Mercury levels measured on a series of sediment cores taken from the Mackenzie Delta showed no enrichment of mercury in the upper layers suggesting no increase in inputs of mercury from any sources. A notable exception to the above observation is seen in Giauque Lake, which was impacted historically by the operation of a gold mine that used mercury in the gold recovery process. Core samples taken from Giauque Lake were found to provide accurate accounts of the history of the mine operation. Elevated mercury levels have also been recorded on sediment samples collected from the east end of Great Bear Lake near former silver mine operations.

In Yellowknife Bay on the North Arm of Great Slave Lake, elevated arsenic levels have been measured throughout the bay (SRK 2002). The accumulation of arsenic in the lake sediments has been attributed to uncontrolled releases to the atmospheric and aquatic environments from the Giant Mine and Con Mine during the early years of their operation. While the Giant Mine and the Con Mine, also located near the City of Yellowknife, continue to release treated effluents to Yellowknife Bay, arsenic levels in the lake sediments originated primarily from historic operations.

**iii) Why is it happening?**

The decline observed in most POPs in lake sediments is related to declines in atmospheric concentrations over northern Canada. Decreases in the HCH pesticides are due to restricted usage of chemicals and to microbial degradation of residual levels found in the environment. The main exceptions are the insecticides dieldrin and endosulfan, which are still being used in some parts of the world (INAC 2003). There is no clear indication whether mercury levels in the atmosphere, which is the main source of mercury input to the aquatic environment, are increasing or decreasing over northern Canada.

### iv) What does it mean?

The concentrations of POPs in lake sediments in the NWT are generally not considered to pose a risk to sediment-dwelling organisms or to fish. As a consequence of restrictions on the use of several toxic insecticides and pesticides, the concentrations in lake sediments are decreasing. While some POPs are amenable to biodegradation, most are only slowly degradable in the environment. The cold conditions prevalent most of the year in the NWT also does not favour biodegradation of POPs.

Of the metals, mercury is of the greatest concern due to the fact that it biomagnifies in the food chain. Elevated mercury levels in some fish species in some parts of the NWT has caused consumption advisories to be issued. Monitoring data on mercury levels in lake sediments do not indicate an increasing trend which suggests that there has not been an increase in mercury input sources in the NWT. Atmospheric levels of mercury, which is the principal source of mercury input to the aquatic environment, similarly do not show an increasing or decreasing trend.

### v) What is being done about it?

Actions to reduce or eliminate sources of POPs and mercury have been initiated by several countries including Canada. Continued initiatives through the United Nations and other international bodies are being pursued to research the toxicity and global transport of contaminants in the Arctic circumpolar regions.

### vi) What are the information gaps?

Information on PCBs, pesticides, polycyclic aromatic hydrocarbons (PAHs), dioxins and furans and heavy metals in sediments is very limited with exception of specific investigations on the Slave River at Fort Smith and the Liard River above Kotaneelee River. Long-term monitoring of river sediments and periodic collection of lake sediment core samples is required to better understand the fate of contaminants in the benthic environment.

### 3.2.5 Surface Water Quantity

#### i) What is being measured?

Stream flows have been measured at a number of locations in the Mackenzie River Basin since the early 1960s. Some stations have been monitored continuously since that time while others are monitored only during the ice free period. For the most part, flow monitoring is carried out by the Water Survey of Canada and by INAC.
Records of water usage are maintained by the GNWT and INAC.

#### ii) What is happening?

**Mackenzie Great Bear Sub-basin**: Flow at the mouth of the Mackenzie River averages approximately 9,000 cubic meters per second of which 60% originates from Great Slave Lake and 20% is provided by the Liard River. Great Bear Lake provides about 4% of the flow in the summer and 12% in the winter when flow in other tributaries is reduced. The historic record of flows in the Mackenzie River (see Figure 3.2-10), is seen to vary substantially from year to year over the forty period of record. Analysis of the flow record by the MRBB (2004) and others has indicated no significant trend in mean annual flows in the Mackenzie River.

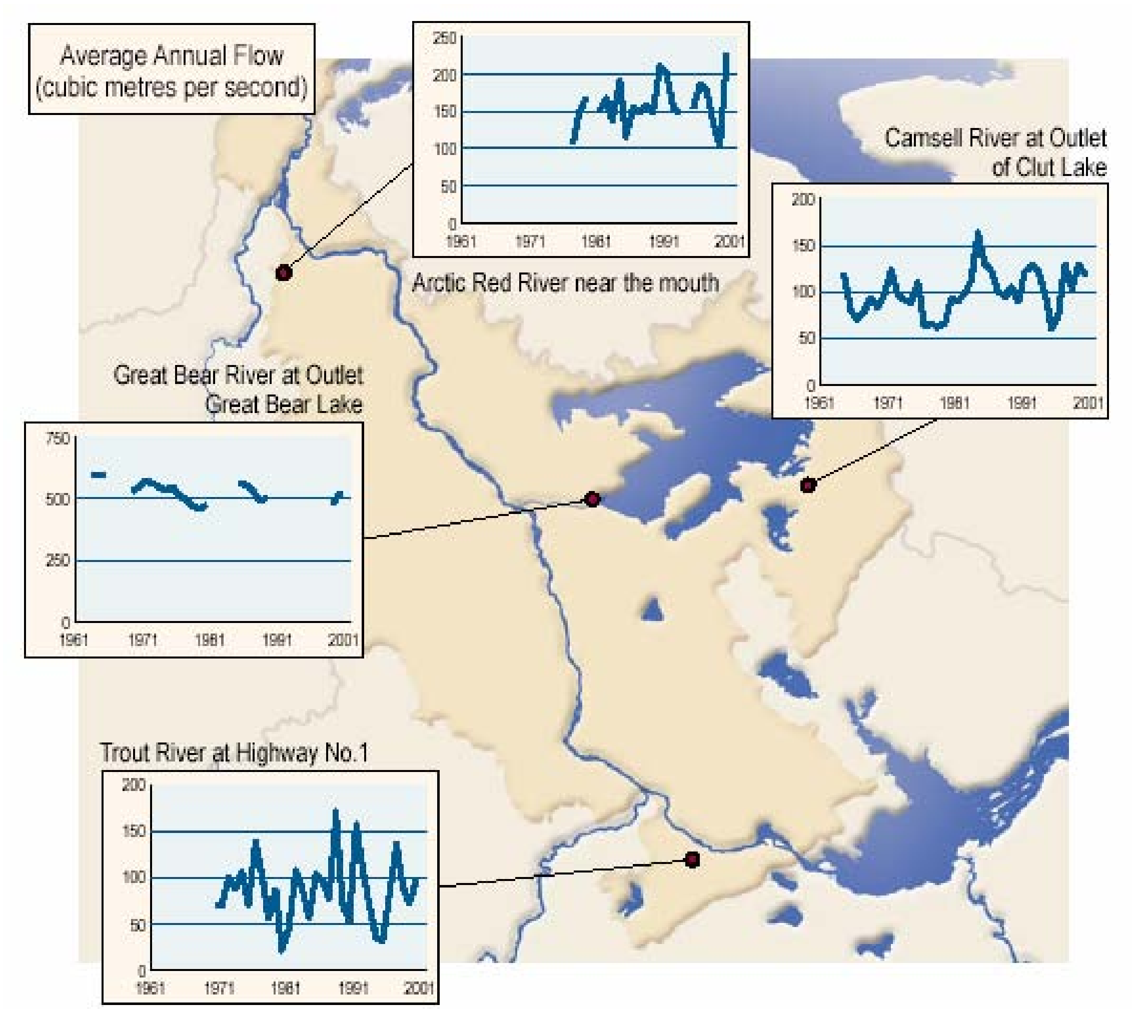
The annual hydrograph of Great Bear River presented on Figure 3.2-11 illustrates the effect of water storage in Great Bear Lake in attenuating variations in the outlet flow. The mean daily discharge rate only varies by about 100 cubic meters per second over the course of a year (MacDoanld *et al*. 2004). Excess water that flows into the basin during snow melt and rainfall events is stored in the lake. Figure 3.2-12 summarizes the long-term record of annual surface water levels measured on Great Bear Lake. The lowest levels were recorded in the 1940s and the highest during the mid 1950s. The data suggest a slight downward trend since the 1960s; however, this may simply reflect a natural cycle.

Water use by ten licenced communities and one licenced industry in the sub-basin in the year 2000 is shown on Figure 3.2-13. The total volume of water withdrawn in 2000 by the communities equalled 874,425 cubic meters and by the lone industry was 2.8 million cubic meters. The combined flow of all water users equalled an extremely small fraction of the flow in the Mackenzie River.

**Great Slave Sub-basin**: Flow in the Slave River has been found to be affected by the operation of the Bennett Dam some 1,500 kilometres upstream of Great Slave Lake (MRBB 2004). Average flows from May to October have been reduced by 20% while the average minimum winter flow has doubled. These effects are demonstrated on Figure 3.2-14.

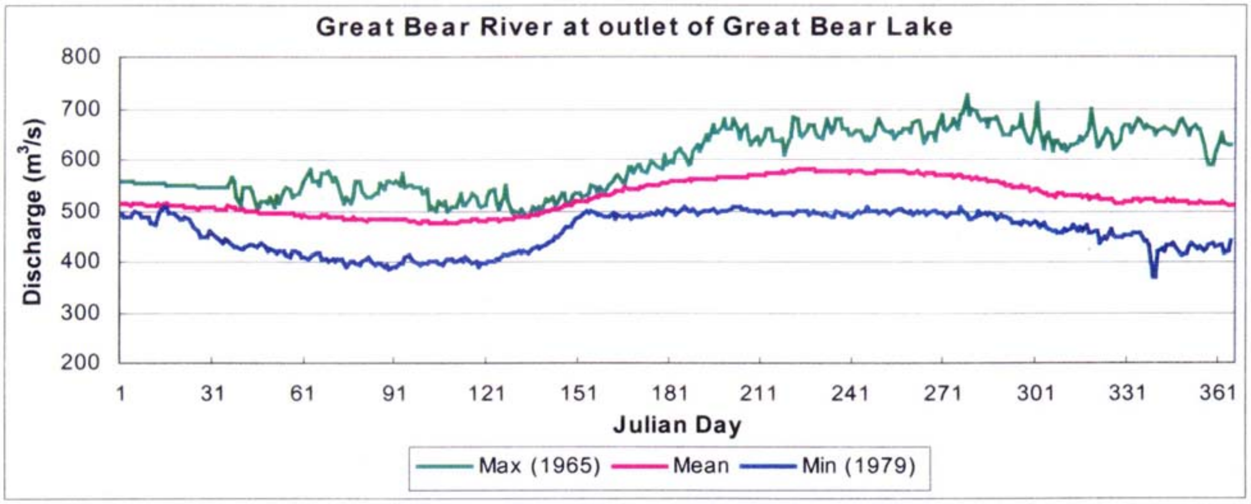
**Peel Sub-basin**: Flow in the Peel River is affected by snowmelt in the May or June period, particularly in the small headwater streams that originate on the Peel Plateau. Rainstorms can also result in dramatic increases in steam flow in the Peel River and its tributaries. Figure 3.2-15 presents the maximum flow record over the 1960 to 2000 period at the Canyon Creek station. The figure indicates that the high flows recorded between the mid 1960s and early 1980s have not been matched in recent years.

**FIGURE 3.2-10**
**AVERAGE ANNUAL FLOW IN FOUR TRIBUTARIES OF THE MACKENZIE GREAT BEAR BASIN**



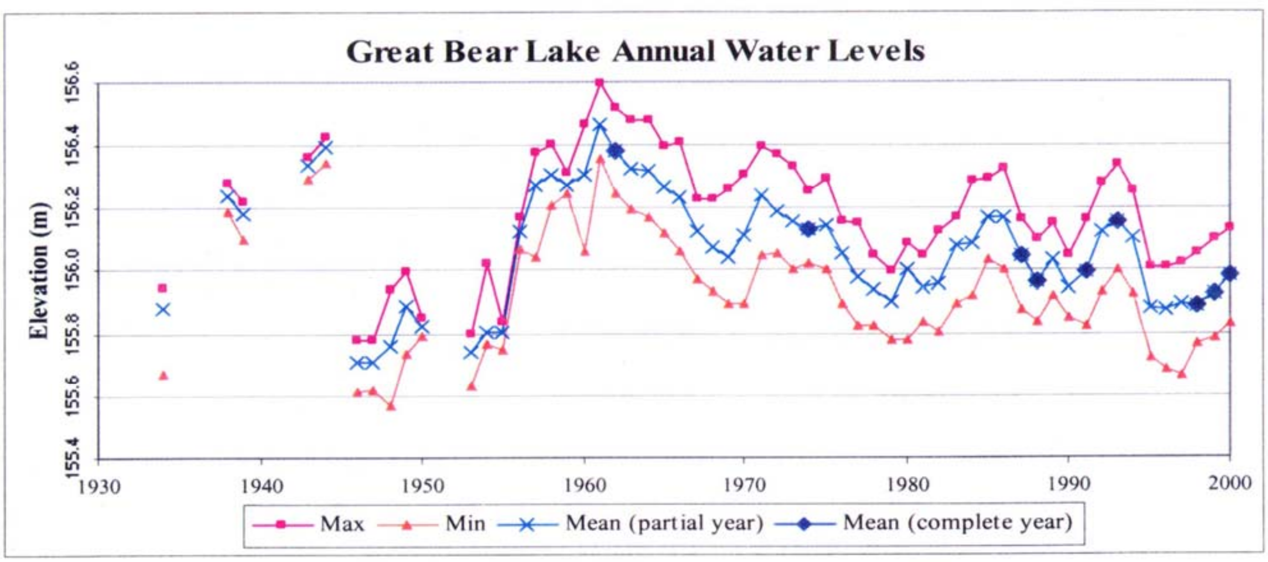

*Source: Mackenzie River Basin State of the Aquatic Ecosystem Report 2003. Mackenzie River Basin Board 2004.*

**FIGURE 3.2-11**
**ANNUAL HYDROGRAPH OF THE GREAT BEAR RIVER, 1961-1999 (KOKELJ 2001)**



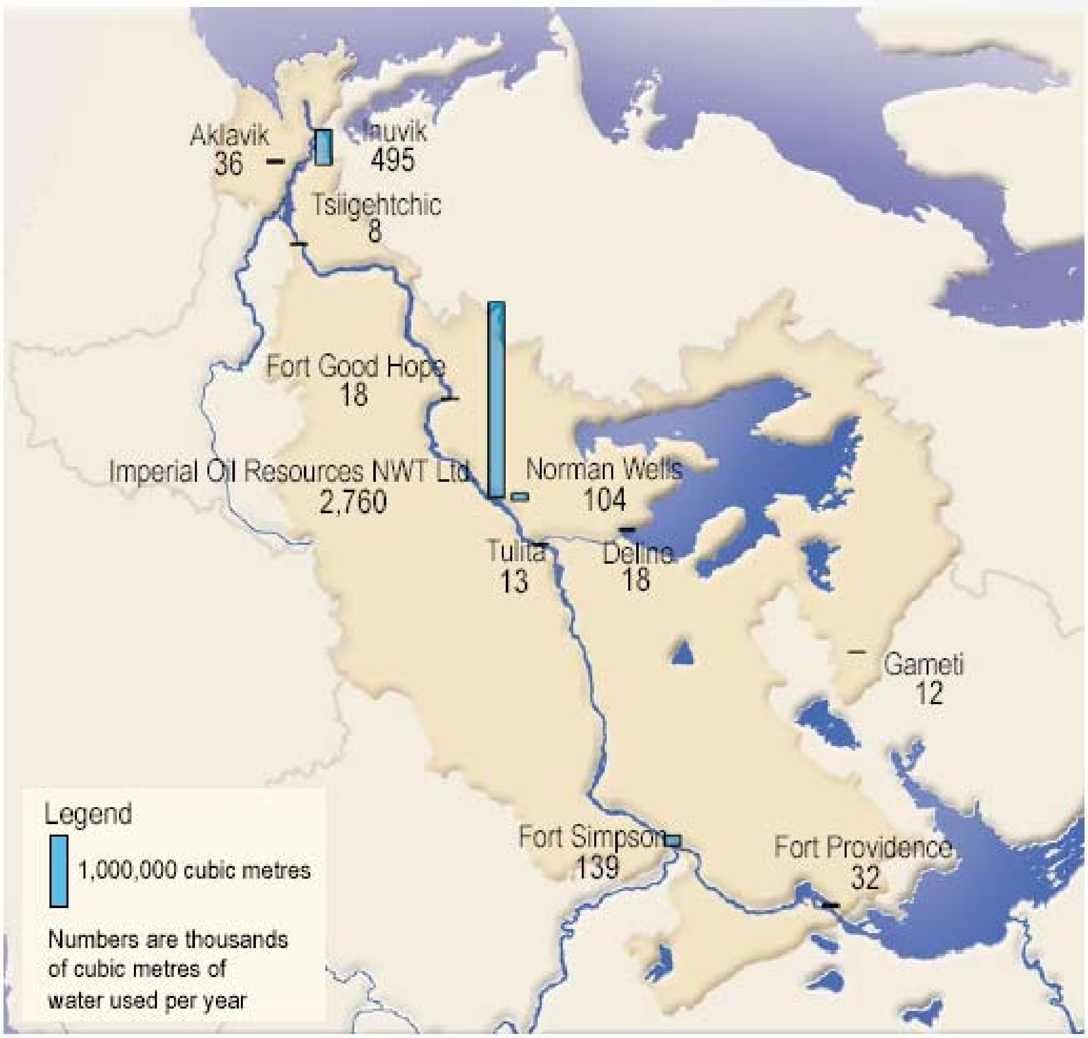

*Source: MacDonald et al. (2004).*

**FIGURE 3.2-12**
**ANNUAL SURFACE WATER LEVELS FOR GREAT BEAR LAKE, 1934-2000**



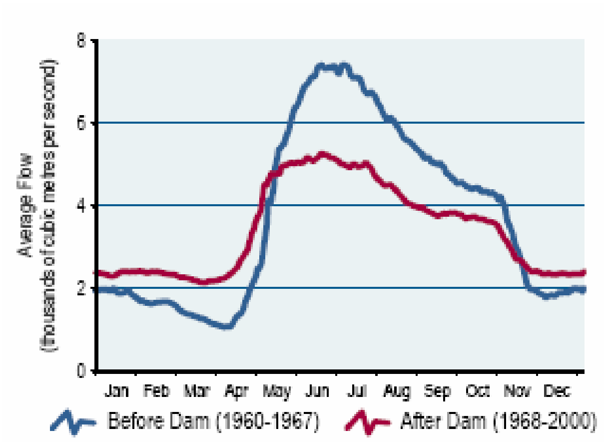

*Source: MacDonald et al. (2004).*

**FIGURE 3.2-13**
**INDUSTRIAL AND DOMESTIC WATER USE ALONG THE MACKENZIE RIVER SYSTEM**



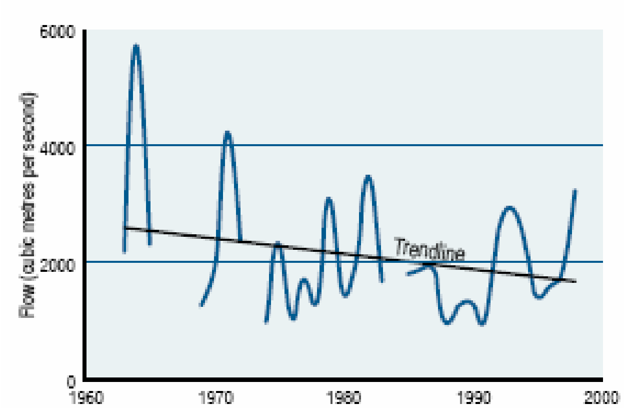

*Source: Mackenzie River Basin State of the Aquatic Ecosystem Report 2003. Mackenzie River Basin Board 2004.*

**FIGURE 3.2-14**
**AVERAGE FLOW IN SLAVE RIVER**




*Source: Mackenzie River Basin Board 2003.*

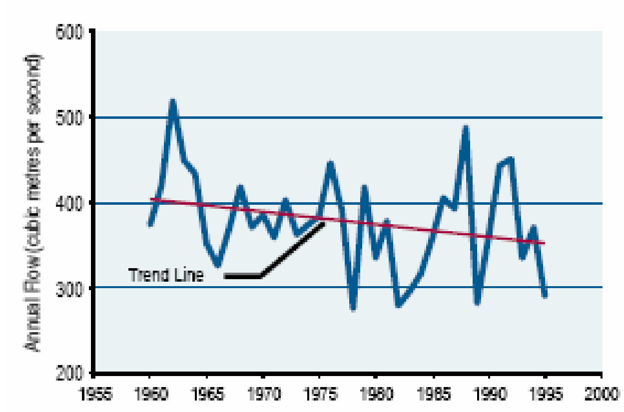
**FIGURE 3.4-15**
**HIGH FLOWS AT CANON CREEK STATION IN PEEL SUB-BASIN**




*Source: Mackenzie River Basin Board 2003.*

**Liard Sub-basin**: Flow is recorded on the Liard River at five-stream flow stations. Average annual flows measured at Upper Crossing (see Figure 3.2-16) were found to decline by 12.5% between 1960 and 1995 (MRBB 2004). Similar trends were reported at two other downstream flow monitoring stations.

**FIGURE 3.2-16**
**AVERAGE ANNUAL FLOWS ON LIARD RIVER AT UPPER CROSSING**




*Source: MacDonald Environmental Services Ltd. (2004).*

### iii) Why is it happening?

River flow is influenced by several factors including landscape features and climate change effects. The MRBB (2004) in its report suggests that the decline in flow in the Liard River may be related to a decrease in precipitation reported at monitoring stations in the study area. On the Peel sub-basin, it was speculated that warmer temperatures may have contributed to more frequent snow melts and thus a reduction in peak flows. On the Slave River, operation of the Bennett Dam has had a marked effect in reducing peak summer flows and augmenting winter time minimum flows. In contrast, a significant change in flow in the Mackenzie River has not been observed.

### iv) What does it mean?

Changes in river flow rates may affect habitat and populations of fish and other aquatic species. Reduced river flows may also affect shoreline erosion, channel scouring, and sediment deposition. These factors could have a significant effect on the formation of the Slave River Delta. It is not clear whether there would be any measurable impact on the Mackenzie River Delta. In all cases, the potential effects of climate change will require several years of additional monitoring to discern the extent of potential effects.

### v) What is being done about it?

Environment Canada and INAC continue to monitor climate and river flows throughout the region. Research is also continuing, examples being the Mackenzie GEWEX Study and the Canadian Climate Impacts and Scenarios project.

#### vi) What are the information gaps?

River flow monitoring data suggest that there may be a change in the average flow peak flows in some sub-basins however; there are no clearly defined trends. Continued flow monitoring together with monitoring of climate data will be required to better understand the effects of climate change on river flows in the NWT.

### 3.2.6 Ferry and Ice Bridge Seasons

Transportation routes in the NWT are dependent on ferry and ice bridge crossings on the Mackenzie River at five locations; Yellowknife Highway at Fort Providence, Mackenzie Highway at N'Dulee and Liard River, Dempster Highway at Tsiighetchic and Peel River.

#### i) What is measured?

The number of days each year that the crossings are open for ferry service and for winter road use are recorded.

#### ii) What is happening?

The number of days each year that ferries operated and the winter bridge crossing was open between 1990 and 2002 is shown on Figure 3.2-17. At the two southern crossings the number of days of ferry service increased and the ice bridge was at Fort Providence was open for fewer days. A similar consistent trend was not observed at the northern most crossing.

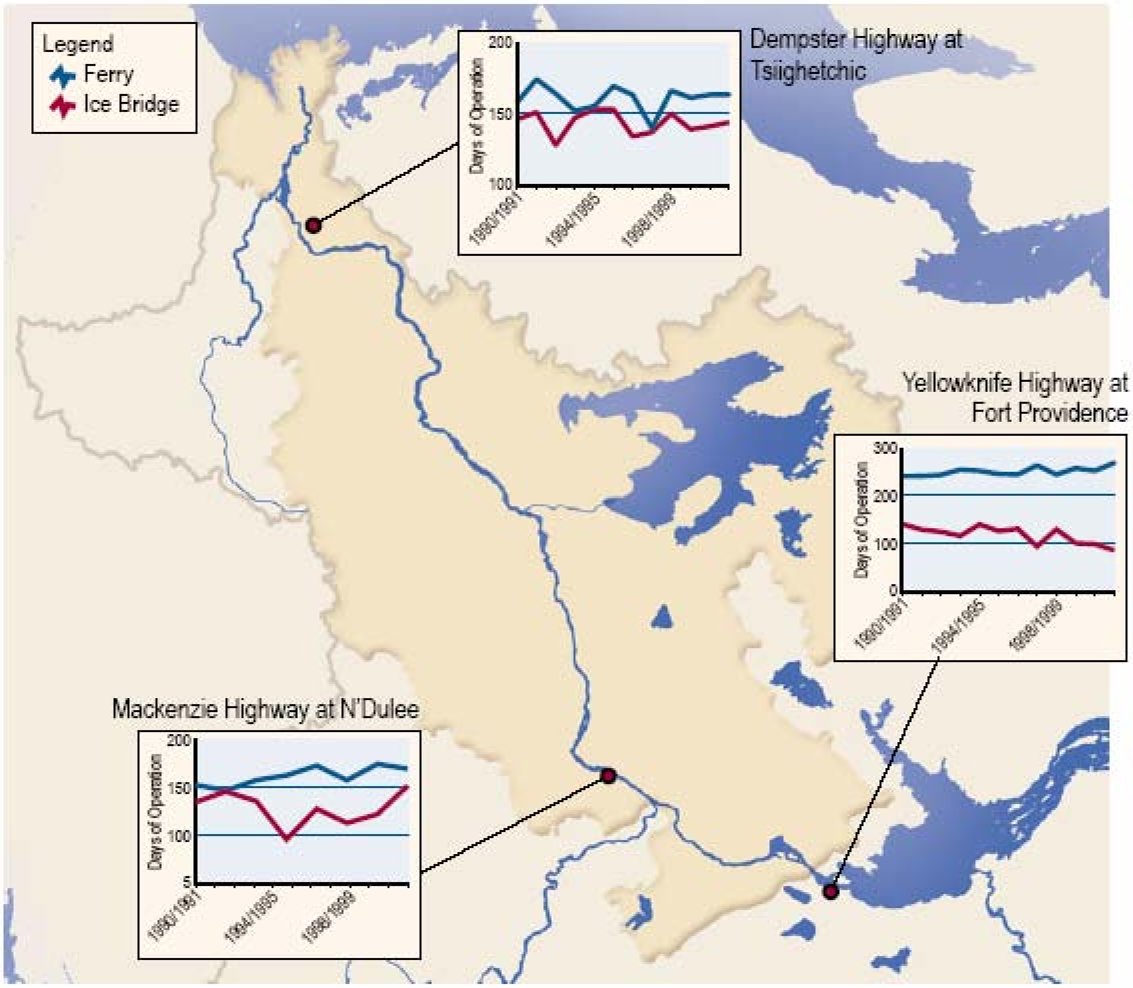
#### iii) Why is it happening?

Warmer temperatures in the southern part of the NWT is believed to be a factor contributing to the longer ferry operating season at Fort Providence. It is reported (MRBB 2004) that changes in technology and improvements in operating methods have enabled longer ferry and ice road operating seasons which may have offset some of the effects of climate change.

#### iv) What does it mean?

The transportation system at the Mackenzie River crossings has continued to operate efficiently with few interruptions despite the rise in air temperature that has been observed. Should temperatures continue to rise as many expect, than it is possible that ferry seasons will become longer. It is also anticipated that the frequency of interruptions in ferry service may increase due to more frequent ice jams and reductions in water flow.

**FIGURE 3.2-17**
**NUMBER OF DAYS EACH YEAR THAT FERRIES OPERATED AND THE WINTER BRIDGE CROSSING WAS OPEN BETWEEN 1990 AND 2002**




*Source: Mackenzie River Basin Board 2003.*

### v) What is being done about it?

The MRBB (2004) notes that the NWT Transportation Department is committed to ensuring that the three major river crossings remain open for as much of the year as possible. With the increased activity in the NWT, it is possible that a bridge may be built across the Mackenzie at Fort Providence.

### vi) What are the information gaps?

Ferry and ice bridge services are important components of the transportation network in the NWT. Continued monitoring of climate change, river flows, frequency and timing of ice jams and days of operation of the ferry and ice bridge operations will be important in determining effects of changing conditions on the viability of these services.

### 3.2.7 Overall Assessment

In 2000, the National Round Table on the Environment and the Economy, launched the Environment and Sustainable Development Indicator initiative to identify the assets necessary to sustain a dynamic economy and a healthy society and environment for Canadians. Fresh Water Quality is one of the six national-level environmental indicators that are to be used for reporting on an annual basis. This initiative gave rise to the development of a standardized Water Quality Index (WQI) protocol by the Canadian Council of the Ministers of the Environment (CCME) in 2001. The index compares measured water quality to CCME Canadian Environmental Quality Guidelines (CEQGs) and site-specific water quality objectives where appropriate. The WQI values range from 0 for poor water quality to 100 for excellent water quality. The water quality categories include Excellent, Good, Fair, Marginal and Poor.

The MRBB's State of the Aquatic Ecosystem Report (2004) compared water quality measurements from the Liard, Peel, Great Slave and Mackenzie-Great Bear sub-basins to CCME CWQGs. Guideline values were found to be frequently exceeded for water quality variables such as turbidity, total aluminium, copper, iron and zinc. It was noted that CCME guidelines for these contaminants were exceeded most often during high river flow conditions. As metals and other substances are usually bound to suspended solids (particles) during periods of high flow, they have a much reduced effect on aquatic plants and animals. It was concluded therefore that surface water quality in the Mackenzie River Basin was capable of supporting all the basin's native aquatic plants and animals (MRBB 2004). Also, they are effectively removed by sedimentation and filtration in drinking water supply treatment plants.

In addition to the above work, water quality data for several sites in the Mackenzie-Great Bear Sub-basin were evaluated against site-specific water quality objectives using several different protocols as recommended by the CCME Water Quality Index technical sub-committee (Sharma 2002, Halliwell 2004). Based on the results of the assessment using the background concentration technique, water quality in the basin was characterized as 'excellent' to 'fair' (Halliwell 2004). Water quality at all sites in terms of major ions (chloride, sulphate, fluoride, calcium and sodium) was categorized as excellent with no obvious increasing or decreasing trends. Due to the high suspended solids load carried in the Mackenzie River and its tributaries, trace metal concentrations frequently exceed guideline values for protection of aquatic life and the waters were categorized as marginal to poor.

In summary, water quality in the Mackenzie River and its tributaries largely reflects natural conditions. There are localized areas with elevated metals or nutrients attributable to wastewater discharges or industrial effluents but the effects are not obvious at the regional level due to the large flow carried by the Mackenzie River and its major tributaries. Stricter regulations and technological improvements have resulted in reductions in contaminant loads entering the environment and in improvements in receiving water quality (MRBB 2004). Current initiatives to remediate abandoned mine sites and former military sites in the NWT will also contribute to improvements in environmental quality near these sites. Similarly, the creation of monitoring oversight committees on new developments which involve Aboriginal people will help ensure that future impacts are minimized.

Continued water quantity and quality monitoring is required to measure the effects of climate change in the North. While flows in some tributaries have remained fairly constant, flows in other tributaries (e.g., the Liard River) have been seen to show a decreasing trend consistent with climate change model predictions. Other predicted changes include the timing of ice formation and break-up, loss of permafrost conditions in areas with discontinuous permafrost, frequency and intensity of peak precipitation events. All of these factors may affect not only water quantity but also water quality. In addition, water resource development projects, such as the W.A.C. Bennett hydroelectric dam on the Peace River, can have a significant effect on both flow and sediment loads. It is important therefore, that comprehensive flow and quality monitoring be carried out so that adaptive water management strategies can be formulated to take into account the potential effects on water resources in the NWT of all of these factors.

With the exception of some instances of elevated metals at a local scale (e.g., arsenic in Yellowknife Bay), the overerall condition and anticipated trends for sediment quality were found to be favourable based upon the information available. However, it was found that information on PCBs, pesticides, polycyclic aromatic hydrocarbons, dioxins and furans, and heavy metals in sediments is very limited with the exception of specific investigations on the Slave River at Fort Smith and the Liard River above Kotaneelee River. Long-term monitoring of river sediments and periodic collection of lake sediment core samples is required to better understand the fate of contaminants in the benthic environment.

## 3.3 ARCTIC FRESHWATER ECOLOGY

### 3.3.1 Monitoring and Research Activities

Freshwater research in Arctic Canada and much of what is known about freshwater ecology has been discovered from three programs (Welch 1996):

- The first was the Char Lake Program (1969-1973) at Resolute. Researchers described lake energy flows and trophic dynamics. Char Lake was representative of lakes with sedimentary rocks of the high Arctic Archipelago.
- The second was the Saquaqjuave (Saq) Program (1977-1983) on the northwest coast of Hudson Bay, near the hamlet of Chesterfield Inlet. The program focussed on whole-lake fertilization experiment (phosphorus and nitrogen). Saq lakes were representative of small lakes in the central barrens. P&N, Jade and Far lakes were exposure lakes, and Spring Lake was a reference lake.
- The third was the Lionel Johnson's Char and Lake Trout Program at Nauyak Lake, Kent Peninsula, and his work elsewhere in the arctic, which produced much of the information on arctic fish populations (Johnson 1980 and references within).

Smaller scale research work occurred at Keyhole Lake on Victoria Island, Lake Hazen and many others on Ellesmere Island, Sophia and Amituk lakes on Cornwallis Island, and Netiling and Ogac lakes on South Baffin. It is of note that comprehensive research on large to very large arctic lakes in Arctic Canada are missing. Lakes over 1,000 $km^2$ lying in the Northwest Territories (NWT) include Great Bear Lake (31,328 $km^2$), Great Slave Lake (28,568 $km^2$), Lac la Marte (1,776 $km^2$), and MacKay Lake (1,061 $km^2$).

NWT freshwater ecosystems provide a resource base for many people, including food and recreation for those who live both within and adjacent to the region (Gitay *et al.* 2001). These ecosystems are characterized by low water temperature and, in some cases remain frozen in summer (Anisimov and Fitzharris 2001). Polar freshwater systems are distinguished from temperate and tropical systems by the seasonal variation in incoming solar radiation with 24-hour sun in the summer to near complete darkness in the winter (Anisimov and Fitzharris 2001). This fluctuation results in large annual changes in biota and, in fact, the maximum daily radiation received in mid-summer by arctic lakes is greater than tropical lakes (Horne and Goldman 1994).

The Mackenzie Delta is the largest Delta in Canada and the second largest northern delta in the world (Marsh 1998). The Mackenzie Delta alone has 25,000 lakes. This bounty of lakes differs from temperate and tropical areas where deltas have marshes and swamps. Likewise, NWT lakes do not show the same organic material infilling that is characteristic of temperate and tropical lakes. Infilling changes result from the deposition of sediment in the lakes, the draining of lakes as the main river channels cut into the banks, the formation of deltas that divide larger lakes into smaller water bodies, the melting of permafrost immediately surrounding the lakes which results in enlargement of the lake and the creation of new lakes as channels are abandoned (Marsh 1998).

NWT channels and rivers also show constant water level change throughout the year due to freezing and thawing, not only because of changes in volume but also because ice slows water movement (Marsh 1998). Although ice jams can occur at both freeze-up and break-up and both times can result in partial blockage leading to very high water levels in the upstream areas, the break-up jams are typically the largest and therefore most important (Marsh 1998). Ice thickness is controlled by both air temperature (colder temperature means thicker ice) and snow cover (less snow depth means thicker ice). Lake ice in the NWT usually reaches 0.6-1.5 m thick and small shallow lakes may only reach depths of 1-2 m. Therefore, even small changes to depth may result in freezing of the entire water body (Marsh 1998).

Lakes actually receive very little snowmelt from the surrounding areas because most of the water is absorbed by the soil only to subsequently evaporate or transpire. Except under channels and lakes, much of the Mackenzie Delta, and the rest of the NWT, is underlain by permafrost. Loss of surface water to groundwater is usually very small because the lakes tend to be underlain with silts and clays that have low permeability (Marsh 1998).

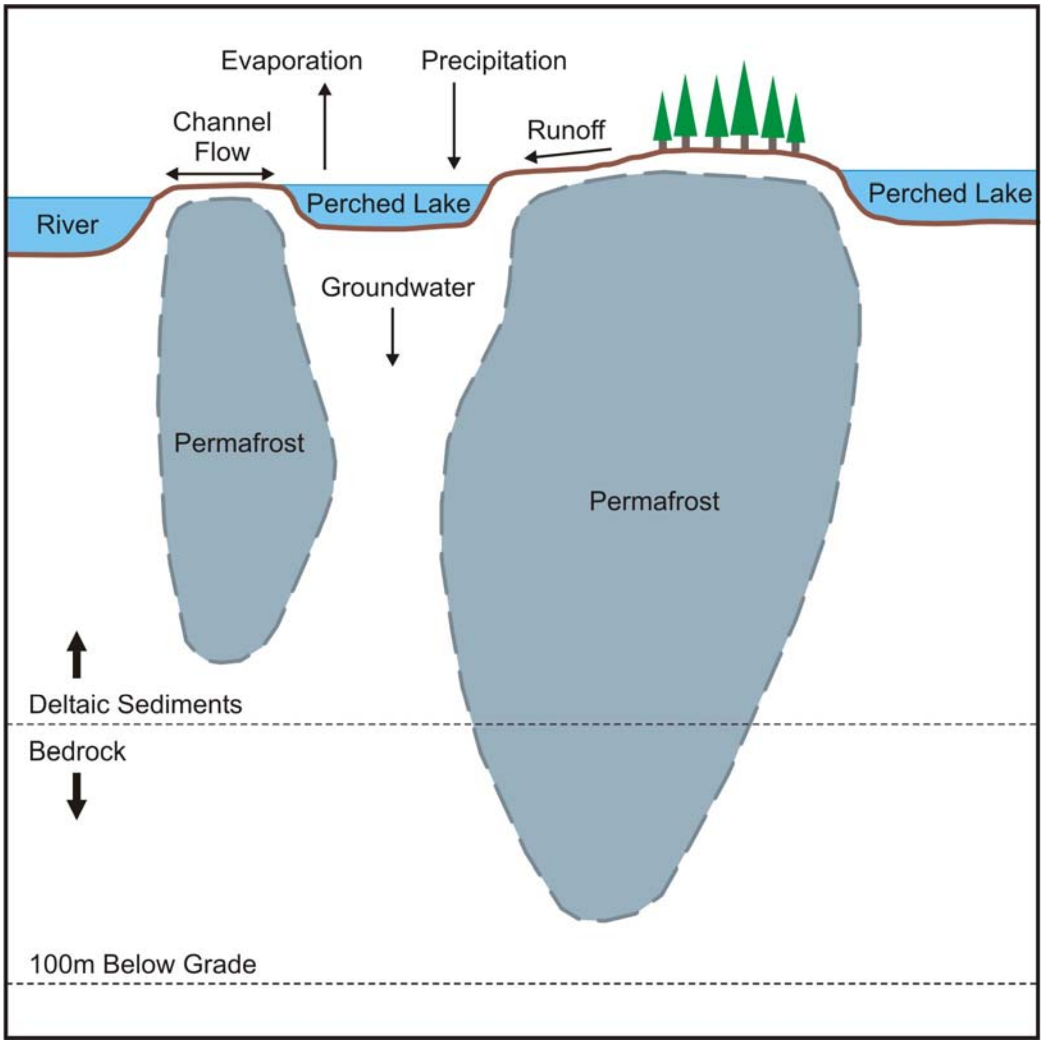
Typical of the Mackenzie Delta, perched lakes sit at elevations above river channels. Figure 3.3-1 is a diagram of the water cycle for perched lakes. The large grey areas represent the permafrost layer. These perched lakes require periodic flooding; typically from ice jamming. Usually this flooding occurs annually or at least every 2 to 5 years but on the highest lakes, it may only occur every 10 years (Marsh 1998).

Despite the permafrost and the long ice periods and snow cover, the Mackenzie Delta area is very productive biologically (Marsh 1998). NWT, and the Arctic/sub-Arctic in general, are home to a variety of highly distinct biomes, including many migratory species (Anisimov and Fitzharris 2001).

Summer primary production may actually be inhibited because of high levels of incoming solar radiation, which inhibits photosynthesis. This inhibition may not be compensated in some of the more shallow lakes. However, this loss of production may be compensated by benthic algal or moss growth (Hornes and Goldman 1994).

On-going threats to the northern environment include the extraction of oil and mineral resources, especially because of the associated disturbances caused by construction of roads and pipeline corridors. Changes in land use can lead to soil erosion, which threatens the availability of clean water (Macdonald *et al*. 2003). The entire NWT is being and has the potential to be further impacted by climate change, hydroelectric development, mining development and contamination at abandoned mine and former military sites (Marsh 1998).

**FIGURE 3.3-1**
**SIMPLE WATER CYCLE OF PERCHED LAKES**




*Source: Marsh 1998.*

### 3.3.2 Freshwater Stressors

Freshwater ecosystems in the NWT are sensitive to a wide range of anthropogenic and natural stressors. These stressors include:

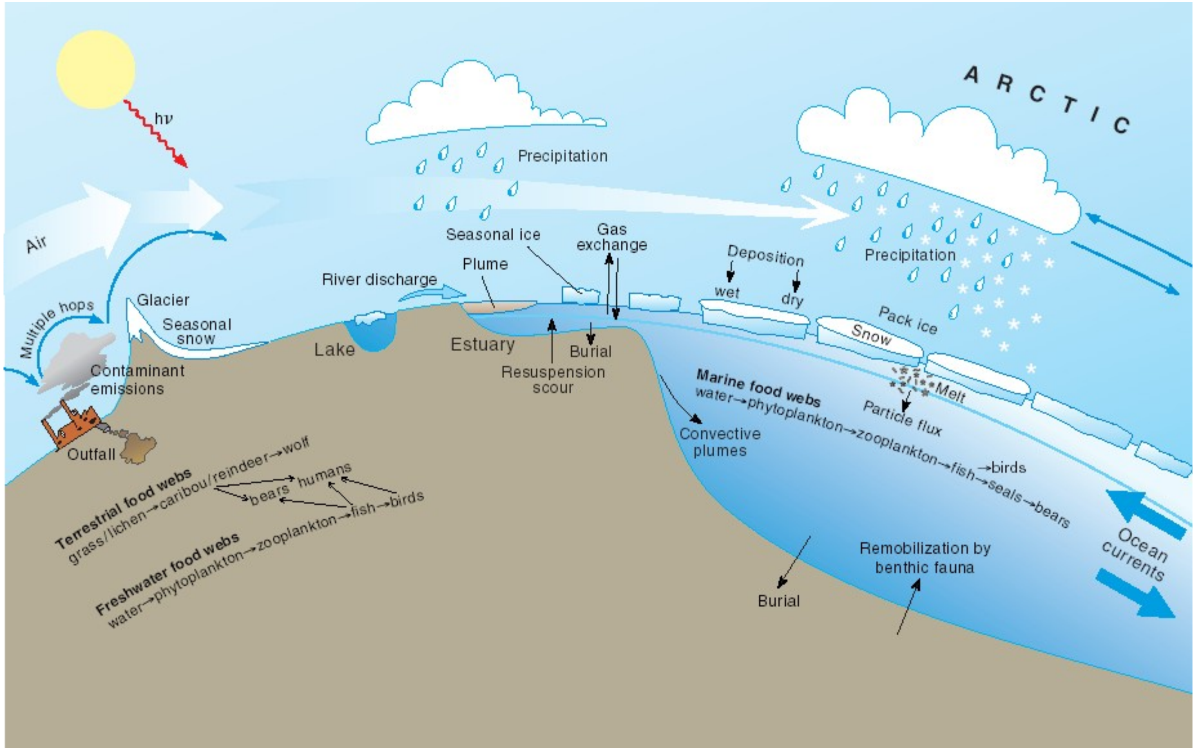
- Organic and Inorganic Contaminants;
- Harvesting;
- Habitat Disruption and Disturbance;
- Species Introduction;
- Climate Change.

### *3.3.2.1 Contaminants*

The term contaminant as used herein encompasses a host of organic and inorganic constituents, some of which occur naturally and others that are the product of human activity. These contaminants may be derived from local sources or originate in far away places. Local sources of contaminants include mine water discharges, sewage treatment plant effluents, forestry industry runoff, petroleum industry releases, surface and subsurface drainage from contaminated sites and other facilities as well as natural sources such as erosion of soils, weathering of exposed mineral veins and releases from forest fires. Many chemicals are also transported globally through atmospheric processes and subsequent deposition (MRBB 2004). The major sources of atmospheric contaminants to the NWT are countries other than Canada (INAC 2003). A simplified schematic of atmospheric transport and deposition processes and pathways of contaminant movement through the Arctic environment is presented on Figure 3.3-2.

Of most concern in recent times has been the effect of climate change on contaminants. The difficulty in understanding change results from the inability to detect trends because data collection is neither long nor comprehensive. Additionally, there is a lack of understanding of the linkages between easily understood changes like ice cover and those of greater complexity like ecological structure and function and the hydrological cycle (Macdonald *et al.* 2003). It is agreed that there will be surprises and that some of the most significant changes are likely to be lurking in the subtle and non-intuitive linkages that exist between global and regional pathways; particularly for contaminants. In this regard, the potential exists for surprising changes to occur in the complex processes of bioaccumulation and biomagnification (Macdonald *et al.* 2003).

**FIGURE 3.3-2**
**SIMPLIFIED PATHWAY OF CONTAMINANT TRANSPORT**
**IN THE ARCTIC ENVIRONMENT**




*Source: AMAP 2002.*

### *3.3.2.2 Harvesting*

Fishing, whether for commercial, sport or subsistence (traditional) purposes, is an important source of household food and income for residents of the NWT (NWT Biodiversity Team 2004). Fishing is also an activity with important cultural and social connections to the land, particularly for the aboriginal inhabitants of the NWT (NWT RWED 2000). In the past, much of the catch was used as food for dog teams (NWT RWED 2000, MRBB 2004). In general, population numbers, trends and catch rates have only been sporadically investigated for both commercial and sport fisheries (MRBB 2004), except on Great Slave and Great Bear lakes.

While most fish populations and stocks remain healthy because of the low human population density over the landscape, local overexploitation has occurred in some areas. This has resulted in community based management plans that use both traditional and scientific knowledge so that harvesting can be balanced with community needs (NWT RWED 2000). Management plans also aim to sustain stocks so that they can balance competing harvest from subsistence, sport and commercial fishing. However, at least on Great Slave Lake, while the sport fishing pressure has increased, commercial fishing is actually declining (MRBB 2004). Within the NWT, user groups and management boards have been established to make recommendations regarding the harvest of fish species in particular areas. For example, the Great Bear Lake Watershed Working Group and the Great Slave Lake Advisory Committee work to assess fishery activities on the respective lakes and make recommendations to the federal Department of Fisheries and Oceans (DFO) regarding user allocations and allowable catch levels. DFO also develops management plans for some stocks (NWT Biodiversity Team 2004).

The only large-scale commercial fishery in the NWT is the year-round fishery on Great Slave Lake that has been active since the 1940s. This fishery provides primarily whitefish, lake trout (*Salvelinus namaycush)* and northern pike (*Esox lucius)* to the local and U.S. markets at levels that are below the total allowable catch for the lake. Other commercial fishing operations occur in Kakisa Lake and the Mackenzie Delta (NWT Biodiversity Team 2004). Sport fishing lodges and outfitters are located throughout the NWT to service the demand, including that from other parts of Canada and elsewhere.

#### *3.3.2.3 Habitat Disruption and Disturbance*

In more southern environments, habitat change and exotic species introductions have caused the most damage to wild native species with subsequent impact on the economy (NWT Biodiversity Team 2004, MRBB 2004). Fish species that already have limited habitat will always be most susceptible to habitat changes (NWT Biodiversity Team 2004).

The Great Bear Lake Watershed Working Group, composed of representatives from the local community and aboriginal groups, a non-government organization and the federal and terrestrial governments, is working with the goal that "Great Bear Lake must be kept clean and bountiful for all time." To this end, the group has developed a management framework and is working on management plans for the lake. On a regional scale, environmental agreements are signed between governments and proponents to set out specific environmental protection responsibilities for specific projects such as that for the diamond industry (NWT Biodiversity Team 2004).

Factors that contribute to habitat disruption and disturbance include natural and semi-natural events. Natural events may include increased wave action on lakes, which would increase the potential for significant shoreline erosion and sediment release into the water column. Semi-natural events include factors such as climate change, which is likely to result in changes in ice thickness, snowfall cover depth, permafrost conditions and river and lake water levels. In addition, anthropogenic factors that contribute to land use changes include mining and hydroelectric developments, land clearing and so on. In mining where earth works are built in water bodies to contain tailings (i.e., the gangue material left after removal of valued minerals) or other mining activities alter water bodies, fish compensation plans are implemented with the objective of achieving no-net loss of fish habitat.

#### *3.3.2.4 Species Introduction*

Species introduction may prove to be one of the most damaging stressors to native species and communities. The scientific communities' ability to estimate the risk that exotic species pose to freshwater systems is hampered by the lack of knowledge of the damage that they may have on the northern ecosystem (NWT Biodiversity Team 2004). As such, governments and stakeholders must work together closely in order to assess the risks versus the benefits of such actions.

Current Canadian legislation provides a list of species that must be prevented from entering Canada. However, this style of reactive legislation requires prior knowledge of the species entry as well as potential for damage to the receiving ecosystem. The *NWT Wildlife Act* provides some measure of protection against species introduction by requiring that the importation of wildlife first be permitted. With respect to the NWT freshwater systems, legal introduction of fish has included rainbow trout (*Oncorhynchus mykiss)* and brook trout (*Salvelinus fontinalis)*. However, this type of introduction is no longer permitted (NWT Biodiversity Team 2004).

While new vertebrate populations are often detected soon after introduction, detection of alien invertebrates or smaller life forms is difficult. Lack of information in the NWT on freshwater systems is an issue (NWT Biodiversity Team 2004).

Pathways of introduction include the pet industry, road and ship travel, road maintenance, land clearing, land restoration, farming and importation. However, the NWT does not have an international shipping port, and this eliminates a major means of introducing foreign species. Other tools that can be used to block the importation of foreign species include education, inter-jurisdictional cooperation, monitoring for species and preventative policies and legislation (NWT Biodiversity Team 2004).

#### *3.3.2.5 Climate Change*

The NWT hydrological system is particularly sensitive to climate change because of the dominance of frozen water, ice, snow, glaciers and permafrost, in controlling and influencing the water cycle. Changes in temperature and precipitation will ultimately combine to change the hydrological cycle of the NWT (Anisimov and Fitzharris 2001).

Physical changes will occur as a result of climate change, which will affect the warming or cooling across the freezing threshold (Anisimov and Fitzharris 2001). However, physical changes due to warming are still somewhat speculative and effects may offset each other.

An earlier transition from winter to spring and more water storage capacity as permafrost is lost is expected and this is anticipated to result in a more drawn out melt with less intense runoff resulting in less seasonal fluctuation in flow (Anisimov and Fitzharris 2001). It is expected that with warming, more precipitation will be delivered as rain resulting in flattening of the seasonal flow cycle and an increase in winter flow under ice (Anisimov and Fitzharris 2001). A decrease in ice jams may cause problems in perched lakes that rely on seasonal high floods to receive water (Anisimov and Fitzharris 2001). However, warming may also result in a shortened snowmelt that results in flooding followed by drought in the later growing season and this will be reinforced by land use changes including forest harvesting (Gitay *et al.* 2001) and, rivers may also become more prone to ice jams potentially resulting in larger flood peaks (Anisimov and Fitzharris 2001). Finally, it is also expected that evaporation and transpiration will increase and thus likely result in a reduction in the ponded water and runoff (Anisimov and Fitzharris 2001).

Loss of permafrost will allow for water exchange between surface water and groundwater that was once blocked by the permafrost layer and this new exchange could lead to drainage of smaller ponds. This same loss of permafrost may also lead to the formation of new wetlands or ponds, even drainage systems through thermokarst development (Anisimov and Fitzharris 2001). Thermokarst results from the melting of permafrost that subsequently collapses forming mounds, pits, troughs and depressions that may fill with water (Gitay *et al*. 2001).

Warming is generally expected to result in shifts in geographic distribution of freshwater biota and the potential to affect the freshwater food chain (Macdonald *et al*. 2003). Climatic warming of 4-10ºC, as predicted by the end of the century, is likely to lead to increases in decomposition, nutrient release and primary production (Gitay *et al*. 2001). Although microbial decomposition will be enhanced with increases in water temperature, species such as Arctic grayling (*Thymallus arcticus)* and trout will not benefit. Similarly, changes in water level will affect any fish that depend on small refugia in the winter or freshwater coastal corridors (Macdonald *et al*. 2003).

Changes in snow and ice cover will result in changes to the light and nutrient availability of freshwater systems (Macdonald *et al.* 2003). Total productivity should increase with an increase in the ice-free season, thinner ice cover and warmer overall water temperatures (Anisimov and Fitzharris 2001). The shortened ice season may result in thinner ice cover allowing for more under-ice productivity from increased solar radiation penetration and less ice jamming (Anisimov and Fitzharris 2001). This may be further enhanced by increases in available organic matter and nutrients that will drain from the more biologically productive terrestrial system and the thawed permafrost layer (Anisimov and Fitzharris 2001, Macdonald *et al*. 2003) and because less ice cover will allow for greater mixing of relatively nutrient rich runoff during freshet (Macdonald *et al*. 2003).

An increase in under-ice productivity due to the decrease in ice thickness will result in an increase in oxygen production and decrease in the potential for winter fish kills. However, the depth of mixing and lower oxygen concentrations that will result from the longer ice-free season may stress coldwater organisms (Anisimov and Fitzharris 2001).

From the human perspective, it will not be the overall change in temperature that will cause the greatest impacts but the change in seasonal timing. The greatest warming has occurred in January and July. Between 1846 and 1995 there was a mean delay of 5.8 days and 6.5 days per century respectively for freeze-up and break-up of ice, implying a 1.2ºC temperature increase per century (Macdonald *et al*. 2003).

In the NWT, longer ice-free seasons are likely to result in increases to shipping, tourism, oil and gas exploration and other industrial activities that bring the potential for associated contamination and the introduction of exotic and pest species and diseases. It is also possible that warmer temperatures will result in increased agriculture, which will bring associated issues such as potential soil erosion, increased water use and pesticide, herbicide and fertilizer use. It is also possible that warmer temperatures will result in demographic shifts such that the population increases resulting in increased demand on the local environment and associated local contaminant release from power use, fuel consumption, and sewage production (Macdonald *et al*. 2003).

### 3.3.3 Freshwater Environmental (FE) Indicators

Freshwater fishes total 48 species in the NWT, and a good number of them offer a potential for monitoring trends and cumulative impacts on the freshwater environment. Some fish species such as non-anadromous Arctic char, Dolly Varden (*Salvelinus malma),* inconnu (*Stenodus leucichthys),* or the strictly freshwater Arctic grayling, bull trout (*Salvelinus confluentus),* burbot, lake trout, northern pike, walleye and whitefish can be monitored for a variety of stressors. It can be argued that such freshwater “resident” fishes are more appropriate species for monitoring changes in the environment than the “migrating” or anadromous fishes such as the sea-run Arctic char, Dolly Varden or inconnu, which have a more complex life-history period in the sea and therefore incorporate a “marine environment” component into their physiology and growth patterns.

Freshwater "resident" fishes positioned high in the food web are particularly sensitive to environmental changes, accumulation of contaminants, and overexploitation due to localized fishing pressure. The large, exclusively freshwater fishes are an important source of fish food to humans year round and are prized sport fish.

The report prepared for the NWT CIMP and Audit Working Group by INAC (2004) entitled "*A Preliminary State of Knowledge of Valued Components*" identified Fish Habitat, Fish Population, Fish Harvest, and Fish Quality as Valued Components (VCs). The report also identified several potential indicators that could be utilized to measure changes and trends over time due to environmental stresses. Table 3.3-1 lists those indicators that are believed to be potentially most useful and the rationale for their selection.

Table 3.3-2 provides a qualitative overview of the availability of data to define baseline conditions. To date, the data collected is limited to fish habitat, harvest, and management issues (including contaminant levels in fish) that are of importance to humans. Such information is available for Great Slave Lake and Great Bear Lake, and some inland lakes in the upper Mackenzie River system and northern Mackenzie River. However, as such data are not available on a representative number of waterbodies, from small creeks to large lakes, and on several sub-watersheds throughout the NWT, it is not feasible to establish baseline conditions, evaluate the status of the fish Valued Components (VCs), assess cumulative impacts other than in general terms, or analyze data for trends, except on harvest tonnages on a local and regional basis.

**TABLE 3.3-1**
**POTENTIAL FRESHWATER ENVIRONMENTAL QUALITY INDICATORS AND RATIONALE FOR SELECTION**

| VC | Indicators | Rationale |
|---|---|---|
| | **Fish Habitat, Population and Harvest** | |
| Fish Habitat | • Aquatic habitat structure and quality<br>• Spawning, rearing and over-wintering locations | • Key determinant of Arctic freshwater processes at all ecosystem levels<br>• Sensitive to climate change, incl. wetlands and lakes drained, increased erosion/siltation and increased landslides frequency associated with melting permafrost; measurable over NWT by satellite<br>• Duration of waters and extent of ice cover; measurable over NWT by satellite<br>• Important determinant of harvesting, transportation, and development activities |
| Fish Population | • Distribution and abundance | • Low to mid-level consumer, eats invertebrates and smaller fish and is eaten by birds and mammals<br>• Widely distributed over the landscape<br>• Vulnerable to environmental changes and fish species invasions |

**TABLE 3.3-1 (Cont'd)**
**POTENTIAL FRESHWATER ENVIRONMENTAL QUALITY INDICATORS AND RATIONALE FOR SELECTION**

| VC | Indicators | Rationale |
|---|---|---|
| **Fish Habitat, Population and Harvest** | | |
| Fish Harvest | • Population size and age/size distribution of fish stocks<br>• Fish condition (including maturity and fecundity) | • Low to mid-level consumer, eats invertebrates and smaller fish and is eaten by humans<br>• Widely distributed over the landscape<br>• Important traditional food source for residents and supports economically important commercial and sport fisheries<br>• Vulnerable to over-exploitation<br>• Population dynamics and fish condition monitored<br>• Vulnerable to environmental changes and fish species invasions |
| **Fish Quality** | | |
| Fish Quality | • Contaminant levels<br>• Diseases and parasites | • Low to mid-level consumer, eats invertebrates and smaller fish and is eaten by birds, mammals, and humans<br>• Widely distributed over the landscape<br>• Important traditional food source for residents and supports economically important commercial and sport fisheries<br>• Contaminant levels, and diseases and parasites monitored |

**TABLE 3.3-2**
**QUALITATIVE ASSESSMENT OF THE AVAILABILITY OF DATA TO DEFINE BASELINE CONDITIONS IN THE NWT**

| Valued Component | | Data Available | | | |
|---|---|---|---|---|---|
| | | Poor | Moderate | Fair | Excellent |
| Fish Presence: | Habitat | √ | | | |
| | Population | √ | | | |
| | Harvest | | √ | √ | √ |
| | | | | | |
| Fish Quality: | Contaminant levels | | | √ | |
| | Diseases & Parasites | √ | | | |

Note: For Great Slave and Great Bear lakes, data available are from fair to excellent.

#### *3.3.3.1 FE Indicator – Fish Habitat*

The NWT offers a diversity of aquatic habitats that support a variety of aquatic flora and fauna. The habitats include headwater streams originating high in the mountains on the western flank, numerous small and large rivers (including the Mackenzie River), numerous small lakes, two very large water bodies (Great Bear and Great Slave lakes), extensive wetlands and deltas (including the Mackenzie Delta) and finally the Beaufort Sea. Each of these habitats supports many species that rely on the aquatic environment. The status of these ecosystems and habitats may be affected by a range of factors including changes in land use, industrial developments, construction of pipeline and transportation corridors, long-range transport of contaminants and climate change.

**i) What is being measured?**

Habitat investigations in the NWT have generally been restricted to project or site specific endeavours including:

- Habitats assessments completed when housing, residential/commercial, transportation, mining, gas pipeline or industrial developments are being proposed.
- Habitat data compiled along with fish stock and harvest evaluations for Great Slave and Great Bear lakes and their tributaries.

Detailed descriptions on aspects relating to fish spawning, rearing, and overwintering areas are not generally available, unless there is a good reason to obtain it. Such information often relies first on local knowledge, then is substantiated with radio-telemetry data of adults, trap netting, examination and release of adults, and the collection of eggs and the capture of fish larvae and/or young-of-the-year on spawning and nursery areas. A second approach adopted by governments has been to define local potential spawning areas of fishes, along with some data indicating the relevance of these areas for fishes. Investigational work is needed to compile and review this material.

Climate change studies such as the Mackenzie GEWEX Study (MAGS 2005) relate to fish habitat by monitoring and developing an understanding of how climate variability and change affect the atmosphere and hydrological system of the Mackenzie River Basin.

In the Liard River system, a downward trend in annual stream flow has been observed from 1960 to 1995. The Liard mountain areas are prone to landslides due to heavy summer precipitation, melting permafrost, and deforestation (MRBB 2004). Changes in stream flow and landslides can have major effects on fish and fish habitat. In the Peel River, annual maximum stream flow measured at Canyon Creek has decreased, and much of the watershed has been warmer than usual in recent years (MRBB 2004). As a result, changes in river channels and plant succession would ultimately affect invertebrates and fish. In the Great Slave basin from 1964, peak spring freshet flows have occurred two days earlier per decade on the Hay River. In addition since 1953, the annual Slave River peak flow has occurred on average six days earlier per decade (MRBB 2004). Fish migration, spawning and other key activities, often timed around peak discharge rates, may be initiated earlier, with consequences that are unknown at this time. In the Mackenzie-Great Bear basin, flow has varied greatly from year-to-year and thus no consistent trends have been observed.

**ii) What is happening?**

Climate change is expected to directly and indirectly affect fish habitat and its biodiversity. These effects will be gradually induced as a result of physical and chemical changes. Increasing water temperature and precipitation, thawing of permafrost, reductions in durations and thickness of lake and river ice, increases in water infiltration in soils, changes in the timing and intensity of runoff, and increases in the amounts of contaminants, nutrients, and sediments are all predicted to occur (ACIA 2004).

**iii) Why is it happening?**

Changes in hydrological conditions due to climate warming are expected to affect freshwater habitats. Consequences of climate warming induced changes to aquatic ecosystems are being observed and documented by the Mackenzie GEWEX Study (MAGS 2005). These changes have yet to be correlated with changes in life-histories and population dynamics in fishes.

**iv) What does it mean?**

Increases in water temperature, thawing permafrost, ice cover changes on rivers and lakes, and increasing levels of contaminants, are some examples of changes that will affect fish habitat. Less than optimum thermal conditions may significantly reduce the ranges of some arctic freshwater fishes, including broad whitefish (*Coregonus nasus),* Arctic char, and Arctic cisco.

With rising temperature and permafrost thawing, drainage from lakes and rivers into groundwater is expected to occur with the consequence that fish habitat may be eliminated in some areas. On the other hand, collapsing of the earth surface will create depressions where new wetlands and water bodies may develop and add new fish habitat to other areas. Major shifts in the landscape may occur along with fish habitat and fish species.

Changes in the timing of ice break-up will affect water temperatures, dissolved oxygen levels, nutrient supplies, sediment loads, and water levels. A change in any of these physical and chemical attributes has the potential to alter the freshwater species composition. A longer ice-free period may also increase evaporation, and lower water levels, however, this effect may be countered by in increase precipitation. Low flows and flood patterns will modify the sediment loads carried by streams and rivers. All of these environmental changes will be reflected by changes in the species composition of freshwater ecosystems (ACIA 2004).

Climate warming is anticipated to increase the rate of contaminant transfer to the Arctic. An increase in atmospheric moisture and precipitation will increase the levels of mercury and persistent organic pollutants (POPs) that are deposited in NWT. With rising temperature, ice and permafrost will melt, mobilizing contaminants. An increase in contaminant levels in arctic lakes can be expected to translate into higher levels in fish, and episodes of high levels of contaminants in watercourses may have lethal effects on aquatic life (ACIA 2004).

**v) What is being done about it?**

Fish habitats have been and will continue to be assessed on a need / regular basis at new and proposed project sites. To monitor flow and climate, Environment Canada will continue the Mackenzie GEWEX Study (MAGS 2005), and important supporting data will be generated through this program to understand fish habitat changes.

**vi) What are the information gaps?**

Aside from fish habitat assessments near residential, transportation, and industrial sites, fish habitat information is not commonly collected in the NWT. Within government agencies with objectives to protect and enhance aquatic ecosystems, there has been no consolidation of programs or data, which would allow for an assessment of parameters as indicators of well-functioning aquatic ecosystems over time. As a result, it is not possible to assess changes in fish habitat status. Information on fish habitats and indicators for Great Slave and Great Bear lakes may require some attention to become readily available, and may need to be augmented. Such information for the whole of NWT would be prohibitive and is not considered a gap in the baseline data.

<u>Fish habitat data (spawning, rearing, and overwintering):</u> Effort should be made to compile this data on various fish habitats for the Great Slave and Great Bear lakes, as it relates to the fish harvest data. This data should reach a level of detail that would be useful for future comparisons.

<u>Monitoring of physical changes to habitat, which might result from natural occurrence as bank slumping or from industrial activity:</u> Archiving of high-resolution satellite images of NWT would allow future comparison of changes in the physical environment that could potentially

affect freshwater habitat. This would be of particular importance in the future if habitat changes due to bank slumping over (major) fish spawning areas are found to occur and affect fish population parameters, such as year-class strength and harvest. Targeted areas for investigations should include Great Slave and Great Bear lakes, and possibly areas such as in the upper Mackenzie River system and the northern Mackenzie River regions.

#### *3.3.3.2 FE Indicator – Fish Population*

Within the NWT, 48 fish species, primarily freshwater, inhabit the Mackenzie River system and countless lakes. In general, there is “little” information on these species and their populations or stocks (RWED 2000, CIMP 2005). In particular, fish species other than commercially harvested species have not received much attention, and these account for approximately 36 species of the total of 48 species. For the harvested fish species, data are available on stock status in Great Slave and Great Bear lakes and the upper Mackenzie and northern Mackenzie regions (DFO Science Stock Status Reports), as discussed in a subsequent section.

Fish distribution data along with habitat preferences, physiology and ecology are most useful to study effects from changes in environmental factors and climate on fishes. Such data are generally not reported in the NWT. As well, information on their basic life history patterns is also missing (RWED 2000).

**i) What is being measured?**

Studies available on the biology of various fish species, populations and stocks include:

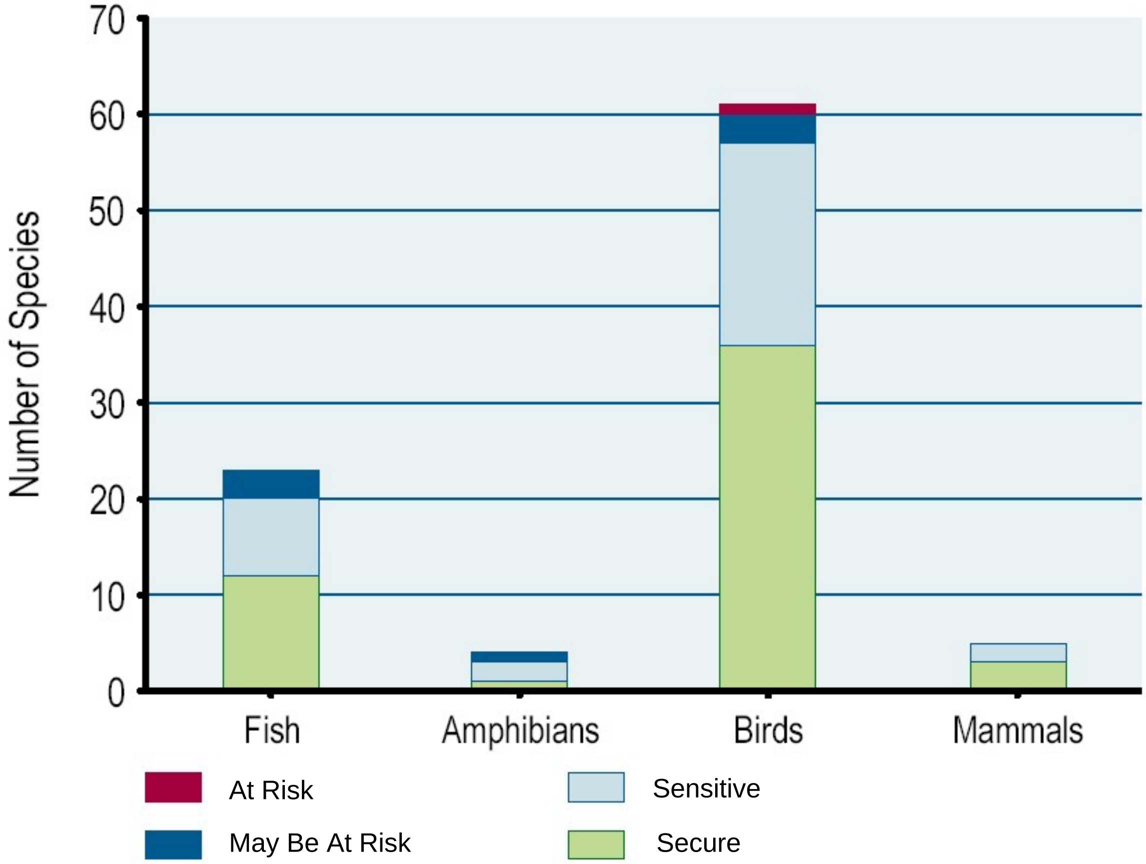
- Some 1970’s fish surveys from the Mackenzie Valley Impact Study Reports (DFO 1970-79), which data need to be up-dated;
- The range extension of bull trout in Liard and Mackenzie River basins, with notes on identification and distribution of Dolly Varden in the western Canadian Arctic (Reist et al. 2002);
- The General Status Ranks of Wild Species, which have been assigned to a number of freshwater fish species (RWED 2000). One of four ranks was provided: “at risk”, “may be at risk”, “sensitive” or “secure”. In some fishes, the problem with current status was related to lack of information;
- The stock status in Great Slave and Great Bear lakes on some fish species, and;
- The DFO Science Stock Status Reports on some fish species and stocks, including Mackenzie River Inconnu (DFO 1998), Hornaday River Arctic Char (DFO 1999), Rat River Dolly Varden (DFO 2001), Firth River Dolly Varden (DFO 2002), and Big Fish River Dolly Varden (DFO 2002).

**ii) What is happening?**

The Department of Fisheries and Oceans fish survey of the 1970s for the Mackenzie Valley Impact Study needs to be up-dated. Little data is available for the non-commercial species. Some information exists on commercial fish populations and their distribution in the NWT, but it needs to be compiled appropriately and augmented. Research on fish taxonomy, communities and assemblages, life history types, population structures, and biogeography of Arctic fishes, including landlocked and anadromous fishes are being lead by Dr. Jim Reist of DFO. This research program is much needed. Fish distribution (and of communities/assemblages) is not documented and is expected to change with climate warming.

Within the NWT, three fish species are listed as "may be at risk", eight species are considered as "sensitive", and 12 are assigned the "secure" status (Figure 3.3-3) according to the list of species at risk assessment provided by the NWT Department of Resource Wildlife and Economic Development (RWD 2000) for the Mackenzie River Basin. The short jaw cisco (*Coregonus zenithicus)*, the bull trout and the inconnu of the Upper Mackenzie River and Great Slave Lake are listed as "may be at risk" species due to excessive harvesting.

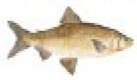
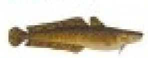
**FIGURE 3.3-3**
**NUMBER OF AQUATIC AND RIPARIAN-DEPENDENT WILDLIFE SPECIES AT RISK IN THE MACKENZIE RIVER BASIN WITHIN NWT**




*Source: Mackenzie River Basin Board 2004.*

The population status of some fish species in Great Slave Lake is summarized in Table 3.3-3. In the 1960s and 1970s, changes occurred in the fish populations and assemblages caused by commercial gillnetting, certainly with some decline in the populations of some species. Lake trout declined dramatically, while inconnu and walleye populations were reduced locally. In recent years, fish stocks in Great Slave Lake are reported as stable (MRBB 2004).

**TABLE 3.3-3**
**STATUS OF MAJOR FISH SPECIES IN GREAT SLAVE LAKE**

| Species | Population Status |
|---|---|
| Lake Whitefish  | The lake whitefish population appears to be stable in the western basin of Great Slave Lake, where this species is commercially fished. Fishing at or below the current quota appears to be sustainable. |
| Lake Trout  | Lake trout accounted for 64% of the catch in 1945, when commercial fishing began, but accounted for only 4% of the catch in the western basin in 1985. Although populations in the west basin have declined dramatically, populations in the East Arm are doing well. However, increasing pressures from recreational fishing in the East Arm may be of concern. |
| Northern Pike  | Stocks appear to be stable in all areas of the lake, although this assessment is based on inadequate information. |
| Walleye  | Information about walleye populations is inadequate. While there is concern for Hay River and Little Buffalo River populations harvested for subsistence and sport, no current problems with fish stocks have been reported. The Mosquito Creek population was overexploited from 1973 to 1988, but closing that sport fishery has resulted in a stable population. |
| Inconnu  | Spawning stocks on the Taltson, Little Buffalo and Hay rivers were extirpated by the 1960's. The Buffalo River stocks were overfished in the late 1970s and early 1980s. Protection has helped but inconnu still needs protection and updated assessment. Stocks on the Slave River and in Great Slave Lake appear to be stable. |
| Burbot  | There are currently no concerns regarding the burbot stocks. |
| Sucker  | There are currently no concerns regarding the sucker stocks. |

*Source: Mackenzie River Basin Board 2004*.

In the Mackenzie Great Bear basin, an assessment of stocks for the inconnu in the Mackenzie River, as well as for twelve lakes in each of the Deh Cho and Sahtu areas have recently been completed. This type of assessment, however, is not usually performed on a regular basis.

### iii) Why is it happening?

On Great Slave Lake, exploitation has affected fish populations and stocks. Commercial fishing for instance decimated the lake trout stocks in the West Basin of the lake, as the species is unable to withstand intense commercial gillnetting. In contrast, whitefish is more resilient and commercial fishing has not affected their populations to the same degree (MRBB 2004).

### iv) What does it mean?

Overall, the NWT ecozones are largely untouched by human activities, and as a result, relatively few species are at risk compared with areas in Canada's south. Great Slave Lake fish are exploited by several types of fisheries activities, which can affect and deplete populations and stocks. It is therefore imperative to manage the fisheries with proper planning and regulations, record and monitor harvests, and assess the stocks (MRBB 2004).

On Great Bear Lake, a quota was placed on the trophy lake trout stock in 1987. Although there have not been any lake trout population studies on Great Bear Lake since 1984, it is believed that the lake trout population is not at risk as annual harvest have been well below the quota (MRBB 2004).

### v) What is being done about it?

Overall, DFO performs management and research activities on fish populations and stocks in co-operation with stakeholders. Research by Dr. Jim Reist and colleagues are examples.

The NWT Department of Resources, Wildlife, and Economic Development (RWED) compiles data on the status of fishes, populations and stocks, and uses this information to set conservation objectives. A committee to assess the status of species at risk in NWT is in the planning stage under proposed legislation. New legislation is to be introduced to protect species at risk in NWT.

With respect to Great Slave Lake, the East Arm is managed for a trophy lake trout fishery and some inshore areas are for subsistence fishery. The incomplete fishery information has lead DFO to take a conservative approach in protecting fish stocks. On Great Bear Lake, fish management is carried out through a cooperative arrangement between the various local, regional, territorial and federal parties. A five-year study is underway to assess the lake trout population in Keith Arm (MRBB 2004).

**vi) What are the information gaps?**

Information on distribution and abundance of fish species (commercial and non-commercial): Fish distribution, communities and assemblages, life history types, population structures for Arctic freshwaters are relatively unknown. This type of data is most important for the study of cumulative impacts and climate warming. Major changes in fish distribution (communities/assemblages) are expected. It has been postulated that some fish species that are currently present in the southern regions of the NWT will disappear and be replaced by other fish species found further to the south that have adapted to warmer water conditions. In this regard, the distribution of commercial and non-commercial fish species should be monitored on the most important water bodies in the NWT.

Data from the fish harvest could be useful to derive population and stocks parameters: These data can be used to derive population parameters relating to: (1) Energy Use; growth and reproductive investment, (2) Survival; age structure and length frequency analysis, and (3) Energy Storage; condition. Fish abundance is measured from fishing effort indices. Sufficient information appears available to derive new data, even assess trends at some local and regional levels within the NWT.

Freshwater fishes that “may be at risk”: Freshwater fish species that are listed as “may be at risk” is an example of an area where there is a lack of information that should be resolved. Fish species monitoring is important for a continued awareness of changes to the ecosystem.

Freshwater fish populations and stocks: Population and stock status of most species is relatively unknown and more work is needed on that subject. For instance, on Great Slave Lake, fish stock assessment studies are needed to determine the current status of lake trout as well as other important fish species throughout the lake. In the Mackenzie-Great Bear Sub-basin, broad whitefish and lake whitefish remain the most sought after species for food. However, status on these species, populations and stocks are unknown.

### *3.3.3.3 FE Indicator – Fish Harvest*

Throughout the NWT, fishing is a most important activity whether it is for subsistence, sport or commercial purposes. These different aspects of fishing bring competing demands on the natural aquatic resource and pose a challenge to fisheries managers. Overall, information on subsistence, sport and commercial harvests is diverse making interpretations difficult to apply over the NWT (MRBB 2004).

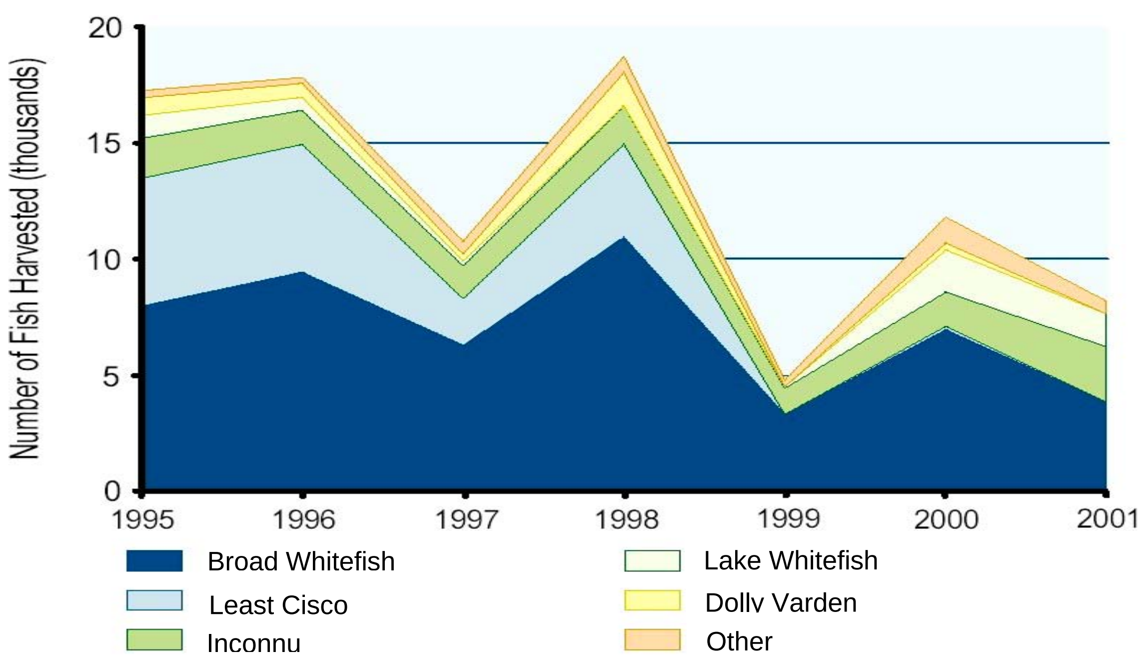
Commercial fisheries harvest whitefish (broad whitefish and lake whitefish, inconnu (coney), lake trout, northern pike, burbot or loche (*Lota lota)*, and walleye (*Stizostedion vitreum)*. While most of the fish populations and stocks remain healthy over the landscape, few populations or stocks have been as overexploited in the past by the localized fishing than Arctic char (*Salvelinus alpinus)*. Today, Arctic char is the subject of community-based management plans designed at sustaining harvest over time in those areas once overexploited (RWED 2000).

### i) What is being measured?

From the several harvest studies available, information can be sorted for the Peel Sub-basin, the Great Slave Sub-basin, which includes Great Slave Lake, and the Mackenzie-Great Bear Sub-basin, which includes Great Bear Lake.

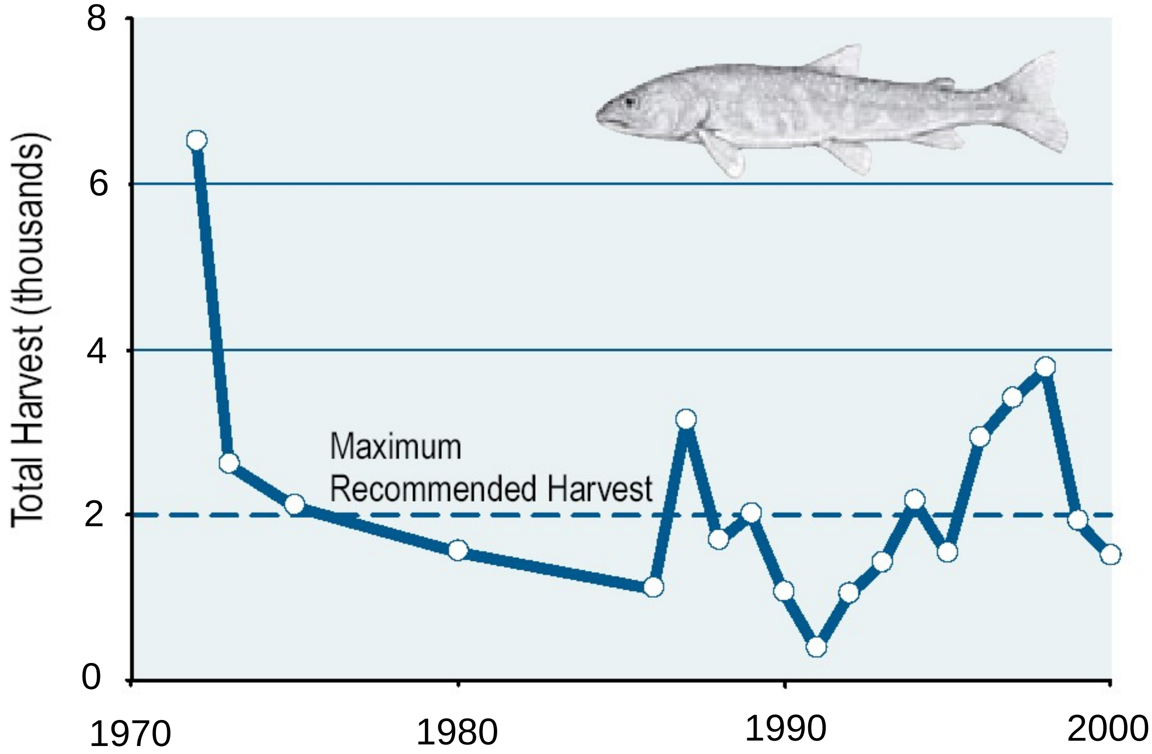
In the Peels Sub-basin at Fort McPherson, the subsistence fishery has been recorded for the Tetlit Gwich'in First Nation (Figure 3.3-4). Several fish species are part of the catch but the most important one was the broad whitefish. The maximum recorded harvest was 18,000 fish in 1998. Furthermore, for the Gwich'in of Aklavik and Fort McPherson, the Rat River (Char) Dolly Varden stock thought of as being over-harvested became a concern and a monitoring program was initiated in 1995. The Dolly Varden stock was estimated in the range of 10,000 to 15,000 fish. At an annual sustainable harvest of 10 to 15%, the recommended DFO maximum harvest was calculated at 2,000 fish annually (Figure3.3-5).

**FIGURE 3.3-4**
**CATCH RECORD AT FORT MCPHERSON, PEEL RIVER BASIN**




*Source: Mackenzie River Basin Board 2004*.

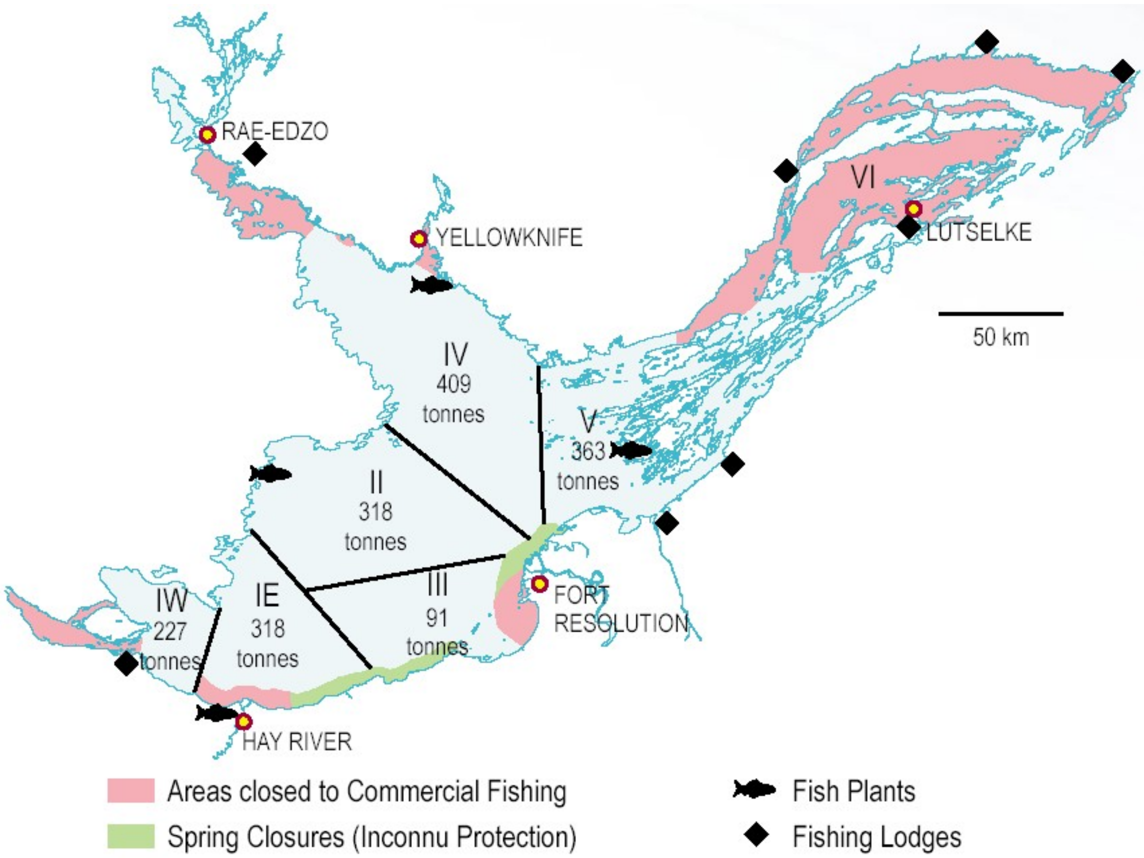
**FIGURE 3.3-5**
**DOLLY VARDEN HARVEST IN THE RAT RIVER**




*Source: Mackenzie River Basin Board 2004.*

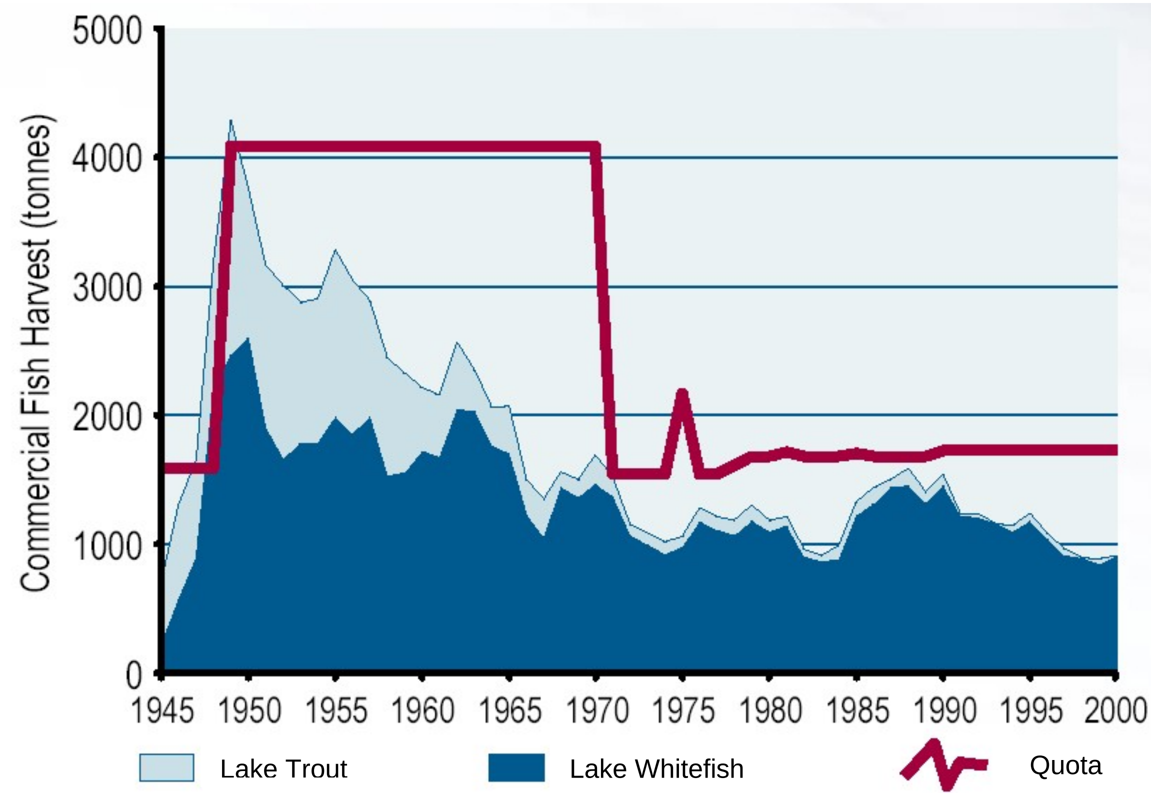
On Great Slave Lake, fisheries management is a matter of achieving a balance between subsistence, sport and commercial fishing versus the sustainability of all fish species and stocks. Great Slave is divided into six management areas (Figure 3.3-6), each with its own fisheries plan. Commercial fishing occurs in the western and central areas, while the East Arm area is managed as a trophy lake trout fishery and some other areas are managed for subsistence fishing. In the western area, the commercial fishery has been primarily targeted at lake whitefish since the collapse of the lake trout stocks in the mid 1960s. Trends over time of the commercial harvests show declines in harvest of both lake trout and lake whitefish (Figure 3.3-7). Lake whitefish represents 68% of the commercial catch in recent years. The trophy lake trout sport fishery has increased in the East Arm. Available surveys from 1986 to 1994 indicate that the sport fishery has nearly doubled during that period.

**FIGURE 3.3-6**
**MAP OF ADMINISTRATIVE FISHING AREAS IN GREAT SLAVE LAKE**




*Source: Mackenzie River Basin Board 2004*.

**FIGURE 3.3-7**
**COMMERCIAL FISHING HARVEST AND QUOTA FROM GREAT SLAVE LAKE, 1945 TO 2000**



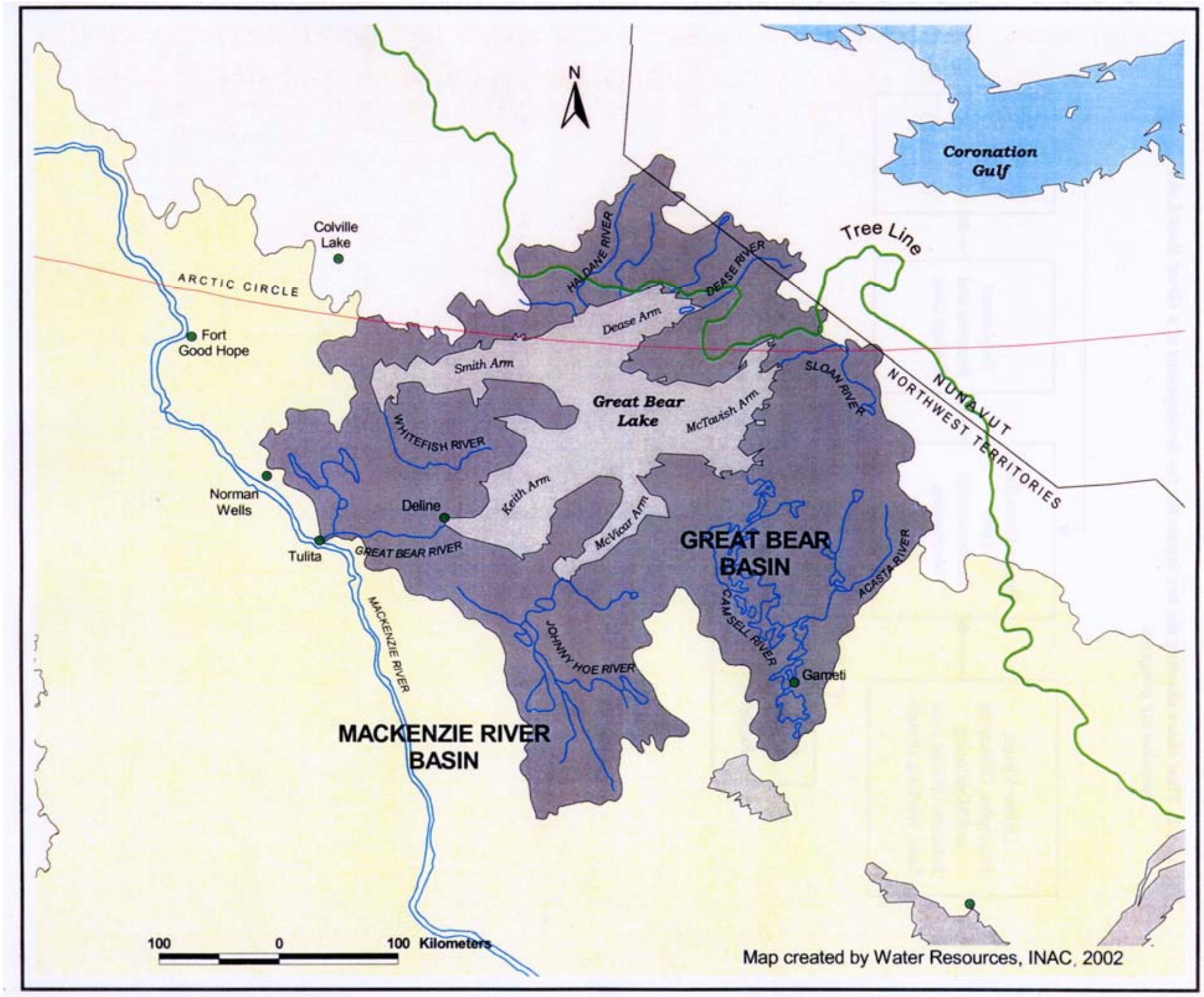

*Source: Mackenzie River Basin Board 2004.*

In the Mackenzie-Great Bear Sub-basin, subsistence harvests have been monitored since the early 1990s in the Inuvialuit, Sahtu, Gwich'in and Deh Cho areas. First Nations have traditionally harvested inconnu in the Mackenzie River and Delta, and at present levels of harvest, populations are in an excellent state under current habitat protection of the Delta. Recent harvests of broad whitefish in the Delta are also only 5 to 10% of the estimated harvest numbers of the 1950s. Subsistence fisheries occur in the Inuvialuit, Gwich'in, Sahtu and Deh Cho areas. Beginning from the early 1990s, several years of monitoring indicate that broad whitefish and lake whitefish are the two most important species harvested. Inconnu and lake cisco are also important in other communities.

The trophy lake trout fishery on Great Bear Lake is shared between the subsistence and sport fisheries, as well as one commercial fishery. The lake is divided into five lake trout management areas, with one area (Keith Arm) still without a fishery plan. Figure 3.3-8 shows the boundaries of the Great Bear Lake watershed and the five arms comprising the lake. The lake trout harvest from

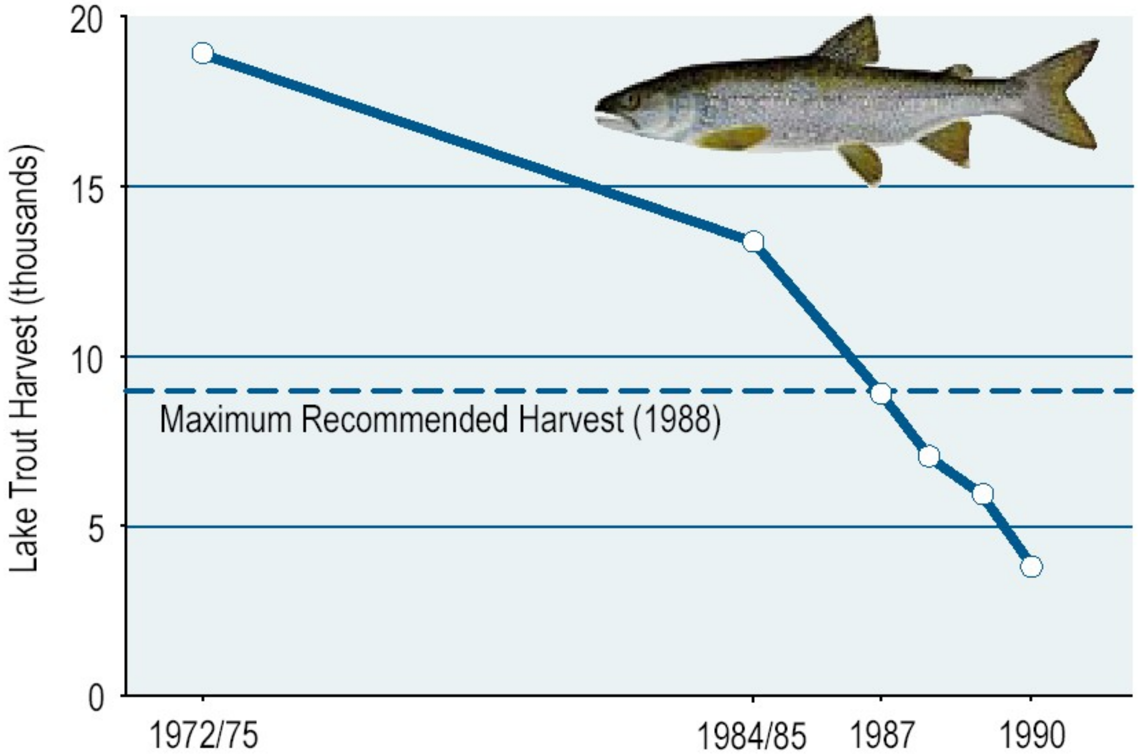
Great Bear Lake declined steadily from the early 1970s to 1990 (Figure 3.3-9) and is believed to be in good shape.

**FIGURE 3.3-8**
**BOUNDARIES OF THE GREAT BEAR LAKE WATERSHED AND THE FIVE ARMS COMPRISING THE LAKE**




*Source: MacDonald et al. (2004).*

**FIGURE 3.3-9**
**LAKE TROUT HARVEST IN GREAT BEAR LAKE, 1972 TO 1990**




*Source: Mackenzie River Basin Board 2004*.

### i) What is happening?

*In the Peel Sub-basin at Fort McPherson, it is expected that the fish harvest will continue to be recorded due to the importance of the subsistence fishery to the Tetlit Gwich'in First Nation (MRBB 2004). However, for the Gwich'in of Aklavik and Fort McPherson, the Rat River (Char) Dolly Varden stock has not been monitored since 2001.*

The largest commercial fishery in the NWT is in the western and central areas of Great Slave Lake. Commercial fishing is not allowed in certain areas important to subsistence fishing, or the East Arm, which is managed for trophy lake trout sport fishery.

Great Bear Lake fishing also includes subsistence, sport and commercial, but the latter is only present in some local areas of the lake. The management goal of Great Bear is to conserve a world-class trophy lake trout fishery. The lake trout stock declined until 1984, when studies demonstrated that conservation measures were warranted and quotas were put in place. The current harvest is considered below the maximum sustainable yield.

**ii) Why is it happening?**

In the Peel Sub-basin at Fort McPherson, the Tetlit Gwich'in First Nation has traditionally relied on the subsistence fishery. In particular, the Dolly Varden is one of the highly desired species but few populations are found in the region. As a result, over-harvest has occurred in recent years, leading to the 1997 Charr Fishing Plan, where fishers voluntarily reduced their catch by 30% since 1998.

In the Great Slave Sub-basin on Great Slave Lake, the commercial harvest has declined since 1990. This is due to a reduction in fishing effort and number of commercial boats on the lake. As for the sport fishery, it has increased due to a considerable growth in the Yellowknife population, improvements in highways and increased tourism.

The Mackenzie Delta, with Inuvik as the largest community in the Mackenzie-Great Bear Sub-basin, has the most important subsistence and sport fisheries. Subsistence fishing has declined in recent years due to a decrease in the number of dog teams, which were fed fish. The decline in the number of trout harvested from Great Bear Lake is due to a more conservation-oriented sport fishery, including a catch and release policy.

**iii) Why is it happening?**

The reduced take of commercial, subsistence and sport fish is due in large part to the adoption of fisheries management plans and harvest quotas aimed at preserving the long-term viability of fish stocks in key fishing areas.

**iv) What does it mean?**

*In the Peel Sub-basin at Fort McPherson, fish harvest studies are important in determining the subsistence use of fisheries resources for the Tetlit Gwich'in First Nation. From these studies, sustainability of harvesting fish and potential effects on the aquatic ecosystem can be evaluated. In addition, for the Gwich'in of Aklavik and Fort McPherson, following a voluntary reduction in the catch of the Rat River Dolly Varden stock, it is predicted that it will sustain itself if the harvest is maintained at the 1999-2000 levels.*

In the Great Slave Sub-basin on Great Slave Lake, the use of the fisheries resources has the potential to seriously affect populations and stocks of fishes. Therefore, it is important that the fisheries be managed, regulated, recorded and monitored over time, along with fish stocks evaluation when applicable (See Section 3.3.3.2; FE Indicator – Fish Population).

In the Mackenzie-Great Bear Sub-basin, subsistence, sport and commercial fishing are most important, although there has been a decline in subsistence fishing (fish food to dog teams). Broad whitefish and lake whitefish remains the most sought after species for food. However, harvest status on these species, as well as the status on populations and stocks is unknown. In Great Bear Lake, earlier studies showed that the lake trout population had declined until 1984. To maintain a trophy fishery, quotas were assigned for each management area of the lake in 1987, for a grand total of 9,000 fish. Since then, and currently, the lake trout harvest has been much lower than the maximum sustainable yield.

### v) What is being done about it?

In the Peel Sub-basin at Fort McPherson, the Gwich'in Renewable Resources Board continues its fish harvest studies. For the Gwich'in of Aklavik and Fort McPherson, the Rat River Dolly Varden stock is managed through co-operative arrangements between Renewable Resources Boards, Renewable Resource Committees in each of the communities, and DFO. Allowable harvests, licensing of sport and commercial fishing as well as fish stocks studies are decided by these agencies.

In the Great Slave Sub-basin on Great Slave Lake, DFO is responsible for the fisheries management as well as the fish stocks assessment. However, the Great Slave Lake Advisory Committee makes recommendations to DFO on matters of fisheries management. DFO restricts the commercial fishery with quotas, minimum gillnets mesh sizes and limiting number of commercial operators. Regarding lake trout sport fishing, DFO is conservative in its approach with daily catch and possession limits lowered to one and two fish respectively, and mandatory use of barbless hooks since 2004, along with live release practices.

In the Lower Mackenzie River and Delta, a fishery plan has been completed for inconnu. For that same area, a stock status report and management plan for lake whitefish and broad whitefish has been completed as well. In the Mackenzie-Great Bear Sub-basin, management of the fisheries is based on cooperative programs between Renewable Resources Boards, Renewable Resources Committees, and NWT Department of Resources, Wildlife and Economic Development, which make recommendations to DFO. For Great Bear Lake, a lake trout study is underway in Keith Arm and a fishery plan is under development.

**vi) What are the information gaps?**

Subsistence, sport and commercial fisheries:

- In the Liard Sub-basin of the NWT, the First Nation's subsistence fishery is not monitored (MRBB 2004).
- On Great Slave and Great Bear lakes fishing pressures have the potential to affect, even disrupt fish populations. It is imperative that the fisheries are looked at closely and managed to ensure sustainability of stocks overtime. Detailed information is required about fish populations and stocks in order to achieve a corresponding good level of fisheries management. On Great Slave Lake, additional information is needed on the subsistence and sport fisheries to complete the understanding of the fisheries resources. Current harvest data for subsistence fisheries are available for Fort Resolution and Fort Smith only.
- In the Mackenzie-Great Bear Sub-basin, subsistence, sport and commercial fishing are most important. Broad whitefish and lake whitefish remains the most important catch. Harvest status on these species is unknown and needed.

#### *3.3.3.4 FE Indicator - Fish Quality*

Fish such as lake trout, northern pike, walleye, burbot, whitefish and inconnu are increasingly subject to degradation in quality because of contaminants, as well as diseases and parasites. Numerous contaminants have been studied, and since fish play an important part in traditional diets for NWT inhabitants, contaminant levels occurring in fish flesh have been of particular concern. There are three basic classes of contaminants that are generally considered to be of concern; heavy metals, POPs and radionuclides.

Heavy metals that have been found at elevated levels in fish include mercury, cadmium, lead, arsenic, copper, selenium and zinc. POPs that have been found in fish include polycyclic aromatic hydrocarbons (PAHs), chlorinated phenolics, hexachloro-benzene (HCB), hexachloro-cyclohexane (HCH), dichloro-diphenyl-trichloroethane (DDT), polychloro-biphenyls (PCBs), chlordane, toxaphene (chloro-bornanes), dioxins and furans and dieldrin. Of the three classes, radionuclides have received the least attention.

The presence or absence of diseases and parasites is a more visual clue for fish quality. Diseases and parasites are often identifiable at a glance either externally or internally upon cleaning. However, easy identification does not necessarily translate into recognition of changes in fish quality either spatially or temporally.

**i) What is being measured?**

Availability of baseline fish quality data varies by watershed, lake or river and fish species. Although fair amounts of sporadic information exist on specific fish species in certain water bodies, there is a general lack of long-term, comprehensive monitoring (CIMP 2005).

Longer-term monitoring of contaminants in freshwater fish has been conducted at Fort Good Hope, Great Slave Lake and Slave River. Current data collection includes:

- Burbot for heavy metal and POPs contaminants at Fort Good Hope by DFO since 1999.
- Burbot, and late trout for heavy metal and POPs contaminants as well as early warning for new contaminants from Great Slave Lake (West Basin and East Arm) by Environment Canada, and DFO since 1999. Some similar information has been collected since the 1970s.
- Burbot for heavy metal and POP contaminants from Slave River by Environment Canada and DFO since 1999. Similar information was also collected from 1993 to 1995.
- Lake trout for metals and POPs in Great Bear Lake by DFO.
- Lake trout or whitefish in 10 other lakes every five years.

<u>Heavy Metal</u>:. *Levels of mercury have been measured since the early 1970s. However, these samples have been limited to commercially important species as well as a range of sizes. More recently, the focus has been on capturing a broader range of sizes from fewer locations. However, the overall data is still largely from fish that are of commercial or traditional interest (INAC 2003). Current data collection includes*:

- Mercury, selenium and arsenic in western NWT by DFO and Environment Canada since 1996.

- Mercury information was collected from the Sahtu and Deh Cho regions from 1996 to 2000.

- Mercury in predatory fish in lakes of the Fort Simpson area by Environment Canada and DFO since 1998. Previous research for some lakes (Cli Lake, Little Doctor Lake, Willow Lake, Sibbeston Lake and Tsetso Lake) is available.

- Metals in whitefish, northern pike, walleye and lake trout from Lac Ste. Therese by DFO.

Persistent Organic Pollutants: *Aside from previously mentioned studies, no other studies that focus on POPs in the NWT were identified.*
Radionuclides: *Studies specifically designed to measure radionuclides in the NWT were not identified.*

Observation of diseases and parasites in fish are not regularly monitored in the NWT. Information that has been collected is by traditional knowledge and not using any particular methodology (CIMP 2005). A community-based monitoring survey conducted by the Arctic Borderlands Ecological Knowledge Co-op in the communities of the lower Mackenzie River basin is active. Annual surveys are conducted to record resource users including fish for quantity and quality by species and location.

**ii) What is happening?**

The fish contaminant, disease and parasite information that has been collected thus far in the NWT has provided a base of information on which to build. However, the Mackenzie basin has undergone exceptional warming since the 1960's. Although this has not been clearly characterized in the complex hydrology of the Mackenzie River, any change related to atmospheric contaminant pathways due to global warming is likely from the North Pacific (influences alternate between Pacific and Eurasian air masses; AMAP 2002).

Although a comprehensive study has not been completed, there exists large spatial variation in contaminant concentrations in predatory fish within the NWT (INAC 2003). A five-year study on the Slave River (1990-1995) showed low levels of liver enzyme inductions indicating that the environment was relatively pristine (Sanderson et al. 1998). It is of note that fish have a limited ability to degrade contaminants like POPs, as they are excreted very slowly.

Heavy Metals: *Most data produced with respect to heavy metal contamination in fish is on mercury because of human consumption concerns. However, studies have looked at arsenic, cadmium, lead and selenium although levels for these parameters are rarely of concern (INAC 2003).*

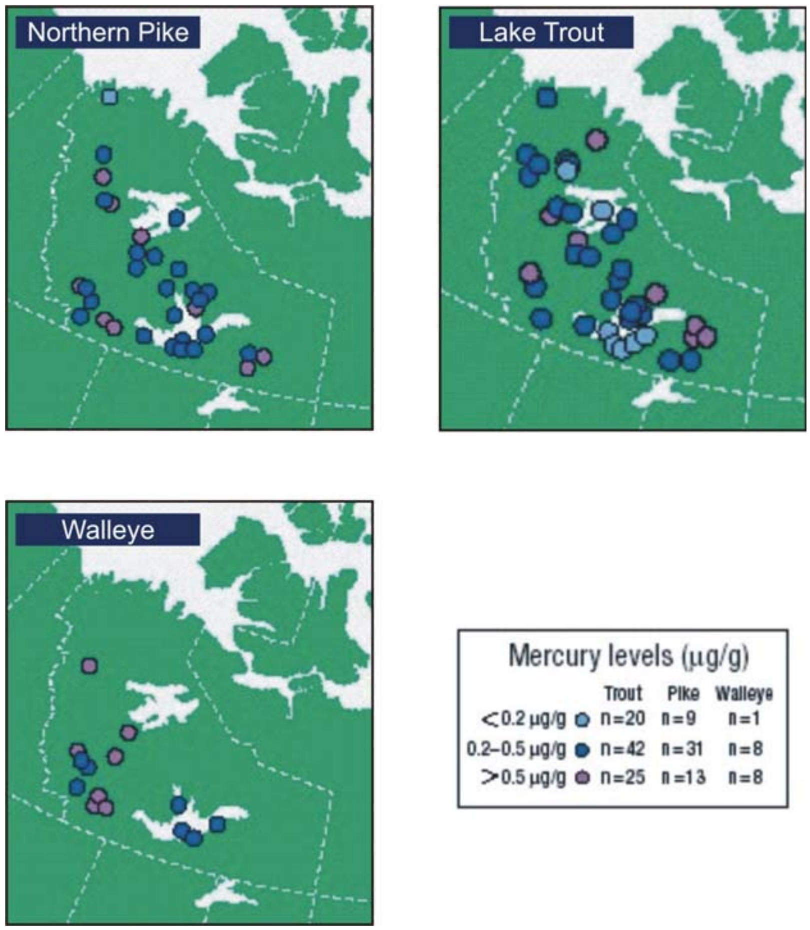
Health advisories for mercury have been issued for some fish species, including northern pike, lake trout, burbot, whitefish and suckers, in several NWT lakes (INAC 2005). Some of these lakes may have naturally high mercury levels (MRBB 2004, INAC 2005), while others are the result of anthropogenic sources. An example of the latter situation is the ban that was put in place in 1978 on consumption of fish from Giauque Lake, which was impacted by mercury leaching from tailings at Discovery Mine (MRBB 2004).

Fish exposed to high mercury levels suffer damage to gills, sense of smell, blindness and a decreased ability to absorb nutrients through the intestine (AMAP 2002). Grayling embryos exposed to mercury may have decreased growth and decreased ability to capture prey later in life thereby decreasing their ecological fitness. Similar results were observed for juvenile walleye (AMAP 2002). Cadmium exposure can interfere with calcium metabolism. In lake trout, poorer foraging behaviour was displayed, along with a decrease in prey capture success, as well as a decrease in thyroid function after exposure (AMAP 2002).

Mercury is the only contaminant that is consistently greater than guideline limits for consumption (<0.2 µg/g (wet weight) by people who eat large amounts of fish) or commercial sale (<0.5 µg/g (wet weight)) (INAC 2003). Evans *et al*. (2003) report that between 88 and 91% of lakes surveyed in the Mackenzie River Basin have mean mercury levels in predatory fish above the 0.2 µg/g guideline and some 25 to 45% have mean mercury levels above the 0.5 µg/g. Figure 3.3-10 presents mercury concentrations for northern pike, walleye and lake trout found in the NWT.

A survey of lakes in the Deh Cho and Sahtu settlement regions found mercury levels between the 0.2 and 0.5 µg/g guideline values in 60% of lake trout lakes, 50% of northern pike lakes and 42% of walleye lakes (Evans *et al*. 2003). Another 27% of lake trout lakes, 38% of northern pike lakes and 40% of walleye lakes had mercury levels above the 0.5 µg/g guideline. Evans *et al*. 2003 report that consumption advisories have been issued on 16 of 29 lakes in these regions.

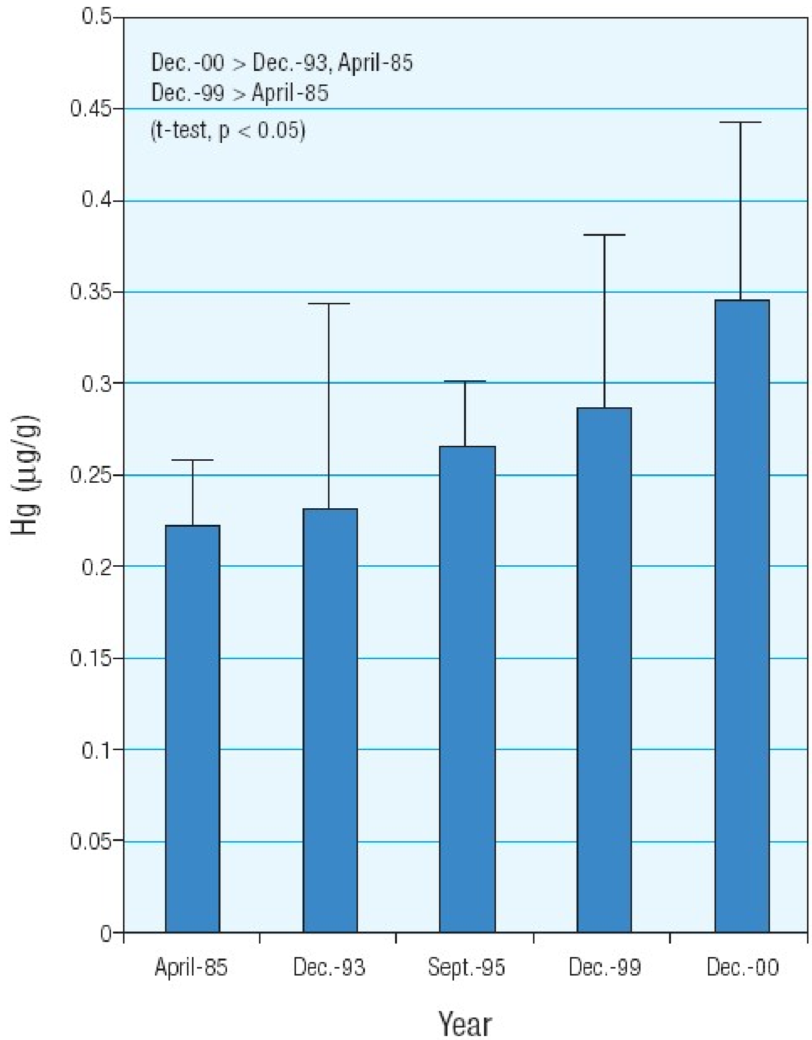
**FIGURE 3.3-10**
**MERCURY CONCENTRATION IN NORTHERN PIKE, LAKE TROUT AND WALLEYE IN NWT LAKES**




*Source: INAC 2003.*

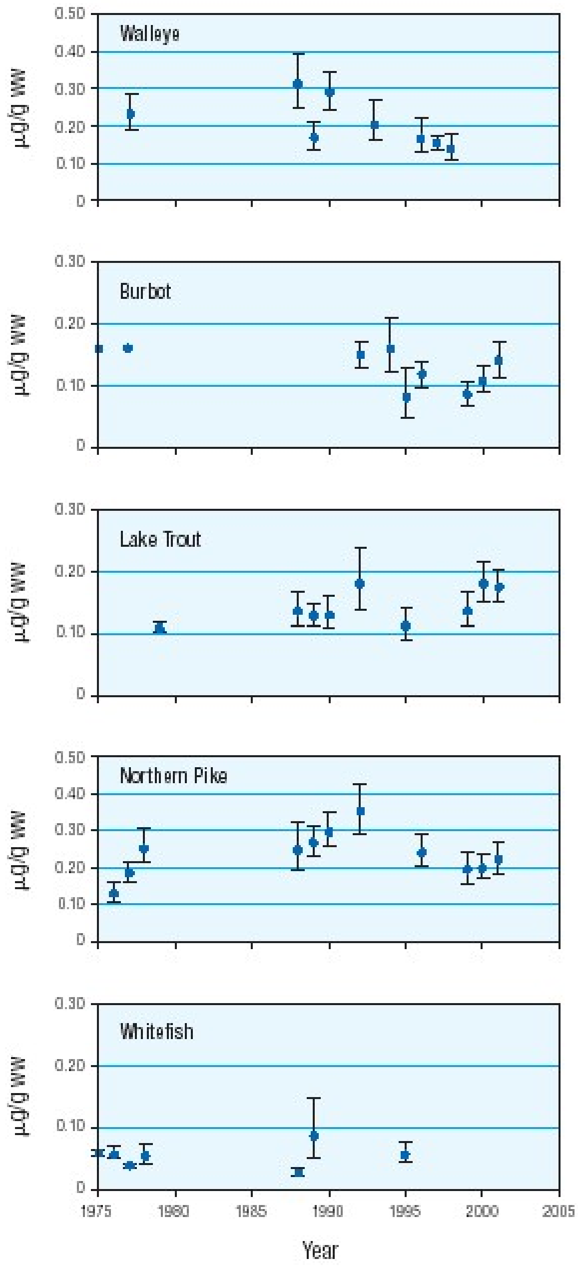
Figure 3.3-11 shows mercury concentrations in burbot livers from Fort Good Hope between 1985 and 2000 (AMAP 2002). The figure shows an overall increase of approximately 36% in mercury concentrations over the fifteen year time period. Similarly, Figure 3.3-12 presents temporal trends of mercury concentrations in walleye, burbot, lake trout, northern pike and whitefish from Great Slave Lake from the 1970s to 2001.

**FIGURE 3.3-11**
**MERCURY CONCENTRATION IN BURBOT LIVER OVER TIME AT FORT GOOD HOPE, NWT**




*Source: INAC 2003.*

**FIGURE 3.3-12**
**MERCURY CONCENTRATIONS IN FISH MUSCLE**
**(GEOMETRIC MEANS ± 95% CONFIDENCE LIMITS)**
**FROM GREAT SLAVE LAKE**

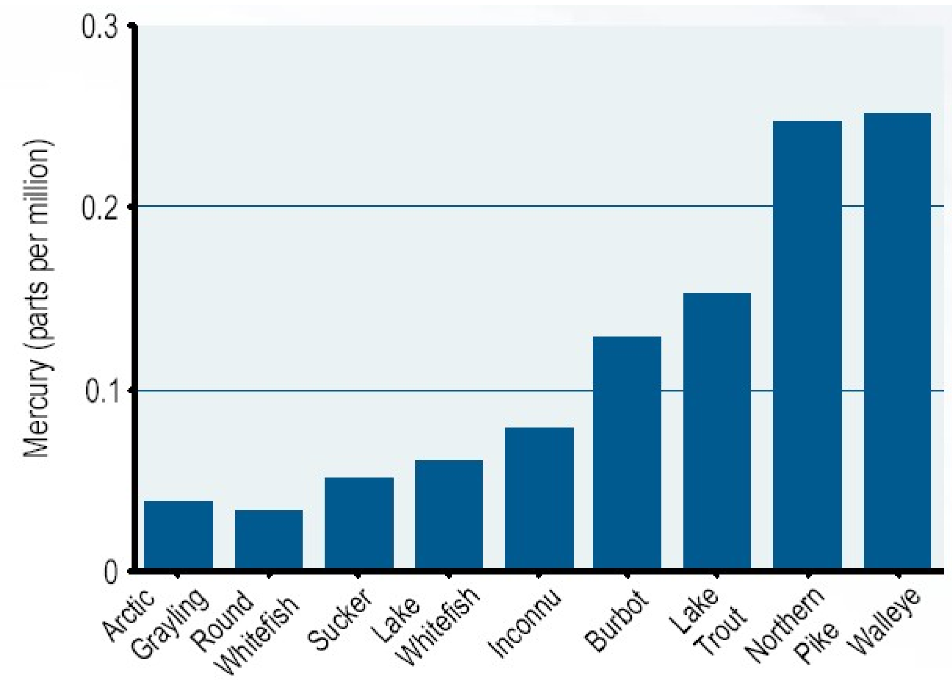



*Source: INAC 2003.*

Frequently, predatory fish like walleye, northern pike and lake trout have higher mercury levels because concentrations biomagnify through the food chain versus fish species that feed lower in the food chain such as lake whitefish, which mainly feed on zooplankton and benthos (AMAP

2002, INAC 2003). Figure 3.3-13 clearly shows biomagnification up the food chain in species from Great Slave Lake.

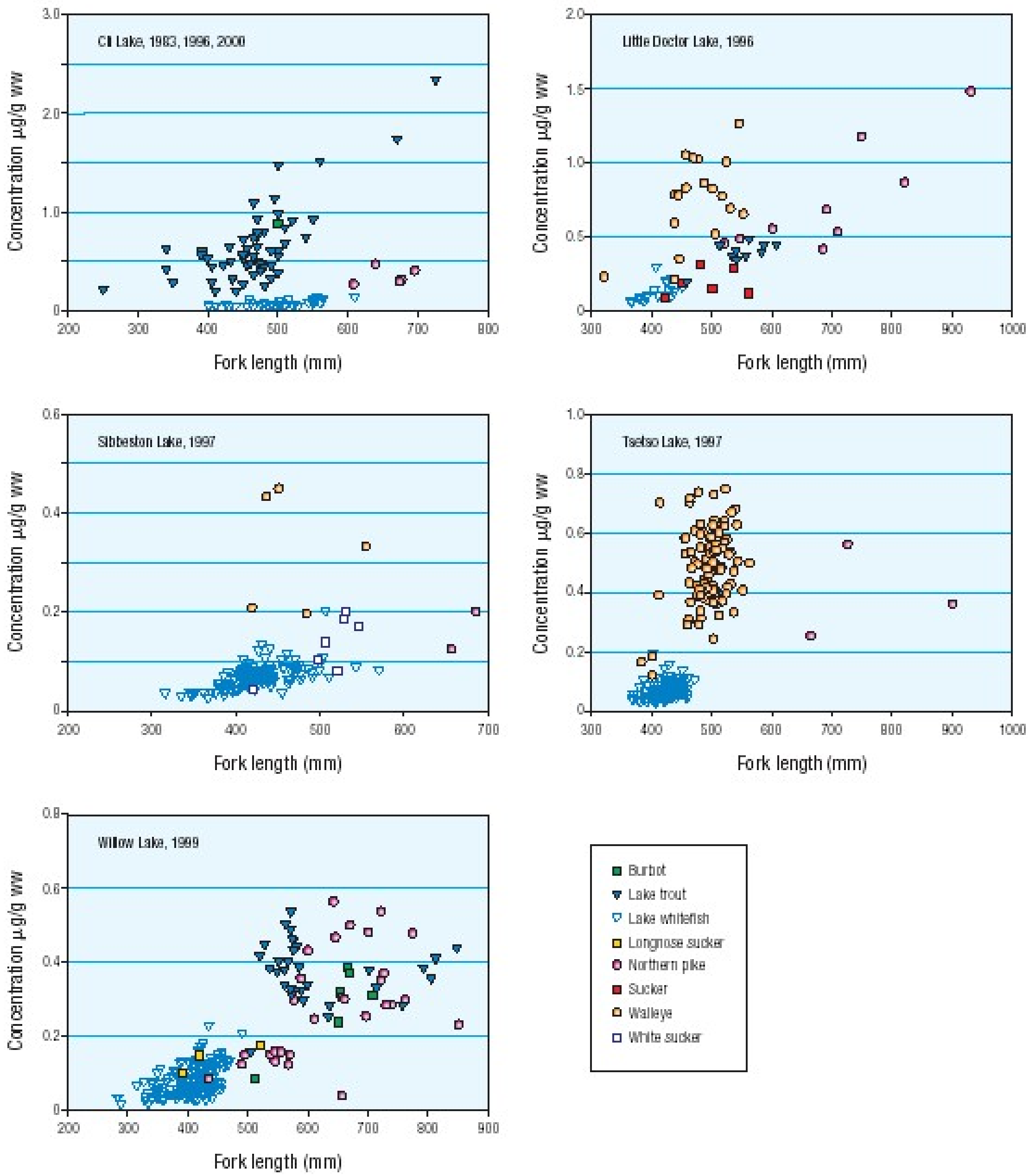
**FIGURE 3.3-13**
**BIOMAGNIFICATION OF MERCURY IN PREDATORY FISH IN GREAT SLAVE LAKE**




*Source: Mackenzie River Basin Board 2003.*

As a rule, high mercury levels are found to be associated with larger and older predatory fish, often more than 10 years in age. Figure 3.3-14 presents the relationship between mercury concentration and fish fork length from five lakes in the NWT.

**FIGURE 3.3-14**
**MERCURY CONCENTRATION VERSUS FISH FORK LENGTH**




*Source:INAC 2003.*

Different fish species and tissues within species contain varying heavy metal concentrations. For example, arsenic and cadmium concentrations tend to be higher in liver tissue versus muscle. At the species level, cisco had the highest arsenic concentrations whereas the highest cadmium concentrations were found in walleye liver (INAC 2003).

Water chemistry parameters, such as the humic content, and dissolved oxygen may also play a role in the uptake of mercury. Mercury in the water phase is bioavailable and is greater in streams with higher humic levels (INAC 2003).

One potential effect of global warming is an increase in water temperature, which would result in an increase in fish metabolic rates and therefore an increase in the volume of water passing across the gills. A consequence of such an increase in the metabolic rate would be an increase in the uptake of metals. This may be exacerbated by an increase in the bioavailability of mercury with an increase in water temperature (MRBB 2004).

Persistent Organic Pollutants: The same human health driver does not exist for POPs as it does for mercury although a health advisory for burbot from the Slave River near Fort Smith for toxaphene contamination was made in 1992 (MRBB 2004).

Dioxins and furans are among the most toxic POPs because they can affect health in so many ways including wasting, damage to the immune system and liver, endocrine disruptions and problems with fetal development. Because they tend to be fat soluble, they also biomagnify through the freshwater food chain causing higher concentrations in top predators like northern pike and lake trout.

Levels of chlorinated dioxins and furans in burbot showed a decrease in the early 1990s (Figure 3.3-15) as pulp mills located within the Mackenzie River Basin decreased effluent concentrations of these organic compounds (MRBB 2004).

A comparison of burbot livers from Fort Good Hope showed a slow decline in the major organochlorines and toxaphene from the mid-1980s to 1999 (Figure 3.3-16) (AMAP 2002). However, a study from 1993-1999 in Great Slave Lake showed that toxaphene levels in burbot exceeded levels associated with bone development effects in catfish (AMAP 2002).

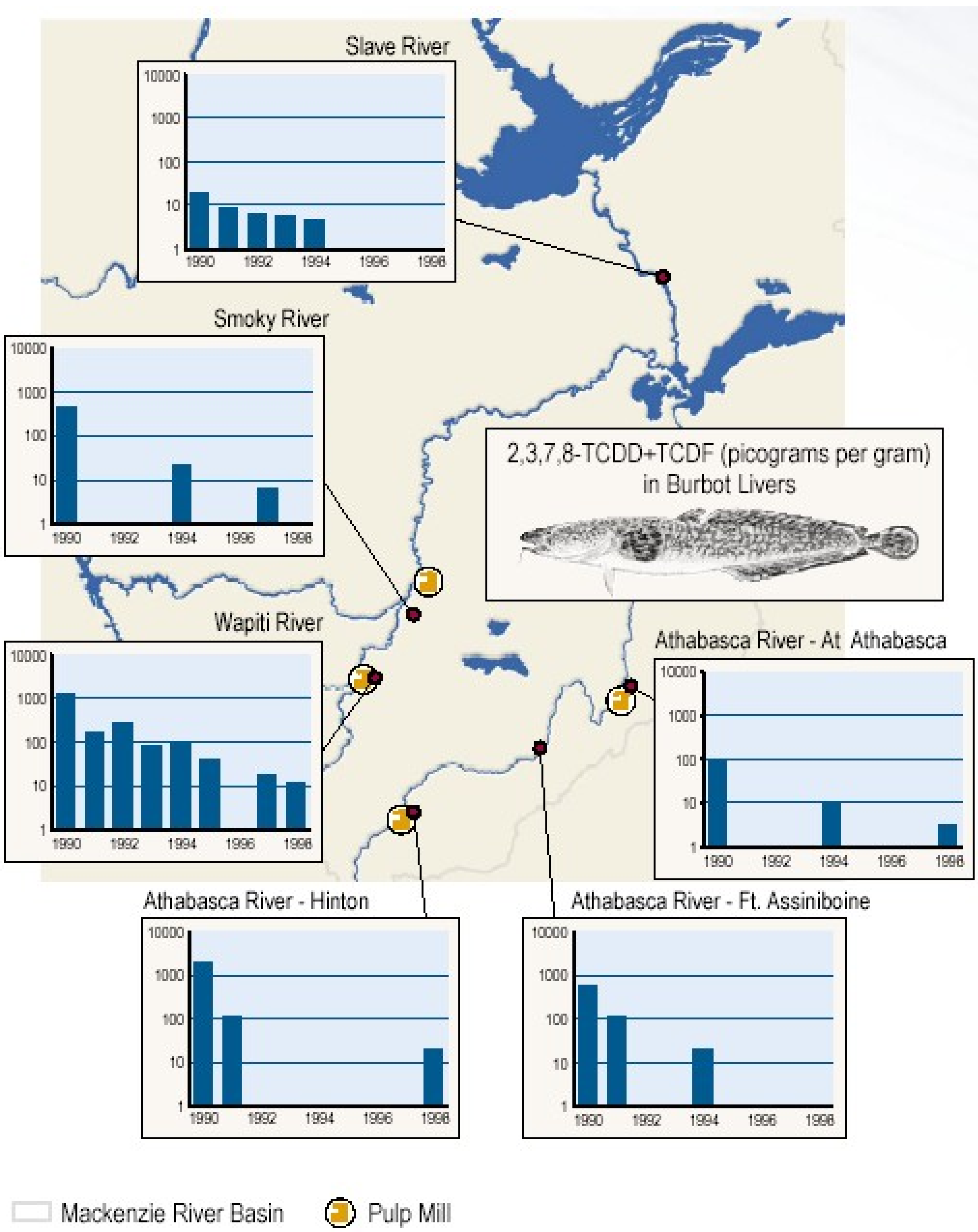
To accurately assess spatial and temporal trends of POPs, the length, age and growth rates of fish must be considered because each of these factors affects concentration (AMAP 2002). It is particularly important that these factors be taken into account when comparing studies between different lakes or rivers.

Based on the lack of EROD induction[6], the potential for POPs to be causing significant influences on fish health in NWT fish is low (INAC 2003). Nevertheless, monitoring of POP

[6] EROD induction refers to a test that measures the level of a biomarker that indicates the level of enzyme activity in breaking down compounds, specifically ethoxyresorufin in the EROD test. The presence of this activity is low, often undetectable, in uncontaminated organisms but highly activated in the presence of contaminants.

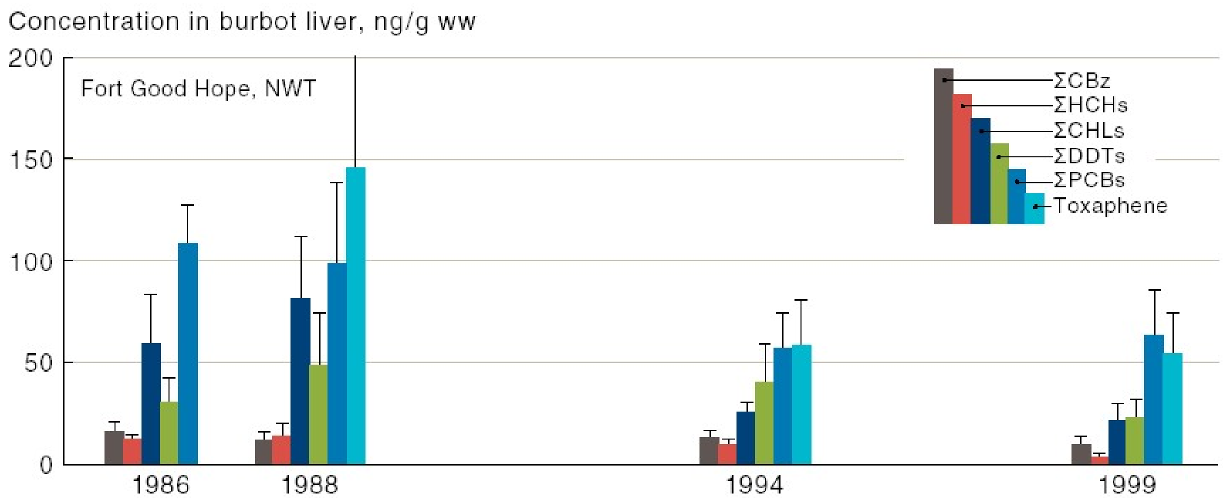
levels ensures that if levels become significant, they will be identified. Current research with respect to climate change impacts on POPs is focused on potential changes to pathways and not influences on individuals or populations.

**FIGURE 3.3-15**
**DECLINES IN DIOXIN AND FURAN LEVELS IN BURBOT LIVERS NEAR PULP AND PAPER MILL SITES**




*Source: Source: Mackenzie River Basin Board 2004.*

**FIGURE 3.3-16**
**CHANGES IN POP CONCENTRATIONS IN BURBOT LIVER FROM THE FORT GOOD HOPE AREA**




*Source: AMAP 2002.*

Radionuclides: Although the potential for human health impacts from radionuclide contamination of fish in the NWT exists, only limited data has been gathered on radionuclide levels in fish. An investigation of radionuclide levels in fish near the former Port Radium radium/uranium/silver mine site on Great Bear Lake showed low levels in lake trout and lake whitefish muscle and liver samples and herring whole body samples (SENES 2004). An assessment of the whole body dose to these species using measured levels in the lake water and sediment in combination with fish tissue data demonstrated that the combined dose from internal and external exposures were well below acceptable levels.

In the NWT, the lack of information about the rates of diseases and parasites in fish does not allow for analysis of changes in their occurrences. However, interviews with First Nations fishers indicated that parasites are more abundant in some areas of the NWT including the lower portion of the Laird Sub-basin. Residents along the Slave River reported a general decline in fish health with an increase in deformities and signs of disease (MRBB 2004). Fish in the lower Mackenzie River area are reportedly good with only a few incidences of parasites, soft flesh, poor liver quality or body marks like scabs (ABEKC 2003). Although it could be expected that climate change and the anticipated increase in water temperature could result in changes in occurrence of diseases and parasites, no studies to investigate this effect were identified for fish in the NWT.

### iii) Why is it happening?

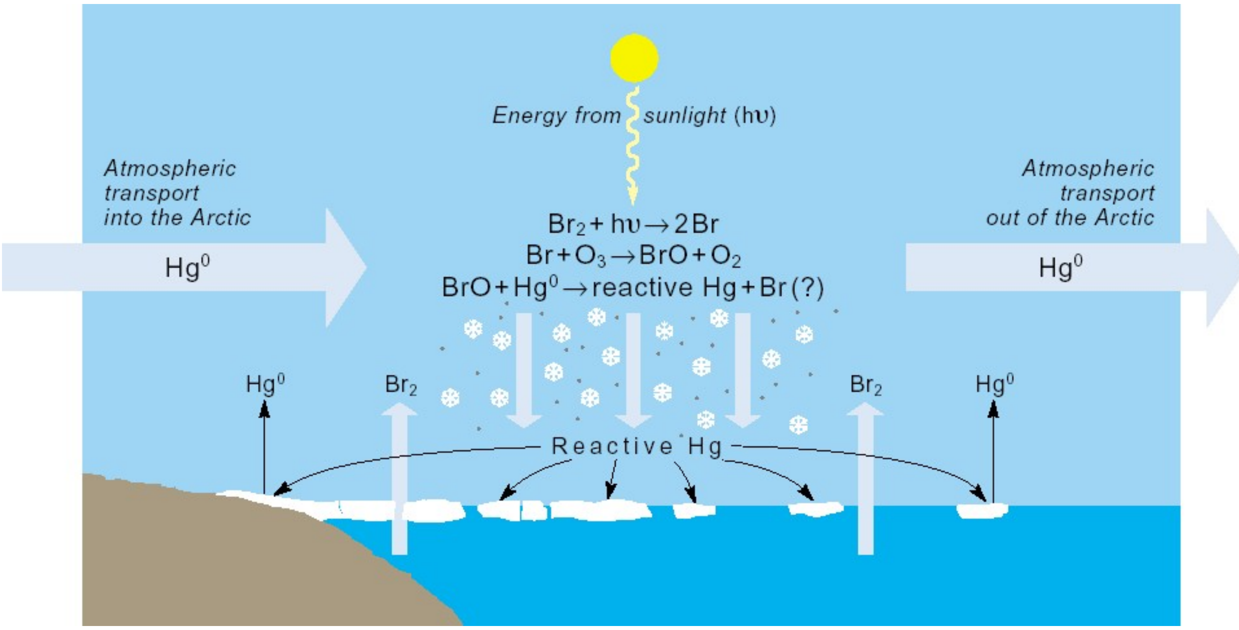
- Transport of contaminants to the Arctic includes atmospheric transport in both the gaseous phase as well as by particle adhesion and transport by both ocean currents and rivers (INAC 2003). For example, the transport of POPs to Great Slave Lake occurs from the south via the Peace River to the Athabasca River and finally through the Slave River (AMAP 2002). Once contaminants are present in the aquatic environment, accumulation of contaminants in aquatic plants and fish occurs. Fish exposure pathways include uptake through the gills, the skin and by direct digestion (INAC 2003).

Heavy Metals: *The sources and pathways of heavy metals other than mercury are not well known. In general, these sources are identified on an individual lake or system basis once contamination is found. For example, abandoned mine sites may be a source of several metals. Likewise, areas with natural outcropping of mineral deposits are potential sources of metals.*

*By contrast, investigations into the sources and pathways of mercury have received much more attention. Long-range atmospheric transport has been identified as being a major source of mercury in the NWT. A simplified schematic of the reactions that occur and contribute to mercury deposition is presented on Figure 3.3-17.*

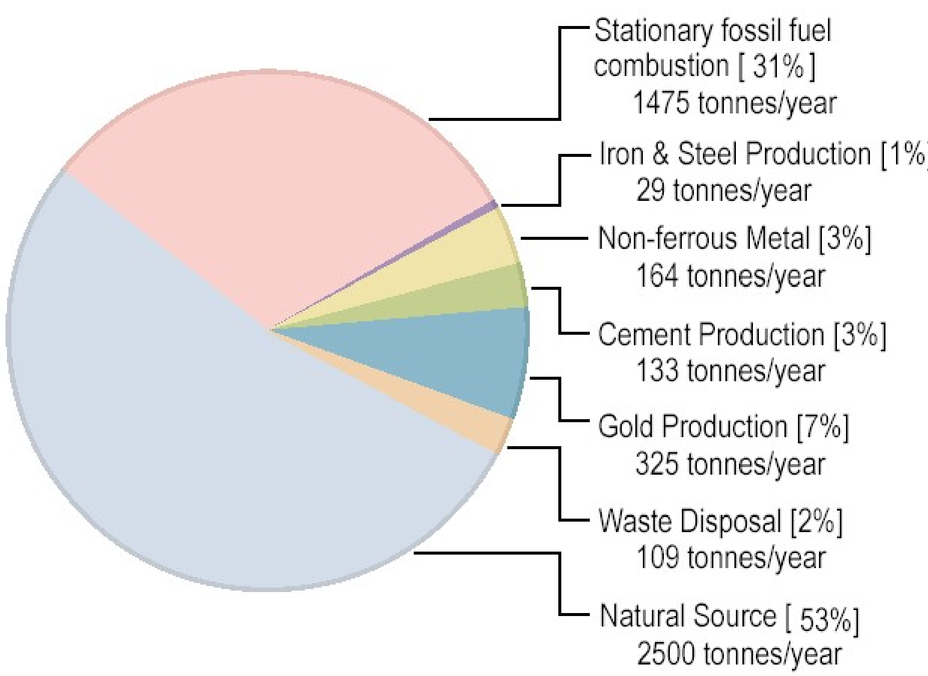
*While initiatives have been taken to reduce mercury source emissions in North America and Europe, this has not translated into a reduction in the mercury level in the atmosphere over the Arctic. It may be that these recent reductions are offset by increases in emissions from Asia. Anthropogenic mercury is released to the atmosphere through coal burning, waste incineration and industrial processes. Natural atmospheric mercury is emitted from volcanoes and forest fires (AMAP 2002). Figure 3.3-18 shows a breakdown of atmospheric mercury sources. Unique pathways seem to concentrate mercury in bioavailable forms in the Arctic and NWT.*

**FIGURE 3.3-17**
**SCHEMATIC SHOWING REACTIONS THAT CAUSE DEPOSITION OF ATMOSPHERIC MERCURY**




*Source: AMAP 2002.*

**FIGURE 3.3-18**
**SOURCES OF ATMOSPHERIC MERCURY, BOTH ANTHROPOGENIC AND NATURAL**




*Source: Source: Mackenzie River Basin Board 2004.*

Persistent Organic Pollutants*: POPs provide the best evidence that pollution in the NWT is primarily from the south because they are not typically used locally in large amounts (Macdonald 2000). POPs tend to be anthropogenic in origin, persistent in remaining in their original or stable form for decades, bioaccumulate throughout the life cycle of a fish, and they tend to be toxic at low concentrations. Levels of POPs are mostly due to past emissions but, new POPs have been found as well. POPs are generally man-made chemicals with applications as insecticides and in industrial processes.*

Radionuclide*: In the NWT, radionuclide sources include natural deposits, atmospheric fallout from nuclear weapon testing conducted from the 1940s through 1980, transportation accidents and industrial process by-products (for example testing during the laying of pipe). However, the most common source of radionuclides in any Arctic environment is through accidents resulting in releases including those involving stockpiles of radioactive waste (AMAP 2002). While it is unclear how much radioactivity is distributed through the environment in the NWT, radioactivity levels measured in terrestrial animals and fish indicate that radioactivity is not a concern.*

*Parasites and diseases may be transported in the holds of ships destined for the NWT. Although the majority of fish parasites and diseases are endemic to the NWT, as water temperatures increase, the range of parasites may change and stress may increase the incidence of disease.*

### iv) What does it mean?

Contaminant levels in fish are affected by not only the concentrations found in lake or river water but also the type of fish, where it lives in the system, how old it is and what it eats. Older fish may have higher levels of contaminants such as mercury which bioaccumulate in species higher in the food chain. Predatory fish, those that primarily eat other fish, like northern pike, walleye and lake trout, typically have the highest levels of contaminants.

As well as being important culturally for many NWT inhabitants, fish are generally an inexpensive, readily available and generally healthy source of protein (MRBB 2004). To protect the health of people living in the NWT, health advisories for mercury have been issued respecting certain species of predatory fish on twelve lakes in eth NWT (Giauque Lake, Lac Ste Therese, Lac Tache, Little Doctor Lake, Lac a Jacques, Thistlewaite Lake, Keller Lake, Cli Lake, Turton Lake, and Manuel Lake) (INAC 2005).

The presence of diseases and parasites can either make fish unsafe or, at best, undesirable for human consumption. This could impact the ability of NWT inhabitants to utilize this readily available source of food and could have other economic impacts, such as on tourism, if fish quality declines too far.

**v) What is being done about it?**

The first phase of the Northern Contaminants Program (NCP) began in 1991 and was completed in 1997. This phase focused on gathering data to determine contaminant levels, their geographic extent, sources of contamination in the northern atmosphere, environment and people as well as the expected duration of the problem. The results of this phase were synthesized in the 1997 Canadian Arctic Contaminant Assessment Report. The second phase began in 1998 and continued to March 2003. This phase identified three primary study interests: (1) survey, monitoring and temporal trends of traditional food sources and wildlife health, (2) impacts and risk of item 1 on human health, and (3) determining temporal trends of contaminants of concern in key Arctic indicator species and air (INAC 2003). As part of this program, the NWT Environmental Contaminants Committee provides northern residents with information about contamination so that informed choices can be made with respect to fish consumption.

The Arctic Monitoring and Assessment Programme (AMAP), a joint effort of eight Arctic countries, Arctic aboriginal organizations and other observer countries and organizations, began monitoring and assessing anthropogenic pollution in the Arctic in 1991 with a first report published in 1997. NCP is Canada's primary contribution to AMAP.

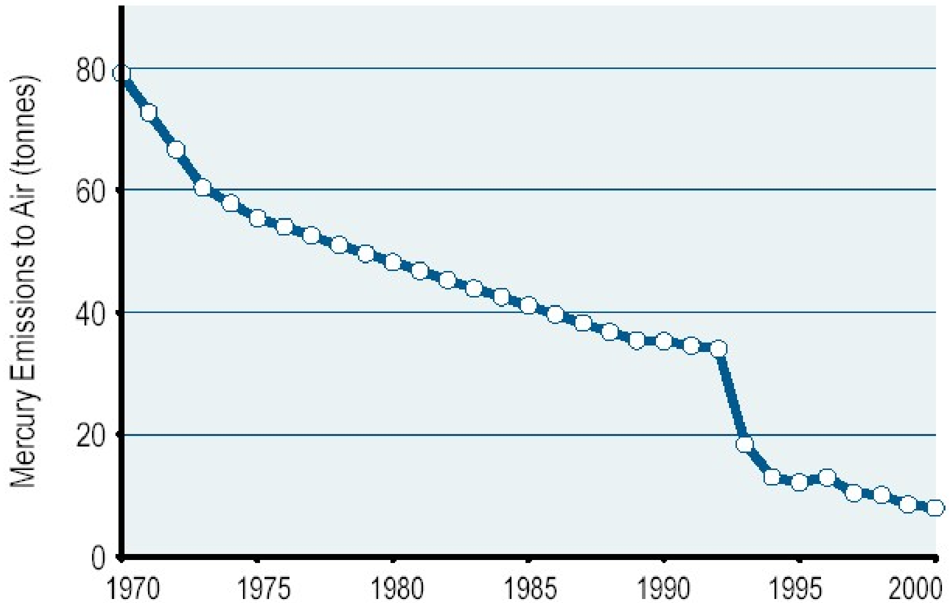
Current contaminant clean-up efforts in the NWT by the INAC and other federal departments are focused on priority abandoned mines. Industry and sewage treatment is also more closely regulated (MRBB 2004).

There are few guidelines for contaminant concentration levels designed to protect fish. Instead, guidelines are focused on the protection of consumers.

<u>Heavy Metals</u>. *Lead is a great example that demonstrates the effectiveness of pollution control. Emissions of lead in 1995 were nearly two thirds lower than those from 1983 (AMAP 2002). This decrease is primarily a result of restrictions of lead in gas.*

Government regulations, such as the Canadian Environmental Protection Act (CEPA), industry cooperation and technological advances have resulted in a decrease in anthropogenic mercury emissions (Figure 3.3-19). However, there is a need for continued international efforts to decrease mercury emissions.

**FIGURE 3.3-19**
**DECLINE IN CANADIAN ANTHROPOGENIC MERCURY EMISSIONS BETWEEN 1970 AND 2000**




*Source: Source: Mackenzie River Basin Board 2004.*

Persistent Organic Pollutants. *The largest contributor of dioxins and furans, pulp mills, are no longer permitted to emit these compounds in their effluent under the CEPA. The industry has implemented technological advances to meet these regulations (MRBB 2004).*

Along with ongoing studies to measure POPs like PCBs, DDT and toxaphene, an effort is being made to investigate new contaminants like brominated flame retardants, fluorinated organic compounds and chlorinated paraffines.

Radionuclides. *With little known about quantities of radionuclides in the NWT, clean up and regulation will continue as required when contamination is identified.*

Other than trying to prevent the introduction of new parasites and diseases, little is done and/or can be done to prevent the spread of fish diseases and parasites.

### vi) What are the information gaps?

Identification of the impacts of climate change on contaminant pathways and effects: More research is needed to understand how climate change and variability will affect the ways in which heavy metals, POPs, and radionuclides are transported to, and within the NWT, as well as how they accumulate and impact biota. There is, as yet, not enough information collected to understand with any certainty how climate change will impacts contaminants and contamination in the NWT (AMAP 2002).

Comprehensive monitoring of contaminants in fish (geographically and temporally): Information regarding contaminant levels by species, types of contaminant and geographic areas (CIMP 2005) especially collecting data to elucidate temporal trends statistically (INAC 2003). Specific areas that require more information are Great Slave Lake and Great Bear Lake because of their importance with respect to human health risk (MRBB 2004) and the Slave River to monitor upstream impacts (Sanderson *et al.* 1998). There is also a need for larger numbers of samples so that statistical comparisons can be made between age and size differences (INAC 2003).

Improved understanding of the biological impacts of contaminants on NWT fish: There is an overall lack of information with respect to biological effects of contaminants on the NWT fish. Furthermore, there are few guidelines set for the protection of fish (INAC 2003), particularly with respect to body burden versus levels found in water and sediment. Specific research needs to determine threshold effects for NWT fish species rather than comparison of burden levels to laboratory studies on non-Arctic species (INAC 2003).

Improved understanding of the pathways and distribution of mercury: A better understanding is needed of the pathways and processes that influence mercury distribution in the Arctic, as well as that for other metals. The relative importance of freshwater and sediment sources versus atmospheric sources has not been determined (AMAP 2002). More information is required to determine the relative contribution of natural versus anthropogenic sources (INAC 2003).

Identify all heavy metals of concern: Consideration should be given to heavy metals that have not, as yet, received attention including platinum, palladium, rhodium and thallium (AMAP 2002, INAC 2003).

Identify effects, sources and prevalence of cadmium: The sources and biological effects of cadmium require more study and in particular, the role that soil and rock plays as a natural source of cadmium (AMAP 2002).

Monitor POP levels and effects (geographically and temporally): Studies should continue to monitor trends in POP levels, as well as to increase the ability to detect effects at the individual and population levels (AMAP 2002).

Ensure early identification of new POPs: Research must be directed at ensuring our ability to detect new and currently used POPs to stay ahead of emerging issues rather than responding once impacts have been observed (AMAP 2002, INAC 2003). Research should also involve the archiving of tissue, so that as new chemicals are identified, archived tissue can be analyzed to establish baselines (INAC 2003).

Identification of POP sources and particularly local sources: Although it is commonly believed that most POP contamination has its origin outside of the NWT, limited information is available regarding the contribution of local contamination such as from burning municipal waste and the DEW-line sites (INAC 2003).

Improved understanding of the presence, quantification and distribution of radionuclides in the NWT: More research is needed to understand the vulnerability of the NWT and potential impacts from radionuclides. There is also a need to look at the remobilization of radioactive compounds from sediment (AMAP 2002). It is unclear if the extent of radioactive contamination in the NWT has been quantified.

Quantification of dose levels and effects on NWT fish: Up-to-date information is needed with respect to the effects of radiation on fish to minimize uncertainties (AMAP 2002).

Development of fish specific guidelines for dose levels: Past dose limits have been focused on human (AMAP 2002). There is a need to develop limits for the protection of fish during all life-history stages. This is particularly important at chronic low-dose levels.

Conduct surveys to catalogue and document the levels of fish diseases and parasites found in the NWT.

Monitoring of diseases and parasites as indicators of fish quality: This type of investigation could be performed on a need basis, or as part of general monitoring added to community and contaminant monitoring efforts (CIMP 2005).

## 3.4 CONCLUSIONS AND RECOMMENDATIONS

Based upon the review of previously completed studies looking at components of the freshwater aquatic environment, the current conditions and trends for the NWT were found to be for the most part favourable. For some indicators the condition and/or trends were identified as unfavourable or deteriorating at a local scale, or, for the whole of the NWT, uncertain. Regarding the latter, such a finding was generally the result of inadequate monitoring data from which to draw conclusions, and in other instances uncertainty was associated with difficulty predicting actual impacts of climate change.

Recommnedations specific to the components assessed in this review are identified below:

Surface Water Quality

- Future monitoring of surface water quality needs to be maintained as it will be useful in determining changes in water quality as they relate to climate change effects.
- The number of long-term monitoring stations in the NWT is limited in comparison to the geographic size; therefore, expanding the current regional surface water quality monitoring to include key locations in unmonitored watersheds would be beneficial.
- Integration of more intensive local research (e.g., mine-specific aquatic effects monitoring) into the long-term monitoring network database would be another means of expanding the water quality database.

Sediment Quality

- Information on PCBs, pesticides, polycyclic aromatic hydrocarbons, dioxins and furans, and heavy metals in sediments is very limited with the exception of specific investigations on the Slave River at Fort Smith and the Liard River above Kotaneelee River. Regional monitoring would be useful.
- Long-term monitoring of river sediments and periodic collection of lake sediment core samples is required to better understand the fate of contaminants in the benthic environment.

Surface Water Quantity

- Future monitoring of surface quantity needs to be maintained to measure the effects of climate change on long-term average flows, extreme flow events and timing of snow melt and freeze over.

Ice Phenology

- Climate warming is anticipated to increase the frequency of interruption of the ferry service due to more frequent ice jams and reductions in water flow.
- Continued monitoring of river flows, frequency and timing of ice jams and days of operation of the ferry and ice bridge services will be important for determining the effects of climate change.

Fish Habitat

- There is only limited data to define baseline habitat conditions in the NWT.

- Aside from fish habitat assessments near residential, transportation, and industrial sites, fish habitat information is not commonly collected in the NWT. Within government agencies with objectives to protect and enhance aquatic ecosystems, there has been no consolidation of programs or data, which would allow for an assessment of parameters as indicators of well-functioning aquatic ecosystems over time.
- There is a need to compile data on various fish habitats for Great Slave Lake and Great Bear Lake, as they relate to fish harvest data. These data should reach a level of detail that would be useful for future comparisons.
- Archiving of high-resolution satellite images of the NWT would allow future comparison of changes in the physical environment that could potentially affect freshwater habitat.

Fish Population

- The data available to define baseline conditions in the NWT are limited.
- Great Slave Lake fish are exploited by several types of fisheries activities, which can affect and deplete populations and stocks. It is therefore imperative to manage the fisheries with proper planning and regulations, record and monitor harvests, and assess the stocks.

Fish Harvest

- Data from fish harvests could be useful to derive population and stock parameters relating to: (1) Energy Use; growth and reproductive investment, (2) Survival; age structure and length frequency analysis, and (3) Energy Storage; condition. Sufficient information appears available to derive new data, even assess trends at some local and regional levels within the NWT.
- Fish stock assessment studies are needed on Great Slave Lake to determine the current status of lake trout as well as other important fish species throughout the lake.
- On Great Slave and Great Bear lakes the fisheries need to be looked at closely and managed to ensure sustainability of stocks overtime. Detailed information is required about fish populations and stocks in order to achieve a corresponding good level of fisheries management.
- On Great Slave Lake, additional information is needed on the subsistence and sport fisheries to complete the understanding of the fisheries resources.
- In the Mackenzie Great Bear Sub-basin, subsistence, sport and commercial fishing are most important. Broad whitefish and lake whitefish remains the most important catch. Harvest status on these species is unknown and needed.

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