ERRATUM No. 1 June 6, 1996

Northern River Basins Study, Report to the Ministers 1996

I. **Section 7.7-Recommendations by the Science Components, Page 233, INSERT:**

Distribution of Contaminants in the Water, Sediment and Biota of the Northern River Basins: Present Levels and Predicted Future Trends

By: John H. Carey, Olga T.R. Cordeiro, and Brian G. Brownlee
National Water Research Institute
Burlington, Ontario

Monitoring and Reporting

1. Given the low levels of organochlorines in water, sediment and biota by the end of the study period, it is recommended that the design and purpose of existing water quality monitoring programs be reviewed based on the NRBS findings. There appears to be no need for intensive basin-wide monitoring for these contaminants. Periodic monitoring, on a two or three year cycle, for contaminants in relevant compartments only, for example PCBs and chlorinated dioxins/furans in fish and PAHs and resin acids in sediment, should be sufficient to detect changes in the basin.

2. Mercury levels in certain areas of the basin, for example the lower reaches of the Athabasca River, are high and likely exceed human health consumption guidelines. It is recommended that mercury levels continue to be monitored regularly, particularly in the lower Athabasca River and western Lake Athabasca.

3. Burbot or, failing that, one of the sucker species are likely the most suitable large fish for use as an indicator species for biological monitoring. It is recommended that whitefish not be used for biological monitoring in this system.

4. It is recommended that a combination of the NRBS results from the broad spectrum analysis and selected target compound analysis be used to establish a baseline finger-print pattern of contaminants in effluents and ambient waters against which future changes can be assessed through the use of pattern recognition techniques.

5. It is recommended that a data management system be established to allow storage and access of all contaminant data collected by governments, industry etc..

6. In view of the unique character of the NRBS samples and their potential value to future generations, it is recommend that government agencies undertake to ensure that the NRBS samples are adequately stored so that they can be made available as a baseline reference for future studies.

Fish Consumption/Water Quality Guidelines

7. In light of the dramatic decreases in chlorinated dioxin and furan concentrations in fish observed by the NRBS after bleaching changes by the pulp mills, it is recommended that these bleaching changes be permanent for the mills and that fish consumption advisories based on chlorinated dioxin/furan concentrations be reviewed.

8. It is recommended that better dietary intake information or subsistence fish consumers in the basin be collected. This information is needed to help establish fish consumption guidelines based on human health for these people.

Research

9. It is recommended that the apparent local hot spots of PCB and metal contamination identified during the study be further documented and where the elevated levels are confirmed, that small site specific studies be conducted to identify the sources.

II. **Section-NRBS Documents, Page 273, INSERT:**

No. 147 Mill, T., P. Sparrow-Clarke and R. S. Brown 1996. *Fish Distribution, Movement and Gross External Pathology Information for the Northern Rivers in Alberta.*

NORTHERN RIVER BASINS STUDY

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REPORT TO THE MINISTERS 1996

Canada

Alberta

Northwest Territories

The Final Report and associated publications are also available on CD-ROM. Further copies of this report and other Northern River Basins Study products can be obtained from:

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Cover Photo: Athabasca River north of Fort McMurray. Photo by F. Korbut

Back Cover: Top: Fishing near Whitecourt. Photo courtesy of Alberta Tourism Partnership.
Middle: A stemless lady slipper found north of Fort McMurray. Photo by F. Korbut.
Bottom: Dog sled. Photo by Leonard Flett.

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DEDICATION

This report is dedicated to the memory of Mr. Bev Burns who served as co-chair to the Northern River Basins Study Board from 1991 to 1994. Bev was a man of vision and wisdom who articulated the concept of the NRBS as a social experiment as well as a scientific study. Bev also played a major role in shaping the course of the NRBS. His dedication to the environment and the people of the north will be remembered. In his honour, Study members established a scholarship at the University of Alberta for deserving students in the field of environmental studies.

TRANSMITTAL LETTER

June 5, 1996

The Honourable Sergio Marchi
Minister of Environment
Government of Canada

The Honourable Ron Irwin
Minister of Indian Affairs and Northern Development
Government of Canada

The Honourable Ty Lund
Minister of Environmental Protection
Government of Alberta

The Honourable Stephen Kakfwi
Minister of Renewable Resources
Government of Northwest Territories

Dear Ministers:

On behalf of the Northern River Basins Study Board, we are pleased to present this Report to the Ministers. The report summarizes the Study's key findings and policy recommendations based on approximately 150 technical reports and reviews.

Since the Study's inception, considerable activity and innovation has occurred. Key to the Study's success was an open communications policy and a commitment to public input and participation.

Ongoing cooperation and positive interaction between members of the Study Board, representing diverse stakeholder and interest groups, helped ensure a balanced and comprehensive Study program and final report.

One factor which was critical to the Study's success involved the unprecedented participation and input of members of the public, and environmental and aboriginal communities. This involvement helped assure that the research program was responsive to community and stakeholder expectations.

As well, considerable efforts were contributed by a number of Canada's most accomplished scientists in providing expertise and accessing some of the most advanced technology available. This helped assure that the science initiated and completed by the Study was accurate, credible and responsive to changing environmental factors.

The following report contains scientific findings and recommendations which the Study Board believes will help guide future management of the Peace, Athabasca and Slave river basins for the social, environmental and economic well-being of Alberta, the Northwest Territories and Canada.

The Study Board extends its warmest thanks and appreciation to the numerous individuals and organizations that have assisted in the preparation of this Report to the Ministers. In particular, the Study Board wishes to thank those individuals who attended and participated in 17 Community Workshops held earlier this year throughout the northern river basins. These workshops provided important local comments and advice to the Study Board as it developed its final recommendations.

We as individuals find this report to be a complete and accurate representation of the findings of the Northern River Basins Study and respectfully submit it along with appropriate recommendations for consideration by the Ministers.

Dr. G. Burton Ayles	Mayor Dennis Bevington	Dr. Stephan Gabos
Dr. Bob James	Mr. Donald J. Klym	Mr. David Livingstone
Mr. Danny MacDonald	Mr. Dave MacDonald	Mr. Gerald McKeating
Mr. Robert McLeod	For Chief Bernie Meneen	Mr. Vern Moore
Mr. James R. Nichols	Mrs. Lucille Partington	Mrs. Lucille Polukoshko
Mayor Michael Procter	Mr. Fred Schulte	Chief Johnsen Sewepagaham
Councillor Diane Slater	Mrs. Elizabeth Swanson	Mr. Doug Tupper
Mr. Lawrence Villeneuve	Dr. Ron Wallace	Dr. Brian Wheatley

KEY FINDINGS AND RECOMMENDATIONS

Introduction
From its beginning in 1991 to its completion in 1996, work completed by the Northern River Basins Study (NRBS) within the Peace, Athabasca and Slave river basins remained timely and relevant. The NRBS was launched in response to concerns expressed by northern residents following the 1991 approval of the Alberta Pacific Pulp Mill in Athabasca, Alberta. As the Study closes, new developments are being discussed in northern Alberta.

During the Study's four-and-one-half years of scientific work, about 150 projects or "mini studies" were initiated. Results of these studies were combined with extensive traditional knowledge research, public input and intensive analysis by some of Canada's most esteemed scientists.

This information and recommendations by the Study Board bring together findings, conclusions and recommendations which are hereby presented to the Ministers representing the governments of Canada, Alberta and the Northwest Territories.

The Report provides a valuable benchmark that defines the state of the Peace, Athabasca and Slave rivers as they currently exist. In some cases, scientists and Study Board members are concerned about current conditions within the river systems and recommend immediate action. However, overall the Study believes that there is sufficient time through good management and planning to preserve and protect the northern rivers while supporting wise sustainable development.

The specific river reaches where remedial action is needed illustrate the sensitivity of the river ecosystems and underline the importance of action. Even during the course of the Study, technological improvements and more stringent regulations have resulted in measurable improvements in conditions in certain areas. At the same time, NRBS scientists discovered new challenges to the health of the aquatic ecosystem, particularly from a cumulative effects perspective.

The Study demonstrated conclusively that residents of the river basins care deeply about the ecological state of the region in which they work and live. Their support of the Study has signalled the importance of public involvement in setting goals and devising management plans for the basins.

These four factors combined — the timeliness of the Study, its value as a benchmark, the importance of technological and scientific advances, and public concerns, indicate the need for action on the Board recommendations as soon as possible. This is the responsibility of Canada, Alberta and the Northwest Territories in their stewardship of the natural resources of the basins. Given that stewardship, one may have confidence that continued use and prudent development can occur in balance with protection of the natural ecosystem and preservation of the culture and evolving lifestyles of the traditional residents.

The following text discusses the Study's key findings and recommendations that, in the Board's view, warrant special attention by governments. Additional Board recommendations are found in Section 4.0, as well as those advanced by NRBS researchers in Appendix 7.7.

Quality of Fish and Water

The most common questions posed by basin residents during consultations with the Study Board are "Can we eat the fish?" and "Can we drink the water?" The Study has been able to provide some information with regard to these questions. Dioxin and furan levels in fish have declined significantly over the period of the Study, and levels of polychlorinated biphenyls (PCBs) in fish appear to be within generally accepted consumption guidelines. Research confirms, however, that levels of toxic dioxins, furans and mercury still exist in a number of important fish species located in certain river reaches.

Provincial fish consumption advisories are in place at certain sites to protect residents from consuming harmful quantities of contaminants in fish. In the northern river basins, fish are a major source of food for some basin residents, in particular, aboriginal peoples living in remote northern communities. **In the interests of human health, the Study Board recommends that federal and provincial authorities re-evaluate fish consumption guidelines for the northern river basins in light of NRBS findings and dietary patterns of residents (see Recommendation 12).**

With regard to drinking water quality, the NRBS concludes that the large majority of basin residents receive good quality water from municipal treatment facilities. However, NRBS researchers found several instances where the quality of treated drinking water did not meet guidelines.

In the Alberta portion of the basins, a number of small treatment facilities (generally serving less than 500 residents) have difficulty at times meeting water quality guidelines with respect to turbidity and microbial contamination. There are 85 small facilities operating in Alberta, serving a total population of approximately 21 900. Individuals receiving water from these facilities may be more susceptible to waterborne diseases, such as giardiasis ("beaver fever"), salmonellosis and shigellosis.

Visits to several small treatment plants reveal that difficulties are often related to maintenance and operation, rather than inadequate treatment systems. **The NRBS Board recommends that governments should increase their efforts in petitioning smaller communities to educate and train facility operators regarding the need to properly operate water treatment facilities (see Recommendation 3). This includes the use of existing programs for operator training, certification and assistance. The Board also calls for authorities to ensure the adequacy of treatment facilities in these areas.**

At least 25 per cent of basin residents obtain their water directly from rivers, lakes, springs, wells and dugouts without treatment by conventional facilities. NRBS studies found that surface water sources in the Study area often contain bacteria and should be treated prior to consumption.

Ecosystem Health

A main objective of the NRBS was to define the combined effect of multiple developments on the Peace, Athabasca and Slave river ecosystems. Researchers used a variety of methods to measure how environmental stressors are affecting aquatic life.

Many reaches of the Peace, Athabasca and Slave rivers appear minimally affected by environmental stress. In other reaches, however, fish and other aquatic organisms are experiencing stress. Reaches immediately downstream of pulp mills, for instance, contain a higher proportion of fish that are sexually immature. Among sexually mature fish, sex hormones tend to be lower and some of the fish collected in these reaches display physical abnormalities such as tumours or growths.

While NRBS studies couldn't clearly measure the nature and extent of these problems, the results raise significant concern that environmental stress may be affecting the health of aquatic life within certain river reaches. The NRBS Board feels that this issue demands further attention to ensure that present and future developments do not impair the ecological well being of the rivers. **Accordingly, the Board recommends that the Ministers initiate a comprehensive study of hormone disruption and reproductive biology of fishes throughout the basins (see Recommendation 15).**

Nutrients / Dissolved Oxygen

Aquatic organisms require dissolved oxygen to survive and reproduce. Several natural and human-caused factors can deplete the amount of dissolved oxygen in river water. Winter ice cover prevents air from entering the water system. The decay of organic material, such as plants or organic substances in sewage and pulp mill effluent, consumes oxygen. The addition of nutrients (i.e., nitrogen and phosphorus) in wastewaters can also lead to reduced dissolved oxygen levels by stimulating algal and plant growth that consume oxygen as they decay.

In Alberta, the level required to protect the health of aquatic life is set at 5 mg/L under the *Alberta Surface Water Quality Objectives.* While average dissolved oxygen levels in the mid-water column of the Athabasca River rarely fall below 6.5 mg/L, levels in or at the riverbed can be lower. Lower dissolved oxygen levels (i.e., 3 - 5 mg/L) can disrupt the growth, development and ultimately the survival of sensitive aquatic species that spend at least a portion of their lifecycle in or adjacent to the riverbed. This includes several important fish species, such as mountain whitefish and bull trout, as well as the bottom-dwelling organisms upon which they feed.

These findings suggest that present Alberta guidelines may not adequately protect aquatic life at localized sites within the basins. **The Board recommends that the governments of Alberta and Canada initiate studies to determine the winter dissolved oxygen requirements for fish and other aquatic species in the various reaches of the northern rivers. It further recommends that Alberta adopt the more conservative guideline set forth by the Canadian Council of Ministers of the Environment (6.5 mg/L) as an overall provincial approach for making decisions on future development proposals (see Recommendation 2).**

The Board also feels that current nutrient regulations and monitoring practices may not adequately protect long-term environmental health in the basins. NRBS studies have revealed that nutrient inputs from pulp mills and municipalities have enriched aquatic communities immediately downstream of their outfalls, especially in the Athabasca and Wapiti / Smoky river systems. Currently, the problem is primarily aesthetic and relates to the amount of algae immediately downstream of the outfalls. While this initial effect is localized, nutrients may eventually accumulate in downstream sections of the rivers and cause nutrient / dissolved oxygen difficulties in the long-term. Nutrient enrichment may also alter characteristics of the aquatic food chain and effect contaminant bioaccumulation. For example, this process may explain higher PCB levels in fish below pulp mills in a nutrient-rich environment.

Further population increases and development of the basins are imminent and will no doubt place added nutrient-related pressures on the northern rivers. The NRBS Board is not satisfied that current nutrient regulations and monitoring requirements can adequately protect the long-term environmental health of certain river reaches. **The Board recommends that the Ministers improve**

the quality of analysis and reporting of monitoring of nutrient and biological oxygen demand throughout the basins, especially for municipal sewage treatment facilities and pulp mills (see Recommendation 2). The Board also recommends further reductions in phosphorus concentrations in both pulp mill and sewage effluent.

Flow Regulation

British Columbia's W.A.C. Bennett Dam was constructed in the late 1960s to meet growing demands for hydroelectricity. NRBS studies confirm that the dam has a significant impact on the flow patterns, sediment transport, river morphology, ice formation and habitat along the mainstem Peace River.

Changes to flow and ice patterns are at least partly responsible for the lack of ice-jam induced floods in the Peace-Athabasca Delta. In the absence of these floods, the delta is slowly drying out — profoundly affecting the natural environment and the traditional lifestyles of local residents. NRBS research also suggests that flow regulation by the dam is affecting the rate of growth of the Slave River Delta into Great Slave Lake.

Several attempts have been made to replenish water levels in the Peace-Athabasca Delta. These efforts have successfully restored water levels in the lower lakes and channels but could not flood the elevated lakes (or "perched basins"). Several new and potentially more effective options were identified within the NRBS and one of its companion initiatives — the Peace-Athabasca Delta Technical Studies.

In light of improved understanding of the mechanisms controlling flooding of the Peace-Athabasca Delta, the Board feels that these new remediation options warrant serious consideration. **Accordingly, the Board recommends that the governments of Canada, Alberta and British Columbia implement an action plan for remediating the Peace-Athabasca Delta (see Recommendation 7-1) in consultation with affected basin residents.**

Previous remediation attempts were frustrated by the absence of natural flow patterns on the Peace River. The Board stresses that economic factors in hydroelectric production must not be allowed to take precedence over environmental stability. **The Board recommends as a principle for any future negotiations regarding mitigation measures, that the operational regime of the Bennett Dam be modified to aid the restoration of the Peace River and the Peace-Athabasca Delta (see Recommendation 7-2).**

Key Issues by River Reach

The NRBS research program has greatly enhanced understanding of how the Peace, Athabasca and Slave rivers respond to developments within the basins. Given this new information, researchers were able to identify critical environmental issues and management challenges within individual river reaches. A few areas deserve special attention: the Wapiti / Smoky river system, and the Athabasca River between Hinton and below Whitecourt.

Of these, the Wapiti / Smoky river system is most stressed by development. Among other developments, the system receives discharges of nutrients and contaminants from sewage and pulp mill effluent emanating from the Grande Prairie area. Since it produces lower annual flows than the mainstem Peace River, the Wapiti / Smoky system is less able to assimilate wastes and more vulnerable to the effects of development. While dioxin and furan levels in sediments and aquatic life are declining, levels are still among the highest in the basins. Levels of PCBs in fish from the Wapiti River doubled between 1992 and 1994.

Several lines of research suggest that the Athabasca River from Hinton to below Whitecourt is exposed to environmental stress. Levels of certain industrial contaminants (PCBs, dioxins, furans and others) and metals downstream of Hinton are higher than in other river reaches. Fish and large aquatic invertebrates exhibit signs of stress that may be related to contaminants. Higher incidences of fish abnormalities are also reported downstream of Whitecourt. Nutrients from industrial effluent and municipal sewage have stimulated algal growth to levels of aesthetic concern.

The Slave River Delta lies at the northern tip of the Study area. Fish sampled in the delta were large and in good physical condition. However, these same populations showed signs of environmental stress. Although there is evidence of contaminants deposited in the delta and Great Slave Lake, the actual exposure of fish to these contaminants remains unknown.

In light of these findings, the Board recommends that the Ministers initiate action to protect the Wapiti / Smoky river system from further development-related stress and apply reach-specific guidelines and associated regulatory requirements recognizing the small size of this river system. It further recommends enhanced monitoring and research in the Athabasca River from Hinton to below Whitecourt (see Recommendation 10).

Pollution Prevention

NRBS research findings confirmed that rivers are being affected by human developments. Ultimately, it is always more costly, both economically and ecologically, to restore a contaminated river system than to prevent pollution at its source. However, it would be difficult for *all* sources of pollution to be eliminated from the basins environment. Some pollutants arise from distant sources and are carried to the basins in the atmosphere. Still others (e.g., agricultural runoff) are difficult to trace back to their point-of-origin.

The NRBS Board feels that these difficulties should not deter efforts to reduce and eliminate identifiable pollution sources to the rivers. In addition, NRBS studies and consultations reveal that some basin residents advocate the notion of "zero discharge." **The Board recommends that regulatory agencies within the basins declare and implement pollution prevention as a primary environmental objective and as an important component of sustainable development (see Recommendation 1). The Board recommendations contain specific provisions for persistent toxic substances and nutrients. It also urges governments to pursue international arrangements to eliminate the use, generation and discharge of airborne pollutants.**

Basin Management

Ultimately, rivers and other water bodies are the final repository for many wastes arising from land-based activities. In this way, the condition of rivers reflect activities throughout the basins. The Board has formulated a series of policy-related recommendations urging enhanced inspection, enforcement and planning to protect water quality and quantity.

One of these recommendations deals with a successor organization to the NRBS Board. In an NRBS survey of households and stakeholder organizations, a large number of respondents supported the establishment of an ongoing intergovernmental and stakeholder committee that would be responsible for the protection and wise use of the northern river basins. **The Board considered several options and proposes that governments with jurisdiction over the northern river basins create such new bodies as necessary to advise governments on matters related to the aquatic and riparian ecosystems of the northern river basins.** The Board offers a specific recommendation on the nature and possible structure of a new body. However, it is also clear that a range of contrasting opinions exist on how specifically the need may be met. The Board's detailed recommendation and discussion (see Recommendation 23 and Appendix 7.8) are designed to provide guidance in this area.

An effective monitoring program is an integral part of any management plan. Currently, monitoring within the basins is performed by a number of agencies, such as industries, municipalities, universities and governments. **The NRBS Study Board recognizes the need to harmonize individual monitoring efforts and recommends the creation of an Integrated Ecosystem Monitoring Committee (IEMC). Functioning within the framework of a successor organization, the IEMC would coordinate and oversee technical and scientific aspects of water quality, water quantity and biota monitoring in the northern river basins to ensure minimal duplication of effort and greatest collective efficiency (see Recommendation 11).**

Timeliness is crucial in the establishment of both the IEMC and the successor organization. **To maintain the momentum initiated by the Northern River Basins Study, the Board recommends the establishment of a steering committee to facilitate the transition to other bodies or successor organizations by April 1, 1997 (see Recommendation 24). The Board also strongly endorsed the early signing of the *Mackenzie River Basin Transboundary Waters Master Agreement* (see Recommendation 23-1).**

Study Process

One of the key findings of the NRBS has been the success of the study process itself. Although initiated by governments, the NRBS was set up to be "arm's length" from those governments. The

Ministers appointed a Study Board that represented many interests associated with the Peace, Athabasca and Slave river basins, including industry, environmental groups, aboriginal peoples, health, agriculture, education, municipalities and the federal, provincial and territorial governments. While their interests are diverse, the Board members provided broad, comprehensive direction to the Study, and they became united in their shared vision of wise management and sustained use of the rivers.

This representative system was further strengthened by sustained and deliberate involvement of basin residents in the Study process, through a proactive communications strategy with regular news releases, attentive media relations and frequent community meetings. This provided basin stakeholders with up-to-date information and ensured that their questions and concerns were received and considered in a timely fashion. In accord with Board policy, all information from the Study was promptly released to the public, and a final series of community workshops assisted the Board in developing its recommendations.

An important finding of the Study is that public involvement is a contemporary and politically sensible way to operate that it is of immeasurable value in sustaining public good will for any study. Very useful information was gathered through the public process that influenced the science program and subsequent results.

The broadly representative Board and the inclusion of open public participation gained greater acceptance and credibility for the Study than could ever be achieved through a closed process. **Recognizing the numerous benefits of public involvement, the Study Board recommends that meaningful public participation become an integral part of future studies within the basins (see Recommendation 20).**

Further Recommendations
The Study Board also forwards a number of other recommendations to the Ministers. In Section 4.0, the Board identifies several research and monitoring needs, such as studies to define the extent of PCB contamination in the basins and to describe the effects of oil sands on aquatic life. Several management recommendations are also outlined, dealing with water management, land and water use planning, water quantity / quality planning, water diversions, and inspection and enforcement activities. Additional Board recommendations, further discussion on the recommendations noted above and summaries of recommendations made by NRBS researchers are detailed in the body of this Report.

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PREAMBLE

Stretching from the Rocky Mountains of Alberta and British Columbia to the northern plains of Saskatchewan to the shores of Great Slave Lake in the Northwest Territories, the Peace, Athabasca and Slave river basins encompass an area of immeasurable value. Together, they cover an area greater than Nova Scotia, Newfoundland and New Brunswick combined, and support a wide expanse of relatively unharvested, aspen-dominated boreal forest. They also host two large freshwater deltas — traditional havens for wildlife and migrating waterfowl.

These northern basins are still viewed by many as the "last frontier" where traditional lifestyles and cultural values can survive and prevail. Some residents believe that this way of life is being compromised to serve another societal goal; that of growing economic development. Others feel that growing economic development is a natural, desirable and justifiable process. The basins are rich in resources, predominantly oil, oil sands, natural gas, coal, commercial fish and fur, productive soils and forest products. These resources must be managed wisely to protect the environment and support the continued use of renewable resources.

The Northern River Basins Study (NRBS) initiated research and gathered basic information to better understand the cumulative impacts of development. Simply put, what is the combined effect of all forms of development on the natural aquatic ecosystem? This basic question leads to a series of concerns that science must address. These concerns include the accumulation of contaminants over time and space, the effect of contaminants and nutrients on the aquatic ecosystem, and the combined effect of a number of environmental stressors on the quantity and quality of fish and water. The NRBS endeavoured to address these and other related concerns with a view to promoting wise management of the basins' resources.

The Study adopted a fresh approach to both science and process. An innovative and practical science program was geared to answer 16 environmental questions that reflected societal concerns and scientific needs. The information required to answer these questions was then grouped under eight headings, each to form a component of the Study and each supported by expertise from universities, governments, industry and the private sector. A high level of coordination among these groups resulted in an integrated and flexible research program that minimized overlapping activities.

Another strength of the Study was the meaningful inclusion of traditional environmental knowledge in the science program. The NRBS Board negotiated a formal agreement with the Grand Council of Treaty 8 First Nations for researchers to collect information and chronicle the traditional environmental knowledge of many native peoples residing within the basins. Their knowledge, combined with those of other traditional and local residents, has extended the reach of the scientific information-gathering process — providing insights into the influence of human activities.

Every attempt was made to employ a comprehensive approach in the program design — one that recognizes the complex interrelationships between land, air, water, living organisms and human inhabitants of the basins. Recognizing limits to time, finances and mandate, the research program was focussed on the three rivers and their main tributaries. Apart from being ecosystems in their own right, rivers act as "integrators" within the larger ecosystem. If one can imagine the ecosystem as a living organism, then flowing waters like the rivers are its veins and arteries — supporting life and transporting nutrients and wastes between its various components. In this way, patterns of development are reflected in the rivers.

The Study included approximately 150 project reports. A series of synthesis reports summarized these findings in the context of current and background information related to the impact of human activities on the basins. This report builds upon that base to make recommendations for future management of the basins. Taken together, the NRBS reports are a benchmark statement of the present state of the rivers and what steps should be taken to preserve their value as ecological resources.

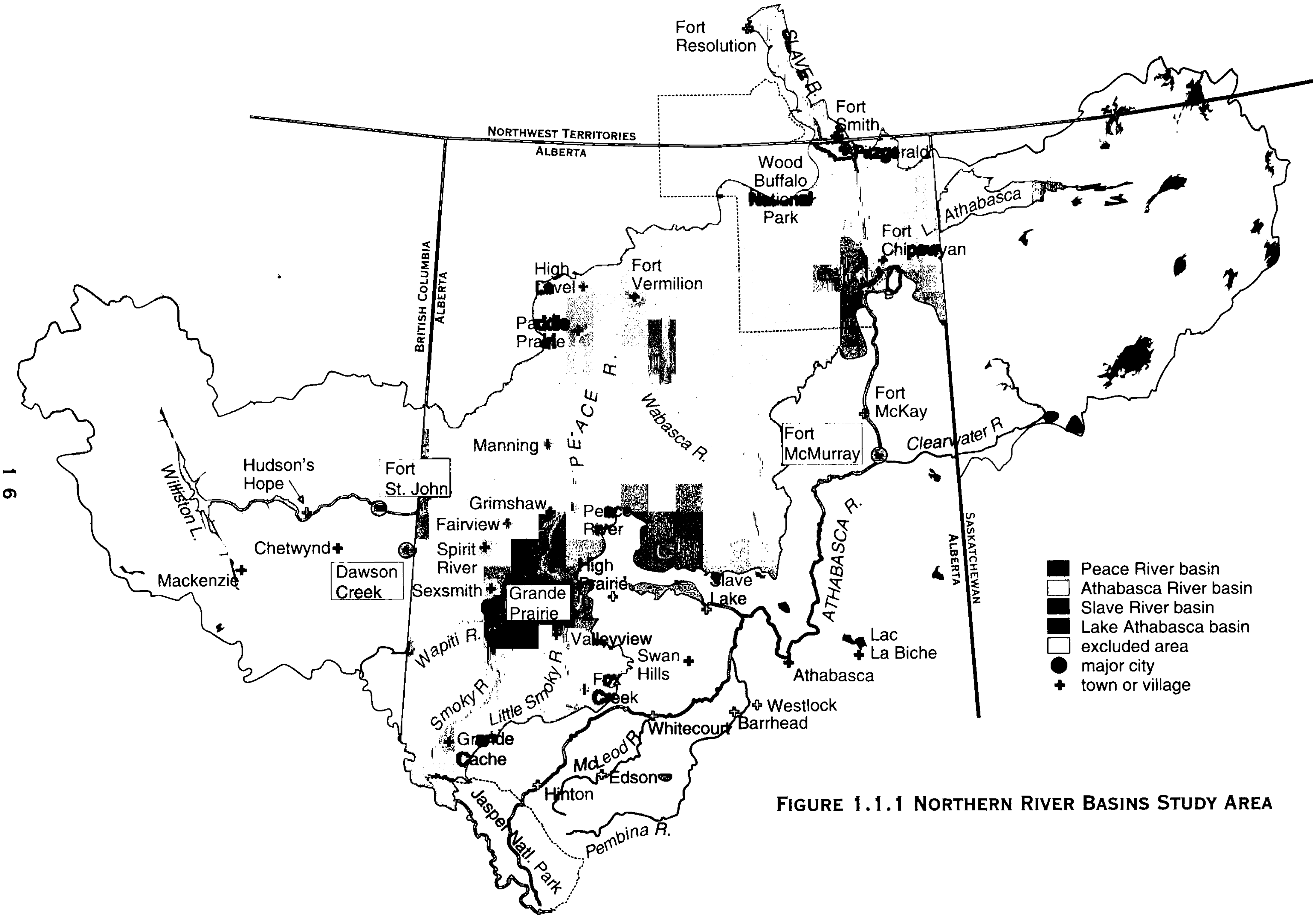
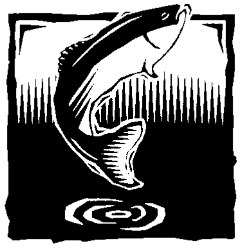


FIGURE 1.1.1 NORTHERN RIVER BASINS STUDY AREA



1.0

BACKGROUND

1.1 INTRODUCTION TO THE NORTHERN RIVER BASIN

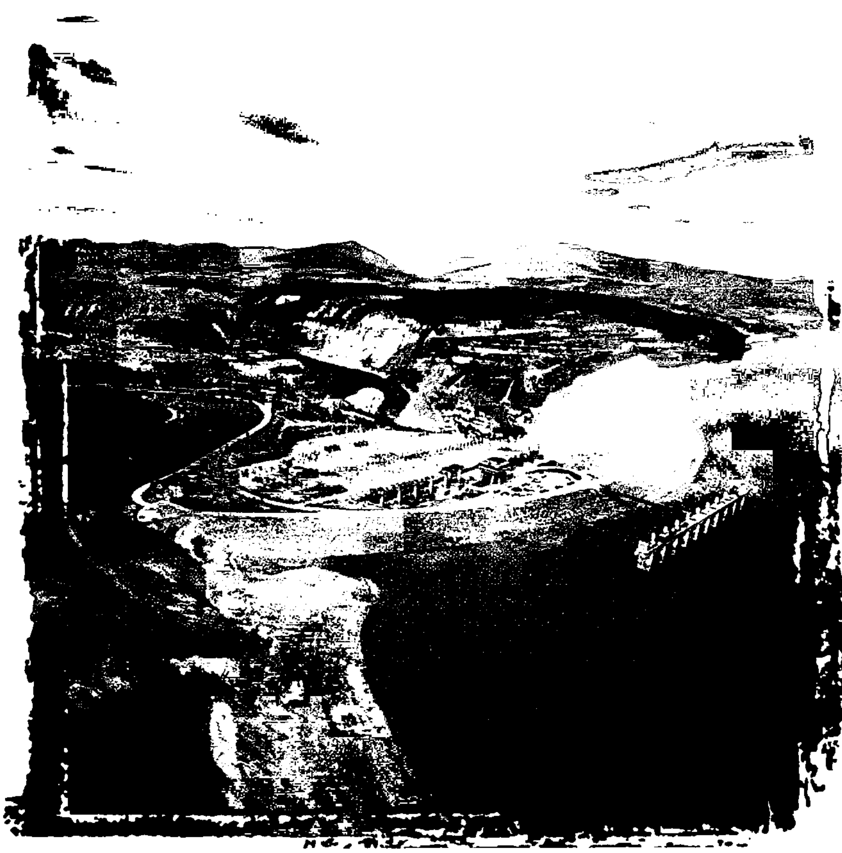
Residents of the Peace, Athabasca and Slave river basins live in an expansive and picturesque natural environment. Combined, the three basins cover 580 000 km^2 and extend across large portions of Alberta, the Northwest Territories, British Columbia and Saskatchewan (Figure 1.1.1).

The Northern River Basins Study (NRBS) was established in 1991 to provide fundamental information regarding the impact of human activities and development in the river basins. The Study area is defined as the Alberta and Northwest Territories portions of the Peace, Athabasca and Slave river basins. To understand the purpose for the four and one-half year study, it is first necessary to become familiar with the rivers and the issues that surround them.

1.2 THE PEACE RIVER

The Peace River has its origin in hundreds of cold mountain streams in the Rocky Mountains of British Columbia. Each spring, water from melting snow and ice trickles down from the mountains and eventually drains into Williston Lake, the largest man-made lake in British Columbia.

Less than 30 years ago, the northern and southern ends of the reservoir would have appeared as the Finlay and Parsnip rivers. The rivers have since been backflooded by the creation of the W.A.C. Bennett Dam near the town of Hudson's Hope, British Columbia. Williston Lake feeds the dam's hydroelectric generators, and the Peace River now flows from the reservoir's eastern arm.



courtesy of B.C. Hydro

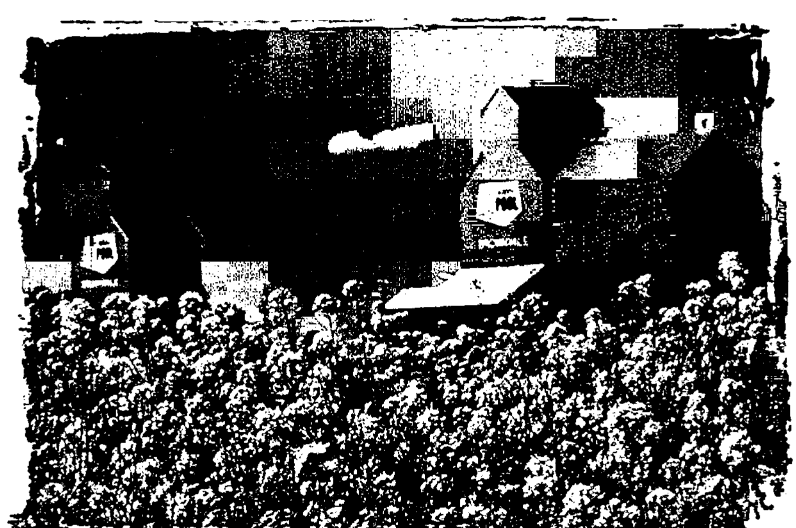
The W.A.C. Bennett Dam in British Columbia

The Bennett Dam has altered the flow and characteristics of the Peace River. Unrestricted, the level of the Peace River varied seasonally — high flow in the spring and low flow in the winter. The dam dampens these highs and lows to ensure peak energy generation potential during the winter months when electrical demands are high. Moreover, the water that passes through the dam is drawn from the lower portion of Williston Lake that remains unfrozen during the winter. These changes in water levels and temperature can alter many aspects of the ecosystem, such as the quantity of habitat, the movements of fish and animals, and the period to which the river remains frozen (see Section 3.5 for more information related to the Bennett Dam and its effects).

The reservoir is used by local pulp and paper mills as a corridor for transporting logs and as an outlet for their waste waters. There are three mills located in the general area of Williston Lake. The Fletcher Challenge and Finlay Forest Industries mills are located in the town of Mackenzie. The Louisiana-Pacific mill, which is located further east in the town of Chetwynd, does not rely on local surface water supplies and has little or no impact on water quality. The two mills in Mackenzie, however, are licensed to discharge waste effluent into the reservoir and, ultimately, these wastes flow into the Peace River.

The flow of water past the Bennett Dam marks the beginning of the Peace River. The river flows eastward, carving a deep chasm in the undulating landscape and passes through the Peace Canyon Dam. It is joined by the Halfway River to the north and passes near Fort St. John — the oldest white settlement on mainland British Columbia and a former outpost of the fur trade. Further east, the Peace is joined by the Pine River near the town of Taylor, where it encounters the Fibreco pulp mill.

The river then crosses the border into Alberta's northern agricultural region — an area that stretches south to the city of Grande Prairie and north along the river to the town of Fort Vermilion. Much of the soil in this area once lay at the bottom of ancient glacial-meltwater lakes. Today, the gently rolling plains surrounding the river are a patchwork of fields and forests. Canola, alfalfa, clover and oats are a few of the region's main crops (see Section 3.2 for more information related to agriculture). Aspen and balsam poplar dominate the forests, often interspersed with white spruce and jack pine.



courtesy of Alberta Tourism Partnership

Canola fields in northern Alberta.

The river passes south of the town of Fairview, traversing a high, walled canyon-like reach that was studied during the mid-1980s as a possible site for the Dunvegan Dam and Reservoir. The Peace is later joined by the Smoky River from the south. Together with its tributaries, the Smoky River drains roughly 20 per cent of the Peace River basin and extends as far south as Jasper National Park. As with any tributary, the Smoky brings with it the history of its journey, written in the nutrient and chemical contents of its waters. The areas that the river drains are developed extensively for forestry, agriculture, coal, oil and gas. The river also receives effluent from the Weyerhaeuser Canada pulp mill through one of its major tributaries — the Wapiti River. Just past its picturesque confluence with the Smoky River, the Peace flows past the town of Peace River. Here the river cuts deep into the surrounding grasslands to form a green valley surrounded by high, steep bluffs.


courtesy of Alberta Tourism Partnership

The Daishowa-Marubeni pulp mill is located roughly 25 km north of the town. A little further north, the Cadotte River joins with the Peace River. The Cadotte River is not a major tributary to the Peace, but it drains an area that is underlain by a relatively large oil sands deposit. Commercial-scale operations are currently underway to extract and refine this non-conventional source of oil. The extraction process involves injecting pressurized steam into the deposit to melt the tar and places demand on local surface water supplies. The mixture of tar and water is then pumped out of the ground and refined.

The agricultural corridor surrounding the Peace River continues as the river travels north past the Métis Settlement of Paddle Prairie. Further on the river veers east, passing near various native settlements representing Dene Tha', Cree and Beaver nations. Agricultural development along the Peace River slowly phases out east of Fort Vermilion, a town that is over 200 years old and a former outpost of the fur trade.

Outside the town of Fort Vermilion, the Peace is joined by one of its major tributaries, the Wabasca River. Each year, cobble and other materials are washed down the Wabasca, forming a fan-shaped bank of material at the river's mouth. Historically, spring floods on the Peace River have stripped away these banks of material and washed them towards the Peace-Athabasca Delta. Many speculate that the Bennett Dam has reduced the Peace River's ability to "scour" away these deposits, resulting in a growing bank of material.

East of the Wabasca, the Peace River passes through the Vermilion Chutes rapids. During certain times of the year, these rapids have drops of three to five meters — posing a major obstacle for river travel and fish movements. The Caribou Mountains lie to the north — an area of peat, lichen, black spruce and permafrost.

Further to the east, the Peace passes the Jean D'or Prairie and Fox Lake Indian reserves before entering Wood Buffalo National Park. The park is noted for one of the world's largest free-roaming herds of bison and is recognized as a world heritage site. Finally, the Peace River finishes its 2000 km trek as it joins with outflow from the Peace-Athabasca Delta to form the Slave River.


courtesy of Provincial Archives of Alberta

Beaver Indian trading in a Hudson's Bay Co. store in Fort Vermilion, *circa* 1890.

1.3 The Athabasca River

The Athabasca River headwaters are formed by the melting snow and glaciers of the Columbia Ice Field on the continental divide. Finely ground particles of rock (or "rock flour") formed by glacial action lend a silty grey colour to the water. The river travels north, cutting a path through the scenic mountains and forests of Jasper National Park. The landscape that surrounds the river valley is a mixture of open forests and grasslands. White spruce grows near to the waters edge. Further back, forests of Douglas-fir, lodgepole pine, and aspen provide habitat for elk, mule deer and many species of birds.

courtesy of Alberta Tourism Partnership

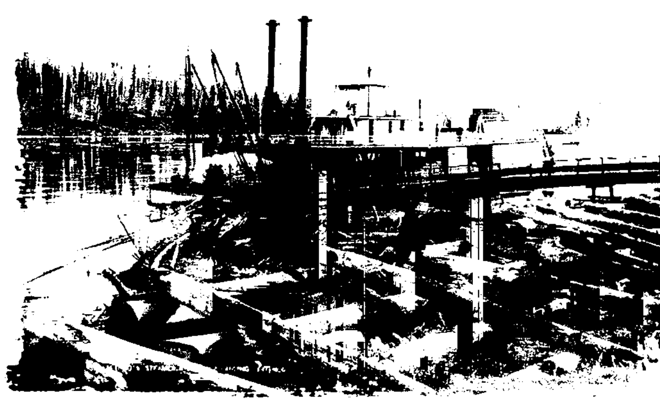
Jasper National Park

As the river leaves the park, the rugged topography softens into rolling foothills. Coal underlies much of these foothills; covering a broad diagonal swath across the province that parallels the Rocky Mountains. Some of western Canada's largest active open-pit coal mines are found in this region.

Further on, the Athabasca River passes the Weldwood pulp mill at Hinton, the oldest of the five mills in the Athabasca River basin. The mill relies completely on the region's softwoods: white and black spruce, lodgepole pine and alpine fir.

The river continues north and swings eastward towards the town of Whitecourt, where it encounters the Millar Western pulp mill and the Alberta Newsprint Company. At Whitecourt, the river is joined by the McLeod River that drains areas with open pit coal mines and limestone quarries to the south. Oil and natural gas deposits are found to the north of the river, near Fox Creek and Swan Hills. In fact, one of the largest producing gas fields in the country is located in the Fox Creek area (see Section 3.2 for general information regarding oil, gas and coal developments). Leaving Whitecourt, the Athabasca River swings north again and is joined by the Pembina River that drains through prime agricultural lands to the south. By now the waters of the Athabasca are brown from the soil and other materials that it has picked up along its course. As the physical environment changes, so too do the numbers and kinds of organisms in the river. These changes continue along the length of the river, corresponding to specific habitat and nutrient requirements of different fish and aquatic organisms.

The Athabasca is joined by the Lesser Slave River, which drains the agricultural and forested areas surrounding Lesser Slave Lake. Another pulp mill, Slave Lake Pulp, is located along the banks of the Lesser Slave River. Beyond Lesser Slave River, the Athabasca dips southward toward the town of Athabasca. Prior to 1904, the town of Athabasca was known as Athabasca Landing and was a site of great importance in northern development. Goods were moved from Edmonton to Athabasca Landing, where they could be barged to northern outposts. The Athabasca Landing Trail, created in the 1870s, was a portage that linked the North Saskatchewan River to the Mackenzie River system, allowing access to the fur trade. With the decline of the fur trade, agriculture, forestry and natural gas rose as the dominant regional



courtesy of Provincial Archives of Alberta

Hudson's Bay Co. steamer "Athabasca" at Athabasca Landing in 1896.

industries. Barge traffic along the river declined after the railway was extended to Fort McMurray in the early 1900s.

Turning northeast once again, the Athabasca River passes by a newer feature to the land, the pulp mill owned by Alberta-Pacific (AlPac) Forest Industries Inc. The river runs through the middle of the AlPac Forest Management Agreement (FMA) boundaries — the area that defines the potential timber supply for the mill. Covering an area of roughly 61 000 km², AlPac's FMA is much larger than that of other pulp mills in the province

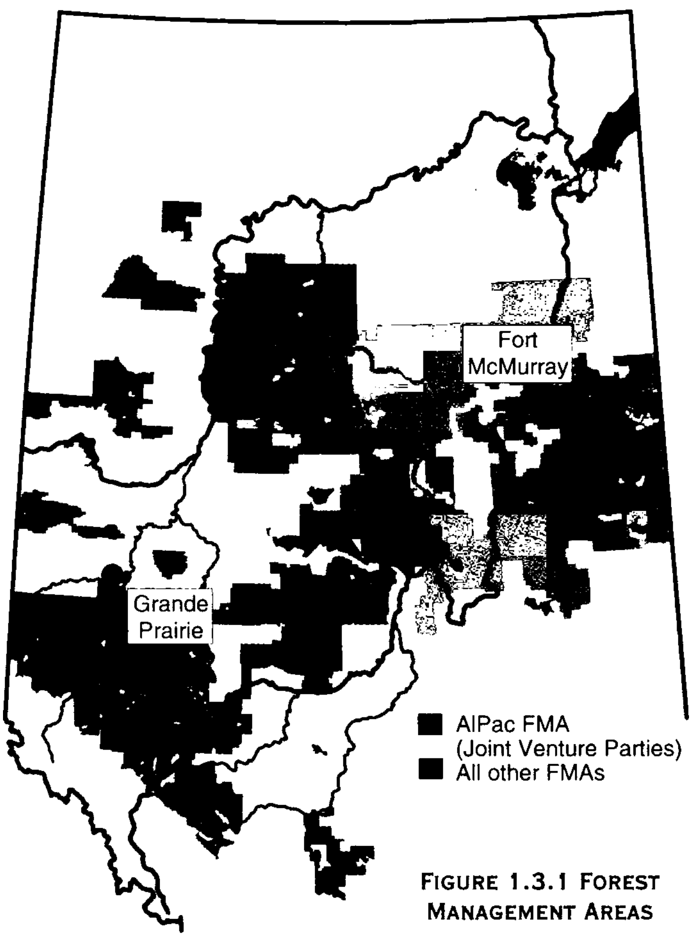


FIGURE 1.3.1 FOREST MANAGEMENT AREAS

(Figure 1.3.1). The pulp mill was constructed to make use of both the hardwood (eg., aspen and balsam poplar) and softwood (eg., white spruce, black spruce and jack pine) resources within the FMA area.

Continuing north through the FMA, the Athabasca is joined by La Biche River that drains the agricultural regions surrounding Lac La Biche. Commercial fishing, oil, lumbering and natural gas also contribute to the local economy of the Lac La Biche area.

The Athabasca River continues northward through the boreal mixed wood forest and evolves into a series of major rapids. The influence of these rapids on the rest of the Athabasca River is quite significant. Not only do they pose an obstacle to river travel, they also serve as a major spawning area for fish, such as lake whitefish and walleye. The turbulence of the water also replenishes levels of dissolved oxygen needed for fish and other aquatic organisms. This aeration takes on an added significance during the winter months, when ice cover blocks contact with the air and dissolved oxygen levels dwindle.

Beyond the rapids, the Athabasca River encounters the city of Fort McMurray. Historically, Fort McMurray was another outpost of the fur trade and a major site for the transport of goods north along the Athabasca River. Here, the river cuts through shallow oil sands deposits and its waters are tinged with natural hydrocarbons. Bitumen (the raw hydrocarbon of the oil sands) is visible as an asphalt-like substance along the banks of the river. Indians once used bitumen to patch their canoes. Today, the Athabasca oil sands provide a non-conventional source of oil that is currently mined by two companies (Suncor and Syncrude) located just north of the city of Fort McMurray.

At Fort McMurray, the Athabasca River is joined by the Clearwater River that flows across the border from Saskatchewan. The Clearwater River's major tributary, the Christina River, drains an area with extensive oil and gas development. The Athabasca continues north past Fort McKay and Bitumont, where the abandoned facilities of Alberta's first pilot oil sands operation can be found. The river then becomes the eastern border of Wood Buffalo National Park, where the terrain becomes wetter and dominated by black spruce and boggy areas. The main portion of the Athabasca and its tributary (the Embarras River) continue on to Lake Athabasca.

Lake Athabasca marks the end of the Athabasca River's 1231 km trek from the Rocky Mountains. With an area of 7936 km², it is the fourth largest lake entirely in Canada. The lake is shared by Alberta and Saskatchewan, and is a valuable local resource for fishing. It is surrounded by areas that are naturally rich in uranium.

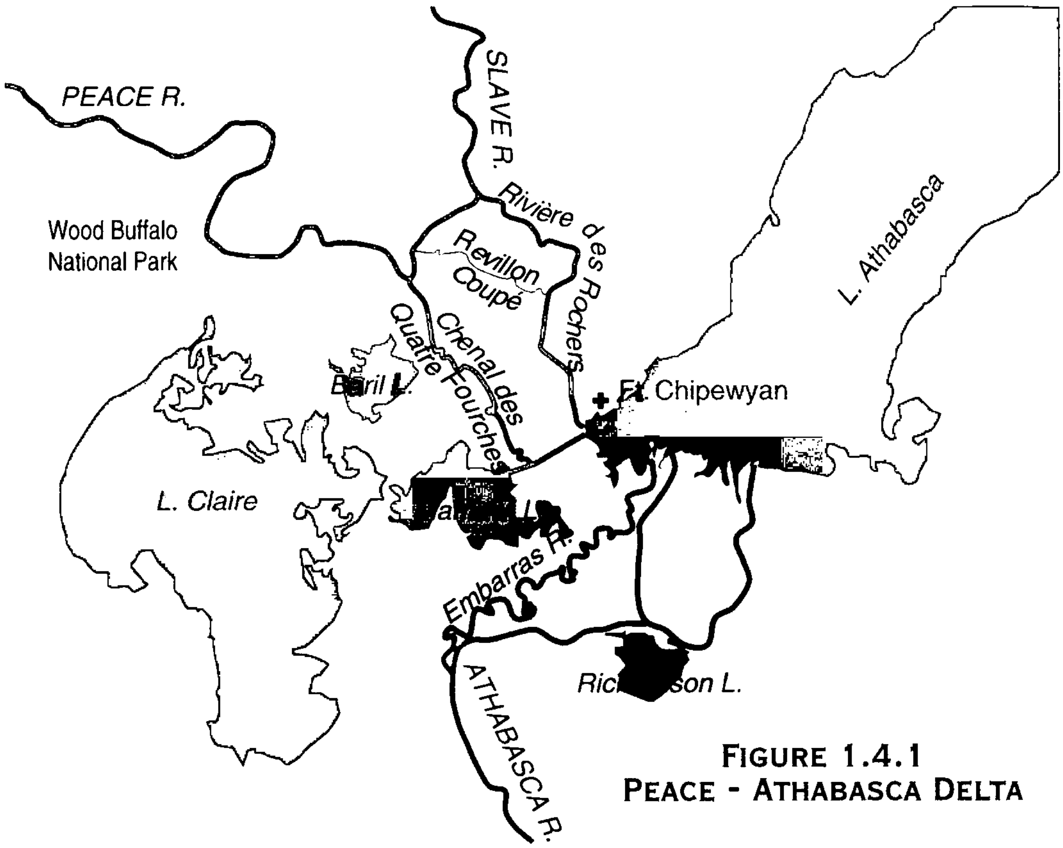


FIGURE 1.4.1
PEACE - ATHABASCA DELTA

1.4 THE PEACE RIVER-ATHABASCA DELTA

The Peace-Athabasca Delta (Figure 1.4.1) is an unique environmental feature. Athabasca is Cree for "where there are reeds," describing the delta's marshes and grasslands. The flat terrain is a patchwork of marshes, lakes, mud flats, sedge meadows, willow and shrub thickets and forests of white spruce and balsam poplar, interwoven by numerous winding channels.

Canada Geese

With its variety of landforms and lush vegetation, the delta has the capacity to support a diverse mixture of animal species. In 1985, the Canadian Wildlife Service counted 220 species of birds, mammals and fish that inhabit the delta during some part of their lifecycle. Well over half of these species are birds. Twice each year, millions of birds follow established routes (or "flyways") on their north or south migrations. All of the four major flyways in North America converge on the Peace-Athabasca Delta. Many birds use the delta as a pit stop to "fuel up" for the rest of their long trek, while others stay on to nest. Among these are tundra swans; snow, white-fronted and Canada geese; Ross' goose and a variety of ducks. In 1982, the delta was recognized by the Convention on the Conservation of Wetlands of International Importance (also known as the Ramsar Convention) as an internationally significant site for waterfowl habitat. The Ramsar Convention was drafted in Ramsar, Iran in 1971 to acknowledge wetlands as areas of international biological significance.

The characteristics of the delta that contributed to the Ramsar designation have been significantly altered. The complex water flows in the Peace-Athabasca Delta are fundamental to its environmental characteristics. Since the landscape of the delta is relatively flat, many of its waterways can flow in two directions. The direction of the flow depends upon the relative water levels in different parts of the delta. When the water level in Lake Athabasca is higher than Claire and Mamawi lakes, water flows westward into the delta. When Lake Athabasca is low, water flows east out of the delta lakes and into Lake Athabasca.

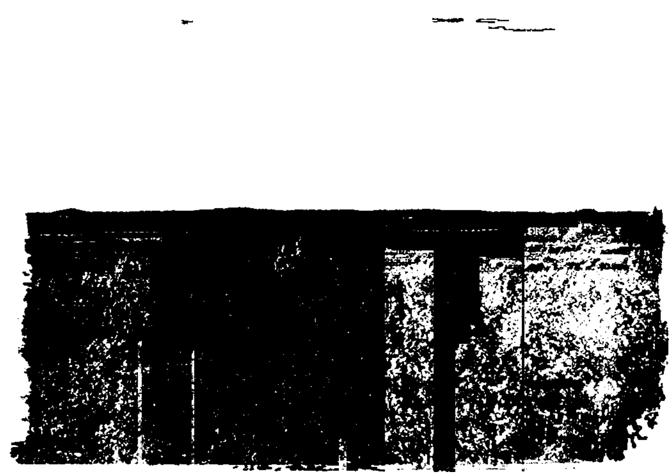
The reversing concept holds true for the channels that drain the delta: Chenal des Quatre Fourches, Revillon Coupé and Rivière des Rochers. Usually, these three channels flow north to meet with the Peace River and then continue north as the Slave River. However, when the flooding of the Peace River rises higher than the water level of Lake Athabasca, water flows south into Lake Athabasca and the delta.

The backflooding of the three channels by the Peace plays an important role in maintaining the delta wetlands. Many of the small lakes of the delta exist as "perched basins" that are only replenished through the periodic, spring ice jam flooding by the Peace River. However, since the construction of the Bennett Dam, these floods have been rare and less extensive. As a result, many of the marshy areas of the delta are transforming into terrestrial landforms dominated by willows and sedges.

The transformation is of concern to both ecologists and local residents. Residents of Fort Chipewyan, located on the shores of Lake Athabasca, rely on the delta for fishing, hunting and recreation. Fort Chipewyan is one of the oldest communities in Alberta. During the heyday of the fur trade, Fort Chipewyan was an important outpost for the Hudson's Bay Company and the delta was renowned for the quantity and quality of its muskrat pelts. However, many of the marshes are now too shallow for muskrats to overwinter. Falling water levels have also decreased habitat for waterfowl and fish.

During the 1970s, a considerable amount of effort went into stabilizing the water levels of the delta through the construction of control weirs along the three channels. The weirs were intended to reduce the outward flow of water while still allowing the Peace River floods to wash into the delta. The weirs proved effective in retaining water, but they could not mimic the natural fluctuations in water levels that are integral to the unique environmental characteristics of the delta. The Quatre Fourches dam was later removed because it kept waters artificially high year-round.

courtesy of B. Fuller



courtesy of Vik Peck

Then and Now: Egg Lake is one of the perched basins of the Peace-Athabasca Delta that is only replenished by periodic overland flooding. Its marshy shores were once a focal point for fur trappers and a haven for waterfowl. In fact, this lake once set the Hudson's Bay Company standard for high quality muskrat pelts. In the absence of these floods over the last two decades, Egg Lake is being transformed into a terrestrial ecosystem marked by grasses and willows. The photo on the left was taken roughly 20 years ago, while the one on the right was taken in 1994.

1.5 The Slave River and Delta

The Slave River drains north, still serving as the eastern border of Wood Buffalo National Park. As it travels towards the Northwest Territories, the river passes by the town of Fitzgerald. Fitzgerald is the last stop before a major series of rapids that culminate in the Rapids of the Drowned just north of the town of Fort Smith. The rapids impede travel and form a natural barrier to the upstream movement of fish, such as arctic lamprey and inconnu. The scenic beauty of the area attracts a growing number of tourists each year and the rapids have become a popular site for white water kayaking and rafting.

The town of Fort Smith marks the crossover of the Slave River into the Northwest Territories. The volume of water flowing across this border is enormous, with an annual flow estimated at 107 billion m^3 (Figure 1.5.1). Due to the high volume of water, the rapids along this stretch of river possess enormous hydroelectric potential and a large-scale hydroelectric development was proposed for the area. Alberta Environment conducted the Slave River Hydro Feasibility Study during the early 1980s to investigate the economic benefit and environmental impacts of the proposed dam. The monetary and environmental costs were deemed too high for the power demand, and the project was put on hold indefinitely.

The Slave Delta lies on the southeast portion of Great Slave Lake, at the end of the river's 434 km course. Covering an area of 640 km^2, the Slave Delta is considerably smaller than its southerly counterpart, but is still a valuable environment for fish and waterfowl habitat. In 1985, the Canadian Wildlife Service reported that 212 species of birds, mammals and fish frequented or live in the Slave Delta.

Fort Resolution on the southern shore of Great Slave Lake marks the northernmost limit of the northern river basins. From there, the waters become part of the Mackenzie River system that eventually drains into the Beaufort Sea.

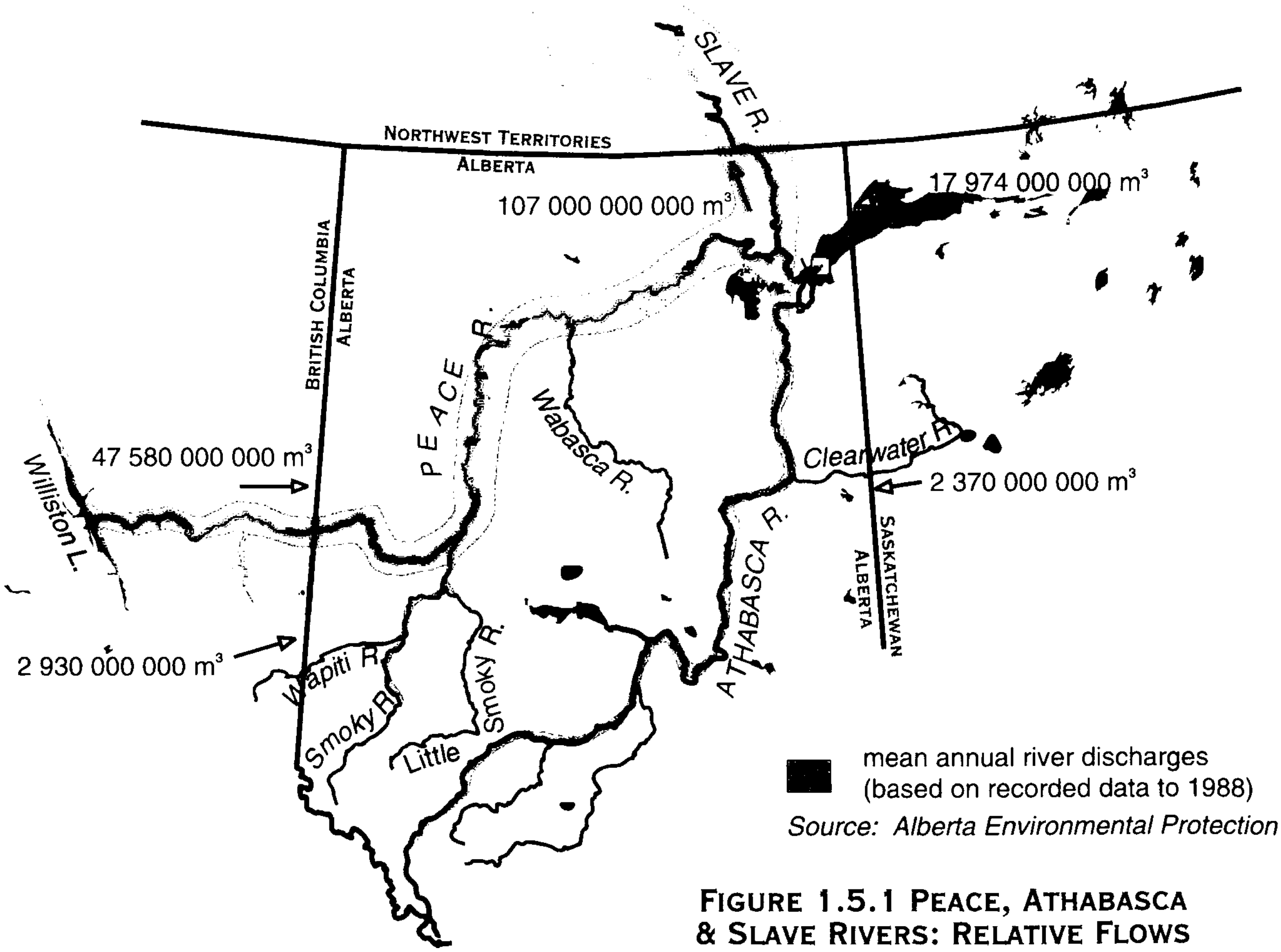


Figure 1.5.1 Peace, Athabasca & Slave Rivers: Relative Flows

1.6 The People of the Basins and the Genesis of the Study

The philosophy that people are an integral part of the environment has unique significance for basin residents. Many still hold to traditional lifestyles that rely on a natural environment. The rivers provide a direct source of drinking water for many inhabitants, and habitat for fish and other game species. The rivers are also a means of transportation and the basis for culture.

For indigenous peoples, the basins hold an added significance. The intimate connection between these peoples and the land spans generations and provides a source of strength and spirituality. Due to their lifelong experience with the rivers, native elders and other traditional residents embrace a wealth of knowledge regarding the natural cycles of the ecosystem and the changes in the land.


courtesy of Alberta Tourism Partnership

Over the last several decades, the rate of development in the basins has accelerated with the growing marketability of the basins' rich resources and the introduction of technologies to harvest these resources. Paralleling this was a growing unease among basin residents that these changes may be damaging the natural ecosystem. To many, "development" had become a word that implies the deterioration of their cultural and natural lifestyles. Inseparable from these sentiments was the realization that prudent management strategies are required to enable the sustained use of the basins' resources for all stakeholders. The groundswell of public concerns regarding northern development would eventually give rise to the Northern River Basins Study.

Issues surrounding the forest industry played an important role in the genesis of the Study. The upswing in the forestry sector was paralleled by a similar rise in environmental awareness across the country. Forestry-related concerns focussed on the effects of land clearing and the potential impacts of pulp mill effluent on the aquatic ecosystem (see Section 3.2 for more information related to forestry and the environment).

In the late 1980s, these concerns came to the forefront with the proposal by Alberta-Pacific Forest Industries Inc. (AlPac) to build a bleached kraft pulp mill on the Athabasca River near the town of Athabasca. AlPac was not the only proposed pulp mill during that time period, but it would hold by far the largest FMA in Alberta and many residents felt the mill was approved with no prior public consultation. As a result, it received the lion's share of public concern and publicity.

In response, a joint Alberta-Canada Environmental Impact Assessment (EIA) of the proposed mill was performed. The AlPac EIA, and the public hearings that followed, planted the seeds from which grew the Northern River Basins Study (NRBS). The review process brought together the three governments that maintain jurisdiction over the majority of the river basins area: Canada, Alberta and the Northwest Territories. In its 1990 report, the joint EIA Review Board identified the need for further investigations to fill knowledge gaps concerning the cumulative effects of contaminants on the Athabasca-Peace river system. Two more environmental reviews followed before final approval was given to the AlPac mill, resulting in several upgrades to the effluent treatment process. In addition, the three governments acknowledged the need for further information regarding the impacts of development on the aquatic ecosystem.

On September 27, 1991 the three governments formally signed the *Agreement Respecting the Peace - Athabasca - Slave River Basin Study Phase II - Technical Studies* (otherwise known as the Northern River Basins Study). The Study area was defined as the Alberta and Northwest Territories portions of the Peace, Athabasca and Slave river mainstems along with their important tributaries and deltas. The Study would be funded to a maximum of $12.3 million, with costs borne equally by the governments of Canada and Alberta.

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2.0 STUDY ORGANIZATION

2.1 OVERVIEW

The Northern River Basins Study formed Phase II of a three-phase approach to basins management. Phase I, which was completed in preparation for the Study, identified what was known about the river basins and what information was still required (see Section 7.1 for more information on events leading to the NRBS). The NRBS has attempted to fill these knowledge gaps and make recommendations for future management and research. In the future, Phase III will enact management strategies based on the recommendations contained in this report.

The NRBS Agreement (see Section 7.2) articulated three broad objectives for the Study:

1) to provide a scientifically sound information base for planning and management of the water and aquatic environment of the Study area so as to ensure its long-term protection, improvement and wise use;
2) to collect and interpret data and develop appropriate models related to hydrology / hydraulics, water quality, fish and fish habitat; and
3) to ensure that technical studies undertaken in the basin are conducted in an open and cooperative manner and that their purpose, progress and results are reported regularly to the public.

A 25-member Board was responsible for the overall management of the Study. The Board included representatives from funding governments, municipal governments, First Nations, industry, education, agriculture, health, environmental groups and the affected public. This diverse membership attempted to ensure that the concerns of area stakeholders and the public were reflected in the Study design and implementation. Two additional seats were reserved for observers representing the governments of British Columbia and Saskatchewan (see Section 7.3 for more information regarding Study organization and Section 7.4 for Board and committee memberships).

The Study Board stated its vision for the Study (see Section 7.3), which was later refined into a set of principles. The Board also generated 16 questions that would fulfill the Study's objectives and respond to public expectations and concerns. None of these questions can be answered in their entirety by any single study or research program. Rather, they represent long-term research goals that were intended to guide the direction of the Study's science program. Fourteen of these questions require a strong foundation in science, while the last two are mainly societal in nature.

The Sixteen Questions:

1. a) How has the aquatic ecosystem, including fish and / or other aquatic organisms, been affected by exposure to organochlorines or other toxic compounds?
   b) How can the ecosystem be protected from the effects of these compounds?
2. What is the current state of the water quality of the Peace, Athabasca and Slave river basins, including the Peace-Athabasca Delta?
3. Who are the stakeholders and what are the consumptive and non-consumptive uses of water resources in the basins?
4. a) What are the contents and nature of contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?
   b) Are toxic substances such as dioxins, furans and mercury, etc. increasing or decreasing and what is their rate of change?
5. Are the substances added to the rivers by natural and man-made discharges likely to cause deterioration of the water quality?
6. What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave rivers? Where and when are they most likely to be exposed to changes in water quality and where are the important habitats?
7. What concentrations of dissolved oxygen are required to protect the various life stages of fish, and what factors control dissolved oxygen in the rivers?
8. Recognizing that people drink water and eat fish from these river systems, what are the current concentrations of contaminants in water and edible fish tissue and how are these levels changing through time and by location?
9. Are fish tainted in these waters and, if so, what is the source of the tainting compounds (i.e., compounds affecting how fish taste and smell to humans)?
10. How does and how could river flow regulation impact the aquatic ecosystem?
11. Have the riparian vegetation, riparian wildlife and domestic livestock in the river basins been affected by exposure to organochlorines or other toxic compounds?
12. What traditional knowledge exists to enhance the physical science studies in all areas of enquiry?
13. a) What predictive tools are required to determine the cumulative effects of man-made discharges on the water and aquatic environment?
    b) What are the cumulative effects of man-made discharges on the water and aquatic environment?
14. What long-term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems? These programs must ensure that all stakeholders have the opportunity for input.
15. How can Study results be communicated most effectively?
16. What form of interjurisdictional body can be established, ensuring stakeholder participation for the ongoing protection and use of the river basins?

2.2 The Science Program

The Study's research program was designed to answer the fourteen scientific questions. The program was broken down into eight component groups: traditional knowledge, drinking water, nutrients, food chain, other uses, hydrology / hydraulics, contaminants, and synthesis and modelling. A high degree of coordination among the component groups minimized overlap and facilitated the delivery of comprehensive results (see Section 7.5 for further information regarding the evolution of the science program). A Science Advisory Committee was appointed by the Board of the Northern River Basins Study to advise them of the quality and implications of the scientific studies.

Expertise from universities and government was brought in to lead each component. Many of these individuals were internationally recognized in their fields, bringing with them knowledge that ensured the science program remained current with scientific developments in Canada and other countries (see Section 7.6. for further information regarding concurrent investigations and companion studies).

The inclusion of traditional knowledge as a component is a divergence from traditional western science. Aboriginal members of the Study Board first brought attention to the value of the large body of environmental knowledge that is housed in the minds of those who live in long-term close contact with nature. The observations and experiences documented in this component were combined with the results of the other science components to provide a more complete picture of changes within the northern river basins.

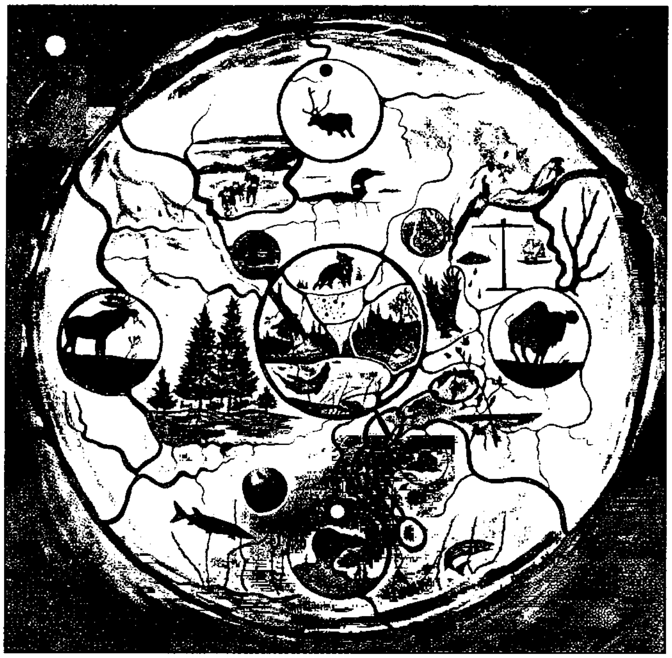
2.3 Human Health

The emergence of the NRBS Human Health Committee and the human health companion study is testament to the power of public participation. The NRBS mandate does not include any specific provisions for investigating human health concerns arising from environmental conditions within the basins. However, while health concerns were nōt written in the mandate, they are never far from the minds of basin residents. Representatives from Health Canada and the Alberta Ministry of Health were included as Board members.

In response to these concerns, the Study Board created the Human Health Committee. The Committee served as a human health-oriented resource to the Northern River Basins Study. The Human Health Committee and the Study Board developed a process for dealing with scientific information that might have health implications.

In coordination with Alberta Health, the Committee also contributed to the design of the Northern River Basins Human Health Monitoring Program. The program is gathering baseline information on human health conditions within northern Alberta and will examine possible links between human health and exposure to environmental contamination. The results will assist in the development of strategies for controlling exposure, promoting health and preventing disease. More information regarding the Human Health study and its findings can be found in Section 3.13.

Pictograph Symbology: A Glimpse of a Greater Vision



Native artist Larry Mercredi used images of nature to depict the interrelationships among the eight research components of the Northern River Basins Study and their connection to the earth. The pictograph was used within Traditional Knowledge interviews as a teaching tool for understanding these relationships and reawakening awareness of the natural environment.

The circle is a symbol of natural cycles. The large circle represents the universe, which embraces many smaller cycles. Each of the research components are circles within themselves, but are combined to reveal a picture of the larger universe.

- ❑ The ***Traditional Knowledge*** Component is located at the centre of the pictograph and is depicted by images of the beaver, the wolf, the otter, the little ones and the seasons. Its central position is indicative of the value it adds to all forms of scientific inquiry.
- ❑ The ***Drinking Water*** Component is symbolized by the evergreens extending their roots into the earth to drink.
- ❑ The ***Nutrients*** Component is depicted by aquatic plants and the food chain reaching into the water where fish and other insects reside.
- ❑ The ***Food Chain*** Component is portrayed by the chain linking various aspects of the ecosystem, such as water, plants, insects, aquatic organisms and wildlife.
- ❑ The ***Other Uses*** Component is depicted by a dog team and a canoeist.
- ❑ The ***Hydraulics / Hydrology*** Component is depicted in the many rivers that weave throughout the pictograph, as well as the wave of water flowing against gravity.
- ❑ The ***Contaminants*** Component is symbolized by centipedes, as contaminants come in many shapes and sizes.
- ❑ The ***Synthesis and Modelling*** Component is represented by the scales, finding balance between the land and the rose.

2.4 COMMUNITY PARTICIPTION

The Northern River Basins Study Board considers its program of public participation to be one of the Study's most positive aspects.

Throughout the Study, comments from residents at community gatherings and workshops, Study Board meetings, science forums, trade shows and other events provided important local information that provided significant background and guidance to the Study Board and staff. From the Study's outset, Study Board members attempted to involve basins residents. Development of the Study's science program and the overall expenditure of Study funds were discussed in an open and transparent manner with considerable public involvement.

This two-way information flow benefitted both the public and the Study, developing a sense of honesty and trust between the Study and the public, in particular with community groups, and aboriginal and environmental organizations. Input from these groups and other parties contributed to making the Study more responsive to local concerns and expectations.

Early in the Study, Community Gatherings helped orient the Study Board with regard to local issues and concerns and provided the initial spark for the development of the Traditional Knowledge program.

In the Study's latter days, more than 500 basin residents and other interested parties attended Community Workshops held in 17 northern river basins communities. These workshops provided Study scientists with an opportunity to share results and findings. Members of the public posed questions and offered a variety of suggestions, comments and recommendations.

These comments were summarized and presented to the Study Board as it developed its final recommendations to the Ministers. Many of these comments formed the basis for additional recommendations, or provided the Study Board with additional background.

The Study's widespread program of public involvement and open communication included the following:

- ❑ Study Board meetings were held throughout the Study area. Members of the public were invited to participate and voice comments and concerns.
- ❑ In most communities, Community Gatherings were held prior to each Study Board meeting. The gatherings provided an "open microphone" for members of the public to express comments, concerns and suggestions.
- ❑ Annual science forums were held. These forums provided the public with an opportunity to receive scientific updates, to pose questions and to provide suggestions.
- ❑ The Study participated in numerous trade shows throughout the basin. At these trade shows, thousands of basins residents received information regarding the Study and provided comments and input which was conveyed to the Study Board.
- ❑ All Study minutes, reports, data and other information were made available to the public in a quick and timely manner. Information was available through the Study Office by mail or through a toll free number, and was also distributed to libraries and government offices throughout the basins.
- ❑ Bi-yearly newsletters were distributed through mail and newspapers to approximately 75 000 households throughout the basins.
- ❑ The Study involved students through a series of visits and presentations to schools throughout Alberta.
- ❑ Wherever possible, the Study made its information available in "meaningful language." Attempts were made to communicate science in words which were easy for basins residents to understand. As well, a number of Cree and Chipewyan language videos and audio tapes were made. Wherever possible, information was presented in communities' preferred form of communication.

In virtually all of the Study's dealings, policies of public information, involvement and input were pursued. This involvement helped bring down traditional barriers between the public and scientific studies of this kind.

Aside from the important scientific work which the Study initiated, the Study Board believes that the sociological successes of the Northern River Basins Study are extremely noteworthy. In many ways, the Northern River Basins Study was regarded as a "social experiment." Representatives from a variety of stakeholder groups were represented at the Study Board table. Many of these stakeholder representatives developed committees and advisory groups with their respective constituencies, facilitating increased public involvement at the Study Board table. As well, many Study Board members representing traditionally competitive or antagonistic groups learned to cooperate and to develop common strategies for the common good of the northern river basins.

The Study Board believes that based on this multi-stakeholder structure, the two-way information flow and public participation, the Northern River Basins Study completed its work with maximum representation and involvement from stakeholders and members of the public. The success of these partnerships warrants attention and consideration by governments, committees, boards and other public organizations in both their current and future dealings.

3.0
Major Findings

3.1 Introduction

The following sections summarize the major findings and critical management issues identified by the NRBS research components in their final synthesis reports. To appreciate the full breadth of scientific efforts that precede this summary, readers are strongly encouraged to read the relevant synthesis and technical reports cited at the end of each section.

As part of their synthesis reports, each component leader was asked to list technical recommendations that may be of interest to scientists, research managers and academics. A summary of science-related recommendations appear in Section 7.7 of this report. Those recommendations dealing with sociological and policy matters comprise the NRBS Study Board recommendations and are found in Section 4.0 of this report.

As described earlier in this report, the Northern River Basins Study was created to fill gaps in understanding of the developmental impacts on the basins environment. Accordingly, the following sections may include information generated by previous or concurrent investigations to provide a contextual setting for understanding NRBS findings.

A number of abbreviations are used in the following sections. For your convenience, a summary of abbreviations is provided at the end of the report.

3.2 Environmental Overview

Introduction

A summary of background environmental information has been compiled and presented in the NRBS synthesis report entitled *Environmental Overview of the Northern River Basins*. The *Overview* report provides a general sense of aspects of the basins that influence, or are influenced by the aquatic environment. It covers numerous topics of interest, including:

- climate
- physiographic regions
- geology
- ecoregions
- surface water characteristics
- current and historic developments
- regulations and regulatory bodies
- current studies
- monitoring
- fish and wildlife species

A comprehensive review of all aspects of the geography of the basins would extend beyond the mandate of the NRBS. This section identifies major developments and briefly describes their impacts on the basins' rivers. More information is available in the synthesis report.

Current Developments

Municipal development

In contrast to their size and richness, the northern river basins are sparsely populated. According to 1991 census figures, approximately 266 000 people reside in the Alberta portion of the basins and 3000 in the Northwest Territories. Of these, ten per cent are aboriginal peoples representing Cree, Chipewyan, Dene Tha', Beaver and Métis (Figure 3.2.1). Fifty-six per cent of Study area residents reside in urban areas (Figure 3.2.2). There are four cities within the basins — Fort McMurray and Grande Prairie in Alberta, and Dawson Creek and Fort St. John in British Columbia.

Municipal sewage is a source of nutrients and contaminants to the river systems, high levels of which can lead to larger amounts of plant growth. The decay of these plants in the winter uses up oxygen that is dissolved in the water — oxygen that is needed by fish and other aquatic organisms.

Large municipalities tend to discharge wastes from sewage treatment plants on a continuous basis, while smaller municipalities empty sewage lagoons once or twice a year.

The amount of nutrients and other contaminants in municipal effluent depends upon the level of sewage treatment.

There are three levels of treatment:

- **primary treatment** removes large suspended or floating substances;
- **secondary treatment** further removes suspended solids and biodegradable material; and
- **tertiary treatment** achieves advanced reduction in nutrients, suspended solids and contaminants.

The majority of municipalities with populations over 500 employ at least secondary sewage treatment.

Sewage is not the only municipal waste that affects water quality. Stormwater runoff from urban areas is often high in automobile wastes, fertilizers and pesticides. In addition, poorly constructed landfill sites have the potential to leak contaminants into groundwater and local surface water bodies.

Agriculture

Approximately 45 000 km^2 of the land surface in the Alberta portion of the basins is under cultivation. These lands can be sub-divided into two broad regions, one to the northwest and the other in central Alberta (Figure 3.2.3).

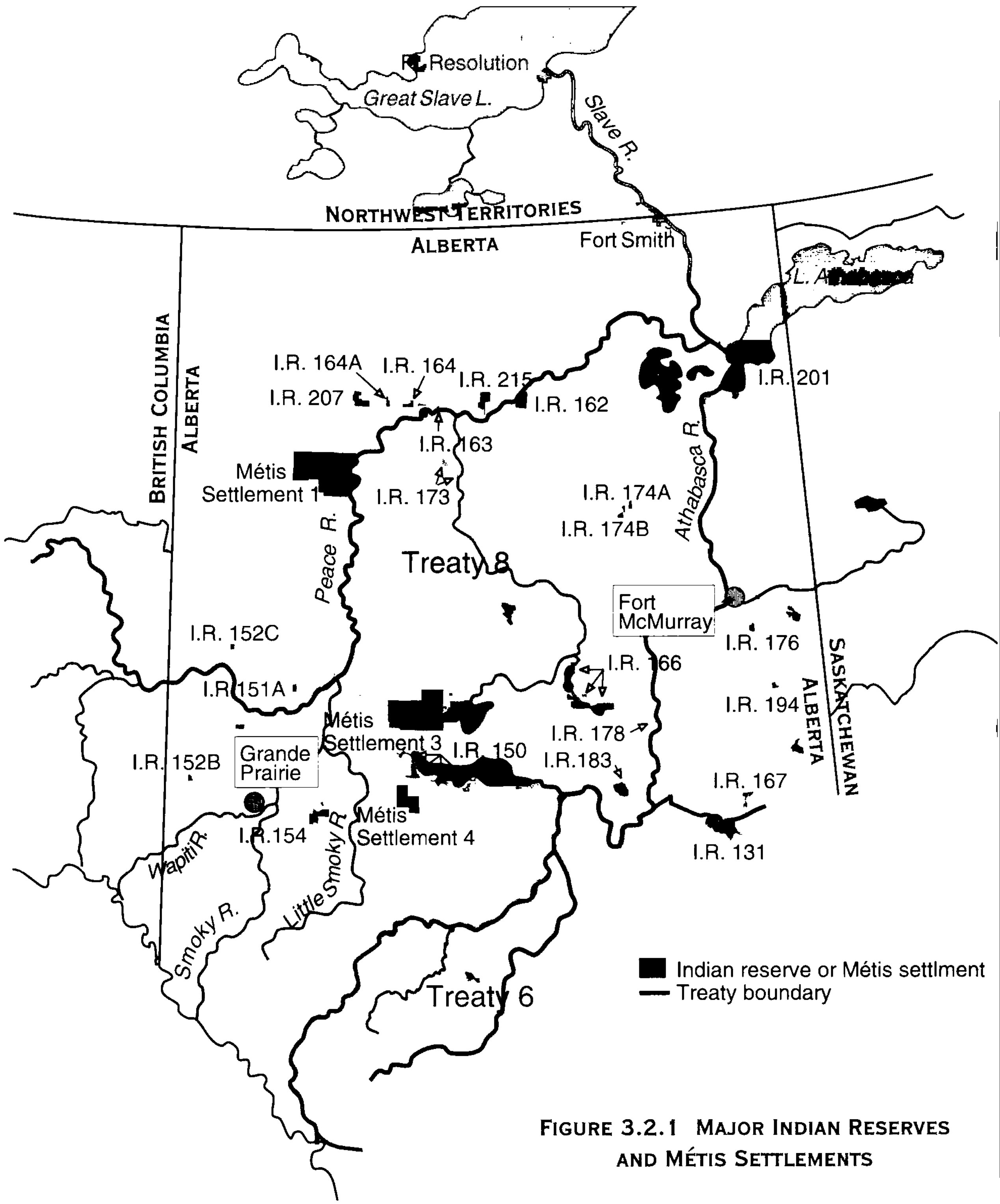


FIGURE 3.2.1 MAJOR INDIAN RESERVES AND MÉTIS SETTLEMENTS

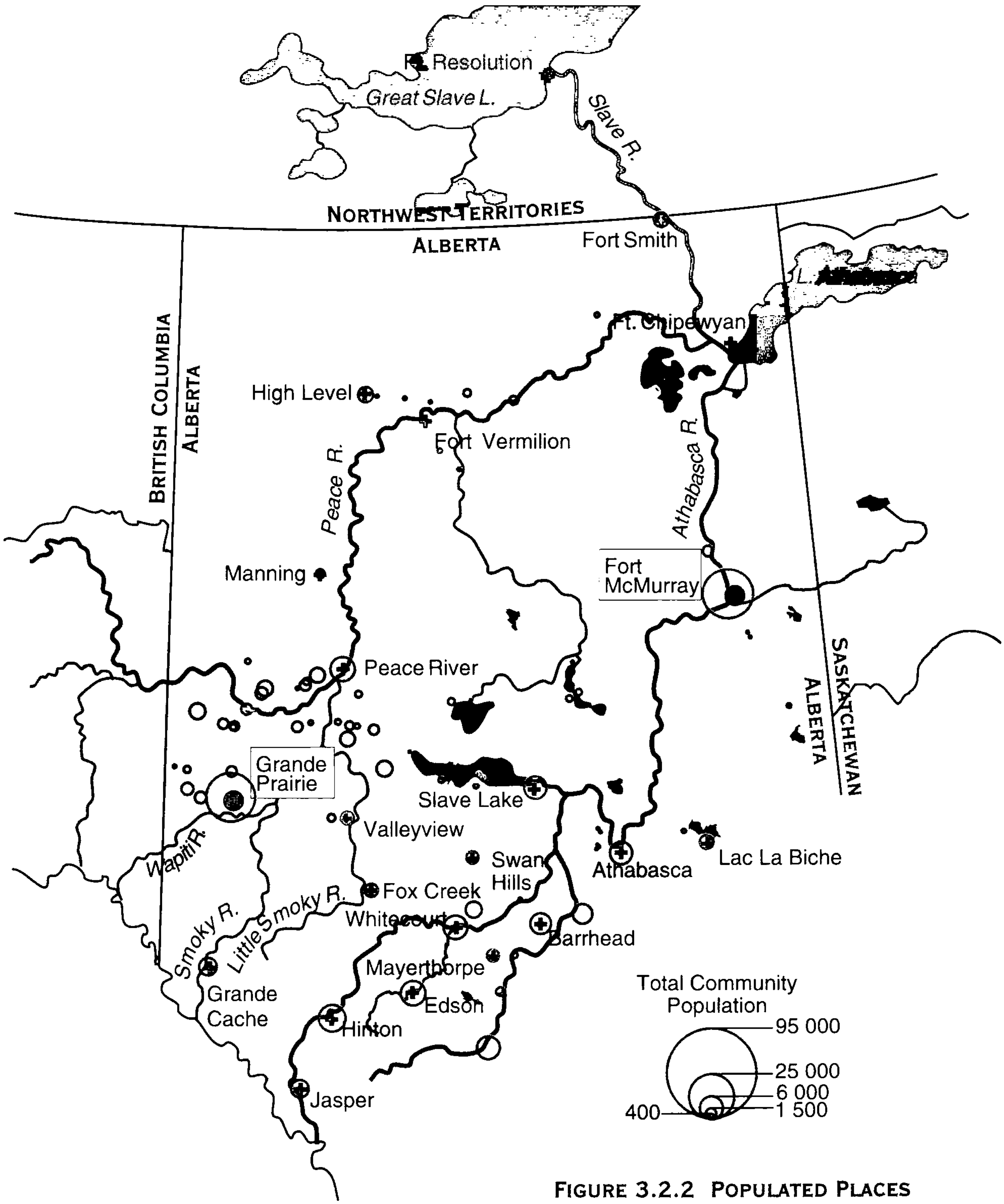


FIGURE 3.2.2 POPULATED PLACES

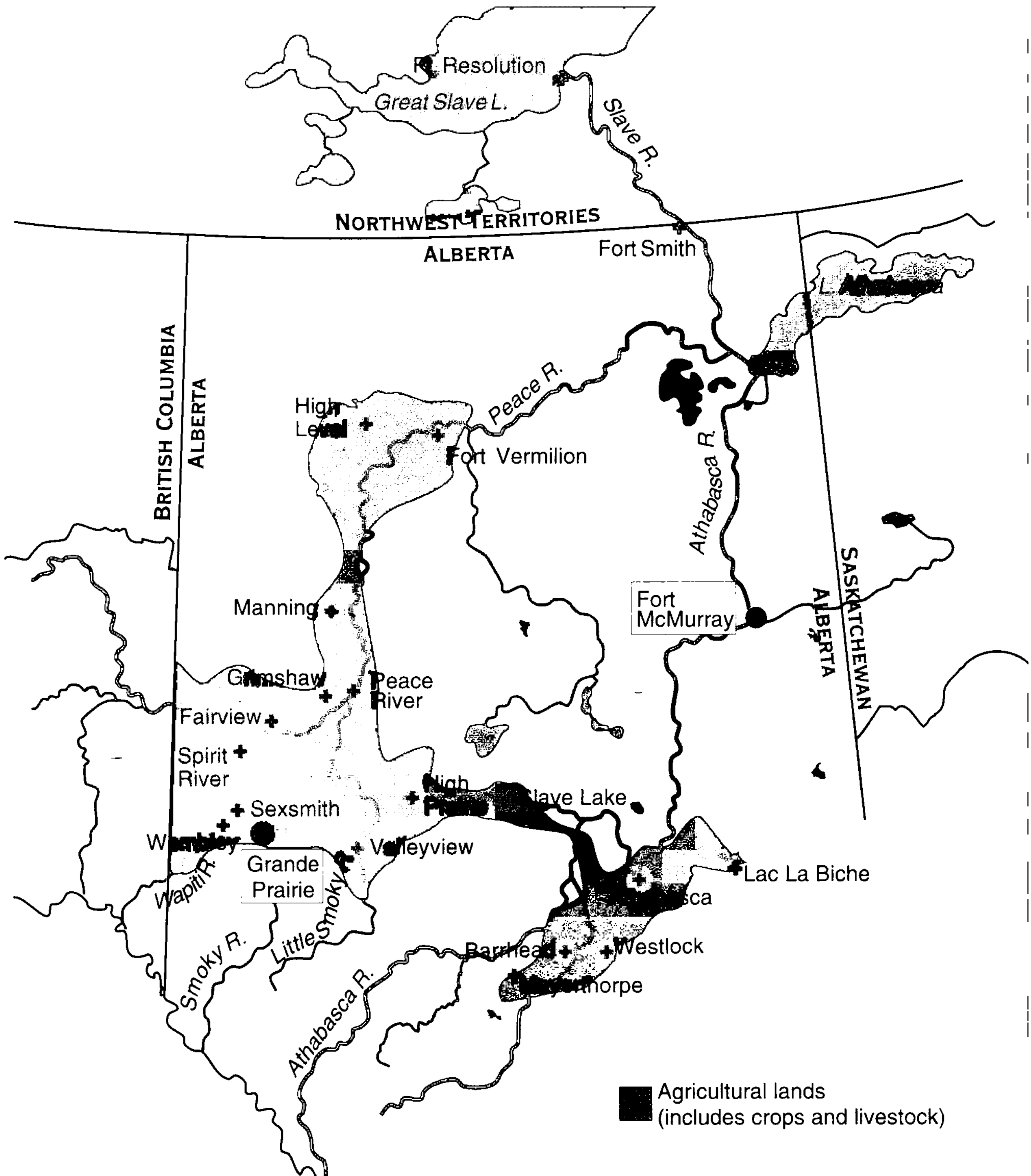


FIGURE 3.2.3 GENERALIZED AGRICULTURAL AREAS

In northwest Alberta, the Peace River country stretches from Grande Prairie-Valleyview to Fort Vermilion and encompasses the most northerly agricultural lands in Canada. This agricultural area also spills over into British Columbia. Canola, oats, peas, barley, tame hay and forage (e.g., alfalfa, timothy and clover) are important crops. There is limited livestock farming, including cattle, bison, elk and some sheep. Beekeeping is another noteworthy activity of the region; the bees supporting a thriving honey industry and serving as important pollinators.

The agricultural lands along the Pembina River basin to Lac La Biche River line the perimeter of Alberta's main agricultural region to the south. Canola, peas, oats and forage crops dominate, with significant stands of barley and some wheat. Beef cattle are the dominant form of livestock, with some hogs, elk and bison.

In contrast to forestry and petroleum operations, some residents contend that agricultural expansion in the basins is reaching its limits. Large expanses of northern land have already been cleared for agriculture. While a large proportion of Canada's undeveloped arable land is still found within the northern river basins, the soils in these areas are generally marginal in quality or require extensive drainage. As a result, nearly all of the economically viable agricultural land in the basins is in use. Climatic changes, soaring world population, or new technologies may change the current economics of developing new farmland in the Study area.

Two main water quality concerns related to agriculture in these regions are soil erosion, and the sediments and chemicals in agricultural runoff. These issues are linked to natural characteristics of northern soils and the impact of present day farming techniques. Solonetzic and Luvisolic soils, which cover large expanses of the northern agricultural area, are naturally susceptible to erosion. Extensive land clearing and drainage expose the soil to the erosive forces of wind and water. With water erosion comes the increased potential for soils, nutrients, pesticides and herbicides to enter local water bodies.

The effects of erosion and runoff are compounded by the practice of summerfallowing — tilling the soil and leaving it uncultivated for a season to control weeds and increase moisture and nutrients. At the same time, the practice can promote erosion. There is a move towards new tillage and seeding practices (such as conservation tillage and direct seeding) that decrease erosion and runoff while protecting soil quality.

Forest Industries

Well over half of Alberta's productive forests are found within the northern river basins. Forestry is a major employer in northern Alberta and ranks high among the primary economic sectors of the province.

The industry has evolved rapidly in the last two decades and continues to grow. The forest industry has diversified to include a variety of wood products, including lumber, oriented strandboard, fibreboard, roofing shakes, fence posts and wood pulp. Historically, the northern Alberta forestry sector has relied strongly on the use of softwoods (such as pine and spruce), but newer technologies make use of hardwoods (such as aspen) in the production of pulp, paper and panelboard. Better methods of controlling fire have aided forest protection.

The management of forestry operations has also evolved. Alberta's forest lands are divided into 10 blocks, each of which has an assigned annual allowable cut based on an estimate of sustainable yield. Commercial harvesting within these blocks is organized under four types of agreements: forest management agreements (FMAs), quota certificates, commercial timber permits and local timber permits. FMAs contain provisions for forest inventory, renewal and protection. Though they cover over 140 000 km^2 of the north, a much smaller area represents harvestable timber.

In 1990, the Expert Review Panel on Forest Management in Alberta compiled a list of public concerns expressed through public meetings. These were grouped into three broad categories:

- ❑ **forest management:** reforestation, FMA planning process, harvesting techniques, disposition of timber, sustained yield, Environmental Impact Assessments for forest operations, integrated resource planning, enforcement and regulation of industry, access control and public use.

- **fish and wildlife management:** access, over hunting, habitat, impact on fisheries, rare and endangered species and general impacts
- **environment:** environmental impacts, use of herbicides, soil erosion, protection of ecosystems, climatic change and technology options

Added to this list are environmental concerns related to pulp mills. Ten pulp mills are currently operating within the northern river basins, employing a variety of process technologies (Figure 3.2.4).

By far the greatest concern related to pulp mills is the potential effect of waste effluent. Some of the toxic effluent compounds become concentrated in food chains and can have harmful effects on fish, fish-eating birds, mammals and (in some cases) humans. As with agricultural runoff and municipal wastes, pulp mills are a source of nutrients that can aggravate conditions in certain stretches of a river.

BLEACHING AND PULPING TECHNOLOGIES:

Bleached kraft mills use a combination of strong chemicals and heat to break down wood chips and separate fibre from lignin. The pulp is then chemically bleached to produce a high-grade pulp for making paper. Traditionally, molecular chlorine was used during this bleaching stage, but environmental concerns have caused many mills to switch to other chemicals (e.g., chlorine dioxide, hydrogen peroxide) that result in lower concentrations of chlorinated compounds in waste waters. As a result, many of today's bleached kraft mills are categorized as "elemental chlorine-free" (ECF).

Bleached chemithermomechanical pulp (BCTMP) mills use a combination of chemicals (usually sodium sulphite), heat and mechanical grinding to break down the wood chips. It is much more difficult to achieve the brightness and quality that is associated with bleached kraft pulp.

Thermomechanical pulp (TMP) mills grind the wood with heat and mechanical action to produce a darker pulp.

Pulp mill technologies are continually being upgraded to reduce environmental impacts and to meet increasingly stringent provincial and federal standards. Scrubbers and air monitoring efforts have reduced air emissions at many sites. The use of molecular chlorine in bleached kraft mills is declining. Kraft mills have already turned to more environmentally friendly alternatives, such as chlorine dioxide, oxygen and hydrogen peroxide.

Petroleum

Alberta's petroleum industry includes conventional oil and gas fields, heavy oil, oil sands deposits and numerous oil and gas processing plants (Figure 3.2.5).

Oil and gas deposits are common across the Alberta portion of the northern river basins, except in the far northeast, where the geology is dominated by the igneous formations of the Canadian Shield. Oil and gas usually occur together and the fields can be divided into areas that are "mostly oil" or "mostly gas."

The Fox Creek area southwest of Swan Hills is one of Canada's largest producing gas fields. One of the other larger producing fields is located in the Elmworth area southwest of Grande Prairie. Sulphur is an economically significant by-product of the gas industry. Natural gas that contains hydrogen sulphide is referred to as "sour gas." Sulphur is extracted from the gas and comprises an important chemical export from Alberta.

Oil deposits can be sub-divided into three categories: conventional oil, heavy oil and oil sands. Heavy oil, found predominantly in the area of Lloydminster, is more viscous than conventional crude. The tar-like "bitumen" found in oil sands is even thicker and must be separated from the grains of sand with steam or by other means.

A few of the major conventional oil fields are found near the areas of Judy Creek, Swan Hills, Mitsue, and Utikuma Lake. Land disturbance is one of the major concerns related to oil drilling. Seismic lines formed by oil and mineral exploration are visible in

	Pulp Mill	Startup	Product	Receiving Water
1	Fletcher Challenge	1972	bleached kraft pulp	Williston L.
2	Finlay Forest Industries	1969	mechanical pulp, newsprint	Williston L.
3	Louisiana-Pacific	1991	bleached chemi-thermomechanical pulp	not applicable
4	Fibreco	1988	bleached chemi-thermomechanical pulp	Peace R.
5	Weyerhaeuser Canada	1973	bleached kraft pulp	Wapiti R.
6	Daishowa-Marubeni	1990	bleached kraft pulp	Peace R.
7	Weldwood of Canada	1957	bleached kraft pulp	Athabasca R.
8	Millar Western Pulp	1988	bleached chemi-thermomechanical pulp	Athabasca R.
9	Alberta Newsprint Co.	1990	thermomechanical pulp, de-inked paper	Athabasca R.
10	Slave Lake Pulp	1991	bleached chemi-thermomechanical pulp	Lesser Slave R.

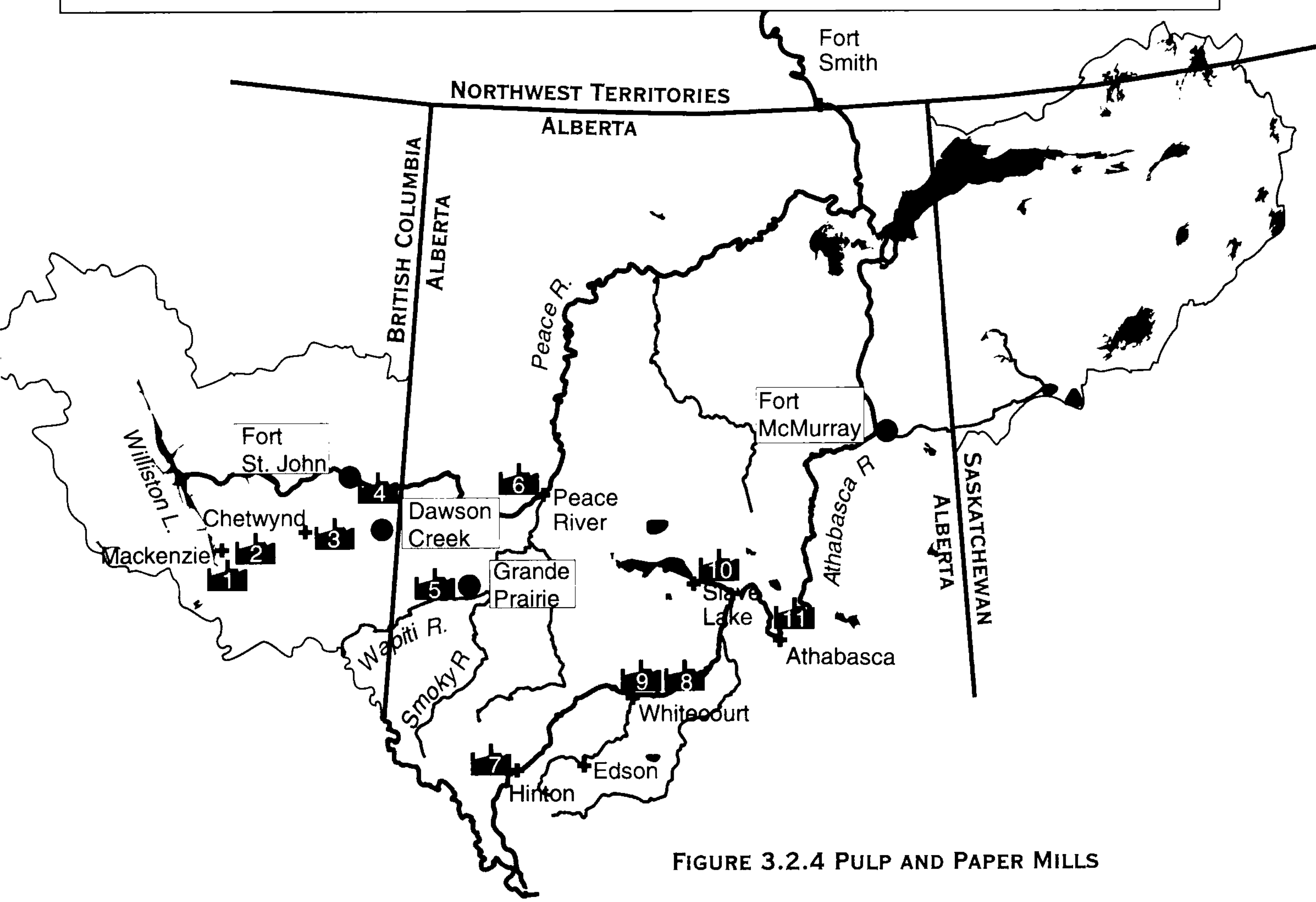


FIGURE 3.2.4 PULP AND PAPER MILLS

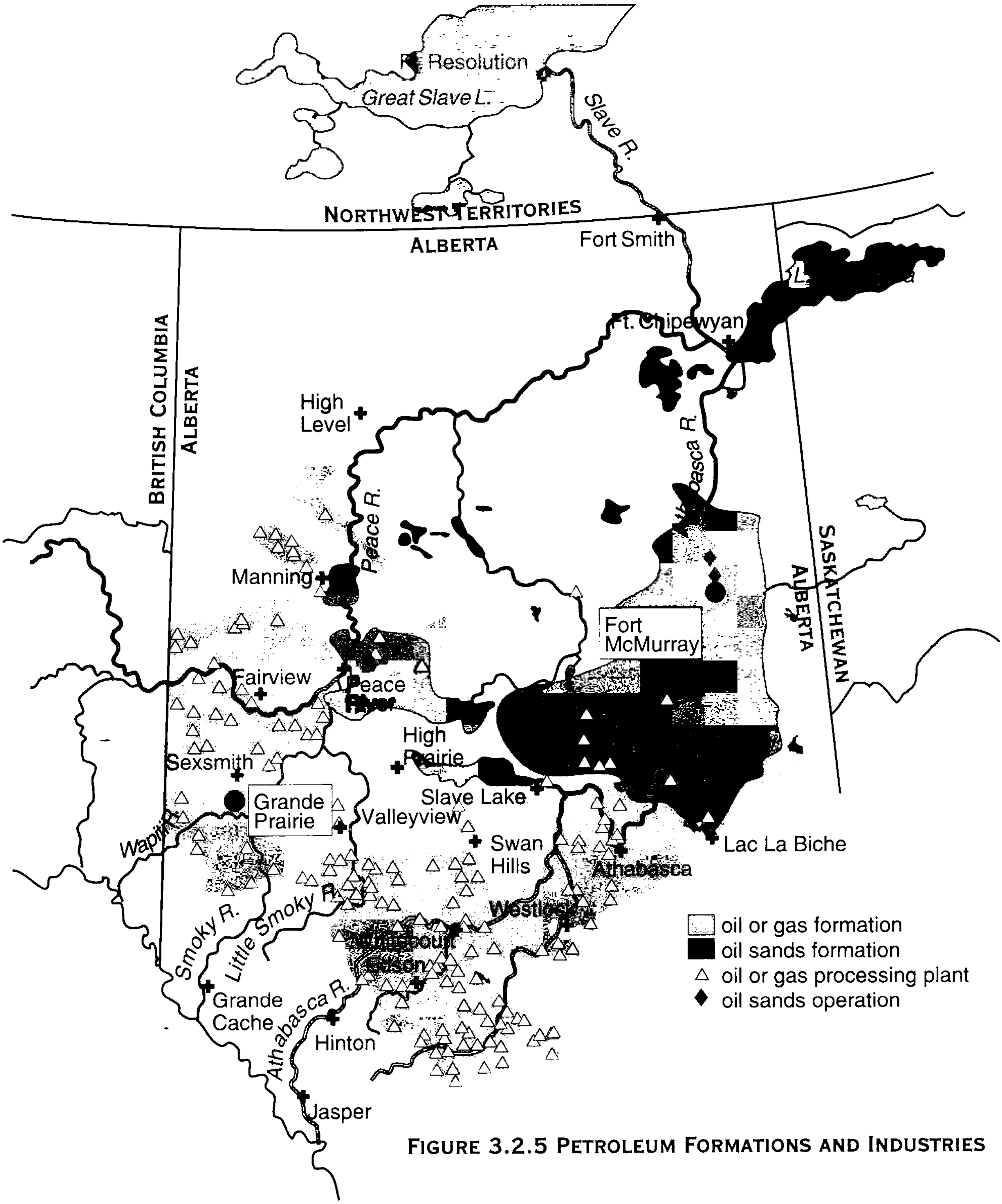


FIGURE 3.2.5 PETROLEUM FORMATIONS AND INDUSTRIES

many areas. Other concerns centre on land management, waste treatment, accidental spills and pipeline / storage tank failures.

The major oil sands deposits within the Study area are located near Fort McMurray, in the upper Wabasca River and near the town of Peace River. The methods for extracting oil from these deposits varies with the depth and characteristics of the materials.

Near Fort McMurray, the oil sands are close to the surface and are mined with draglines, bucket wheel excavators and electric shovels. As with other surface mining operations, land disturbance is an environmental concern. There is also considerable concern regarding tailings ponds located near the Athabasca River. Although the ponds are designed and built to high geo-technical standards, there is always some risk of a breach, no matter how small the probability. A breach would release contaminants into the Athabasca River and local groundwater supplies. The industry is currently developing new technologies to ensure the long-term environmental safety of these sites.

Surface mining is practical for only a small percentage of the Athabasca oil sands deposits. In most areas, the oil sands are too deep and oil must be recovered by *in situ* ("in place") methods such as steam injection or combustion. There are a number of experimental *in situ* recovery plants in all of the major deposits, several of which are nearing or have reached commercial production.

Mining

Apart from the oil sands, coal is the most actively mined fossil fuel in the Alberta portion of the basins. Coal deposits stretch from Beaverlodge to Grande Cache to Cadomin, but only portions of this area are under development (Figure 3.2.6). Exploration and production depend upon many factors, including seam thickness, retrieval costs and coal markets.

Coal mining is concentrated along the foothills that parallel the Rocky Mountains between Gregg River and Grande Cache. Historically, some of the coal in this area was retrieved through underground mines. Remnants of these old mines are visible in a few areas where the tunnels have collapsed and the land has visibly subsided. Today, surface mining has largely replaced underground mines. As a result, one of the chief environmental concerns related to coal mining is land disturbance. Over the last several years, the mines have had growing success in habitat reclamation following closure of open pits. Other environmental concerns are related to the potential for coal mines to contaminate local waters with iron, coal dust, salts and other operational wastes.

Other mining activities in the basins include extraction of sand, gravel, vanadium, peat and uranium. Deposits of salt, limestone, granite, gypsum and silica also have mining potential. Uranium deposits near Lake Athabasca were mined at Uranium City, Saskatchewan but were for the most part abandoned in the 1970s (Figure 3.2.6). Uranium mining operations have environmental implications because they can release radioactive materials into the aquatic environment that are hazardous in high doses to fish and other organisms.

Transportation

Historically and today, the high cost of transportation limits development of the north. Barge traffic, once an important mode of transport along the rivers, is now limited. Most northern communities are now accessible by air. Road access is growing, but a number of small northern communities (e.g., Fort Chipewyan) are accessible by vehicle only during the cold months with the annual opening of the winter roads. Railways are extensive in the southern and western portion of the basins and limited rail transport is available as far north as Hay River in the Northwest Territories (Figure 3.2.7).

There are several environmental concerns related to transportation, including noise pollution, runoff, soil erosion and land clearing to name a few. In comparison to other forms of development, however, transportation has a relatively minor effect on water quality in the northern river basins.

Dams and Reservoirs

A number of dams, reservoirs and water diversions occur within the basins area. The W.A.C. Bennett Dam, located astride the Peace River near Hudson's Hope, British Columbia, is undoubtedly the largest dam in the basins. Completed in 1968, the dam creates the large Williston Lake and regulates water flow into the Gordon M. Shrum hydroelectrical generating station.

Dams create storage reservoirs that have the capacity to regulate the natural flows of rivers and can, in the case of the Bennett Dam, have

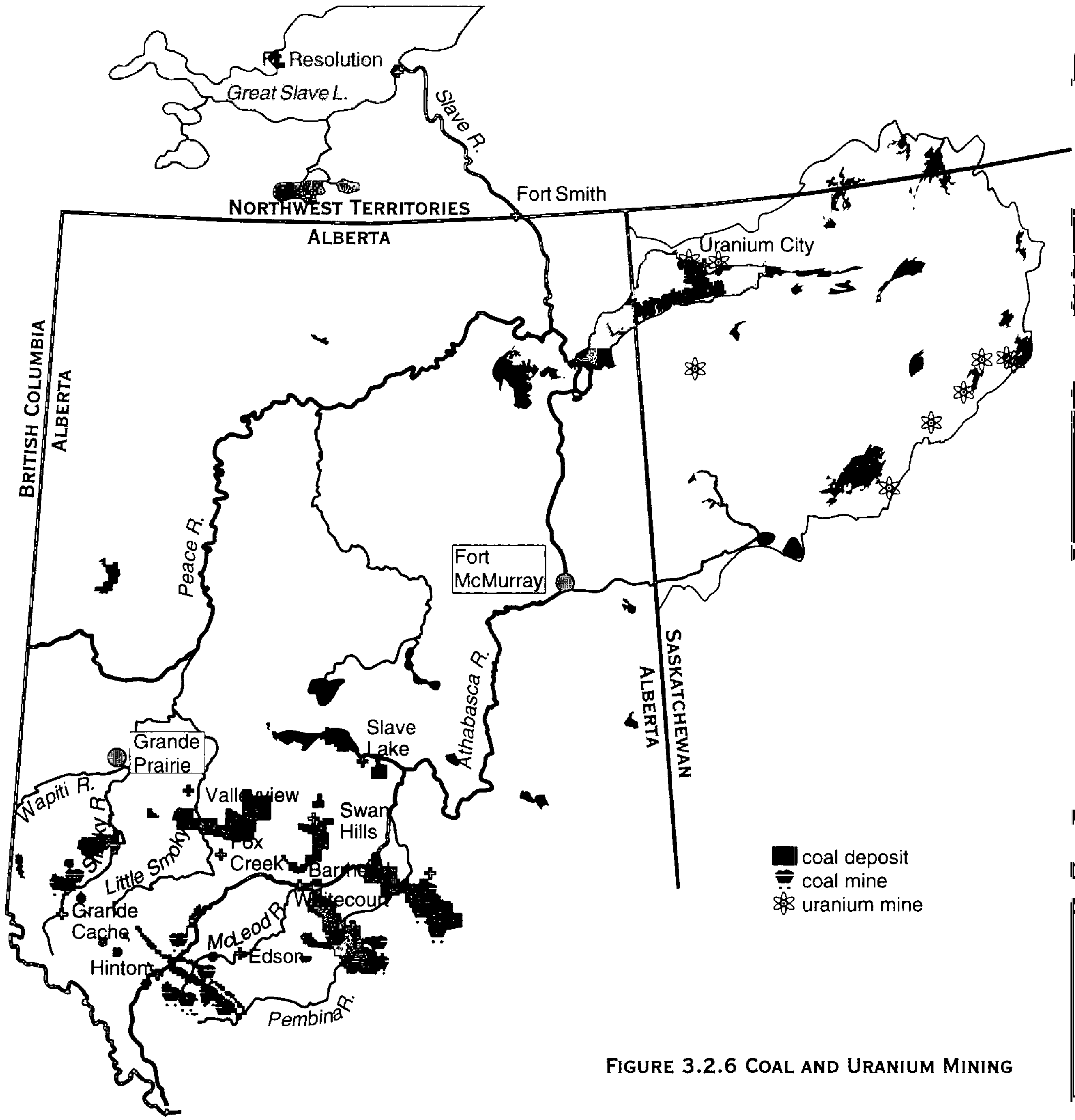


FIGURE 3.2.6 COAL AND URANIUM MINING

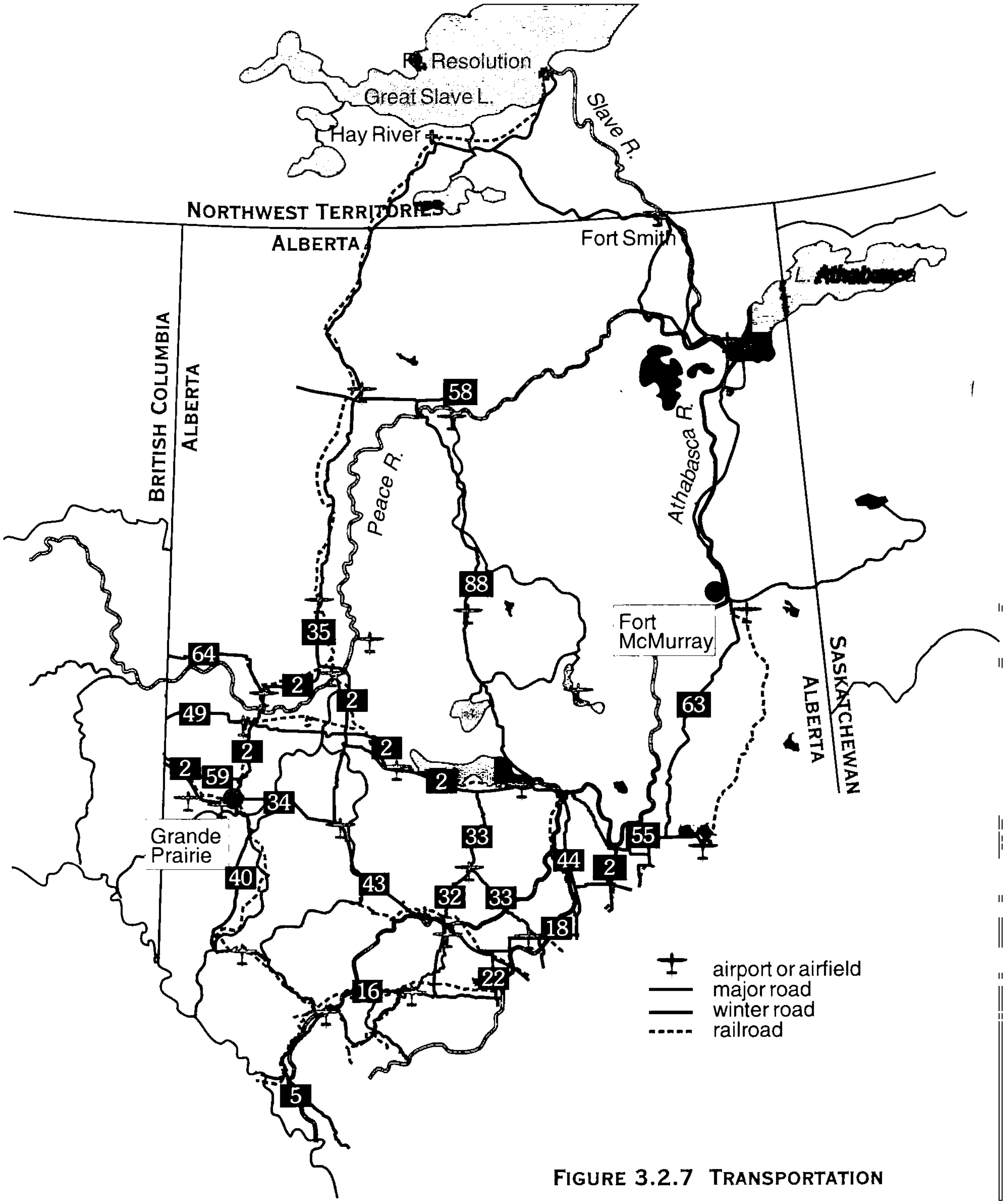


FIGURE 3.2.7 TRANSPORTATION

far-reaching effects downstream. Reservoirs themselves can also have profound ecological effects. They destroy terrestrial habitat, discourage aquatic organisms that require fast flowing water and are well known as a source of methylmercury.

In submerged areas, aquatic microbes convert natural (and relatively harmless) inorganic mercury into methylmercury compounds that accumulate in food webs and can contaminate fish and other aquatic organisms. Mercury methylation occurs naturally in many areas, but reservoirs can constitute a potentially important contaminant source due to the large amount of organic material that becomes submerged.

SCENARIOS FOR FUTURE DEVELOPMENT

In addition to understanding the current state of basin development, it is also helpful to perceive how market forces will shape the growth and types of future economic activities. The Study area's economic base is anchored by four key industrial sectors: agriculture, energy, forestry and manufacturing. All four are influenced by the international market forces of supply and demand, and all have potential implications for water resources within the basins.

Agriculture
Historically and today, agriculture remains an integral part of the economic backbone and land use within the basins. No dramatic growth is expected in the absolute size, scale or regional importance of this mature and relatively stable economic sector. However, the nature of farming activities in the basins is expected to evolve over the next decade. Farm management practices are also expected to change in order to increase productivity while minimizing environmental hazards.

Energy
The energy sector represents a large source of economic activity within the Study area. Energy-related industries within the region focus on non-renewable resources, including coal, oil and gas. There is also a great deal of hydroelectric potential in the basins. No dramatic growth is expected in coal and hydroelectric production within the foreseeable future. In contrast, the outlook for conventional oil, oil sands and natural gas development indicates growth. Oil sands represent the most significant area of potential growth in the NRBS area. Under favourable economic conditions, this industry could attract new investments totalling $20 to $25 billion and at least double in output over the next 25 years.

Forestry
The forest industry has grown dramatically over the past decade and now comprises an important source of regional economic activity. The major growth in this economic sector is linked to the use of remaining non-allocated hardwood forests and product diversification. In particular, strong short-term growth will hinge on expanding production of value-added products, such as pulp, paper, oriented strandboard and other manufactured wood products. Continued long-term growth will be highly dependent on international market conditions.

Manufacturing
Manufacturing accounts for a relatively modest proportion of economic activity within the Study area. Activities focus on processing of natural resources for export or supplying regional needs. The sector is not expected to grow significantly within the foreseeable future, except in relation to value-added processing of forestry products as discussed above.

RELEVANT DOCUMENTS

NRBS Synthesis Reports
Lyons, B. and B. MacLock. 1996. *Environmental Overview of the Northern River Basins*. Northern River Basins Study Synthesis Report No. 8.

NRBS Project Reports
Nichols Applied Management and Economic Consultants. 1995. *Factors Affecting Future Development in Key Economic Sectors in the Peace, Athabasca and Slave River Basins*. Northern River Basins Study Technical Report No. 73.

Other Relevant Documents
Expert Panel on Forest Management in Alberta. 1990. *Forest Management in Alberta*. Alberta Forestry, Lands and Wildlife.

3.3 Use of Aquatic Resources

Related NRBS Question:

3. Who are the stakeholders and what are the consumptive and non-consumptive uses of water resources in the basins?

Introduction

The northern river basins have experienced a great deal of change over the last century, especially during the 1980s. The amount of water used in the area has increased in response to growing industrial and agricultural development and regional population growth. With more than 266 000 people now living in the Alberta portion of the basins and 3 000 in the Northwest Territories portion, it is essential to understand who is using the water and how they are using it. Of particular interest are water quantity and quality requirements for consumptive water uses (e.g., town water supply and agriculture) and non-consumptive uses (e.g., recreation and transportation).

The NRBS Board commissioned a survey to gather facts on all aspects of water use to help formulate its recommendations on future management and monitoring of the northern river basins. The survey was also used to collect information on water management issues and concerns of importance to the residents and users of the basins.

Altogether, approximately 2600 households were asked to complete the survey, of which 1350 agreed to participate. In addition, surveys were sent to 602 stakeholder groups within the basins. Households were grouped into 12 separate regions, since presumably attitudes and perceptions of northern residents differ depending on where they live relative to the rivers. Eight different types of stakeholder groups were identified, and included organizations ranging from the Alberta Canoe Association to Zeidler Forest Industries. Responses were received from 718 households and 183 stakeholder groups. Census data and water licence information confirmed that this stratified sample was generally representative of the basin as a whole. However, readers should note that all statistics in this report pertain only to survey respondents.

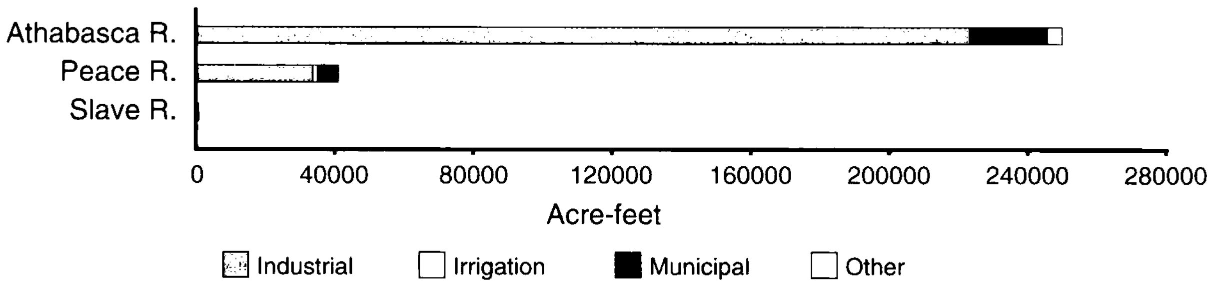
Who Are the Stakeholders?

The majority of the Study area population (57 per cent) resides in the Athabasca drainage, while only 42 per cent live in the larger Peace River basin. The remaining one per cent live in the Peace-Athabasca Delta and Slave River basin. Just over 23 per cent of the population resides in one of the two cities in the Study area: Fort McMurray or Grande Prairie. About 44 per cent live in rural areas. The rate of population growth is lower in this region than in the rest of Alberta, and residents tend to be younger and more mobile. Many more residents than the provincial average work in the primary industries of agriculture, energy and forestry. There is less ethnic diversity within the Study area than province-wide and a much higher proportion of aboriginal peoples whose first language is Cree.

More than one-half of survey participants (54 per cent) have lived in the NRBS area for more than 20 years. On average, they live within 17 km of one of the major rivers. In terms of how they might use or value water, other than drinking water, the survey found that:

- 72 per cent of responding households engage in water-based recreation;
- 29 per cent are involved in farming;
- 8 per cent are members of recreational groups;
- 3 per cent are trappers; and
- 2 per cent are members of environmental organizations.

FIGURE 3.3.1 LICENCED WATER USE FROM RIVER MAINSTEMS



CONSUMPTIVE AND NON-CONSUMPTIVE USES OF WATER

Northern residents and stakeholders use water for a variety of consumptive or non-consumptive purposes.

Consumptive uses of water are those where water is removed from surface or groundwater sources, used, and then returned, usually in a lesser amount and with some change in water quality. Some of these consumptive users (e.g., industries, municipalities and irrigation farmers) require licences while others (e.g., rural households and small farm operations) do not.

Licensed Water Use
Only two per cent of the water licences issued in the Alberta portion of the Study area allow users to draw water directly from the mainstem rivers. However, these 82 licences allow up to 291 000 acre-feet of water to be withdrawn from the rivers each year — roughly half of the total volume of licensed water use in the basins. About 88 per cent of these licences are issued for industrial purposes and most are for the Athabasca River (Figure 3.3.1). There has been a steady increase in licensed water use for industrial and municipal purposes since the 1950s. Industrial uses are dominant in the Athabasca and the Peace rivers, while the Slave River is used primarily for municipal purposes.

Drinking Water: Conventional Sources
The majority of survey respondents (56 per cent) obtain their drinking water from municipal water sources. Approximately 321 municipal water licences have been issued within the Alberta portion of the basins, allowing annual withdrawals up to 28 800 acre-feet of water. Nearly one-half of the licences were issued since 1980. The majority of responding municipalities (94 per cent) believe that their treatment facilities produce water that meets drinking water standards. However, one-third of participating households that draw their water from municipal treatment facilities report quality concerns. Their most common complaint is that the water has a strong chlorine taste — a finding that is corroborated by studies within the Traditional Knowledge and Drinking Water components (Figure 3.3.2).

Drinking Water: Non-Conventional Sources
Forty-four per cent of participating households in the Study area get their water from non-conventional sources such as groundwater wells, dugouts, river or lake water. About 31 per cent, especially farm households, draw water from wells or springs. One-third of these use some sort of treatment, such as distillation, filtration, mineral removal or chlorination. Twenty-seven per cent of well users complain about water quality, especially in terms of high mineral content.

FIGURE 3.3.2 WATER QUALITY CONCERNS FOR CONVENTIONAL WATER SOURCES

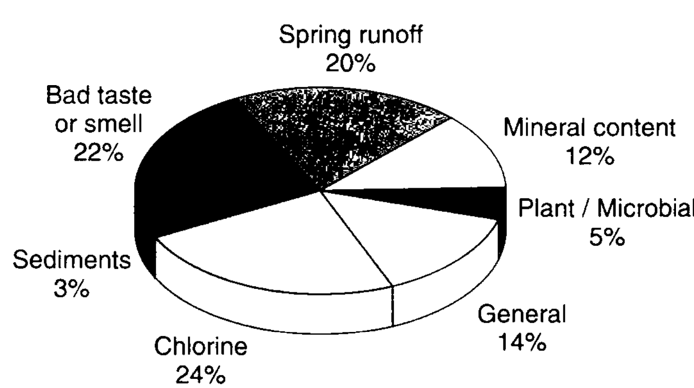
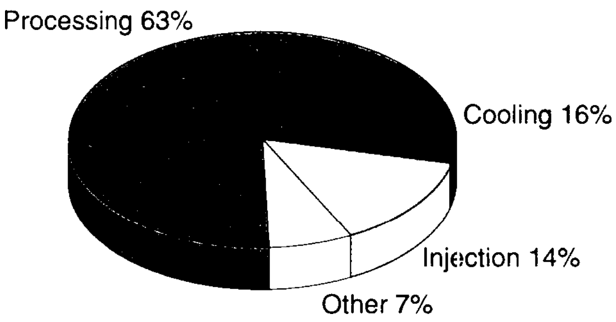


FIGURE 3.3.3 INDUSTRIAL WATER USE



Approximately four per cent of all participating households in the Study area draw drinking water from dugouts, but this practice is much more common in the Peace River basin, where more than ten per cent rely on dugouts for their water supply. Forty per cent of these households treat their water, most with chemicals to control vegetation and bacterial growth. Almost one-half of dugout users express water quality concerns, especially bad taste or odour.

Throughout the Study area, almost three per cent of households responding to the survey draw their drinking water directly from rivers. Forty-two per cent of these treat water either by filtering or boiling. Almost half the river water users express water quality concerns. Most report that water tasted or smelled bad during spring runoff (41 per cent), while some experience taste or odour problems throughout the year (26 per cent). Surprisingly, 24 per cent of these households perceive a chlorine taste in their water although apparently few use chlorine to treat their water. The source of the chlorine is unknown and field tests in the area have not detected chlorine in the rivers.

Members of some stakeholder groups, especially trappers, commercial fishermen and users of commercial recreational facilities, sometimes consume river or lake water. Most of these people treat this water by boiling, filtering or with chemicals. However, some groups — commercial fishermen and fly-in fish camps in particular — use water from surface sources without treating it, thereby posing a potential health threat to workers and clients.

Agricultural Water Use

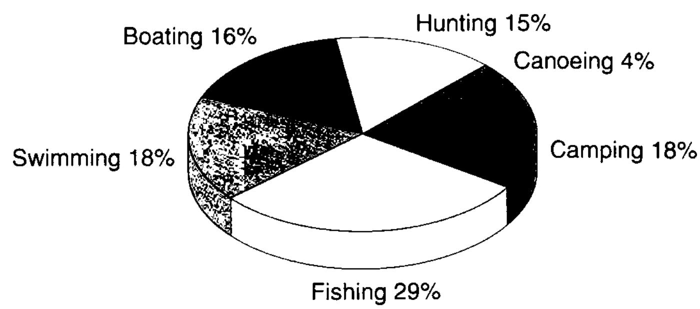
Survey data indicate that there are about 21 600 farms in the NRBS area. Agricultural water use depends on the type of farm operation: grains and oilseeds, livestock, or mixed farms. In Alberta, farms using more than five acre-feet of water per year (sufficient for 200 head of cattle) from surface water sources or dugouts are required to obtain a licence. Licences are also required where water is being used for irrigation. Currently, only 1 080 agricultural and irrigation licences for about 10 540 acre-feet of water have been issued. Survey data also show that about half the farms in the entire Study area use herbicides, pesticides and fertilizers. However, farms in the Peace River drainage are far more reliant on agricultural chemicals. At least 85 per cent of farms in the Peace River basin use one or more herbicides, pesticides or fertilizers.

Industrial Water Use

The volume of water allocated for industrial use in Alberta has increased significantly since the 1950s. Much of this growth occurred during the 1980s, when licensed water use almost doubled. The Study found that 71 per cent of the water used for industrial purposes is obtained from the Athabasca River basin while the larger Peace River basin accounts for 28 per cent. Only one per cent of licensed industrial water originates from the Slave River basin. Most industrial water is used for processing (pulp mills), cooling (thermal power production) and oilfield injection (Figure 3.3.3).

Non-consumptive uses of water are those where water is not withdrawn or removed from a water body. These include human uses for recreation, fishing, trapping or transportation as well as ecological needs for fish and wildlife living in and around rivers, lakes or wetlands.

FIGURE 3.3.4 PRIMARY ACTIVITY ON RECREATIONAL TRIPS



Recreation
More than 82 per cent of surveyed households in the NRBS area participate in outdoor recreation activities, and 72 per cent in water-based recreation. Sites along the mainstems of the Peace, Athabasca and Slave rivers are heavily used and account for about 21 per cent of trips to preferred recreational sites. Fishing is the primary activity on about 29 per cent of recreational trips (Figure 3.3.4). On average, fishermen catch 23 kilograms of fish per year, mainly northern pike and walleye. Just over one-third of them eat part of their catch and they consume an average of 14 kilograms of fish per year. However, a small proportion (three per cent) report eating more than 100 kilograms of fish per year.

Other common recreational activities include swimming, camping, boating, hunting and canoeing. While on recreational trips, 22 per cent of survey respondents drink river or lake water, and water quality is a key concern. Forty-one per cent of households participating in outdoor recreation report a change in water quality or quantity. The most common observation is that the water is now dirtier. Another 13 per cent noticed a foamy scum on the rivers.

Commercial Recreation Operations
About 50 commercial recreation operations exist in the basin, most (87 per cent) with less than ten employees during the peak season. More than half of the clients of commercial recreation operations live in the NRBS area; another 11 per cent originate elsewhere in Alberta. Approximately one-third of clients live outside the province and visit the region. About 27 per cent of visitors to the basin use commercial recreation facilities. Nearly all commercial recreation operators indicate that water resources are important to the products and experience offered to their customers. More than 70 per cent of the operators have witnessed changes in the aquatic resources of the basins during the past ten years. Lower water levels are a major concern for tour boat operators on the Peace River.

Commercial Fishing
Currently, there are approximately 400 commercial fishermen in the NRBS area, down from about 600 in 1990 / 91. Over the past five years they have caught an average of 1.4 million kilograms of fish per year. This represents two-thirds of the total Alberta commercial fish harvest. Lake whitefish account for 70 per cent of the commercial harvest, while northern pike make up 17 per cent. Two-thirds of the fishermen surveyed report that fish populations have changed during the past ten years. The majority of comments (67 per cent) indicate that fish populations in the Lesser Slave Lake area have increased. Seventeen per cent feel that fish are smaller and have more deformities.

Trapping
Alberta trapping statistics suggest that there are about 3 470 trappers in the basin. The majority (62 per cent) have registered traplines. The remainder include trappers on private lands, licensed Métis and Indian trappers, and people licensed to trap in Wood Buffalo National Park. Only about 2 400 trappers were estimated to be active and in 1994 / 95 the value of fur production in the NRBS area was about $1.3 million. The most common trapping species include beaver, muskrat and coyote. Less than half the trappers (40 per cent) report having seen changes in the fur-bearing populations during the last ten years. Many suggest that numbers of furbearing animals have declined but some feel this is due to normal population cycles.

Ecological Uses
Ecological uses of water in a river ecosystem involve both aquatic (or instream) and riparian (or shoreline) uses. The aquatic component, which includes fish and other aquatic life, is dependent upon water quality, minimum stream flow and various temperature-related stream flow characteristics. The riparian ecosystem, which includes vegetation communities and wildlife on floodplains, is also dependent upon certain flow characteristics, such as floods and ice regimes. Human uses of water may directly affect the quantity and quality of water available for ecological uses. Dams and reservoirs, diversions of consumptive uses and effluent discharges can have dramatic effects on the physical, chemical and biological characteristics downstream.

STAKEHOLDER ISSUES AND CONCERNS

The Other Uses Component also gathered information about northern residents and their values, needs, expectations and opinions regarding water management issues in the Study area. The survey focused on a number of issues, including the importance of water quality, key factors affecting water quality and quantity, threats to water quality and quantity, measures of ecosystem health, and preferred recommendations for consideration by the Study Board.

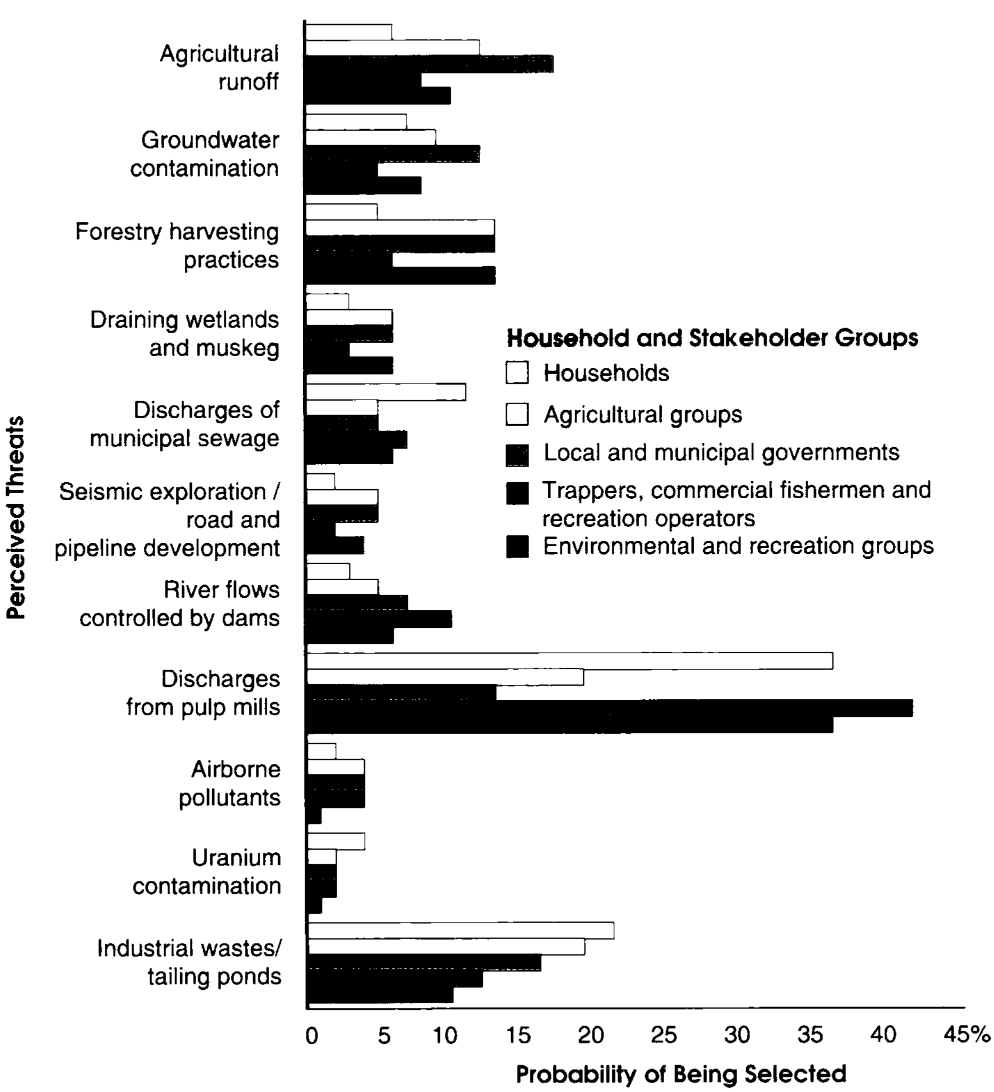
Importance of Water Quality
This section of the survey included a set of statements. Respondents were asked whether they agree, partly agree, disagree or are unsure with regard to the statement. The results show that the surveyed public clearly rejects the statement "Water quality is not a major issue." Seventy-two per cent of respondents disagree with this statement. In contrast, a range of 40 to 70 per cent of respondents from industries, municipalities, agricultural service boards, and other agricultural groups agree that water quality is not a major issue.

Roughly one-half of respondents from northern households (51 per cent) and the majority of environmental organizations, recreational groups and commercial recreation operators disagree with the statement "Water quality issues are limited to a few locations." However, more than 70 per cent of the surveyed agricultural service boards and local governments agree. This reveals an important difference in views between some stakeholder respondents and the public.

Seventy-five per cent of surveyed households agreed, in whole or in part, that "Contamination of northern rivers is a major problem." This includes not only households living adjacent to river mainstems but also people living in regions away from the rivers. They agree that some industries or municipalities should be forced to reduce effluent discharges even if it means closing some operations. While contamination of water is a concern for the majority of basin residents, 45 per cent of industrial users disagree.

More than 90 per cent of surveyed households disagree with the statement that "Existing water management regulations interfere with economic development." The majority of the stakeholder groups, including industrial water users, also believe that regulations are not interfering with development. These views appear inconsistent with current Alberta efforts on deregulation, at least in regard to water management.

FIGURE 3.3.5 PERCEIVED THREAT TO WATER QUALITY/QUANTITY: COMPARISON AMONG STAKEHOLDER GROUPS



A large proportion (80 per cent) of all surveyed stakeholder groups and households agree, in whole or in part, that "No further effluent discharges should be allowed until a river basin plan has been completed." However, there is less support for a river basin plan among industrial water users, local governments and agricultural service boards.

Key Factors Affecting Water Quality and Quantity
Both households and stakeholders were asked to identify the three factors that

have had the greatest effect on the amount or quality of water in the Peace, Athabasca and Slave river basins during the last 20 years. Survey responses were grouped into 14 major categories. For surveyed basin households, pulp mills represent the most frequently mentioned threat to water quality and quantity. Municipal water use and sewage is the second most common concern while other industries rank third. In contrast, local governments rate agricultural practices as the top factor. Logging is identified as one of the top four factors affecting water quality and quantity by all stakeholder groups.

Most Important Threats to Water Quality and Quantity
In this section of the survey, respondents were asked to rank 11 specific threats to water quality and quantity in the basin. In the opinion of surveyed households, pulp mills present by far the greatest threat to water quality (Figure 3.3.5). Industrial wastes and tailing ponds rank second. Discharges of municipal sewage are perceived to be the third most important threat.

Stakeholder groups were also asked to rank the same 11 threats. To municipal and local governments, pulp mills are less of a threat than either agricultural runoff or industrial effluent / tailing ponds. In addition, municipal and local governments are half as likely as the general public to identify their operations — discharges of municipal sewage — as a problem. Environmental and recreational groups share the general public concerns about pulp mills. For them, the second most important threat is the effect of logging and agricultural practices.

Measures of Ecosystem Health
Although other NRBS components are developing procedures for assessing the health of river ecosystems from a technical perspective, households and stakeholders were asked to describe how they would measure river health. The three preferred measures of river health are water quality, fish health, and pollutant levels. For the majority of indicators, monthly monitoring was suggested. The frequency of monitoring reflects a perception of the immediacy of threats. Responding households generally preferred that governments or independent agencies should do the monitoring, but industries should pay the cost of monitoring where industrial effluent is perceived to be a problem. Representatives from local governments and agricultural service boards felt that governments should pay. Industrial water users believed that all users should pay monitoring costs.

FIGURE 3.3.6 MANAGEMENT ACTIONS PERCEIVED TO BE MOST EFFECTIVE: COMPARISON AMONG STAKEHOLDER GROUPS

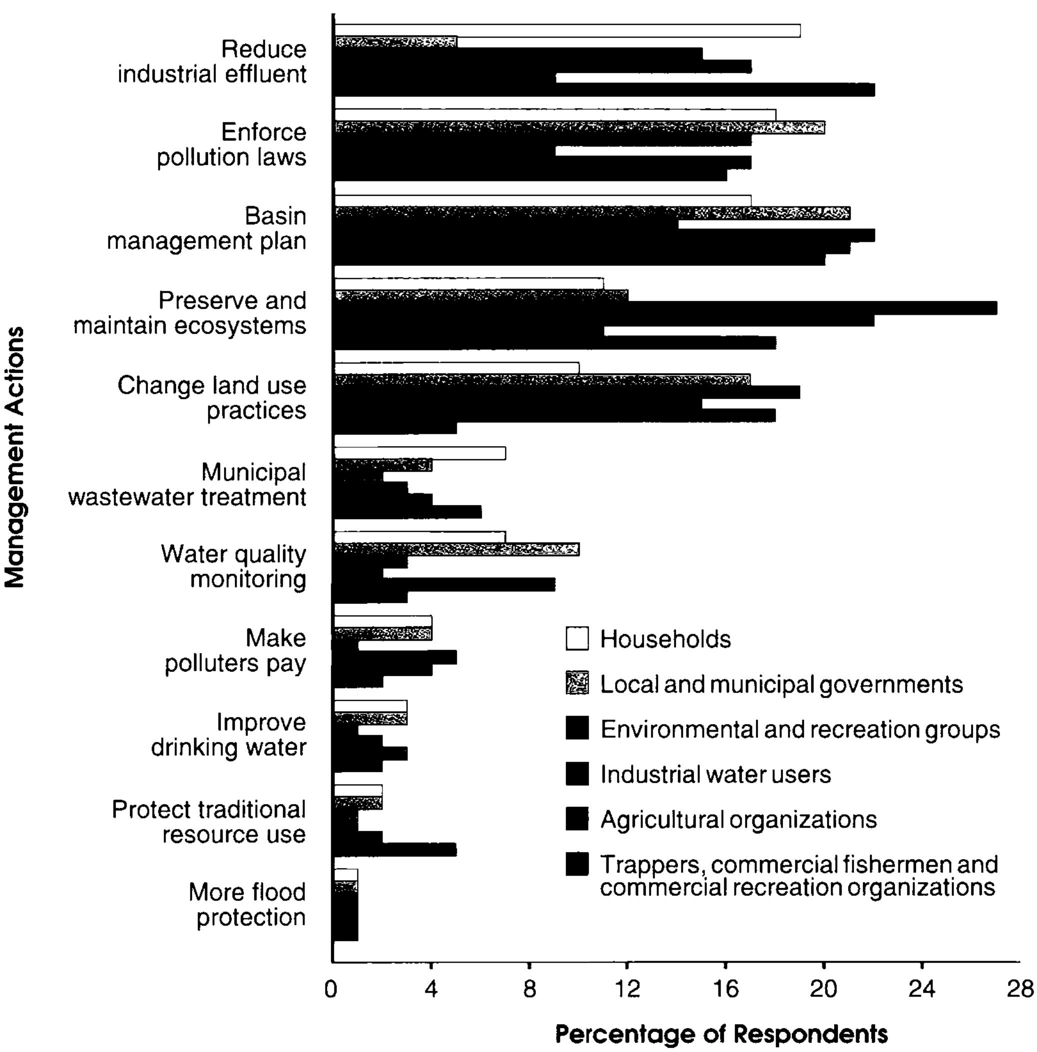


Figure 3.3.6 illustrates those management actions perceived to be most effective among survey respondents. In addition, households and stakeholders had the opportunity to list up to three recommendations that they felt should be made by the Northern River Basins Study Board. The four most important recommendations include reducing effluent loads, monitoring industrial activities, enforcing stricter laws, and stopping selected activity. Some stakeholder groups also recommend the development of a river basins plan.

Reduce Effluent Loads
The top priority for 23 per cent of surveyed households is the reduction of effluent and chemicals discharged into the environment. Certain stakeholders groups, such as trappers and commercial recreation operators, also want an immediate decrease in effluent.

Monitor Industrial Activities
Surveyed households and trappers show relatively strong support for enhanced monitoring of industrial activity. Most suggest monitoring in general, while some propose that effluent from pulp mills and other industry be monitored. However, other stakeholders are less supportive of monitoring. Only 16 per cent of responding local government officials and agriculture groups propose more monitoring.

Enforce Stricter Laws
The third most common recommendation of surveyed households is the need for increased enforcement of stricter laws on pollution and the use of chemicals. Suggested action includes zero tolerance on second infractions and increased inspections. Responding industrial water users, agricultural groups and local governments, however, did not consider the enforcement of stricter laws to be a priority.

Stop Selected Activities
More than 30 per cent of surveyed environmental groups and commercial fishermen recommend that certain activities must be stopped. Suggestions include: zero effluent discharge from new industry, the cessation of clear cut logging, no more dams and the establishment of buffer zones between industrial, logging and farming and basin water courses to protect water quality and reduce sedimentation.

Results of the household survey strongly suggest that residents want the Study Board to make recommendations that will act to quickly resolve current problems. Emphasis is placed on the immediate reduction of effluent loads, more monitoring and enforcement of existing pollution laws, stopping certain activities, followed by the development of a management plan for the basin. In comparison, municipal and local governments, industrial water users and agricultural stakeholders favour more research and planning as part of a long-term solution. This shows an important difference in views between the public and some stakeholder respondents.

RELATED DOCUMENTS

NRBS Synthesis Reports
MacLock, B. and J. Thompson. 1996. *Characterization of Aquatic Uses within the Peace, Athabasca and Slave River Basins.* Northern River Basins Study Synthesis Report No. 7.

NRBS Technical Reports
Drobot Contracting Services and Praxis Inc. 1996. *Water Resources Use and Management Issues for the Peace, Athabasca and Slave River Basins: Implementation of a Householder Survey, January to April, 1995.* Northern River Basins Study Technical Report No. 70.

Golder Associates. 1995. *Water Resources Use and Management Issues for the Peace, Athabasca and Slave River Basins: Design of Questionnaire and Survey Methods.* Northern River Basins Study Technical Report No. 58.

Hoare, T. 1995. *Water Resources Use and Management Issues for the Peace, Athabasca and Slave River Basins: Stakeholder Screening Survey.* Northern River Basins Project Report No. 57.

Nichols Applied Management. 1995. *Factors Effecting Future Development in Key Economic Sectors in the Peace, Athabasca, and Slave River Basins.* Northern River Basins Study Technical Report No. 73.

Praxis Inc. 1994. *Status and Future Requirements for Socio-Economic Research and Public Communications and Consultations.* Northern River Basins Study Technical Report No. 31.

Reicher, P. 1996. *Water Resources Use and Management Issues for the Peace, Athabasca, and Slave River Basins: Implementation of Stakeholder Surveys.* Northern River Basins Study Technical Report No. 75.

Reicher, P. and J. Thompson. 1995. *Water Use and Management Issues for the Peace, Athabasca, and Slave River Basins: Implementation of a Household Survey.* Northern River Basins Study Technical Report No. 69.

Williams, M. 1996. *Water Resources Use and Management Issues for the Peace, Athabasca and Slave River Basins: Best / Worst Analysis of Survey Questions about Threats and Actions.* Northern River Basins Study Technical Report No. 80.

Other Relevant Documents

Statistics Canada. *1991 Alberta Census.*

3.4 Traditional Knowledge

Related NRBS Questions

12. What native traditional knowledge exists to enhance the physical science studies in all areas of inquiry?

Introduction

Traditional environmental knowledge refers to the body of experience that is derived from years of living off the land. In the Study area, much of this information is found in aboriginal cultures, passed down from generation to generation in their oral traditions. Because of their longstanding experience with the land, native elders in particular possess an intuitive ability to distinguish subtle patterns, cycles and changes within the ecosystem. During the course of the Study, the Board recognized that this qualitative knowledge could be used to complement and enhance the largely quantitative information provided by contemporary biological and physical sciences.

The NRBS Traditional Knowledge Component was designed to chronicle the wisdom of people whose lives are integrally linked to the land. The project consisted of three segments: interviews with aboriginal residents, an extensive survey and a search of archival records that provide historical perceptions of the land and its resources. Ten communities located in the far north of the basins participated (Figure 3.4.1) and 264 interviews were conducted with traditional basin inhabitants.

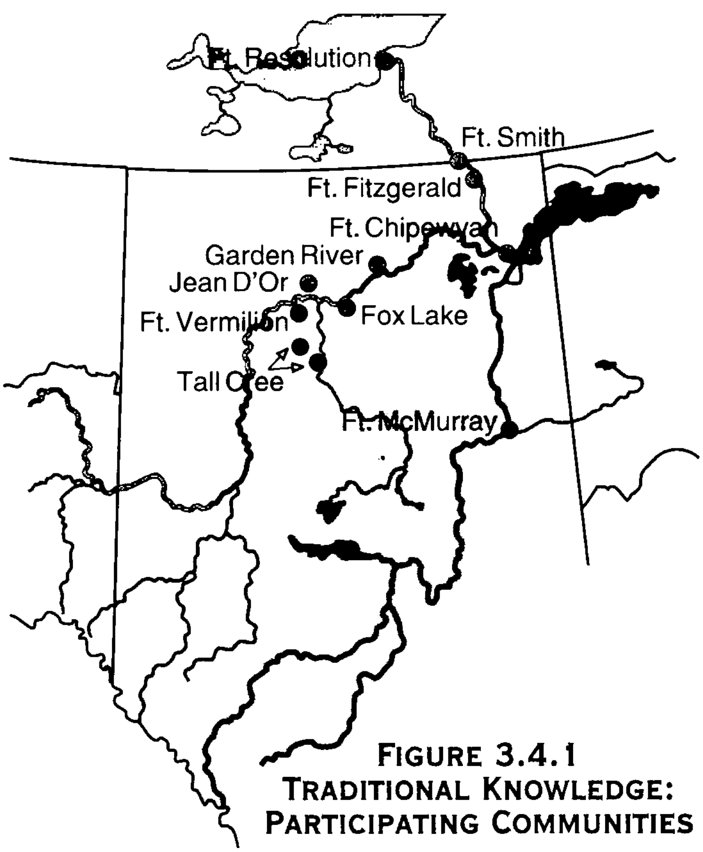


Figure 3.4.1
Traditional Knowledge: Participating Communities

The large amount of information compiled by the Traditional Knowledge Component describes the sweeping social and environmental changes that have occurred within the basins. The records and collective memory of the people span a period of more than two full centuries, and a sizeable database of archival records was compiled. Hundreds of maps were created to capture historic and present patterns in land use, wildlife and other aspects of the basin ecosystem. Readers are encouraged to refer to the synthesis report listed at the end of this section for more detailed information.

The value of traditional knowledge warrants identification as a distinct body of knowledge, with its own perspective and approach. Also, the knowledge retrieved through this project serves as an important historical resource for traditional basins inhabitants. Accordingly, this information has been returned to the respective communities for their use.

Patterns In the Water

Traditional basin inhabitants recognize water as central to the support and quality of their lives. In the past, traditional inhabitants of the basins generally viewed the waters as abundant and clean except during drought periods. Since then, residents have witnessed a number of changes in both the quality and quantity of waters in the northern portion of the basins (Figure 3.4.2).

In the eyes of these northern inhabitants, the quality of water has largely deteriorated

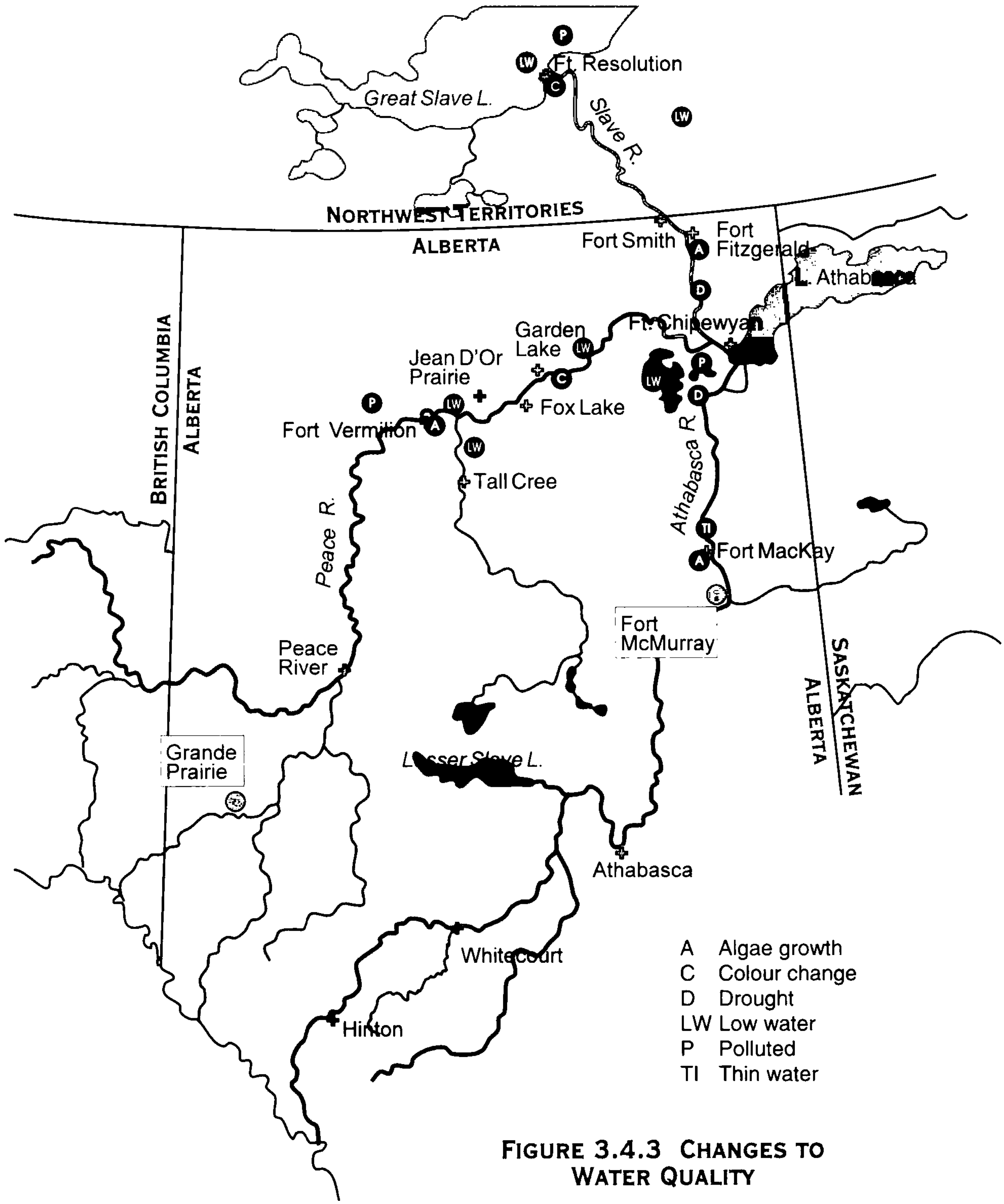
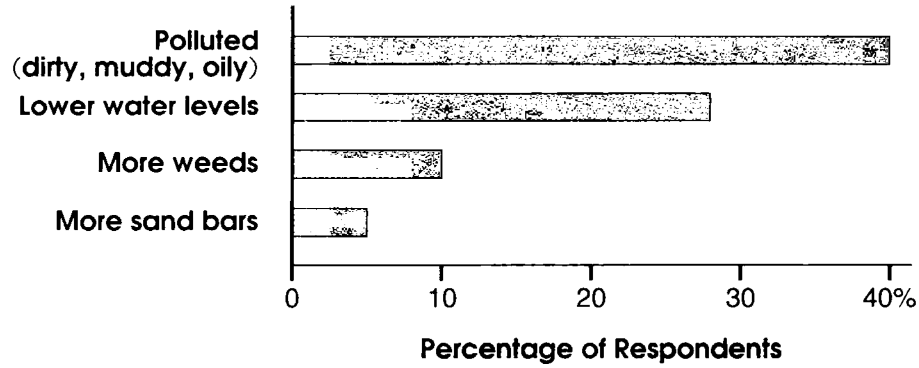


FIGURE 3.4.3 CHANGES TO WATER QUALITY

FIGURE 3.4.2 TOP FOUR CHANGES TO WATER CHARACTERISTICS BASED ON TRADITIONAL KNOWLEDGE SURVEY



(Figure 3.4.3). A large proportion of individuals has noted higher turbidity and sediment loads within the mainstem rivers. According to historical records, high turbidity was common during the spring runoff but lessened during the fall and winter. High turbidity and sediment loads are now seen as year-round phenomena.

A number of individuals, especially in Fort Smith on the Slave River, have had an increasing number of aquatic plant-related concerns over the past five years. Elders and traditional fishermen in Fort Smith have remarked on the overabundance of algae that covers the river banks and clogs their fishing nets.

There is a belief that industry, especially pulp mills, have "poisoned" the waters in their area. Ninety-five per cent of traditional knowledge interviewees still rely on natural water sources instead of municipal water supplies, but a number of individuals no longer trust the quality of surface waters. When asked why these individuals stopped using lake or river water, the predominant concerns were a fear of disease and aesthetic considerations (Figure 3.4.4). Others have noted an oily sheen on the mainstem rivers that leaves a scum in their tea cups.

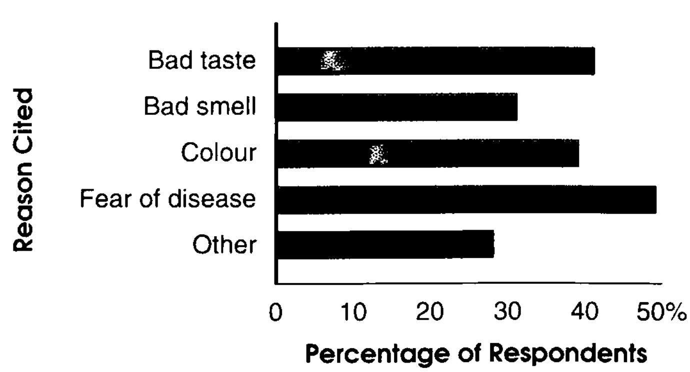
These concerns have prompted many to carry water supplies during wilderness travel instead of drawing water from the land. The practice of using snow and ice as a water source is also being curtailed due to the observation that the snow is "dirtier" and the belief that precipitation is contaminated with industrial pollutants and ash from large forest fires. Many note that treated water has a strong bleach flavour that they associate with various physical ailments — a sentiment also recorded by Other Uses (Section 3.3) and Drinking Water (Section 3.10) components.

According to native elders, the levels and patterns of water flow have fluctuated to a great extent within the river basins. Water levels across the basins appear to have dropped markedly over the last 15 years, and many of the smaller streams and lakes have dried up. Furthermore, the rivers no longer seem to have the capacity to scour sediment deposits downstream — shoreline access is increasingly difficult and sand bars form at a more frequent rate.

Archival records contain a great deal of information related to seasonal flow patterns within the basins. Flood and ice jam events were regularly recorded in the Peace and Athabasca rivers, as well as the Peace-Athabasca and Slave deltas. Aboriginal people noted a reduction in the seasonal flooding of the major rivers, particularly the Peace River.

The most significant ecological impacts of flow alterations are recorded by aboriginal peoples from Fort Chipewyan in the Peace-Athabasca Delta. As described in (sections 1.4 and 3.5) of this report, the perched basins of the Peace-Athabasca Delta are

FIGURE 3.4.4 REASONS FOR NOT USING RIVER OR LAKE WATER BASED ON TRADITIONAL KNOWLEDGE INTERVIEWS



renewed by periodic floods that are largely controlled by the development of ice jams along the Peace River during the spring. In the memory of those who live in the delta, the number of spring floods has greatly reduced since the construction of the Bennett Dam in British Columbia; the last major flood occurred in 1974. In the absence of these rejuvenating floods, two of the perched lakes (Egg Lake and Pushup Lake) have disappeared and many others are drying out. Willows and other terrestrial vegetation now encroach on sites where wetlands once dominated, which in turn affects the animal numbers and species.

Patterns in the Wildlife

With some exceptions, residents of traditional northern communities have observed that fish and wildlife populations have generally declined (figures 3.4.5 and 3.4.6). In addition, species that follow predictable population cycles (e.g., rabbit and lynx) are thought to have longer periods between cyclic low and high populations. Traditional knowledge respondents attribute these changes to a number of factors, including flow alterations, land drying, intensive fires, mining, logging and road development. All of these are thought to reduce or eliminate the capacity of the land to support healthy fish and wildlife populations. The situation is further aggravated by land clearing and improved road access, which allows for easier fish and wildlife harvesting. Numerous comments were made with regard to regional fish and wildlife populations.

Traditional inhabitants feel that the quality and quantity of fish has deteriorated to a large extent over the last 50 years. A number of traditional fishing sites, such as "fish hole" on the Rat River, are now sparsely populated or dried up. Overfishing resulted in the near-extinction of goldeye in the Peace-Athabasca Delta, and populations of whitefish are also declining. Traditional fishermen commented that fish are generally smaller, have poorer taste and texture, and appear unhealthy at some sites. Deformities are often observed in jackfish caught in the vicinity of Pine Creek, Northwest Territories. Residents observe that there are fewer songbirds than in the past. Many native elders also note that drier lands have increased the frequency and severity of forest fires, which has reduced the winter range for caribou.

Alterations to Peace River flows, and the resulting changes in habitat within the Peace-Athabasca Delta, are seen to have impaired the health and numbers of various animals within the region. Traditional inhabitants have observed a significant decline in the health and population of muskrats during the last ten years. The loss of sedge meadow habitat has caused buffalo populations to decline. At the same time, moose populations have increased and stabilized due to the availability of willows and shrubs that are a primary food source. Fewer migratory birds use the delta as a staging and nesting site.

Populations of migratory birds within the Slave River Delta also seem to have declined (Figure 3.4.7). In 1791, Peter Fidler noted that flocks of geese on the Slave River were so thick "they appeared at a little distance as if the river was quite choked up with floating driftwood." This abundance has not been observed in many years. In 1870, "egg gathering activities succeeded in collecting 1000 eggs at Buffalo Lake, Northwest Territories." Eggs are no longer gathered on this lake and no mention was made regarding the plentitude of eggs. Elders believe that the fall migration of many bird species has shifted from the Peace-Athabasca and Slave deltas to the Peace River agricultural region to take advantage of grain crops.

Patterns in Traditional Societies

Traditional basin inhabitants rely on the land for a number of resources, including food, medicine, clothing and income. To aboriginal residents, the land and its waters are also a source of culture and spirituality. They believe that all things in nature are connected and their link to the land is an integral aspect of their lives. Their respect for nature is expressed through their traditional ceremonies and through their traditional land management practices. These people strongly believe that the emotional and spiritual value they place on the environment and their lifestyle is lost

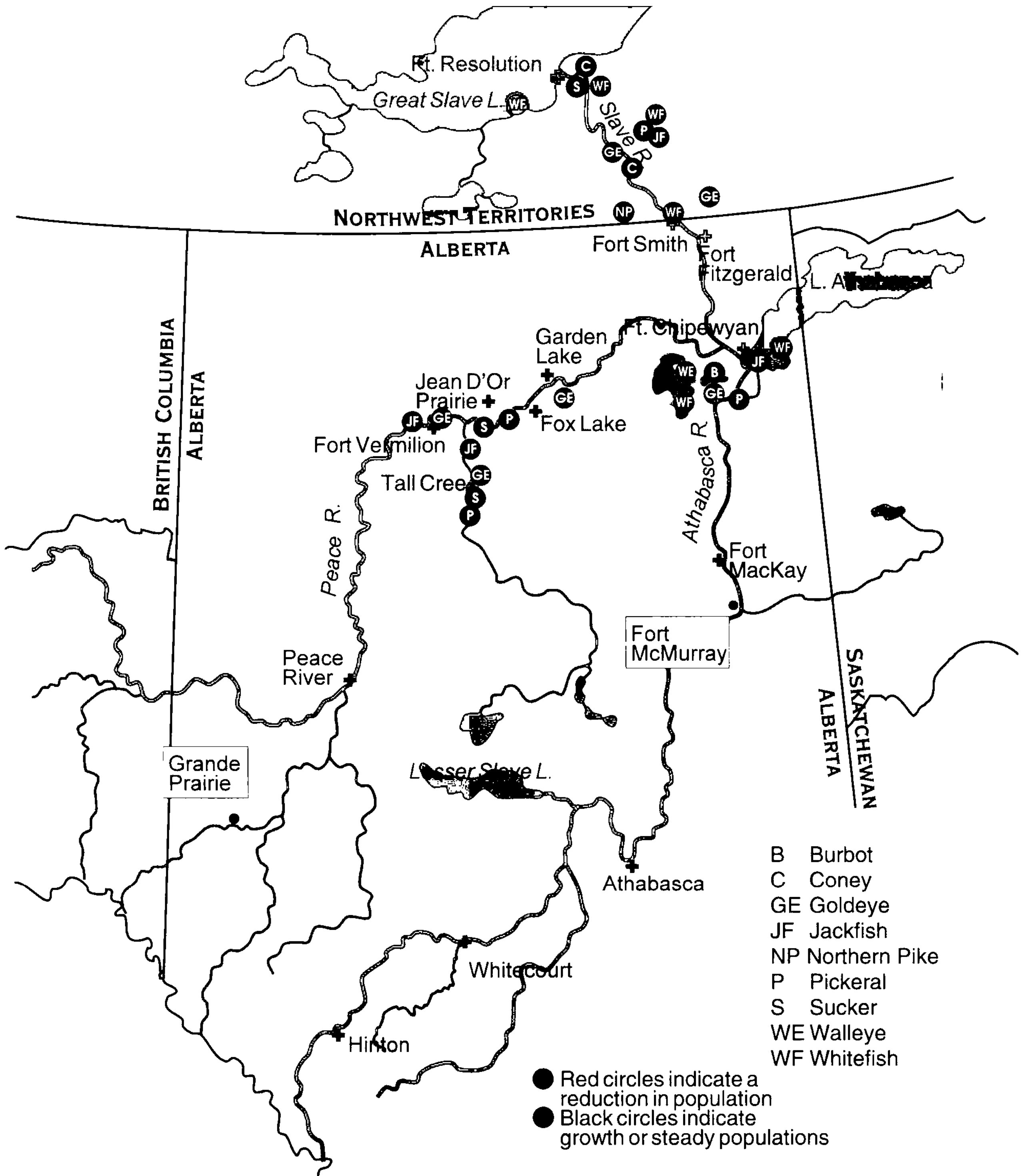


FIGURE 3.4.5 CHANGES TO FISH POPULATIONS

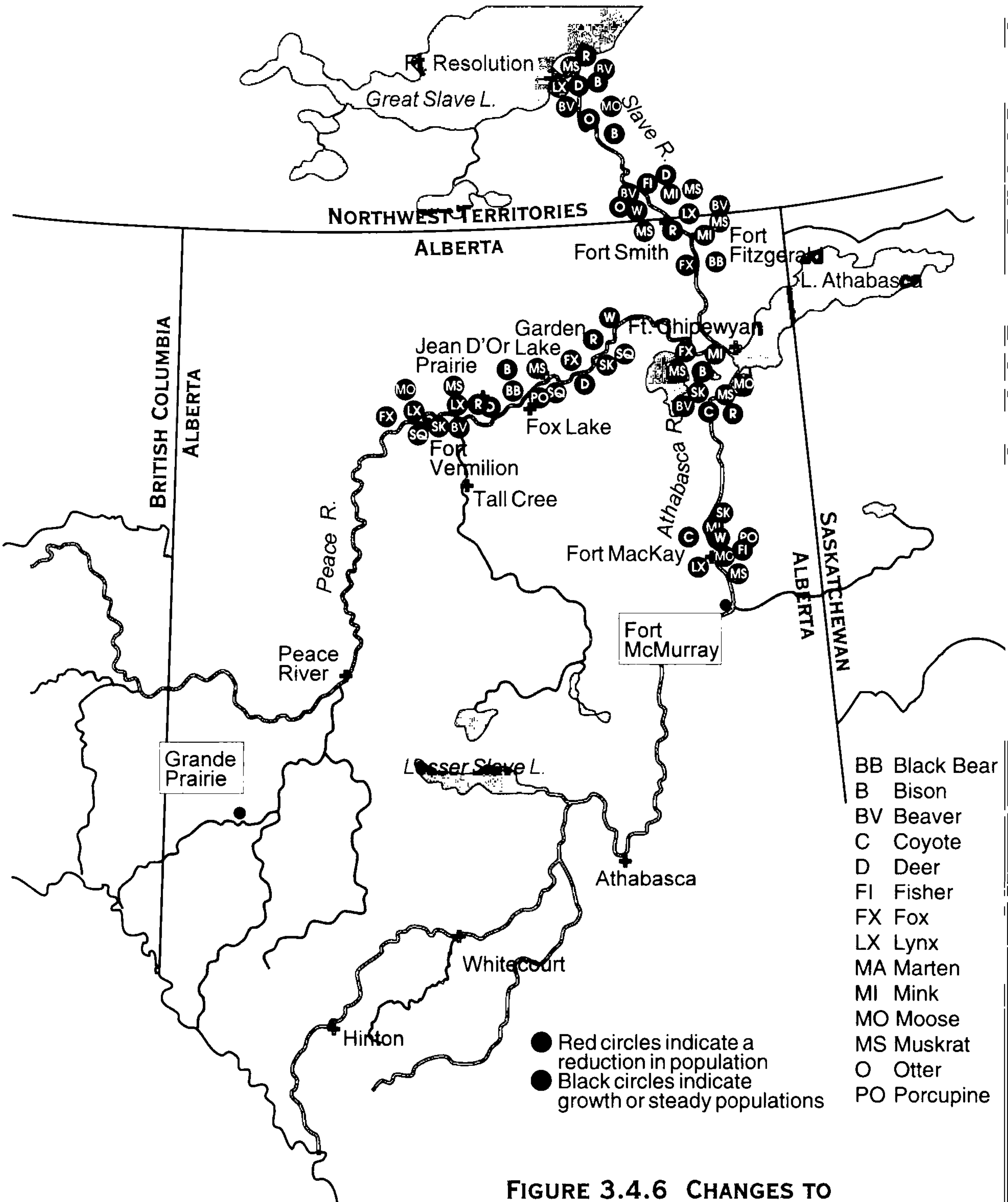


FIGURE 3.4.6 CHANGES TO WILDLIFE POPULATIONS

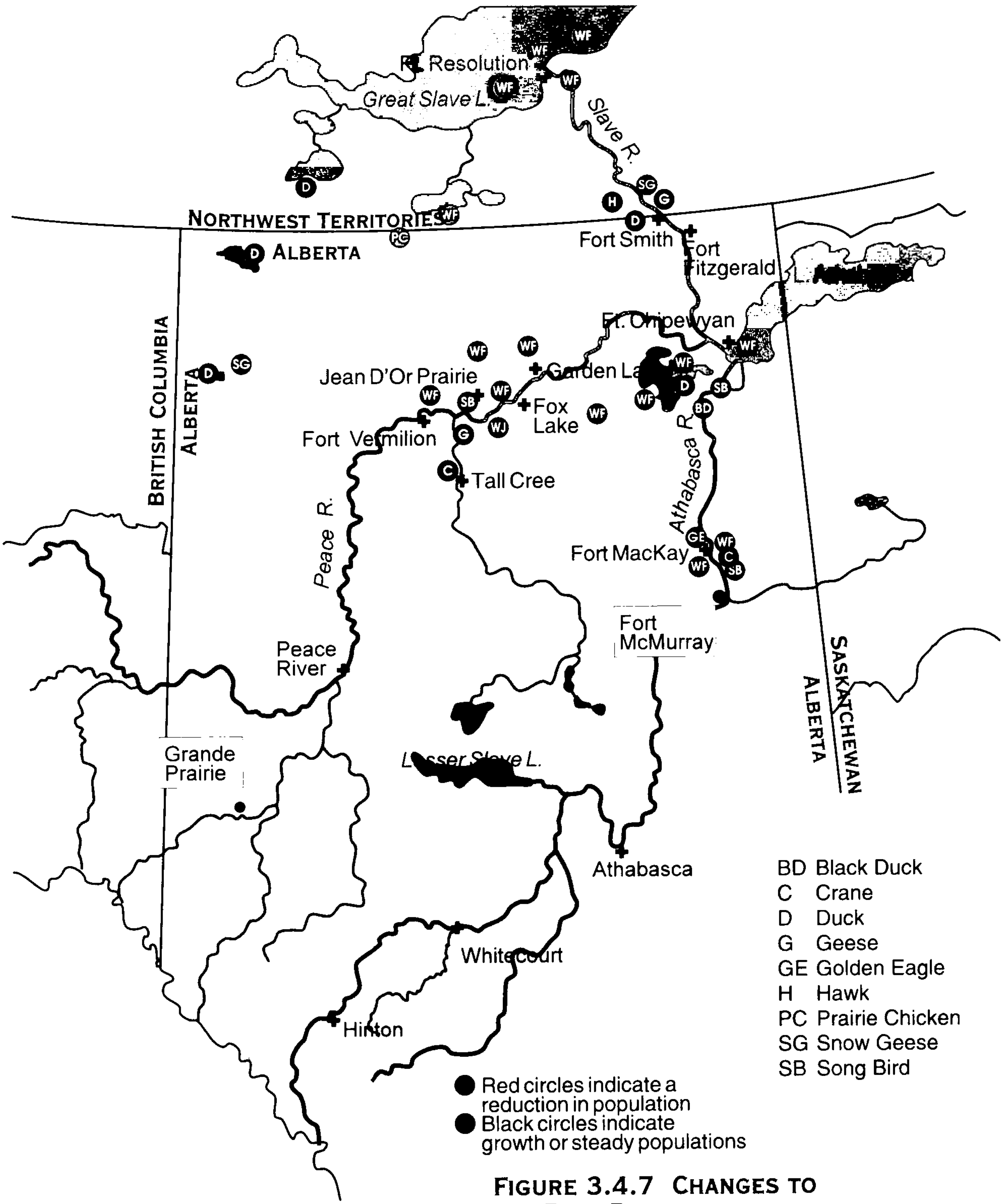


FIGURE 3.4.7 CHANGES TO BIRD POPULATIONS

on governments and industry, which instead measure the worth of natural resources in terms of commercial value.

Historically and today, elders believe that economic development and associated institutional change is destroying their intricate link with the land and preventing future generations from establishing that connection. As early as the fur-trade era, natives were required by the Church to send their children to boarding school. This forced natives to establish a sedentary way of life that further removed them from the traditional hunting economy that existed prior to European immigration and the fur-trade. The extended harvesting of wildlife resources resulted in a growing incidence of starvation and increased reliance on trading posts for food staples. These and other developments are seen as distancing aboriginal peoples from their traditional lifestyle — a lifestyle they believe still holds great value for present and future generations.

Archival information and traditional knowledge interviews suggest that development has caused a deterioration in the cultural and physical health of affected aboriginal communities. One-quarter of those individuals included in the traditional knowledge study claim that development destroyed their valuable relationship to the land. Another 12 per cent say that development crowds them out and they lose control over the land. This effect seems to be more pronounced among younger generations. A large number of native elders commented that their children are losing interest, understanding and respect for the traditional ways of their people. This is compounded by the loss of several sacred sites due to advancing development. The Alberta Housing Building in Fort Vermilion, for instance, was erected on a site of great spiritual significance to First Nations peoples.

Although most respondents feel positive about their health, there is a widespread belief that there is an increased incidence of certain diseases (e.g., heart disease, cancer and diabetes) within traditional communities. Almost one-quarter of respondents state that industrial development has affected their health. When asked how it affected their health, 87 per cent of respondents pointed to air or water pollution. Another eight per cent explained that diminishing wildlife populations had forced them to switch to store bought foods and the chemical additives in these foods affected their health. Alcohol, drugs and a lack of physical activity are also seen as main contributors to the increased incidence of disease. Others feel that the clearing of forested lands for logging, agriculture and other industrial purposes is rapidly destroying natural herbs used in traditional medicines.

Traditional users believe strongly that without significant intervention, the environmental outlook for the basins is bleak. However, a majority does not expect a cessation of development; rather, they support sustainable practices that respect the complex interdependency among living things and include traditional peoples in all decisions that affect their lifestyle. Elders maintain that current land use strategies should include a greater consideration and respect for overall ecological health. The land is a source of food, medicine, clothing and income. It also links them to their traditional ideology and has an important influence on their ability to transfer their knowledge of the biosphere and their way of life. They emphasize the need to protect forested areas from further tree removal and to accelerate reforestation efforts in affected areas. With regard to agriculture, cessation of wetland drainage and the use of alternatives to agricultural chemicals should be considered.

Through participation in this study, traditional peoples have voiced their willingness to share their knowledge as part of a mutually beneficial partnership with governments and industry. They believe that traditional knowledge can provide a number of benefits to environmental inquiry — both by identifying patterns and changes within a developed ecosystem, and by providing guidance on long-term maintenance strategies.

Relevant Documents

NRBS Synthesis Reports
Flett, L., Bill, L., Crozier, J. and D. Surrendi. 1996. *A Report of Wisdom Synthesized from the Traditional Knowledge Component Studies*. Northern River Basins Study Synthesis Report No. 12.

NRBS Technical Reports
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3.5 FLOW REGULATION

Related NRBS Question:

10. How does and how could river flow regulation impact the aquatic ecosystem?

INTRODUCTION

Flow regulation refers to the control of natural water flow to serve some human purpose, usually by withdrawing, diverting or storing it. If combined, the total flow of all diverted water in the country would form Canada's third largest river, smaller only than the St. Lawrence and Mackenzie rivers.

Most of these diversions were created to serve hydroelectric production. With hydroelectric dams, there are two sources of change that affect aquatic ecology: the impoundment of water in a reservoir upstream of the dam, and the control of downstream water flows. These simple alterations can affect many physical, chemical and biological aspects of the environment, including water flow patterns, ice formation, sediment transport, water chemistry, aquatic communities and habitat.

The Peace River has experienced large-scale flow regulation since construction of the W.A.C. Bennett Dam in British Columbia and operation of the Gordon M. Shrum hydroelectric facility. Filling of its associated reservoir — Williston Lake — occurred between 1968 and 1972, resulting in the storage of nearly 41 trillion litres of water.

The NRBS Hydrology Component initiated a variety of studies to better understand the physical, chemical and biological impacts of flow regulation on the basins environment. Challenged by the lack of comprehensive information on this topic, the NRBS studies focussed primarily on the effect of the Bennett Dam on hydrologic regimes and downstream regions within the Study area. This included the development of computer models to help predict the future consequences of flow regulation in the northern rivers. It also involved close collaboration with researchers performing similar investigations within the Peace-Athabasca Delta Technical Studies group.

A more in-depth discussion of flow regulation impacts on the northern rivers can be found in the NRBS synthesis report cited at the end of this section.

EFFECTS ON THE PEACE RIVER

NRBS scientists have confirmed that flow regulation on the Peace River has greatly altered several river characteristics, including seasonal flow patterns, ice cover formation and sediment transport. These, in turn, affect other physical characteristics of the river, including the quality and availability of certain habitat types.

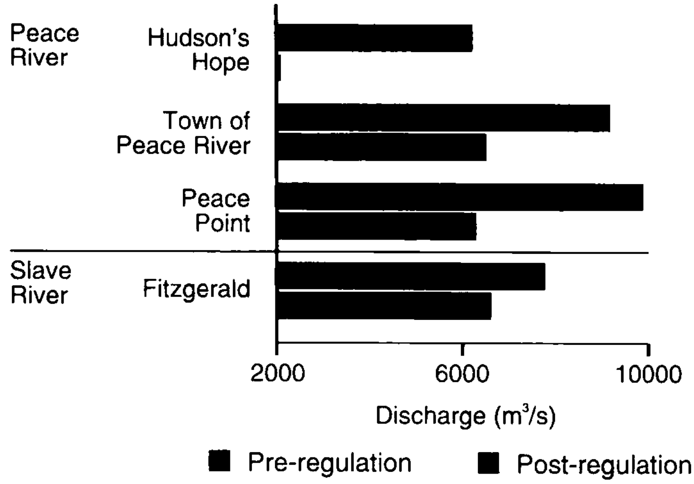
Flow Patterns

Prior to regulation, the Peace River displayed seasonal flow patterns similar to other northern rivers dominated by snowmelt runoff — high flows in the spring and summer, and low in late fall and winter. The Bennett Dam has affected this pattern. While the annual amount of water flowing out of the dam is the same as before regulation, the timing of these flows has been altered. The dam releases significantly greater amounts of water during the cold months to meet rising power demands, and tends to store more water in the summer to refill the reservoir.

One of the effects of flow regulation is to reduce mean annual peak flows (Figure 3.5.1). Immediately downstream at Hudson's Hope, peak flows are only 30 per cent of those recorded prior to regulation by the dam. These effects generally diminish downstream due to the influx of natural tributary flows. Due to the large inflow of water from the Smoky River, for instance, average peak flows at the town of Peace River remain at 71 per cent of historical levels. At Peace Point above the Peace-Athabasca Delta, peak flows are 63 per cent of historically recorded levels. Further downstream at Fort Fitzgerald on the Slave River, the influence of the unregulated Athabasca River boosts flows back up to 85 per cent.

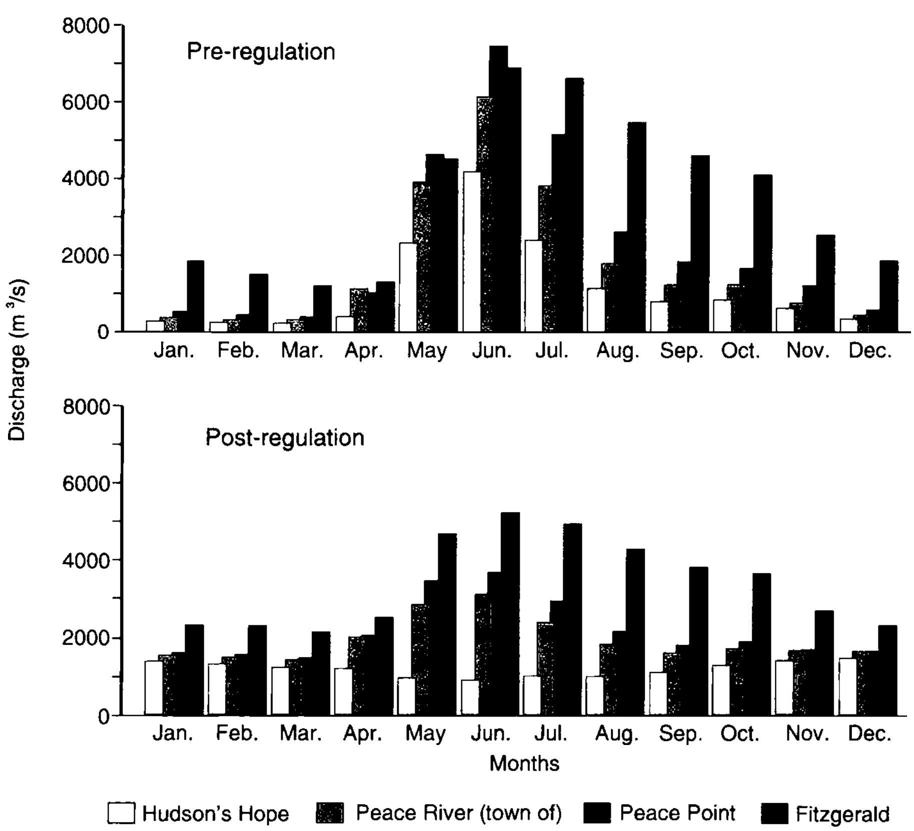
Flow regulation has altered the timing of seasonal high and low flows at locations immediately downstream of the dam. Under current conditions near Hudson's Hope, average seasonal low flows occur in June instead of March and average high flows occur in December instead of June (Figure 3.5.2). Prior to regulation, summer flows near Hudson's Hope were roughly twice that of winter flows. Following regulation, these summer flows have been cut in half and winter flows are four times greater. In fact, summer flows at Hudson's Hope are currently lower than the regulated winter flows (Figure 3.5.2). The situation is less pronounced further downstream. At Peace Point, summer flows are 66 per cent of historic levels, while winter flows are at 250 per cent.

FIGURE 3.5.1 PRE- AND POST-REGULATION MEAN ANNUAL PEAK FLOWS AT SELECTED SITES ON THE PEACE AND SLAVE RIVERS



In light of the higher winter flows on the Peace River since regulation, the relative importance of tributaries to the overall flow volume is greatly reduced during this period. Prior to regulation, tributaries would double the winter flow between Hudson's Hope and Peace Point. The same volume of tributary flow now accounts for only 20 per cent of the winter flow at Peace Point. In contrast, tributaries now have an added significance during the summer months. It should be noted, however, that tributary flows have been relatively less in recent years, which appears to be tied to regional climate conditions.

FIG. 3.5.2 PRE- AND POST REGULATION MEAN MONTHLY FLOWS AT SELECTED SITES ON THE PEACE AND SLAVE RIVERS



Sediment Transport and River Morphology

Most sediments in the Peace River arise from its tributaries downstream of the dam, in particular the Smoky River. Consequently, Williston Lake does not have a large influence on the amount of sediments that flow into the river. However, lower peak flows have reduced the ability of the river to scour away the annual build up of sediments. As sand and silt accumulate in certain sections, the Peace River is slowly evolving into a new shape, resulting in changes to vegetation and wildlife habitat.

The specific changes along each reach of the River depend upon the physical characteristics at each location. Many sections of the River are becoming narrower as sediment accumulates along the shoreline. Islands and sand bars are growing in some regions. Semi-aquatic plants and shoreline vegetation are beginning to colonize these new areas. Many of the small side channels and backwater snyes have been blocked off by silt and are slowly drying out. One of the most noticeable areas of change is the floodplain — the lowland area adjacent to the river that was periodically inundated with water. In the absence of high floods, the flood plain is drying out and being colonized by terrestrial vegetation and wildlife, such as trees and shrubs.

The changes caused by flow regulation are very slow. Several decades will pass until the physical transformation of the Peace River is finished, and it will take centuries until all changes in wildlife and vegetation are complete. However, changes can already be seen along the Peace River.

from Andres 1996

from Andres 1996

Juxtaposed (top) and consolidated (bottom) ice cover

Ice Formation

Ice formation affects many natural processes in a river system, including the type and availability of habitat, dissolved oxygen levels and flow patterns to name a few. Since the Peace River is normally covered with ice for almost half the year, changes to the ice regime caused by flow regulation can have profound ecological effects.

The release of relatively warm water from Williston Lake during the winter months has significantly delayed and shortened the period of ice cover in reaches upstream of Fort Vermilion. Upstream of the British Columbia border, ice cover is the exception rather than the rule. Intermittent winter ice cover forms as far downstream as the town of Peace River. The dam does not seem to have significantly altered the timing and duration of ice cover in the downstream extremities of the Peace River.

from Church *et al.* 1996

As a result of flow regulation, silt is accumulating along the banks of many sections of the Peace River and vegetation is beginning to grow along the shoreline, seen here upstream of Montagneuse Islands.

In select reaches of the Peace River, physical changes in the ice cover have also been observed. These changes are a result of a combination of factors that together alter ice cover formation in some areas. In river systems, ice cover usually begins as a number of flat "pans" that float on the water surface. In many reaches, these pans gently butt against one another and eventually cover the entire surface with a flat layer of ice (i.e., juxtaposed ice cover).

Under higher flows and steeper gradients, the force of the water can cause these pans to collide and be pushed under one another, leading to a thicker, rougher ice cover (i.e., consolidated ice cover). Higher winter flows from Williston Lake have caused this thicker, rougher ice to form in steeper reaches characteristic of the upper and middle portions of the Peace River.

Some areas experience higher freeze-up and water levels that may cause surcharging of aquifers. In the town of Peace River, for instance, elevated groundwater levels have been known to flood the basements of some residences.

Habitat

The assessment of flow regulation effects on habitat was for the most part beyond the scope of NRBS research. A comprehensive assessment would require detailed inventories of habitat and wildlife, including information regarding the preferential use of habitat by wildlife. To understand the cause and effect relationships and to forecast changes into the future would require modelling efforts that are beyond the scope of the Study.

Researchers did undertake to provide an assessment of flow regulation effects on river channel habitat by considering factors such as changes in channel geomorphology, riparian habitat and associated vegetation in representative areas along the Peace River. The effects of flow regulation on the deltas were reported in studies initiated prior to the NRBS and are being considered within the Peace-Athabasca Delta Technical Studies. In the absence of detailed information, researchers speculated about how flow regulation is affecting the availability of certain habitat types within the basin, and how this may affect the distribution of fish and wildlife populations.

Lack of ice cover in the upper reaches of the Peace River encourages animals that require open water (e.g., beaver) and may provide additional winter habitat for fish. The increase in temperature, however, may induce the eggs of fall-spawning fish to hatch prematurely and could affect their survival. Where ice cover forms, nearshore zones may be clogged by frazil ice — the slushy mush of ice spikelets formed by freezing in turbulent waters. Frazil ice may affect the availability and quality of nearshore winter habitat for fish.

The formation of thicker, rougher ice also has implications for the aquatic ecosystem. Open water sections, such as those associated with the Vermilion Chutes rapids near Fort Vermilion, are often important feeding and overwintering zones for fish. Higher winter flows resulting in thicker, rougher ice could reduce valuable fish habitat. In addition, higher water and freeze-up levels may eliminate the fish migration barrier posed by these rapids during the winter.

Changes to the shape of the river can have both positive and negative effects on fish habitat, depending upon the location. Notably, the loss of side channels in many regions represents a sizeable loss in valuable fish habitat. At the same time, the drying out of isolated wetland areas will discourage populations of waterfowl, shorebirds, amphibians and other semi-aquatic species. Along the Peace River mainstem, the most sensitive area for this to occur is in Wood Buffalo National Park. In the short-term, growth of vegetation into the old floodplain and on islands within the river benefits a wide variety of species that like tall shrubs or forest habitat, including many species of mammals (e.g., moose and deer) and birds (e.g., yellow warbler, tree swallow and woodpecker).


photo by V.Peck

Old rock weir spanning the Revillon Coupé

Effects on the Peace-Athabasca Delta

As previously discussed, the effects of the Bennett Dam on water flows tends to decrease with distance from the dam. However, the ecological effects of the dam are perhaps most noticeable at the far end of the Peace River in the Peace-Athabasca Delta.

NRBS work related to the delta was coordinated with the Peace-Athabasca Delta Technical Studies.

Lakes and Channels
It is long established that the decrease in summer flows due to regulation have reduced water levels in the lakes and channels of the Peace-Athabasca Delta. Efforts to combat falling water levels include the construction of several weirs along the channels that drain the delta: one on the west arm of the Quatre Fourches river (now removed), one on the Rivière des Rochers and another on Revillon Coupé. Researchers used a one-dimensional hydraulic flow model to evaluate the effects of flow regulation and the remedial delta weirs on water levels within the main channel systems of the delta.

The model revealed that the weirs have successfully restored mean-annual water levels on many delta lakes and channels to conditions that existed prior to the construction of the Bennett Dam. At the same time, however, the weirs have reduced the natural seasonal fluctuations in water levels. This is an ecological concern, since these fluctuations help to maintain the delta's unique near-shore habitat and waterfowl staging zones. Furthermore, the weirs are not able to restore water levels in the delta's perched or isolated basins.

Perched Basins
During the period when Williston Lake was filled, the shoreline along the delta's perched basins was reduced by 36 per cent and the total water area declined by 38 per cent. This exposed roughly 500 km^2 of mudflats, and marked the beginning of ecological change in the basins. In particular, productive sedge meadow habitat is slowly being replaced by woody vegetation, such as willow and poplar. Further information regarding ecological changes occurring in the delta and their impact on local communities is found in Section 3.4 of this report.

Ecological changes have continued since the filling of the reservoir, due in large part to the disruption of ice and flood patterns. Water levels in the basins are replenished only through overland floods. The floods occurred approximately every second year during the 1960s prior to regulation, but only three times since. Historical records reveal that major flood peaks were produced during ice break-up in the spring. During this time, large volumes of water would back up behind ice jams on the lower Peace River until the river overflowed its banks. The deluge of water was enough to refill the perched basins and scour out stream channels.

The major factors influencing the severity of the ice jams are higher water levels at the time of ice cover formation and relatively smaller tributary flows. As previously mentioned, higher winter flows result in a higher freeze-up elevation along portions of the river. This allows a greater volume of water to flow underneath without breaking the ice, and a greater amount of water is required to stimulate a jam. Furthermore, the floods were associated with high amounts of runoff from tributaries, especially the Smoky River. A preliminary study reveals that the amount of spring runoff from tributaries has been low in recent years. More water is now required to stimulate an ice jam, but less is available.

Given these conditions, the release of water from Williston Lake required to produce these ice jams on a regular basis would be enormous and would have implications for residents immediately downstream of the dam. The dam's economic losses would also be large. Therefore, relying solely on the dam to stimulate ice jams is not a desirable alternative.

Several management operations exist:

- *Construct variable-height weirs to retain water in lakes and channels:* Adjustable control structures could be constructed that would permit the entry of water into individual basins and prohibit drainage when water levels in the main channels and lakes decline. Some success has been had using similar weirs in the past, but funding and ownership / responsibility of these structures poses difficulties that must be resolved. Furthermore, this technique would only succeed in basins that receive water during some part of the year.

- *Utilize hydraulic pumps to flood the perched basins:* Hydraulic pumps are a cost-effective option to adjustable weirs. They could also be used in small-scale efforts to flood the perched basins that are not part of the main flow network.

- *Create an artificial ice dam at a critical point in the delta:* The Peace-Athabasca Delta Technical Studies group has already developed techniques to create artificial ice dams that could be used to backup water during the spring runoff period and achieve mid-scale flooding of the delta landscape. The success of this technique hinges on the timing and magnitude of winter flows, which in turn relies upon climatological conditions and winter flows through the Bennett Dam. From a hydrological standpoint, the best area to create such a dam is found in the Quatre Fourches channel at the site of the old rock weir, but this would not flood perched basins located in the delta's northern regions. A gated structure could be used in lieu of the dam to allow for fish migration.
- *Create an ice dam on the mainstem Peace or Slave Rivers:* The only management technique that could ensure large-scale flooding of the delta and its perched basins is to backup spring runoff behind an artificial ice dam on the Peace or Slave rivers. However, the efficacy of an ice dam would again be dictated by climate and flows through the Bennett Dam.

Further investigations are required to test the efficacy and ramifications of these options. In addition, the latter two options require negotiations with B.C. Hydro to modify winter releases from the Bennett Dam.

Significant difficulty and expense could be avoided if the dam were to extend its high release period during years of high tributary flow. The combination of high tributary and headwater flow would increase the likelihood of ice jam-related floods in certain years without an excessive release of water from the dam. To assist in this effort, it would be useful to have a greater understanding of the processes dictating the level of tributary flows. Lower tributary flows are commonly associated with smaller winter snowpacks, an effect that might be attributed to climate variability.

Habitat

According to interviews conducted within the Traditional Knowledge Component, the loss of wetland habitat within the Peace-Athabasca Delta has had a profound effect on the ecosystem (Section 3.4). According to traditional residents of the delta, wetland meadows and marshy areas continue to be replaced by drier terrestrial plants. This has coincided with a marked reduction of semi-aquatic animals and waterfowl. In contrast, the increasing abundance of willow has provided improved conditions for moose.

Effects on the Slave River Delta

The Slave River Delta is more than 1 500 km downstream from the Bennett Dam, yet NRBS researchers have detected a few effects that may be attributed to flow regulation. Similar to the Peace River, the Slave River Delta now experiences lower peak flows. This has reduced the amount of sediment that is delivered to the delta. As one might expect, these changes are greatly diminished due to the distance from the dam and the influence of other water bodies, notably the Athabasca River and the Peace-Athabasca Delta.

The Slave River Delta is a constantly evolving natural phenomenon. As the delta slowly grows into Great Slave Lake, the physical and ecological features of the region exist in a state of constant change. This natural process is very complex and, as a result, it is difficult to distinguish flow regulation effects from natural phenomena. The full impacts of flow regulation on the Slave River Delta are poorly understood and further studies are required to understand the changing dynamics of the Slave River Delta in response to flow regulation.

Modelling Floods

Researchers from the Hydrology Component developed a flood routing model that will help to demonstrate the impacts of regulation on the flow regime of the Peace and Slave rivers. The new hydraulic model is more versatile than currently available hydrologic routing models, and provides details on water levels, velocities and discharges occurring at any point along the Peace River as a function of time. The model will be used to determine the effects of flow regulation on river channel and delta morphology, nearshore vegetation and aquatic habitat.

The performance of the model has yet to be fully tested. So far, the model has worked well in predicting flow patterns for moderate flood events, such as that which occurred in 1987. Since flooding of the Peace-Athabasca and Slave deltas is related to ice-jam releases, a long-term goal will be to predict the impact of flow regulation on the ice regime.

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Other Relevant Documents

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Prowse, T.D., Aitken, B., Demuth, M.N. and M. Peterson. 1996. *Strategies for Restoring Spring Flooding to a Drying Northern Delta.* Regulated Rivers, 12: (in press).

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3.6 Fish Distribution, Movement and Habitat

Related NRBS Questions:

1. a) How has the aquatic ecosystem including fish and / or other aquatic organisms been affected by exposure to organochlorines or other compounds?

6. What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave rivers? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats?

8. Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish and how are these levels changing through time and by location?

Introduction

The Northern River Basins Study placed emphasis on fish in its efforts to evaluate the effects of development on the basins. Fish provide food, livelihoods and recreational benefits to visitors and residents of the northern river basins. In addition, because of their wide distribution and movements in the basins and their key positions in food webs, they can give indications of the health of the aquatic ecosystem.

It was decided early in the Study that the Food Chain Component would not conduct studies to determine the population dynamics of fish. These were agreed to be too complex, time-consuming and costly to be effectively addressed within the scope of the Study. Instead, fish-related studies were incorporated into a comprehensive approach that linked closely to other research components investigating the physical, biological, chemical, resource use and traditional knowledge aspects of the aquatic ecosystems in the basins. Most of the NRBS fisheries related work in the Northwest Territories took place during 1994. Further information regarding these issues can be found in the aquatic uses (Section 3.3), traditional knowledge (Section 3.4), flow regulation (Section 3.5), nutrients (Section 3.7), dissolved oxygen (Section 3.8), contaminants (Section 3.9) and cumulative effects (Section 3.14) sections of this report.

Goldeye

courtesy of Alberta Environmental Protection

Fish-related information needs were addressed in several ways. Food Chain Component scientists conducted a series of field and laboratory investigations aimed mainly at responding to question number six, relating to distribution, movement and important habitats of fish. Work related to the dissolved oxygen requirements has been incorporated into Section 3.8 of this report. Nearly all field studies of fishes conducted during the course of the study also provided samples of fish for contaminant analyses. Food chain studies were conducted to determine diets of fish, food web relationships among fishes and other elements of the food chain in the river basins and to help assess the likelihood and duration of exposure of fish to contaminant sources.

Research within the Food Chain Component has contributed information related to the distribution, movements, spawning, early rearing and overwintering habitat use of several species. It has also provided insights into the biology of several species, including bull trout, mountain whitefish, burbot, inconnu, spoonhead sculpin and lake chub.

Finally, NRBS researchers discovered new food chain relationships. This will contribute to assessment of the flow of nutrients and contaminants in the food webs of the northern river basins.

PREVIOUS FISHERIES WORK

Work within the Food Chain Component builds upon previous studies within the northern river basins. Much of the previous work concentrated on fish in lakes draining into the mainstem rivers and tributaries of the Athabasca, Peace and Slave rivers. There has also been some extensive work in the lower Athabasca River. Frequently, the work focussed on species with commercial or recreational value. Seldom were studies conducted that focused on the population of fish, their communities or their place in the aquatic ecosystem. Recent work has often been in response to the need to evaluate the status of fish in the rivers and to assess the impacts of industrial development. Four major reports cited at the end of this section serve to summarize the work of previous studies and provide general fisheries information:

- ❑ *The Fish and Fisheries of the Peace River Basin: Their Status and Environmental Requirements;*
- ❑ *Slave River Hydro Feasibility Studies: Fisheries*;
- ❑ *The Fish and Fisheries of the Athabasca River Basin: Their Status and Environmental Requirements;* and
- ❑ *Fishes of Alberta.*

In addition, an extensive bibliographic database of the known literature about fish from the basins, including the many reports on tributary rivers and lakes, can be found in the NRBS technical report, entitled "*Fish and Fish Habitat Bibliographic Database for the Peace, Athabasca and Slave River Basins.*"

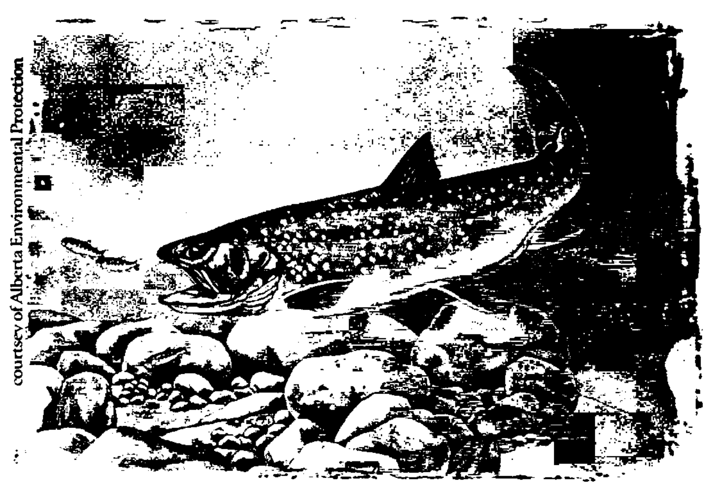
FISH SPECIES AND DISTRIBUTION

NRBS investigations discovered no new fish species but made extensive additions to our knowledge of the distribution of the known species and confirmed the presence of several questionable ones. Precise information regarding where these species are found is documented in the synthesis report cited at the end of this chapter.

FISH MOVEMENT

The physical and chemical features of the river channel and water are forever changing. Consequently, the fish species that live in these aquatic environments are confronted with extreme seasonal and environmental fluctuations that is reflected in their life histories. A key strategy for many species is extensive movement.

Knowledge of these movements, in turn, is important for understanding the exposure of fish to contaminant sources. The proportion of time that the fish spend in the vicinity, or immediately downstream of contaminant sources is a factor in the uptake and accumulation of contaminants.



Bull Trout

Researchers within the NRBS Food Chain Component reviewed more than 30 important studies of fish movement in the NRBS area and conducted additional field investigations in efforts to describe the patterns of movement of fish. Studying fish movement in large river systems is challenged by technical difficulties arising from strong current, turbidity and the open-ended nature of the physical boundaries in which the fish are contained.

NRBS studies found that burbot undertake brief seasonal movements during their spawning period in mid-winter. In contrast, mountain whitefish undergo long and complex seasonal movements within the Athabasca River. The relatively sedentary nature of burbot, combined with their distribution throughout the basins contributed to its selection as a likely indicator for monitoring changes in fish contaminant burdens. Another reason to choose burbot was that contaminant analysis had been performed on this species in previous years through the Slave River Environmental Quality Program.

In addition, intensive investigations in the Slave River Delta have added to knowledge of fish movements and habitat requirements in this area. In particular, the movement patterns of inconnu (an important harvest fish) in the delta can now be described in detail. Significantly, the fish community of the Slave River Delta appeared to be unchanged since the 1980s.

Fish Habitat

Fish require specific habitats to complete the various stages of their lifecycles. To further knowledge of fish habitat in the basins, researchers from the Food Chain Component recorded the physical structures of the river banks, beds and channel features of the mainstem rivers that are known to be important fish habitat features.

Many fish species' life stages include extensive movement between these physical habitat structures. In this way, their habitat needs for spawning and incubation, early rearing of young, feeding and growth, resting, escape from predation and overwintering are met in different locations in the rivers. Extraordinary variation in these life strategies exists between species. There can be complex patterns even within a species, perhaps reflecting different sub-populations.

NRBS studies were the first to definitively characterize the Athabasca River for its entire length (albeit in reaches) and represents the most extensive investigations ever performed in the Jasper National Park portion of the river. NRBS studies described the growth, feeding and early rearing life strategy of mountain whitefish in the upper Athabasca River. Studies also revealed that Athabasca River tributaries in Jasper National Park are important spawning, incubating and early rearing habitats for Athabasca River bull trout and mountain whitefish.

Food Chain Relationships

Knowledge of the food chain in the northern river basins is important for understanding how contaminants move through the aquatic ecosystems. As organisms eat contaminated food, and are in turn eaten, the contaminants are passed up the food chain. These contaminants tend to become more concentrated in the animal tissues as they are passed up the food chain.

For fish in the basins, the food chain was found to be a primary route of exposure to pulp mill contaminants. However, the level of exposure is largely related to individual feeding habits. Fish that feed primarily in tributaries tend to contain lower levels of pulp mill contaminants than those feeding in the mainstems. More information related to contaminant levels in fish can be found in Section 3.9.

GROSS PATHOLOGY OF FISH

The NRBS provided a number of opportunities to collect detailed information regarding fish health (see sections 3.4, 3.8, 3.9 and 3.14). Research within the Food Chain Component was designed to include specific measures of gross external and internal pathology. Over 30 000 fish were captured and measured during the four years of field studies, most of which were released alive after being measured and marked with tags.

Large northern pike chasing perch

Measures of gross pathology included external abnormalities like tumours, lesions, scars or injuries, skin discolouration, deformities and parasites. Some internal measures were taken when fish were sacrificed for chemical or physiological analyses. These measures included tumours, parasites, fat deposits and colouration of internal organs.

The record of external abnormalities provides a simple, mainly qualitative and observational database that can be analyzed quantitatively. Nearly 23 000 fish were examined and analyzed for gross pathological abnormalities. Many of the species found in the basins have some detailed record of these measures. Mountain whitefish, lake whitefish, northern pike, burbot, longnose suckers white suckers were the main species for which gross pathological measures were recorded. This is mostly due to their prevalence in the sample collections. It is not necessarily due to their susceptibility to environmental stresses, although this point requires further study.

Significantly, pathological abnormalities for most species occurred in less than one per cent of the fish in large-scale collections. Occasionally, high frequencies of pathological abnormalities were reported (e.g., 23 of 30 lake whitefish) that may be related to physiological and behavioural responses to spawning. Similarly, suckers (especially longnose suckers) appear to have occasional high frequencies of pathological abnormalities. It is also important to note that fishermen interviewed within the Traditional Knowledge Component reported an increasing number of physical deformities in their catch (Section 3.4).

High frequencies of pathological abnormalities also appear in fish sampled near pulp mill effluent discharges. Detailed pathological studies of fishes near pulp mill effluent sources are needed. Two field studies discovered more pathological abnormalities shortly downstream of mill effluent sources than in the remainder of the Athabasca River.

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courtesy of Alberta Environmental Protection

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3.7 NUTRIENTS

Related NRBS Question:

5. Are the substances added to the rivers by natural and man-made discharges likely to cause deterioration of the water quality?

INTRODUCTION

Nutrients are the substances that plants need to grow. Major plant nutrients include nitrogen, phosphorus and carbon. In river stretches where phosphorus and nitrogen are limited and other factors (e.g., light, temperature, current speed, etc.) permit growth, the concentrations of nitrogen and phosphorus largely determine the growth and abundance of plants and plant-eating aquatic organisms. The sum of all forms of phosphorus or nitrogen is expressed as total phosphorus (TP) or total nitrogen (TN). Only some of this total amount is available to plants. Bioavailable nutrients are chemical forms that can be used by plants to grow and reproduce, such as phosphate, ammonia, nitrate and nitrite. Nutrients that are not in bioavailable forms cannot stimulate plant growth.

Nitrogen and phosphorus arise from several natural and non-natural sources (Figure 3.7.1). When measuring nutrient loadings, it is useful to distinguish between point and non-point nutrient sources. Point sources are easy to measure and regulate because they are confined to a pipe, ditch, channel, tunnel, conduit or some other discrete method of conveyance. In the northern river basins, the more prominent point sources of nutrients include industrial discharges (e.g., pulp and paper effluent) and municipal sewage. Non-point sources are diffuse and difficult to measure. They include surface runoff from agricultural and forested areas, precipitation, dust, tributaries, groundwater and bottom sediments.

The effect of nutrient addition on aquatic communities (referred to as eutrophication) can be positive, negative or negligible depending upon factors such as the present nutrient status of the river and dilution of the added nutrients. Moderate eutrophication may lead to increased fish size and populations that may benefit anglers. The nutrient-poor headwaters of the Bow River, for example, can only support a limited number of fish. Downstream of Calgary, the Bow River supports a thriving sport fishery due to the influx of nutrient-rich sewage that enriches the food chain. In British

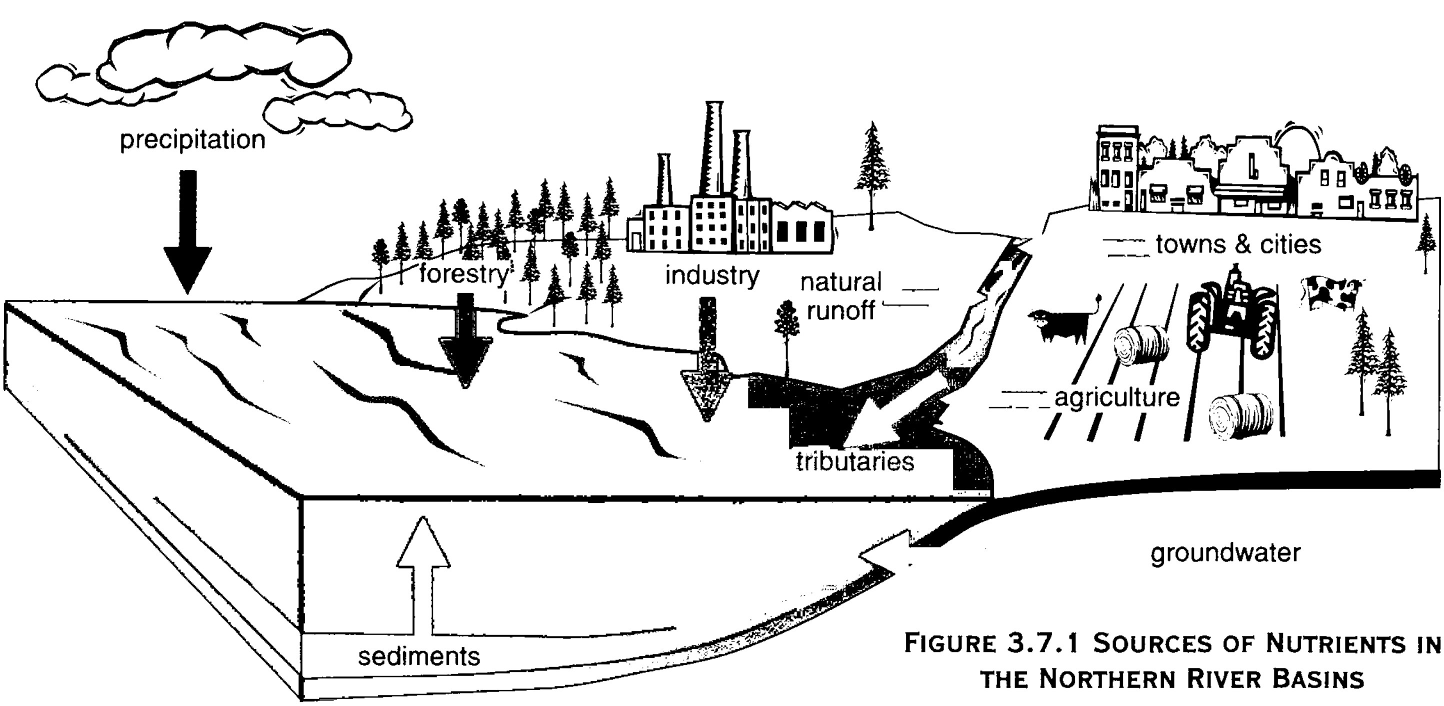


FIGURE 3.7.1 SOURCES OF NUTRIENTS IN THE NORTHERN RIVER BASINS

Columbia, coastal streams are routinely fertilized to enhance salmon production.

Excessive nutrients can have undesirable effects on the ecosystem. In the absence of other growth-limiting factors, excessive nutrients lead to an overabundance of plant growth. When these plants die, they are decomposed by microorganisms that consume oxygen — the more dead plant matter, the more oxygen is consumed. Highly eutrophic systems can become too low in dissolved oxygen at certain times of year (e.g., during winter ice cover and late summer) to support oxygen-sensitive species of fish and other aquatic organisms. The large amounts of algae in eutrophic waters also impact recreational uses and drinking water quality.

On the other hand, nutrient additions may not enrich plant communities if environmental conditions are already too harsh for additional plant growth. Some stretches of northern rivers are too cold, too turbid or too fast flowing to allow for additional plant growth. In these cases, nutrients are flushed downstream or deposited in the sediments where they can promote changes in nutrient conditions of lakes, reservoirs and deltas.

Nutrients are difficult to regulate for several reasons. First, the relative amount of nutrients arising from uncontrollable natural sources (e.g., natural surface runoff) may be great enough that a reduction in municipal and industrial loadings will have no significant impact on water quality. Second, each river responds to nutrients in a different manner depending on its unique natural characteristics. A regulation that works well for one river reach may not apply to another. Third, the optimal level of nutrients depends upon the desired uses for that particular water body or stretch of river.

At the time this report was prepared, there were no numeric federal nutrient guidelines. A draft guideline is currently under review and will be included in the *Canadian Water Quality Guidelines*. In Alberta, nutrient guidelines fall under the *Alberta Surface Water Quality Objectives* which list total phosphorus (TP) at 0.05 ≥mg /L phosphorus and total nitrogen (TN) at 1.0 ≥mg/L nitrogen in surface waters. Alberta pulp and paper mills must perform nutrient monitoring as part of their licensing requirements but have no nutrient limits. Sewage treatment plants in the Study area have neither a monitoring requirement nor a limit for nutrients. However, upgrades or expansion of any sewage treatment plant with projected wastewater flows greater than 20 000 m^3/day must include a plan to reduce total phosphorus concentrations in the effluent to below 1.0 mg/L phosphorus.

Information collected by the Northern River Basins Study aims to provide a knowledge base for making decisions regarding the optimal levels of nutrients in the river basins. These decisions require a basic understanding of the sources and effects of nutrients on the aquatic ecosystem. This section focuses on the Athabasca and Wapiti / Smoky river systems. In comparison to the Peace and Slave rivers, these two systems have relatively smaller annual flows and higher levels of development along their shores. As a result, the Athabasca and Wapiti / Smoky systems have less capacity to assimilate wastes.

NUTRIENT POINT-SOURCES

Figure 3.7.2 identifies the various municipalities and industries that continuously discharge nutrients into the Athabasca and Wapiti / Smoky rivers. It also gives average daily loadings of both total phosphorus and total nitrogen.

Within the Athabasca River basin, there are five pulp and paper mills that contribute nutrients to the river or its tributaries. The total phosphorus and total nitrogen loads from all mills total 331 and 1 041 kg/day, respectively. There are also nine municipal sewage treatment plants that continuously discharge nutrients into the river or its tributaries (no discharge data were available for Fort Chipewyan or Barrhead). The pulp mill at Hinton treats both municipal and mill wastes, and releases them as combined effluent.

Generally speaking, pulp and paper mills release more nutrients than do municipalities. In comparison to non-point sources, both pulp mills and sewage treatment plants are higher in bioavailable phosphorus and nitrogen. This means that they have a greater ability to affect the

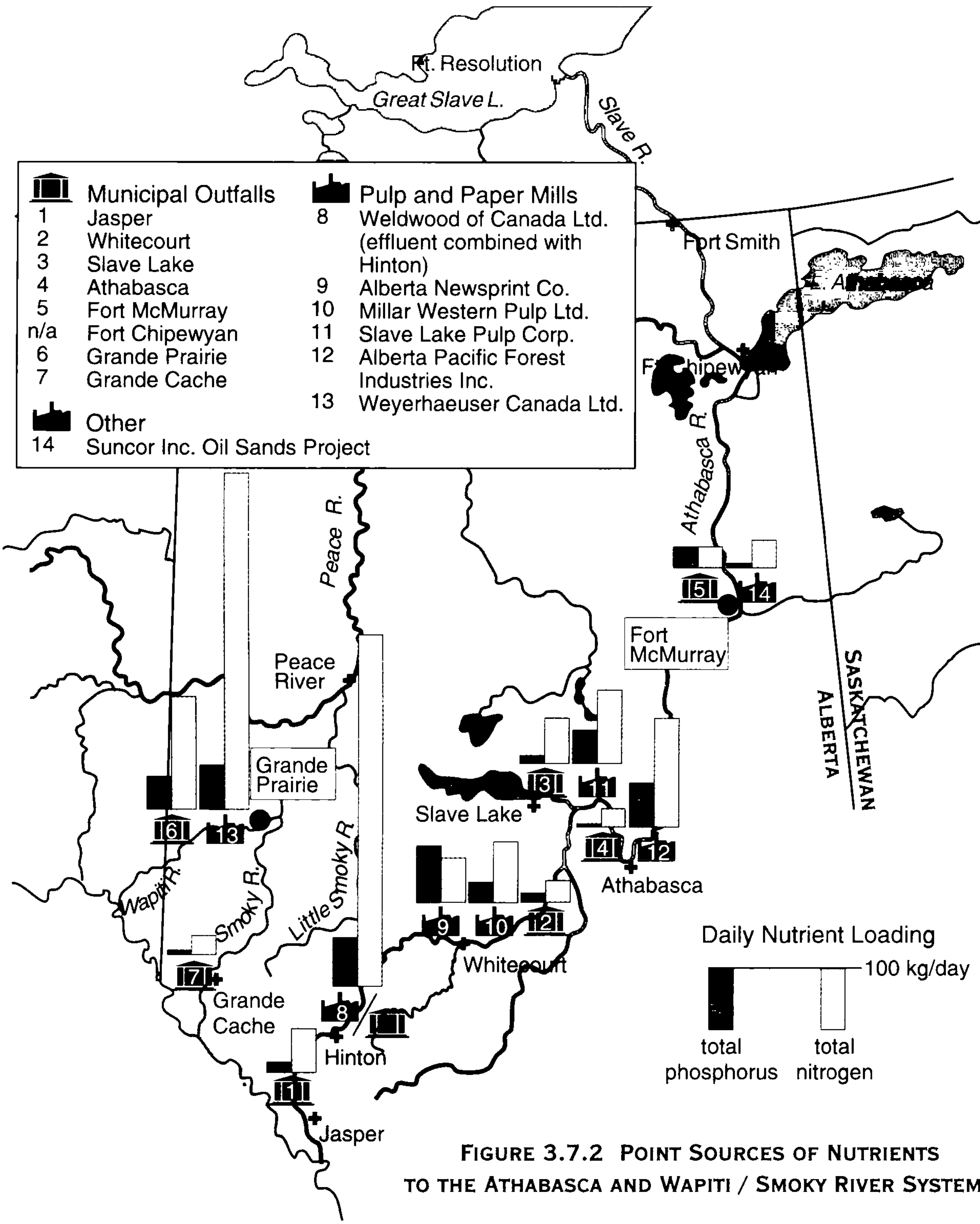


FIGURE 3.7.2 POINT SOURCES OF NUTRIENTS TO THE ATHABASCA AND WAPITI / SMOKY RIVER SYSTEMS

ecosystem than their contribution to total phosphorus and total nitrogen loadings may suggest.

Of the two large oil sands operations in Fort McMurray, only one (Suncor Inc.) continuously discharges utility wastewater. The Suncor effluent has a relatively minor influence on nutrient levels in the Athabasca River. Other activities along the river include four active coal mines, 67 gas plants and 12 gravel-washing enterprises; all of which have little or no discharge to the river. There are also 40 towns and villages which drain their sewage lagoons in spring and / or fall into Athabasca River tributaries. Figure 3.7.3 shows the relative contribution from point sources at several sites on the Athabasca River.

The Wapiti / Smoky river system has fewer nutrient point sources. There is one pulp mill in the river system, located near Grande Prairie that discharges into the Wapiti River. In addition to the pulp mill, there are two municipalities with continuous discharge to the rivers — Grande Prairie on the Wapiti River and Grande Cache on the Smoky River. Sewage from Grande Prairie is a relatively large source of both nitrogen and phosphorus to the river system. In addition to these two municipalities, 28 additional communities in the Wapiti / Smoky drainage basin discharge sewage lagoons once or twice yearly to the rivers or their tributaries. Figure 3.7.3 shows the relative contribution from point sources at several sites on the Wapiti / Smoky river system.

Nutrient Trends

Athabasca River System

Along the Athabasca River, point sources contribute between 6 and 17 per cent of the total annual phosphorous load, the majority of which is attributable to pulp mill effluent. On an annual basis, the Jasper sewage treatment plant accounts for only 8 per cent of the river's total phosphorus load. However, during low flows, Jasper sewage can contribute up to 91 per cent of the total phosphorus load downstream of the town. Likewise, point sources contribute 74 per cent of the total phosphorus load at Hinton and 37 per cent at Old Fort during low flows.

A similar situation exists with regard to total nitrogen. Point sources contribute between 3 and 10 per cent of the annual loadings at various sites in the Athabasca River (Figure 3.7.3). Pulp mills contribute more nitrogen on an annual basis. Municipal loadings are usually less than 1 per cent of the total nitrogen load at any given point along the river, except downstream of Jasper where sewage accounts for an average of 9 per cent of the total nitrogen load on an annual basis. During low-flow periods, Jasper sewage contributes up to 38 per cent of the total nitrogen load.

The effect of point sources on nutrient patterns is evident by looking at concentrations within the river. Increased concentrations of total phosphorus occur downstream of Jasper, Hinton, Whitecourt and Fort McMurray (Figure 3.7.4). This trend is most pronounced during low flow periods in winter, spring (prior to runoff) and fall. The influence of point sources on total nitrogen patterns is not as clear as total phosphorus, but elevated nitrogen concentrations can still be observed downstream of Jasper and Hinton (Figure 3.7.4).

Occasionally, concentrations of both total phosphorus and total nitrogen have exceeded *Alberta Surface Water Quality Objectives.* Between 1980 and 1993, guidelines were exceeded in approximately 20 and 2 per cent of total phosphorus and total nitrogen samples, respectively. For the most part, however, these violations were due to particulate nutrients that are washed down the river during summer high flows when the current is strong enough to scour away material from the river bottom and the shoreline. Since only a small fraction of particulate nitrogen or phosphorus is likely bioavailable, it would not be expected to be a significant factor in encouraging plant growth.

Wapiti / Smoky River System

Less information is available for the Wapiti / Smoky river system, although point sources affect nutrient patterns in this river system. At the mouth of the Wapiti River, municipal and industrial point sources contribute 23 per cent to the annual total phosphorus load, of which roughly half can be attributed to the Grande Prairie pulp mill (Figure

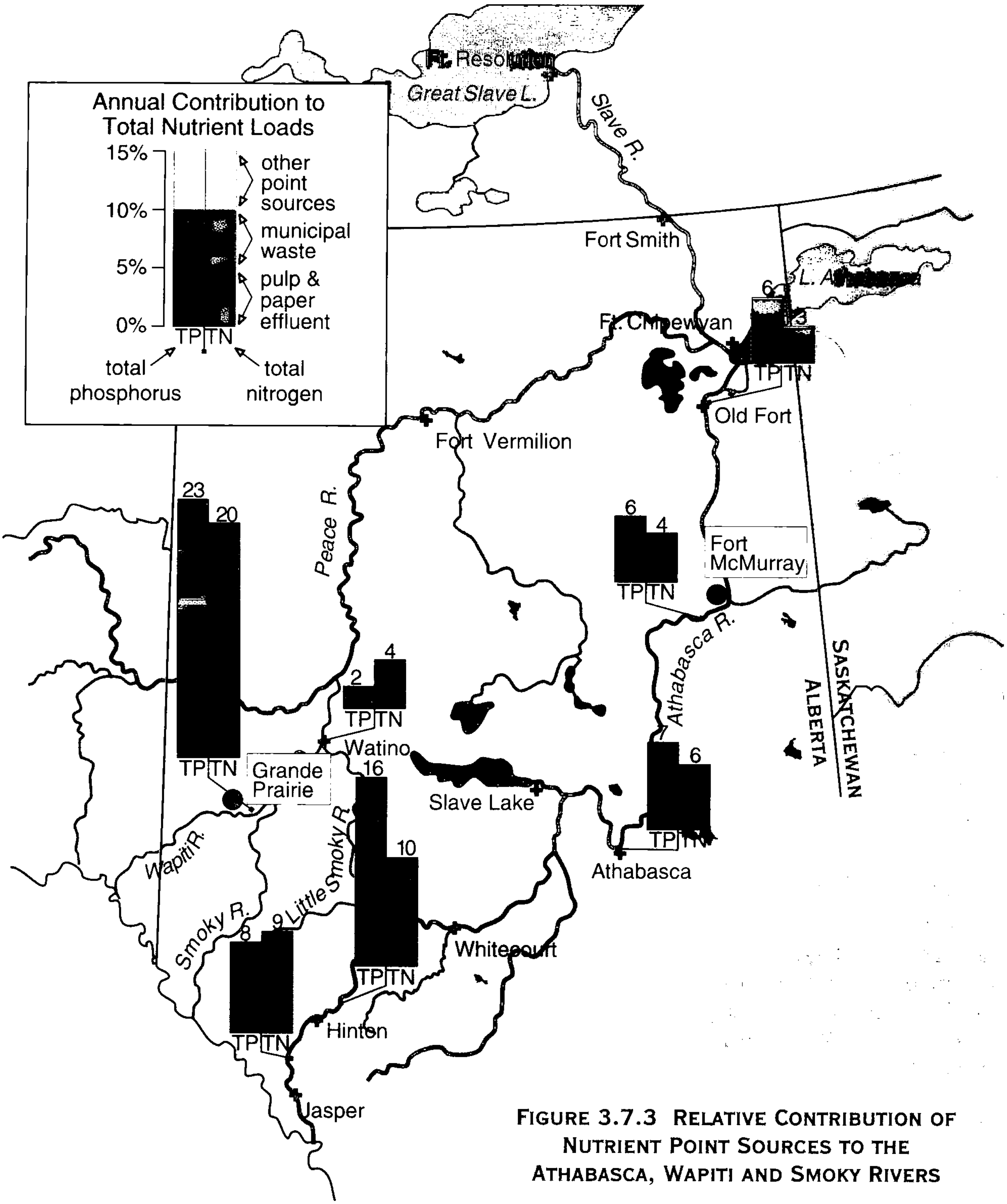


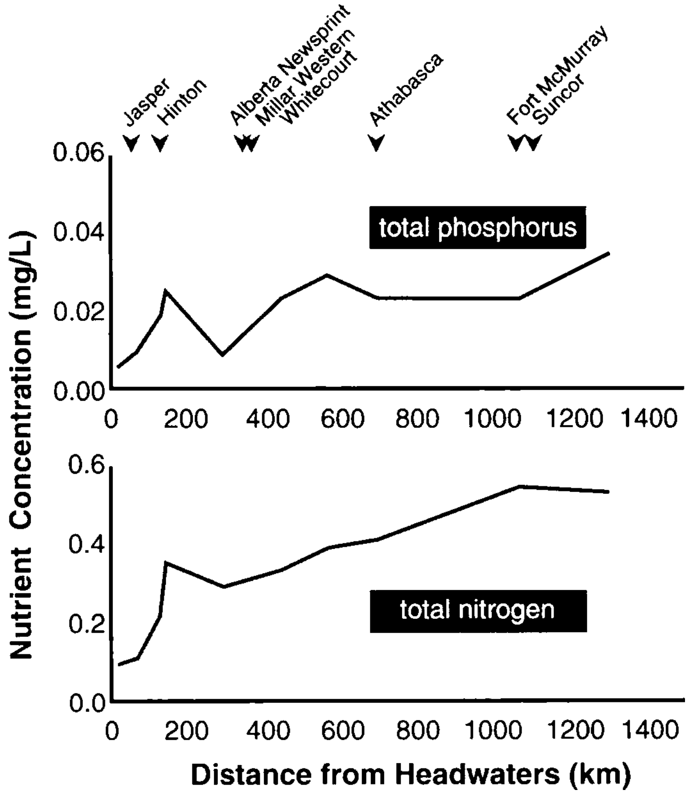
FIGURE 3.7.3 RELATIVE CONTRIBUTION OF NUTRIENT POINT SOURCES TO THE ATHABASCA, WAPITI AND SMOKY RIVERS

3.7.3). During low flows, point sources can contribute up to 42 per cent of the total phosphorus load to the Wapiti river.

With respect to total nitrogen, point sources account for 20 per cent of the total annual nitrogen load at the mouth of the Wapiti River, with only 5 per cent of the total annual load attributable to municipal sources. During low flows, the combined point sources can account for up to 35 per cent of the total nitrogen load.

The influence of point sources is once again evident in nutrient patterns. Concentrations of both total phosphorus and total nitrogen tend to increase past the sewage and pulp mill outfalls in Grande Prairie and then decline after the Wapiti River joins with the Smoky River. As with the Athabasca River, concentrations of total phosphorus and total nitrogen occasionally exceed *Alberta Surface Water Quality Objectives.* In the Wapiti / Smoky river system, however, this phenomenon may be attributed to point sources. Only 12 per cent of water samples exceeded total phosphorus objectives upstream of Grande Prairie compared to 74 per cent at the mouth of the Wapiti River. Similarly, none of the samples exceeded total nitrogen objectives upstream compared to 19 per cent downstream of the city.

FIGURE 3.7.4 ANNUAL NUTRIENT TRENDS IN THE ATHABASCA RIVER (MEDIAN VALUES FROM 1980 - 1992)



EFFECTS OF NUTRIENTS ON AQUATIC ORGANISMS

As the previous sections demonstrate, point sources affect nutrient levels in reaches of the Athabasca and Wapiti / Smoky rivers. At most sites, pulp mills contribute relatively more nutrients than municipalities. But are the added nutrients stimulating the growth of plants and organisms in the Athabasca and Wapiti / Smoky river systems?

NRBS studies showed that pulp mill effluent in the Athabasca and Wapiti / Smoky river systems, to varying degrees, increase the abundance of plants and the growth of benthic invertebrates and fish located downstream of the mills. Pulp mills also discharge contaminants that may limit growth, but these appear not to be present in high enough concentrations to limit the growth of plants or benthic invertebrate communities.

AREAS OF CONCERN

Due to the large nutrient inputs from both natural and man-made sources, many reaches of the Athabasca and Wapiti / Smoky river systems have excessive levels of nutrients during the fall, when flows (and consequently nutrient dilution) is lowest (Figure 3.7.5). While some of the phosphorus in these rivers originates from sewage treatment plants and pulp mills, natural sources may also be important. For example, the Clearwater River contributes a sizeable amount of nutrients to the Athabasca River downstream of Fort McMurray.

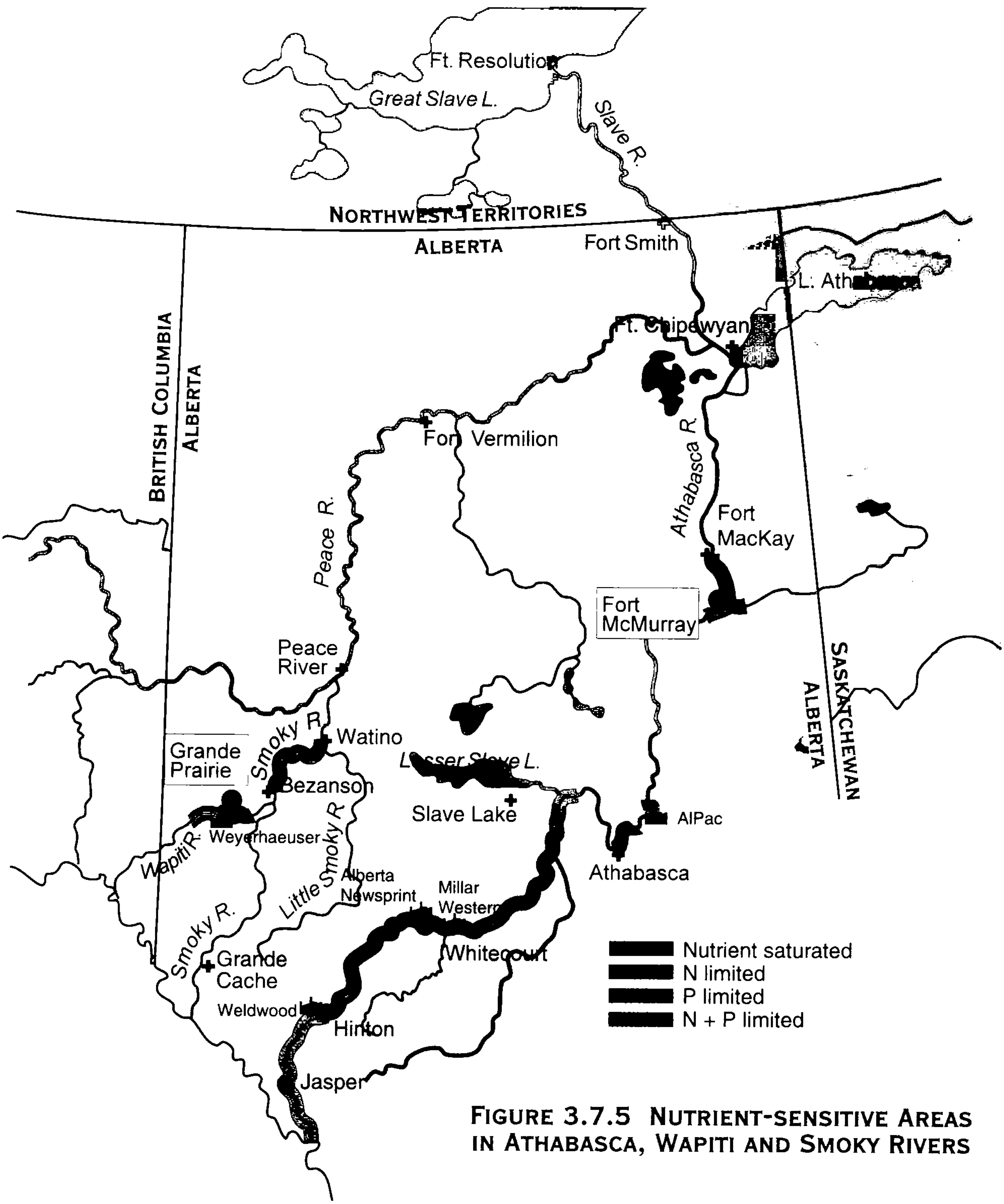


FIGURE 3.7.5 NUTRIENT-SENSITIVE AREAS IN ATHABASCA, WAPITI AND SMOKY RIVERS

To minimize the impact of future development on the rivers, it is useful to know which reaches will still respond to additional nutrient loadings (i.e., growth is "nutrient-limited"). Most of the nutrient-limited sites are located upstream of pulp mills or sewage treatment plants where natural nutrient levels are low. Phosphorus is the limiting nutrient in most of these areas, while nitrogen limitation is more sporadic.

Figure 3.7.5 illustrates zones within the basins that will still respond to further nutrient additions. It should be noted that this is not a complete list — further research is needed to identify all of these zones. In the meantime, future developments could have impacts on the aquatic ecosystem in these river stretches. It is not yet known how much additional nutrients would be required to saturate these sites, but one experiment at Hinton revealed that only a small amount of phosphorus (5 μg/L) was required to saturate the growth of periphyton films (i.e., algal communities living on rocks or sediments at the bottom of a river or lake). Figure 3.7.5 also illustrates the zones of nutrient saturation. Further nutrient enrichment may have no substantial effect on the growth and abundance of aquatic organisms in these areas, but could have consequences for downstream regions in the delta or lakes.

On a positive note, current nutrient levels do not appear to cause the loss of any fish or other aquatic organisms. As such, the concern with increased plant and algal growth in these areas is presently an aesthetic issue related to the amount of green "slime" on rocks downstream of nutrient point sources. Whether these conditions constitute a need for change is a societal decision that must be based on the desired ecosystem attributes for these river stretches.

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3.8 Dissolved Oxygen

Related NRBS Question:

7. What concentrations of dissolved oxygen are required seasonally to protect the various life stages of fish, and what factors control dissolved oxygen in the rivers?

Introduction

As with land-based animals, most aquatic organisms require oxygen to survive. Instead of breathing oxygen from the atmosphere, these organisms extract oxygen that is dissolved in the water. To protect sensitive species and life stages, federal and provincial regulations list minimum dissolved oxygen requirements for surface waters. In Alberta, the level required to protect aquatic organisms in surface waters is set at 5 mg/L under the *Alberta Surface Water Quality Objectives*. Federally, the Canadian Council of Ministers of the Environment (CCME) list higher objectives for cold- and warm-water organisms (Table 3.8.1), especially for early life stages of fish and aquatic organisms.

Oxygen enters a water body through contact with air in a process referred to as reaeration. The amount of oxygen that remains dissolved in water is dependent upon temperature, pressure and salinity. Generally speaking, more oxygen can be dissolved in cold freshwater at higher pressures. When the amount of dissolved oxygen in the water equals the capacity of the water to hold oxygen based on temperature, pressure and salinity, the water is said to be saturated. During the winter, when water temperatures are approximately 0°C, the Athabasca River is saturated at about 13.5 mg/L oxygen.

Winter is a critical time for dissolved oxygen levels. While cold water can hold more dissolved oxygen than warm water, ice cover blocks contact with air and reduces the potential for reaeration. Effluent addition during low winter flows causes dissolved oxygen concentrations in many northern rivers to dip to near critical levels for many oxygen-sensitive organisms. Rapids and turbulent stretches of a river are important reaeration zones during these winter months. Grand Rapids, located upstream of Fort McMurray, remain unfrozen throughout the winter and provide a site of reaeration for the Athabasca River.

Many factors contribute to oxygen loss. Plants and animals take up oxygen in respiration. More importantly, bacteria consume oxygen as they break down dead plant and animal matter. The amount of oxygen used by bacteria to break down dead organic matter, plus that consumed by the chemical oxidation of organic matter in the water column is referred to as biochemical oxygen demand (BOD). The amount of oxygen-demanding organic material released into a river system by natural or human sources is often referred to as the BOD load and is a significant factor in the oxygen level declines in some of the Study area rivers.

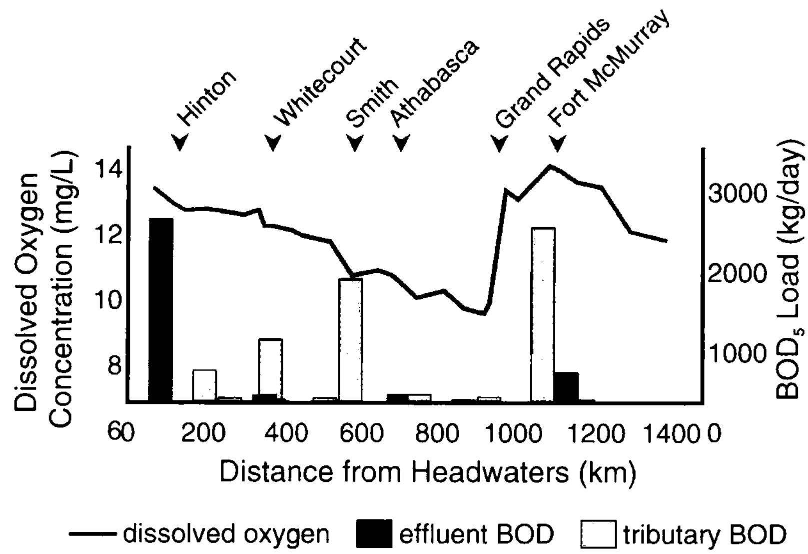
The Nutrients Component coordinated studies to understand and predict the impact of human activities on dissolved oxygen levels within the Study area. Much of this work focused on the Athabasca River. Long stretches of winter ice cover and low flows, combined with the number of industrial and municipal effluent it receives, makes the Athabasca River more susceptible to oxygen problems than the Peace and Slave river systems.

Table 3.8.1 Canadian Council of Ministers of the Environment Objectives for Dissolved Oxygen

LIFE STAGE	Warm-water organisms	Cold-water organisms
Early life stages	6 mg/L	9.5 mg/L
Other life stages	5 mg/L	6.5 mg/L

Figure 3.8.1 illustrates dissolved oxygen trends along the Athabasca River for an average winter with existing effluent discharges. Without these discharges, the oxygen levels throughout the river would be higher in many regions, except in the headwaters above human influence. During winter ice cover, the river experiences dissolved oxygen concentrations less than saturation for its entire length downstream of Hinton, except in the reaeration zone at Grand Rapids. Dissolved oxygen levels rarely dip below the Alberta surface water objective of 5 mg/L or the Canadian guideline of 6.5 mg/L for adult cold-water fish, but in certain areas they do drop below the 9.5 mg/L objective for early life stages of bull trout and whitefish.

FIGURE 3.8.1 DISSOLVED OXYGEN TRENDS IN THE ATHABASCA RIVER (1992)



The dissolved oxygen patterns in Figure 3.8.1 are affected by both natural and man-made BOD sources. In most winters, dissolved oxygen levels tend to drop downstream of the Weldwood pulp mill in Hinton in response to effluent loadings. At times, levels also decline below the junction of the Pembina River with the Athabasca River. Effluent and tributary BOD loadings result in another drop downstream of Fort McMurray.

Historical information suggests that the impact of the Weldwood mill has been decreasing. Figure 3.8.2 illustrates the changes in dissolved oxygen at four sites on the Athabasca River over a period of 40 years. As the figure illustrates, winter levels of dissolved oxygen upstream of Hinton have remained relatively constant. While there are few data for the early years, dissolved oxygen levels downstream of Hinton appear to have decreased in the last two decades following the 1957 startup of the bleached kraft mill. Since then, dissolved oxygen levels have increased in response to mill improvements that decreased the BOD load discharged to the Athabasca River.

FISH REQUIREMENTS

The direct and indirect effects of low dissolved oxygen on fish are well documented. Extremely low oxygen levels lead to cellular breakdown and rapid death in fish. Sub-optimal oxygen levels affect the ability of fish to survive and reproduce by increasing susceptibility to disease, slowing growth, hampering swimming ability and altering survival behaviour such as predator avoidance, feeding, migration and reproduction. Low dissolved oxygen levels can also influence fish indirectly by reducing the survival of organisms they eat.

Environmental contaminants can aggravate the effects of low dissolved oxygen in several ways. Fish that are already weakened by low oxygen conditions are more susceptible to the harmful effects of contaminants. Contaminants may raise the metabolic rate of fish, resulting in a greater need for oxygen. This leads to increased ventilation and greater exposure to contaminants.

NRBS researchers conducted a literature review of dissolved oxygen requirements of fish in northern rivers. These requirements vary among individual fish species and life stages. Acute dissolved oxygen requirements (i.e., the minimal amount of oxygen necessary to avoid short-term mortality, usually under two days) for adult fish in northern rivers are listed in Table 3.8.2. Less information is available regarding chronic dissolved oxygen needs (i.e., the amount of oxygen required for long-term health and survival). Generally accepted chronic requirements are ≥6mg/L for adult fish belonging to the salmon family and ≥5 mg/L for all other fish species.

Adequate dissolved oxygen levels are critical for fish in their early life stages. Since many fish species in the northern river basins spawn in the spring or summer, these early life stages occur at times when dissolved oxygen levels are high. However, eggs laid in the fall give rise to young that develop during winter when dissolved oxygen levels may be lower. NRBS studies on several fish that develop during the fall or winter (including mountain whitefish and bull trout) showed that these species can survive in dissolved oxygen levels as low as 3 mg/L. However, mountain whitefish eggs took longer to hatch, and recently hatched bull trout were under developed at low dissolved oxygen concentrations. Burbot may also experience delayed hatching under lower dissolved oxygen (6 mg/L). Since the riverbed is usually lower in dissolved oxygen than the water column, levels of 6 mg/L or greater may be required in surface waters to achieve 3 mg/L in the spawning beds. The CCME objective is 9.5 mg/L for this life stage in bull trout and whitefish but this level is not met in all parts of the river.

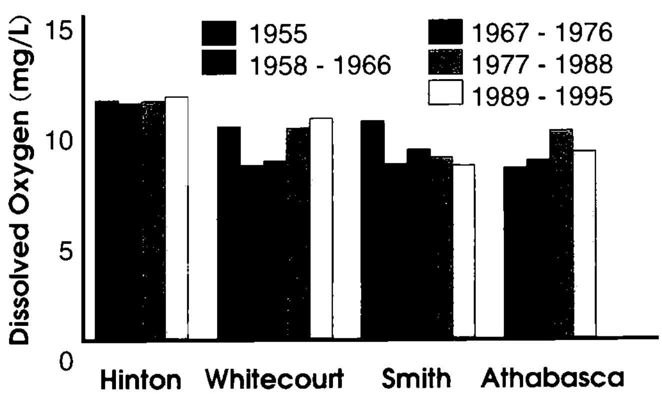
TABLE 3.8.2 ACUTE DISSOLVED OXYGEN NEEDS FOR ADULT FISH IN NORTHERN RIVERS

RELATIVE TOLERANCE	ACUTE DISSOLVED OXYGEN LIMIT	FISH CLASSIFICATION
Sensitive	> 2 mg/L	❑ all salmonids ❑ longnose sucker ❑ burbot
Intermediate	1 - 2 mg/L	❑ all cyprinids except fathead ❑ minnow, walleye, ❑ white sucker, brook ❑ stickleback and goldeye
Tolerant	< 1 mg/L	❑ fathead minnow ❑ northern pike ❑ yellow perch
Unknown	not available	❑ all sculpins ❑ largescale sucker ❑ ninespine stickleback ❑ trout perch

NRBS studies also showed that low dissolved oxygen levels also affect the health of an aquatic insect (the mayfly *Baetis tricaudatus*) — a common fish food source. Mayflies exposed to low dissolved oxygen (5 mg/L) ate less and exhibited a lower survival rate. Benthic invertebrates such as these live in or adjacent to the river bed, where oxygen concentrations can be up to 3 mg/L less than in the water column. Therefore, oxygen levels in the Athabasca River may currently be affecting animals at localized sites.

These results suggest that the current Alberta dissolved oxygen guideline of 5 mg/L will not adequately protect sensitive aquatic species, particularly during their early lifestages. The more conservative CCME guidelines may be a more suitable guideline for setting effluent licence conditions in Alberta's northern waters. Alternately, governments could explore the concept of reach-specific guidelines, which would consider regional differences in aquatic habitat and nutrient loadings. These policy options are examined further in the Board's recommendations to the Ministers (Section 4.0)

FIGURE 3.8.2 FEBRUARY / MARCH DISSOLVED OXYGEN LEVELS IN THE ATHABASCA RIVER UPSTREAM OF SELECTED TOWNS (1955 - 1993)



DISSOLVED OXYGEN MODELLING

Dissolved oxygen models are useful tools to evaluate "what if" scenarios. Models can be used to estimate the impact of new industries and larger communities on dissolved oxygen levels, to evaluate the effectiveness of proposed regulations and to assess cost-effective options for pulp mill and sewage treatment plant upgrades.

Accurate models require a thorough understanding of the complex natural processes that control oxygen levels. Since each river has slightly different characteristics, models must be fine-tuned to the unique properties of each situation. NRBS work has focused on quantifying the natural processes that govern dissolved oxygen levels in the Athabasca River. The values determined for the major processes controlling oxygen levels in the Athabasca River were examined by mathematical modelling using the DOSTOC (Dissolved Oxygen STOCastic) model. The model was relatively successful in predicting large-scale trends in average oxygen concentrations for the Athabasca River, but was unable to capture local oxygen sags downstream of certain pulp mills in some winters. The knowledge generated by this endeavour can now be used to optimize more sophisticated dissolved oxygen models.

RELATED DOCUMENTS

NRBS Synthesis Reports

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MacDonald, G. and A. Radermacher. 1993. *An Evaluation of Dissolved Oxygen Modelling of the Athabasca River and the Wapiti - Smoky River System.* Northern River Basins Study Technical Report No. 25.

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3.9 CONTAMINANTS

Related NRBS Questions:

2. What is the current state of water quality in the Peace, Athabasca and Slave river basins, including the Peace-Athabasca Delta?

4. a) What are the contents and nature of contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?
   b) Are toxins, such as dioxins, furans, mercury, etc., increasing or decreasing and what is their rate of change?

5. Are the substances added to the rivers by natural and man-made discharges likely to cause deterioration of the water quality?

8. What is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location?

13. a) What predictive tools are required to determine the cumulative effects of man-made discharges on the water and aquatic environment?

INTRODUCTION

Environmental contamination refers to the addition of any foreign or unwanted substances into the environment. As such, contaminants include those substances that are harmful to ecosystem and human health, as well as those that are deemed undesirable from an aesthetic standpoint. Within the Northern River Basins Study, researchers studied more than a hundred separate chemical constituents in thousands of environmental samples collected throughout the Peace, Athabasca and Slave river basins.

Within the basins, contaminant levels are controlled by a number of regulations and guidelines designed to protect human and ecosystem health. Contaminants can be controlled at their point of discharge (e.g., *Canadian Environmental Protection Act Pulp and Paper Regulatory Package*), at levels within the environment (e.g., *Canadian Water Quality Guidelines*), or at the level of the consumer (e.g., fish consumption advisories). A summary of Canadian environmental quality guidelines applicable to the northern river basins can be found in the NRBS synthesis report, entitled *"Cumulative Impacts within the Northern River Basins"* that is referenced at the end of this section.

This section summarizes the major sources, distribution and environmental effects of contaminants within the Peace, Athabasca and Slave river basins. It also describes various models designed to predict the fate and distribution of contaminants in the environment andthe food web.

A detailed examination of all contaminants studied within the NRBS exceeds the scope of this report. A more thorough contaminant evaluation is found in two NRBS synthesis reports, entitled *"Distribution of Contaminants in the Water, Sediment and Biota of the Northern River Basins: Present Levels and Predicted Future Trends"* and *"Effects of Contaminants on Aquatic Organisms in the Peace, Athabasca and Slave River Basins."* Descriptions of many contaminants studied within the context of the NRBS can be found in the glossary.

The basins receive contaminants from several point and non-point sources. Principal point sources include effluent discharges from pulp mills, municipalities and oil sands refineries. Key non-point sources include runoff from land-use activities (e.g., forestry and agriculture), oil sands deposits and atmospheric inputs.

Pulp Mills

True to the origin and scope of the Study, substantial research efforts focussed on the sources, distribution and effects of pulp mill contaminants. These contaminants differ with the technology used in the pulp mill (refer to Figure 3.2.4 in Section 3.2 for more information regarding pulp mill locations and technologies). Principal contaminants in bleached kraft mill effluent include:

- organochlorine contaminants, principally chlorinated dimethylsulphones, chlorinated aromatics (including dioxins and furans), chlorophenolics and chlorinated terpenes;
- plant compounds, such as terpenes, organic acids (e.g., resin acids) and aromatic compounds; and
- polycyclic aromatic hydrocarbons (PAHs) and sulphur-containing compounds.

Some of these compounds, such as terpenes and chlorophenolics, have been associated with taste and odour problems downstream of pulp mills. Principal contaminants found in thermomechanical and chemi-thermomechanical pulp mill effluent include a variety of plant compounds such as terpenes and aromatic compounds.

Since the late 1980s, improved technologies (e.g., chlorine substitution) have led to the dramatic reduction of some contaminants in pulp mill effluent, particularly a number of organochlorine compounds, such as dioxins, furans, chlorinated resin acids and chlorophenols. Recent upgrades to the Weldwood and Weyerhaeuser pulp mills at Hinton and Grande Prairie are expected to further reduce discharges of chlorinated organic compounds.

Oil Sands

The Athabasca oil sands near Fort McMurray are a natural source of hydrocarbons. Hydrocarbons are also found in effluent from the Suncor oil sands refinery as are several odour-causing substances.

Atmosphere

Global air currents carry contaminants to the northern river basins, where they are deposited into the aquatic environment. NRBS sediment studies reveal that polycyclic aromatic hydrocarbons (PAHs), the insecticide toxaphene and other organic contaminants such as hexachlorobenzene, polychlorinated biphenyls (PCBs), chlorophenolics, hydrocarbons, dioxins and furans can enter the basins through long-range aerial transport.

Uranium Mines

Uranium mines in the Saskatchewan portion of the basin constitute an historical source of radionuclides to Lake Athabasca (see *Section 3.2* for more information). NRBS studies reveal that radionuclides levels have diminished since most of the mines closed in the 1970s.

Other

Heavy metals, including mercury, are found in sediments across northern Alberta. Williston Lake is another source of mercury, but studies indicate that this contaminant source is fairly localized and does not significantly affect water quality downstream of the Bennett Dam.

Municipal wastes are an additional source of contaminants to the basins, such as nutrients, insecticides and other select compounds. The implications of nutrients in municipal sewage are discussed in sections 3.7 and 3.8.

ENVIRONMENTAL DISTRIBUTION

Early in the Study, researchers realized that most of the contaminants of interest were less likely to be found in water than other parts of the aquatic environment. Accordingly, NRBS contaminant investigations placed emphasis on sediment and aquatic organisms, where the probability of detecting the contaminants is greater.

Significantly, contamination of the basins is low in comparison to other systems in Canada and elsewhere in the world. Furthermore, contaminant levels of fish and wildlife are usually within guidelines for the protection of both aquatic and human health. One cause for optimism is the dramatic decline of chlorinated organics in pulp mill effluent. NRBS research has confirmed that upgrades to mill processes have led to lower environmental concentrations of some organochlorine compounds. In the Peace River, for instance, dioxin and furan levels in burbot livers has decreased by more than 50 per cent since 1992. In addition, radionuclide levels in fish from Lake Athabasca were low and well within general guidelines for human health.

While the levels of persistent organochlorines (such as dioxins and furans) are declining and often below guidelines, their mere presence in the food chain still raises concerns regarding ecosystem health. Furthermore, dioxin, furan and mercury levels possibly exceed guidelines in a few basin locations (see Section 3.13 for more information). This information must still be reviewed and assessed by health authorities in the context of human consumption patterns. Based on the contaminant findings, there are several locations in the basins that warrant special attention because of the levels and numbers of different contaminants observed.

Within the Athabasca River, the reach between Hinton and the Emerson Lakes sampling site (Figure 3.9.1) had the highest levels of dioxins, furans, chlorinated phenols and chlorinated resin acids in NRBS sediment and fish samples. This region is more susceptible to environmental contamination due to an unique combination of development and environmental conditions. Researchers determined that pulp mill effluent tends to enhance natural flocculation (or "clumping") of sediments in the environment. Under low flow conditions, these sediments settle to the bottom sooner than under normal circumstances. Since many contaminants tend to adsorb (or "stick") to sediments, the higher amount of sediments in this reach results in higher contaminant levels shortly downstream of the Hinton combined pulp mill / municipal effluent discharge. Researchers believe that under high flow conditions, these sediments and their associated contaminants are redistributed further downstream.

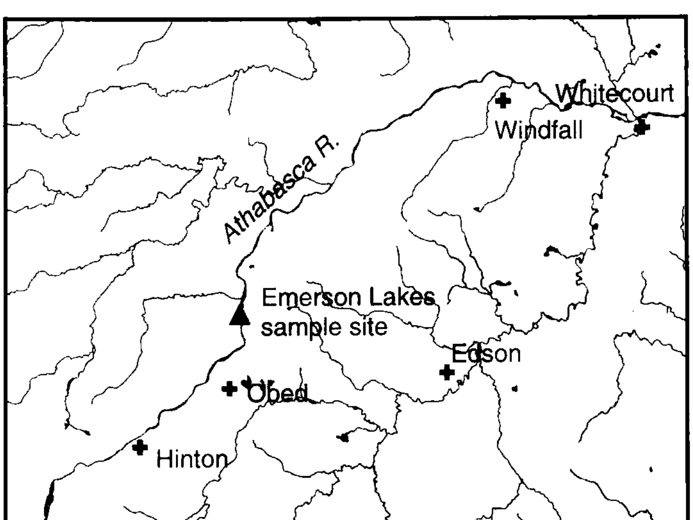


FIGURE. 3.9.1 EMERSON LAKES SAMPLING SITE

Resin acids are natural plant compounds that exist at relatively high levels in pulp mill effluent. Of particular interest are the more toxic chlorinated resin acids that can be formed during the chlorine bleaching process. Several chlorinated resin acids, particularly chlorinated dehydroabietic acid, were determined to exist in both fish and sediments below the mills. Again, improved pulp mill treatment technologies are believed to have resulted in decreases in chlorinated resin acids. Residual levels still exist in fish and sediments.

Metals are not usually major contaminants in pulp mill effluent, but one unusual case was found in the basins. Effluent from the Hinton combined pulp mill / municipal effluent was found to contain unusually high quantities of heavy metals, including aluminum, manganese and zinc. The Hinton effluent almost doubles levels of these metals in this reach of the Athabasca River. The higher levels of these metals is attributable to the waste treatment process.

Higher levels of PCBs, chlorinated resin acids and PAHs in the Peace River system upstream of the confluence of the Smoky River are related to sediment transport / deposition processes. PCB levels vary across the Peace and Athabasca river basins but studies suggest a possible PCB source in the upper reaches of the Peace River basin. Levels of chlorinated and non-chlorinated organic contaminants in sediments from this Peace River reach are also high — a somewhat perplexing finding given that the nearest pulp mill is over 200 km upstream and that there are no other major industrial developments on the system until Grande Prairie.

Highest levels of PCBs in fish were found in the Wapiti / Smoky and Peace systems. In particular, both the Wapiti River and the Peace River above its confluence with the Smoky River were the highest in this system. PCB levels in fish from the Peace River drainage nearly doubled in three areas between 1992 and 1994 — the Wapiti River near Grande Prairie, and the Peace River near Notikewin and Fort Vermilion.

NRBS contaminant studies also revealed that:

- ❏ levels of organic contaminants in muskrats, mink and waterfowl from the Peace-Athabasca Delta meet human health consumption guidelines;
- ❏ none of the 20 organochlorine pesticides tested (including toxaphene) rose above 0.01 μg/L in water;
- ❏ dioxins and furans were non-detectable in recent sediment samples, except for one site below Hinton (Emerson Lakes) and another on the Peace River above the Smoky confluence;
- ❏ radionuclides in fish from Lake Athabasca were at natural background levels;
- ❏ levels of chlorinated resin acids were significantly higher in sediments from the Athabasca River than the Peace River;
- ❏ pulp mill contaminants reach Lake Athabasca and Great Slave Lake; and
- ❏ dioxins and furans in burbot livers declined significantly between 1991 and 1994.

NRBS studies within several research components have collected detailed statistics regarding fish mercury levels and fish consumption habits of northern residents. Patterns of mercury contamination in fish remain virtually unchanged since 1988, and tend to be highest in the lower end of the Athabasca River. Fish consumption advisories related to mercury contamination extend to walleye in the mainstem Athabasca River. Interestingly, levels in all subsistence fish collected from the Peace-Athabasca Delta in a special 1994 / 1995 study were below 350 μg/kg — less than the commercial guideline of 500 μg/kg. This information provides a basis for re-evaluating the applicability of these guidelines to current mercury levels and northern lifestyles.

Environmental Effects

NRBS researchers conducted a series of integrated studies assessing contaminant effects on fish and other aquatic organisms in the northern river basins. These studies involved the use of a suite of biomarkers — physiological and biochemical "yardsticks" by which researchers can measure exposure to specific contaminants.

It is important to note that biomarkers do not necessarily indicate that an organism is being harmed by a specific contaminant. In the same way that a human would sweat on a warm day, biomarkers may simply indicate that an organism is exposed to some chemical or factor that is causing it to exhibit signs of physiological stress. As such, scientists use biomarkers as sensitive early warning indicators of potential contaminant-induced effects on the ecosystem. Further research is required to define the link between these responses and ecological consequences, such as changes to growth, survival and reproduction.

Different biomarkers are used to indicate physiological stress related to particular contaminant levels and degrees of exposure. A summary of the biochemical biomarkers used in the NRBS is found in Table 3.9.1. As the table illustrates, each biomarker responds to more than one contaminant, necessitating a suite of biomarkers to identify the contaminants causing stress in fish from any particular river reach. Measures of fish and macroinvertebrate population / community changes, physical abnormalities and toxicology were also used.

TABLE 3.9.1 PHYSIOLOGICAL BIOMARKERS USED IN NRBS CONTAMINANTS RESEARCH

Physiological Biomarker	Description
mixed function oxygenases (MFOs)	a group of enzymes found predominantly in the liver that facilitate excretion of certain contaminants, including PAHs, PCBs, chlorinated resin acids, chlorophenols, dioxins and furans. Elevated MFO levels indicate exposure to these contaminants.
vitamins A and E	vitamins important to a number of physiological processes and therefore considered a good measure of general fish health; levels of these particular vitamins decrease upon exposure to a variety of contaminants (e.g., PCBs, chlorinated resin acids, chlorophenols, dioxins and furans)
metallothionein	a group of proteins that help to protect organisms from harm by toxic metals; high metallothionein levels indicate exposure to heavy metals (e.g., cadmium and mercury)

EFFECTS ON FISH

To examine what extent pulp mill discharges were causing stress on fish, researchers from the Contaminants Component measured biomarker responses in different fish species from three general regions: near-field (within 100 km from a pulp mill discharge), far-field (greater than 100 km from a pulp mill discharge) and reference (or "control") locations (Figure 3.9.2). These and other studies indicate that some fish in select regions of the basins are showing signs of physiological stress. While there is currently no evidence directly linking these responses to population or community-level effects, further studies are necessary to more closely examine this relationship.

Sex Hormones

According to NRBS results, levels of sex hormones in fish are affected by their proximity to pulp mill effluent sources. Figure 3.9.3 illustrates average levels of the female sex hormone 17β-estradiol and the male hormone 11-ketotestosterone in fish from near-field, far-field and reference sites. Levels of sex hormones in sexually mature female burbot and longnose sucker at near-field sites were significantly lower than measured values at far-field locations. Similarly, hormone levels in sexually mature male burbot from near-field sites was significantly lower than that at reference locations upstream of pulp mills.

The long-term ecological consequences of these depressed hormone levels are currently inconclusive. NRBS scientists found no direct evidence to link depressed hormone levels to impaired reproductive development in individual fish within this survey. At a population level, however, a large proportion of the fish caught in near-field sites were sexually immature for their age and size. Immature fish represented 27, 62 and 35 per cent of fish caught at near-field sites in the Athabasca, Peace and Smoky rivers, respectively. Taken together, the percentage of adult-sized but sexually immature fish was greater than 40 per cent in near-field sites (Figure 3.9.3).

Higher incidences of sexually immature fish are generally described as a reproductive disorder and is usually associated with reductions in size, growth rates and poorer condition. However, these secondary effects were not observed in fish samples. In addition, the sexes were not evenly distributed throughout the basins. Females accounted for 70 per cent of fish caught at reference locations, but only 40 per cent at near-field locations and 34 per cent at far-field locations.

NRBS also assessed hormone levels in smaller fish species with restricted distributions and very small home ranges. In spoonhead sculpin, hormone levels did not differ significantly between fish collected upstream and downstream of the Hinton combined effluent discharge. In both fall 1994 and spring 1995, fish collected below the discharge were older, heavier and fatter than fish collected at the reference sites — probably in response to increased nutrient loadings and subsequent higher productivity. Spoonhead sculpin collected from the near-field north bank (outside the effluent plume) showed responses intermediate between those observed for reference fish and near-field south bank (inside the effluent plume).

Mixed Function Oxygenases (MFOs)
Relative to other sites in northern Canada, MFO activity in burbot liver was elevated at only two sites in the basins: the Ft. McMurray and Wabasca oil sands areas (Figure 3.9.4). There was little evidence to suggest that these elevated MFO levels are related to their proximity to pulp mills.

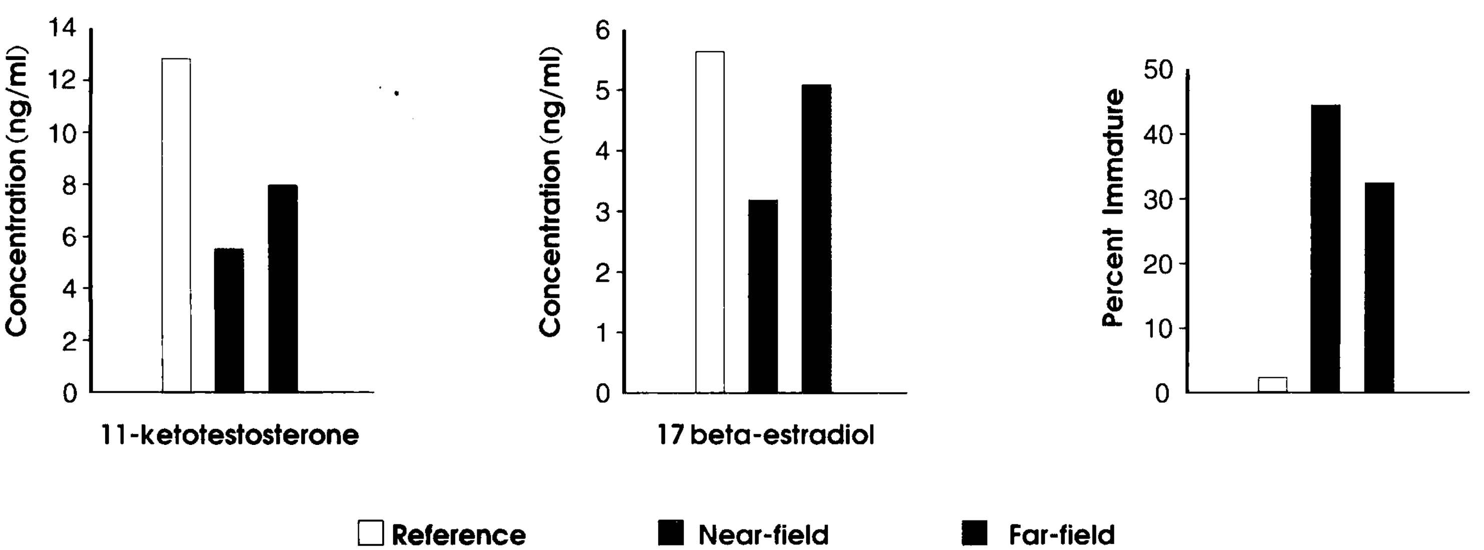
Results from a separate but related study using semi-permeable membrane devices (SPMDs) tend to confirm this finding. SPMDs are fat-filled polyethylene tubes that can be strategically deployed in streams to mimic contaminant accumulation in fish. SPMDs were deployed in both river water and effluent in the Peace, Athabasca and Slave rivers (Figure 3.9.5) . Results indicate that pulp mill effluents are not contributing significant levels of MFO inducers to the Athabasca River. Levels of induction observed for mills in this system were significantly lower than those observed at mills elsewhere in Canada using the same techniques. Of all the effluent sampled, the highest levels of induction were observed in Suncor effluent. In river water samples, the highest levels of induction were observed in the Athabasca River both upstream and downstream of the Suncor discharge.

Vitamins A and E
NRBS studies reveal that despite differences among species, observed vitamin levels were generally high in all species. The one exception to this pattern was observed immediately upstream of Ft. Vermilion, where vitamin imbalances were observed in male and immature burbot. The cause is unknown but is not related to the overall condition of the fish.

Metallothionein
As described above, metallothioneins are a group of proteins involved in the detoxification of heavy metals. Measures of metallothionein in fish collected in the 1994 basin-wide survey indicated that in general, levels were low with the exception of a few specific sites. In particular, burbot collected from the Slave River Delta displayed significantly higher levels.

Relative to other sampling locations, fish in the Pembina River consistently showed elevated metallothionein levels. Overall, metallothionein levels tend to increase from upstream to downstream on the Peace River and on the lower Athabasca River, but there was insufficient evidence to conclude that fish from near-field locations experienced generally higher metallothionein levels than did fish from reference or far-field locations.

FIGURE. 3.9.3 SEX HORMONE LEVELS AND SEXUAL MATURITY IN FISH FROM NEAR-FIELD, FAR-FIELD AND REFERENCE SITES



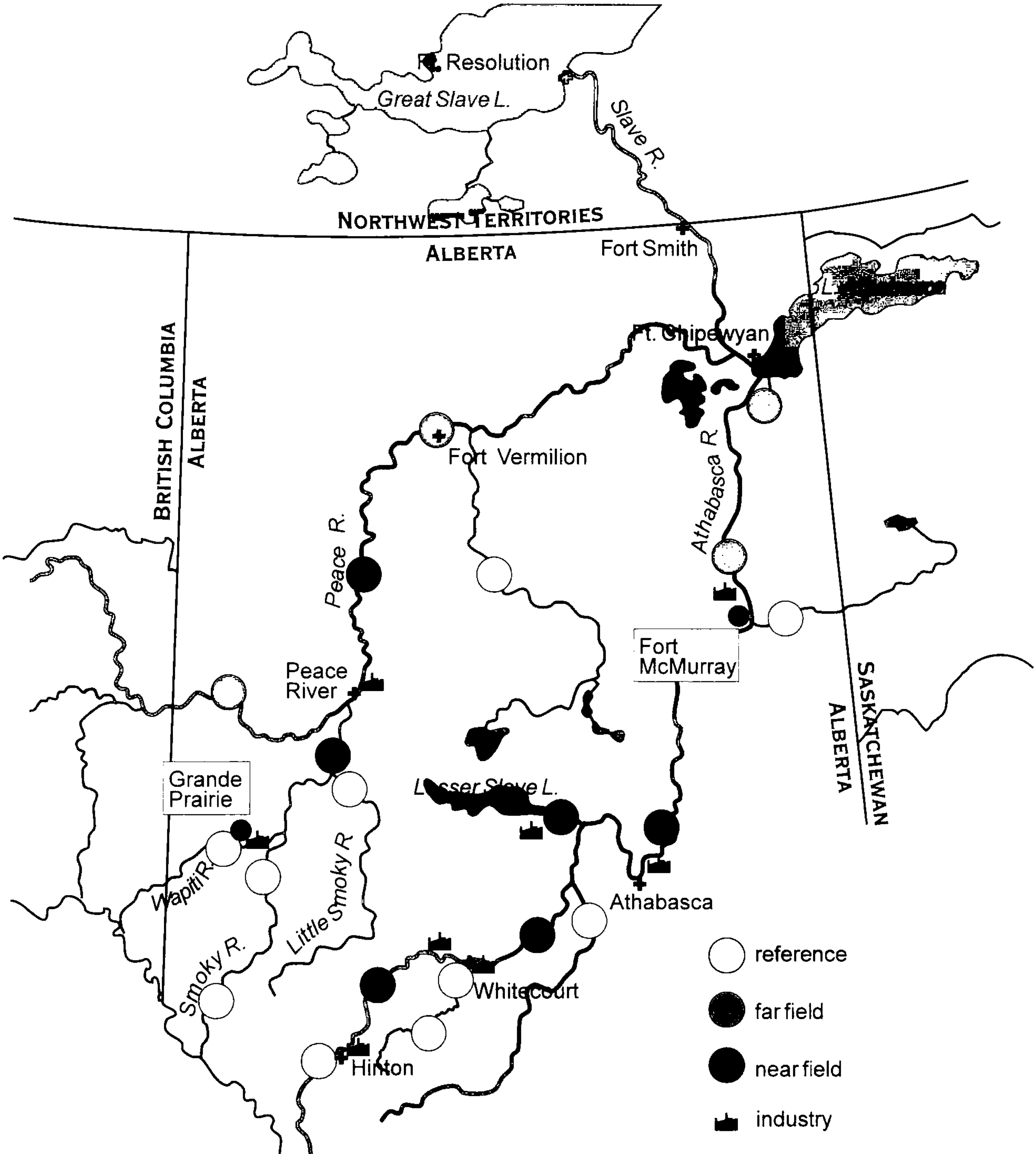


FIGURE 3.9.2 ENVIRONMENTAL EFFECTS: FISH SAMPLING SITES

External Abnormalities
As part of the of the NRBS sampling protocol, captured fish were routinely checked for external abnormalities, including the presence of tumours, lesions, scars, injuries skin discoloration or deformities. Overall, the incidence of fish abnormalities in the basins was quite low (less than one per cent). Certain fish species from particular locations showed a much higher incidence. In some cases, a higher frequency of external abnormalities may result from physiological or behavioral changes associated with spawning. However, the Food Chain Component obtained some evidence of a higher incidence of abnormalities in fish captured immediately downstream of pulp mills. These qualitative results suggest that the frequency of external abnormalities in fish merits further investigation.

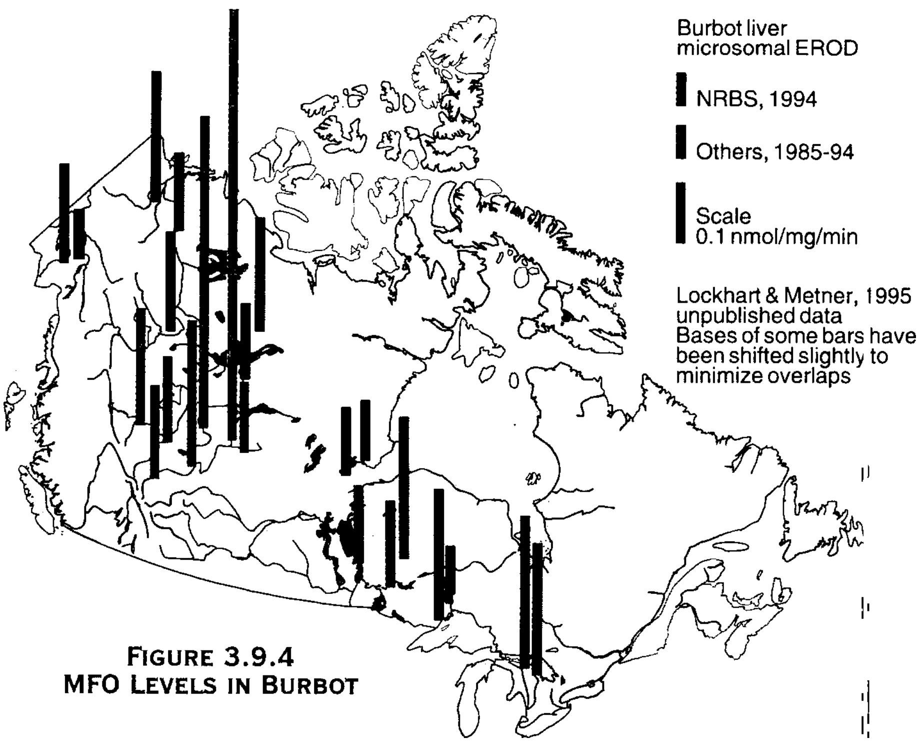


FIGURE 3.9.4
MFO LEVELS IN BURBOT

EFFECTS ON AQUATIC INVERTEBRATES

As with fish, NRBS studies on large aquatic invertebrates (or "macroinvertebrates") indicate that these organisms are also experiencing contaminant-related stress in certain river reaches within the basins.

Sediment Toxicity
Overall, NRBS studies revealed no significant effects of sediments on the survival, growth and fertility of macroinvertebrates. However, the Emerson Lakes area of the Athabasca River emerged as a region containing sediments that could impair fertility in at least one of the test species. In addition, contaminant levels in invertebrates from this reach exceeded guidelines.

External Abnormalities
As in fish, the frequency of external abnormalities among large invertebrates may provide valuable insight into the effects of contaminants on biota. NRBS results suggest that the frequency of deformities in several macroinvertebrates may be higher immediately downstream of a pulp mill discharge relative to those living in reference locations or further downstream. The ecological significance of this observation remains to be determined.

Population / Community Response
Exposure to pulp mill effluent did not produce significant and consistent changes in the overall community structure of aquatic invertebrates.

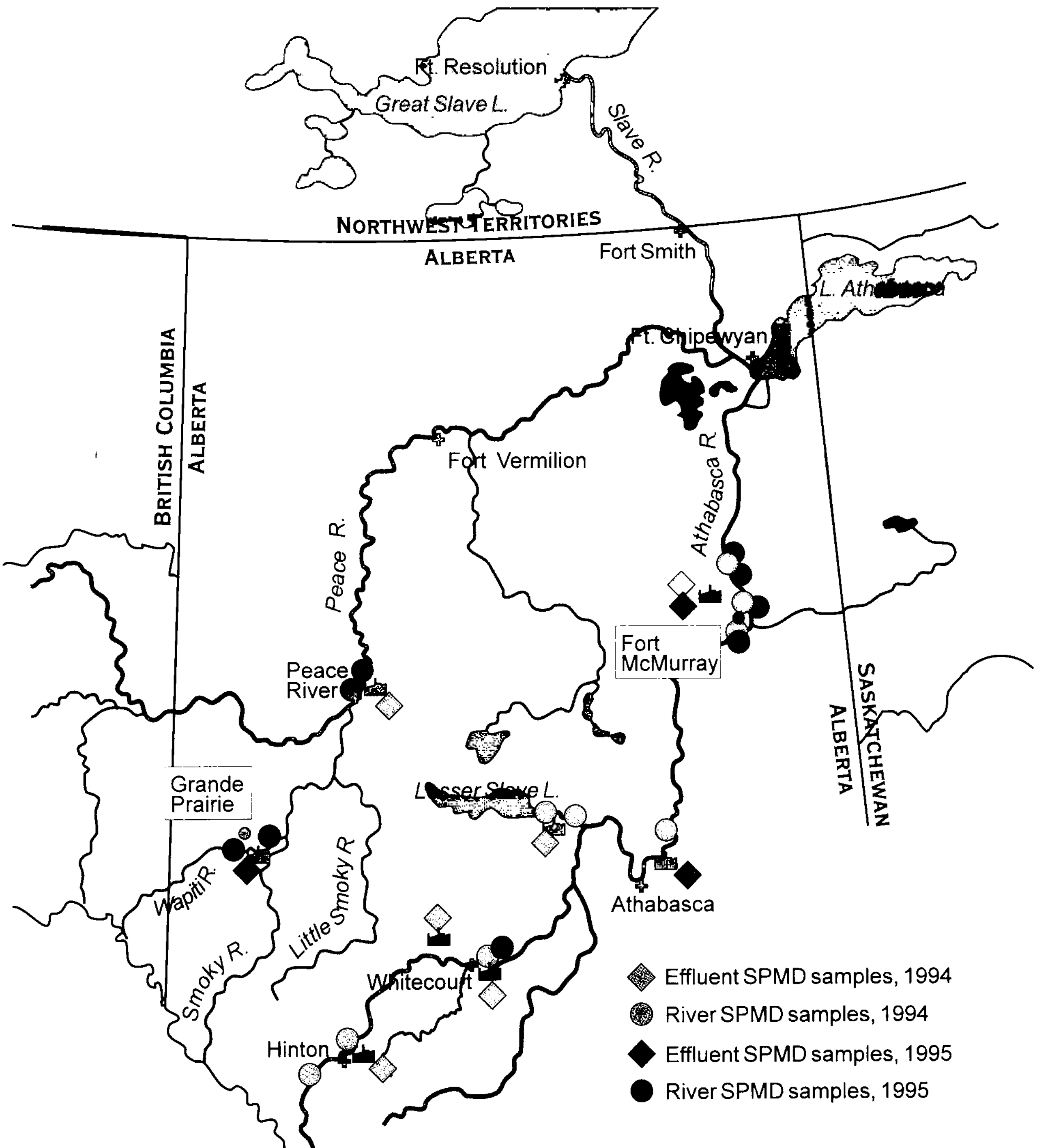


FIGURE 3.9.5 SEMI-PERMEABLE MEMBRANE DEVICE (SPMD) DEPLOYMENT SITES

NRBS experiments demonstrated the growth rate of certain invertebrate species increased when exposed to pulp mill effluent. However, this effect was attributed to nutrient enrichment and there was no evidence to suggest that effluent contaminants affected growth or survival.

CONTAMINANT MODELLING

Researchers within the Contaminants Component created two separate but integrated models for predicting the distribution and fate of contaminants in response to different loadings to the northern rivers, in particular the Athabasca River.

The first model was based on the Water Quality Analysis Simulation Program (WASP) developed by the United States Environmental Protection Agency. The model was designed to predict concentrations of specific chemicals in several ecosystem compartments (i.e., water and sediments) based on different contaminant discharges into the aquatic environment. Seven compounds were chosen for the NRBS model, six of which are found in bleached kraft effluent and one that represented a common polycyclic aromatic hydrocarbon (PAH). The second contaminant model uses output from WASP to predict levels of the same contaminants in the aquatic food chain. Both of these models form the foundation for future assessments of contaminant fate and distribution within the aquatic ecosystem.

RELEVANT DOCUMENTS:

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3.10 Drinking Water

Related NRBS Questions:

8. Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location?

9. Are fish tainted in these waters, and if so, what is the source of the tainting compounds (i.e., compounds affecting how fish and water taste and smell to humans)?

Introduction

Good quality drinking water is essential to life. But what are the characteristics that comprise good water quality? Most would agree that public health is the primary consideration in drinking water quality. In the northern river basins, these concerns are related to levels of chemical and microbial contaminants that stem from a variety of natural and non-natural sources. Based on an average water consumption of 1.5 L a day, a 75 year-old person will have consumed over 40 000 L of water in his or her lifetime. Evidently, water can be an important vehicle for contaminants to enter the body and can significantly impact public health.

Public perception is also a factor in water quality. Aesthetic considerations, such as taste, odour, and appearance are influenced by the substances in water and strongly affect our view of water quality and health. They may also be the first indications of a health hazard. As such, aesthetic considerations must also be considered in any evaluation of water quality.

In Canada, the federal *Guidelines for Canadian Drinking Water Quality (GCDWQ)* are the basis for evaluating the safety of drinking water. In most Canadian provinces and territories, the guidelines serve as recommendations, but in Alberta they are enforced under provincial legislation. The guidelines define minimum quality standards, based on an acceptable level of risk to the population at large. What constitutes an acceptable health risk is a judgement that weighs societal costs against the relative benefit to public health. One could move beyond the *GCDWQ* to legislate the elimination of all detectable contaminants, but the additional benefits to public health may be negligible. This does not mean, however, that we should not constantly strive for better water quality.

The *GCDWQ* outline three different water quality standards. Maximum acceptable concentrations (MACs) are set for those substances that pose a known or suspected health threat. MACs represent the concentrations of constituents that will not result in a significant risk to consumer health over a lifetime of consumption. Interim maximum acceptable concentrations (IMACs) are set for those substances that are assumed to have an adverse effect on health, but for which there is insufficient information to form a reliable MAC. Aesthetic objectives (AOs) are given to substances or conditions that contribute to the consumers' perceptions of drinking water quality but do not constitute a health threat. The guidelines are frequently revised in light of new scientific knowledge. Table 3.10.1 describes a few substances or conditions that appear in the *GCDWQ* that may be of concern to northern residents.

Ordinarily, the guidelines would be used to assess the quality of drinking water that has been processed by a treatment facility, assuming that a great majority of residents receive treated water. This is not necessarily the case in the northern river basins, where many residents (especially those in remote areas) rely on natural water bodies for their water supply. Using information from new studies, historic databases and literature, the NRBS Drinking Water Component has compiled a picture of the use and quality of both treated and untreated drinking water in the Alberta portion of the Study area.

Table 3.10.1 Guidelines for Canadian Drinking Water Quality: Selected Parameters

PARAMETER	DESCRIPTION	GUIDELINE
1,2 dichlorobenzene	a mildly toxic by-product of industry and chlorine disinfection that may cause cancer at higher doses	MAC = 0.2 mg/L AO 0 0.003 mg/L
manganese	a chemical element found naturally in many areas that poses no proven health risk but may produce objectionable tastes and odours in water	AO 0 0.05 mg/L
mercury	a chemical element found naturally in many surface waters; forms of mercury can cause damage to the kidneys and central nervous system	MAC = 0.001 mg/L
total coliforms	the sum of all coliform bacteria (i.e., those associated with the intestines of warm-blooded animals) in water [used to assess the microbial quality of water]	MAC = 0 coliforms / 100 mL(1)
trihalomethanes	a group of halogenated substances that arise as by-products of chlorine disinfection; the most common form (chloroform) may cause cancer and organ damage	MAC = 0.1 mg/L
turbidity	a measure of water clarity used to indicate the effectiveness of water treatment in removing contaminants	MAC = 1 NTU(2) in 95% of samples AO = 5 NTU (if disinfection is not compromised)

(1) Samples indicating less than 10 organisms / 100 mL are considered in compliance if: 1) none indicate the presence of faecal coliform bacteria, a set of microorganisms associated with animal feces and several waterborne diseases; 2) no coliforms are detected in subsequent samples; 3) no more than one sample from a community tests positive on a given day; and 4) no more than 10 percent of the samples test positive.
(2) NTU = nephelometric turbidity unit (a measure of cloudiness)
Source: Federal Provincial Subcommittee on Water, 1993.

Drinking Water Sources and Public Concerns

Conventional drinking water refers to a community water supply that is obtained from a drinking water treatment facility. According to statistics from Alberta Environmental Protection, there are currently 180 such facilities operating in the Peace and Athabasca basins, supplying water to 55 - 75 per cent of basin residents (Figure 3.10.1). Of these facilities, 105 rely upon surface water sources, while 75 draw upon groundwater supplies.

The remaining basin residents obtain water from *non-conventional* sources that may require treatment by individual consumers prior to consumption. The NRBS household survey reveals that the most common sources of non-conventional water are (in order of importance), wells, dugouts, bottled water, river water, lake water and spring water. Other minor sources include rain, snow, ice, muskeg water and water that is tapped from birch trees. Non-conventional drinking water use is more prevalent among those that "live off the land" and is most common in remote northern areas where treatment facilities are often unavailable.

Did You Know:
Results from the Traditional Knowledge Component reveal that 95 per cent of those that "live off the land" rely on non-conventional water sources.

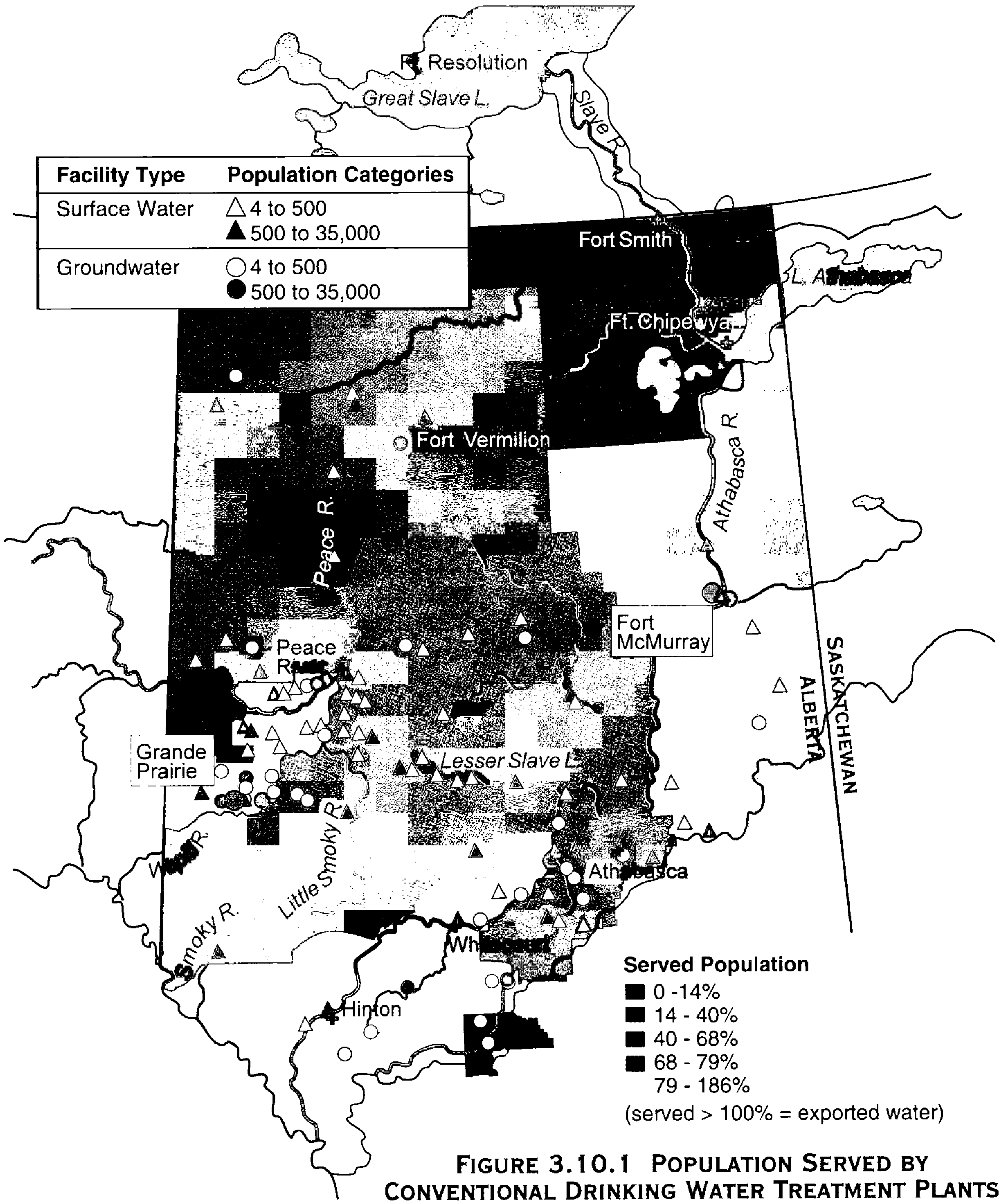


FIGURE 3.10.1 POPULATION SERVED BY CONVENTIONAL DRINKING WATER TREATMENT PLANTS

According to the NRBS household survey, many northern residents are not content with the quality of their drinking water. Thirty-one per cent of surveyed conventional water users report a problem with their drinking water. These concerns are predominantly attributed to high levels of chlorine or a general bad taste or smell (see Figure 3.3.2 in Section 3.3). Several individuals interviewed by the Drinking Water Component associate a health risk with the consumption of chlorinated drinking water. The reported health effects included "vein-clogging", allergic reactions, onset of cancer and general gastrointestinal illnesses.

Approximately 28 per cent of non-conventional water users report quality problems. Bad tastes or odours are a common concern, but other problems are directly related to the raw water source. Dugout users, for instance, reported problems with algae or bacteria, while groundwater wells were often high in minerals. Surprisingly, a large proportion of those that use river water report a perceived taste or odour problem with chlorine.

CONVENTIONAL DRINKING WATER QUALITY

Generally speaking, conventional drinking water within the northern river basins is of good quality. The majority of basin residents receiving conventional drinking water are served by larger facilities that produce high quality water. However, NRBS studies reveal that high quality drinking water may be a challenge for some smaller facilities within the Study area.

Historical records from 1988-1994 reveal that smaller treatment facilities in the Study area have difficulty meeting microbial standards for drinking water. All of the facilities that exceeded *GCDWQ* guidelines were smaller facilities serving populations less than 500 (Figure 3.10.2). Of the smallest sites (watering points serving less than 150 people) approximately 30 per cent have difficulty meeting *GCDWQ* standards for coliform bacteria. This proportion swells to 45 per cent if "poor" samples (those eliminated because the coliforms were too numerous to count) are included. A few of the communities in question may have been exposed to excessive microbial contaminants for seven years in a row.

Smaller communities also tend to have higher turbidity levels in their conventional water supplies, and several sites may have difficulty in meeting *GCDWQ* guidelines for turbidity. Turbidity does not necessarily constitute a health threat, but it can indicate the effectiveness of the treatment process in filtering out harmful chemicals and disease-causing bacteria. The combination of high turbidity and poor microbiological performance indicates a potential health risk to small northern communities. The NRBS Study Board has notified Alberta authorities of this problem.

A few facilities exceeded *GCDWQ* guidelines for chemical contaminants. Most of the poor samples from these facilities exceeded aesthetic objectives for particular parameters (1,2 dichlorobenzene, iron, sodium and total dissolved solids), but in these cases the contaminants were more of a nuisance than a health threat. A small number of surface water facilities, however, exceeded the maximum acceptable concentration for trihalomethanes — a by-product of chlorine disinfection that has been linked to cancer. Three sites exceeded the older *GCDWQ* guideline for trihalomethanes (0.35 mg/L) that was in effect when the samples were collected. If trihalomethane levels remain unchanged, a significant proportion of the surface water facilities

TABLE 3.10.2 PERCENTAGE OF SAMPLES EXCEEDING TRIHALOMETHANES GUIDELINE 0.1 MG/L

COMMUNITY SIZE	WATER SOURCE		
	All NRBS Sites	Surface Water Sites	Groundwater Sites
City	0%	0%	n/a
Town	7%	8%	0%
Village	27%	34%	0%
Hamlet	37%	42%	8%
Water Point	33%	50%	0%
Métis Settlement	50%	50%	n/a
Total	15%	18%	2%

included in this study will likely exceed the more stringent 1993 guideline of 0.1 mg/L (Table 3.10.2).

Generally speaking, smaller facilities serving populations less than 500 and relying on surface water sources have greater difficulty in meeting water quality guidelines. Visits to several small treatment plants reveal that these difficulties may be related to financial and operational difficulties. Small facilities generally have fewer employees. This translates into greater responsibilities for individual operators and less time allotted for separate tasks. The training incentives and opportunities for small facility operators are also fewer than in large facilities where employees receive advanced training for their specific duty. This situation is by no means unique to the Study area. Across the province of Alberta, small treatment facilities are a continual challenge in terms of available finances and technical expertise. In contrast to these findings, an overwhelming majority (96 per cent) of operators responding to the NRBS survey believe that their facilities produce water that meets drinking water standards.

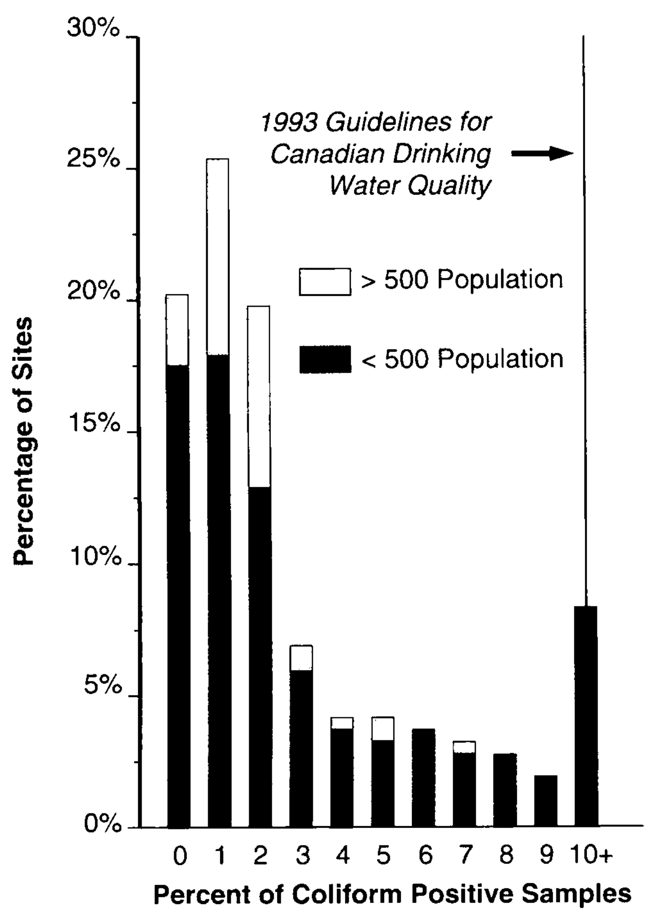
Non-Conventional Drinking Water Quality

With regard to microbial contaminants, untreated surface water within the Study area is generally undrinkable. All surface water samples from the Study area exceeded microbial guidelines. As a consequence, drinking untreated water could pose a serious health risk to consumers.

The same holds true for surface waters that may be considered safe by virtue of their remoteness from human activities. Many microorganisms, such as *Giardia* (the group of bacteria responsible for "beaver fever"), are carried by animals and can infect drinking water despite the absence of human contamination. Snow, for example, is often contaminated by animal feces. Fresh rain water contains very low contaminant levels but can become contaminated with bacteria if collected or stored improperly. Dugout and muskeg waters are also susceptible to bacterial contamination.

Manganese was also found to be a problem in several surface water sources in the Study area, particularly those from the Wapiti / Smoky river system. There are no health risks associated with manganese, but it produces a strong taste and odour that consumers often find objectionable. In contrast to surface waters, groundwater within the Study area is generally of good quality. Protected aquifers are usually free from pathogenic microorganisms and many wells may achieve acceptable water quality without any treatment. However, groundwater is susceptible to contaminants in the soil as well as any substances

Figure 3.10.2
Frequency of Coliform Positive Samples in the NRBS Area (1988-1994)



dropped into the mouth of a well. As a result, care should be taken in the choice and maintenance of groundwater wells.

Non-Conventional Water Treatment
There are a number of chemical and mechanical methods to disinfect or remove contaminants from drinking water, ranging from simple techniques (e.g., boiling or chlorinating) to highly complex mechanical systems (e.g., ultra-violet disinfection or reverse osmosis). Among basin households that rely on non-conventional water sources, only 34 per cent report using some form of treatment. The most common methods are filtering, distilling, boiling and chlorinating. Ultimately, the choice of treatment is up to the individual and depends upon the particular problems associated with the raw water source. A few points for consideration are given below.

Heat remains one of the oldest and most effective methods for eliminating unwanted microorganisms, although there is some dispute over the required boiling time to ensure disinfection. Chlorine is also an effective disinfectant, but many residents have expressed concern regarding its taste and perceived effects on health. A number of individuals interviewed by the Drinking Water Component had access to chlorinated water from a treatment plant, but refused to use it for these reasons.

A number of portable drinking water filters designed for wilderness use are available through camping stores. Basin residents are cautioned that the effectiveness of these devices is not guaranteed. None of the commercially available drinking water filters analyzed in NRBS studies could meet manufacturers' claims as to their abilities. Only one unit could achieve *GCDWQ* turbidity guidelines and efficiently remove particles as small as *Giardia* cysts.

Basin residents should also exercise caution in their choice of bottled waters. NRBS studies revealed that most bottled waters are of good quality, but a few contain higher than average levels of bacteria, organic contaminants (e.g., chloroform) and minerals (e.g., sodium, arsenic and fluoride).

RELATIVE HEALTH RISKS

Guidelines are useful as a ruler to measure water quality, but it is also important to understand the relative risk of individual contaminants so as to better focus treatment efforts.

Microbial contaminants pose by far the greatest health risk to northern residents. A large reservoir of disease-causing microbes occurs throughout northern waters and while treatment may eliminate the immediate health hazard, it cannot eradicate the source of the problem. Moreover, NRBS studies suggest that several water treatment facilities may not be effective in removing disease-causing microbes from drinking water.

However, northern residents are far more concerned about health risks arising from chemical contaminants, particularly those related to chlorine and its by-products. Chemical contaminants are much more difficult to link to disease because an individual can be exposed for months or years before symptoms can be observed. Within the northern river basins, trihalomethanes (a group of chlorine by-products) may be the largest health risk related to chemical contaminants. The chance of contracting cancer from trihalomethanes is extremely small in comparison to catching a bacterial disease associated with inadequate disinfection, but the health consequences are much more serious. Consequently, both of these issues require attention.

OCCURRENCE OF WATERBORNE DISEASE

It is difficult to ascertain whether residents suffer a greater risk from waterborne disease than people elsewhere. Health records reveal a slightly higher incidence of giardiasis (Figure 3.10.3), salmonellosis and shigellosis in the Study area in comparison to the provincial average, but the difference is not great enough to indicate a substantially higher risk of waterborne disease. Furthermore, it is impossible to ascertain from health records whether the disease was contracted from drinking water or some other means.

Another difficulty arises from the methods for measuring microbial water quality. Traditionally, routine monitoring efforts have relied on specific organisms (e.g., coliform bacteria) to indicate the presence of disease-causing microorganisms. These indicators have served us well in the past, as shown by the dramatic decline in outbreaks of typhoid fever and cholera. Yet the absence of these indicators does not mean that water is free of disease-causing bacteria. *Giardia*, for instance, is fairly resistant to disinfection and may pose a health risk even when coliform bacteria are not detected. As it is both technically and financially impossible to monitor each of the thousands of microorganisms in nature, authorities such as the U.S. Environmental Protection Agency now rely on turbidity as a better measure of microbial water quality.

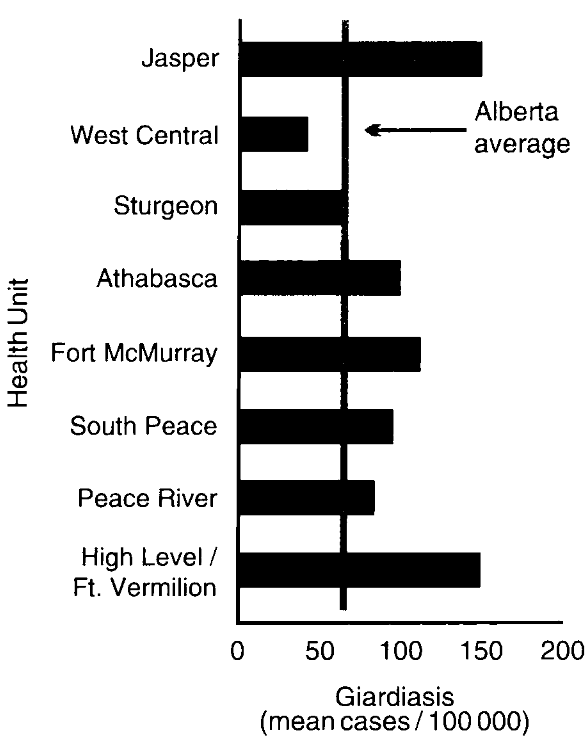
Aesthetic Concerns Related to Industrial Effluent

At the beginning of the Study, bad tastes and odours were reported in fish and water from the Athabasca River downstream of the pulp mill in Hinton. Early studies confirmed that these problems persisted downstream as far as Fort McMurray and consumers feared that the new AlPac pulp mill, once on-line, would cause the situation to worsen.

Recent studies reveal that new technologies greatly reduce bad odours associated with pulp mill effluent. Odour problems downstream of the Hinton mill were significantly reduced following environmental upgrades that included full chloride substitution. Effluent from AlPac and other pulp mills in the basin had a characteristic odour, but the effect on the smell of the river was negligible. Suncor effluent had a strong hydrocarbon smell, but its impact on the Athabasca River could not be distinguished from that arising from natural sources.

Less is known on the topic of fish tainting. A wealth of anecdotal information suggests that fish are tainted immediately downstream of pulp mills and in the oil sands region near Fort McMurray on the Athabasca River. To date, science has not been able to identify the specific compounds that cause these problems.

Figure 3.10.3 Cases of Giardiasis in the NRBS Area



Spill Response Modelling on the Athabasca River

During the course of the Study, public consultations revealed the need for a system that would assist communities along the Athabasca River to respond to potentially hazardous contaminant spills in a timely and effective manner. In response, researchers developed a Spill Response Model for the Athabasca River.

The Spill Response Model is an easy-to-use computer program that can be employed by local authorities to estimate the arrival time of a contaminant spill at a water intake, the time it will take the spill to pass, the peak concentration of the contaminant and a list of downstream community contacts (Figure 3.10.4). This information will empower communities to develop plans that mitigate the immediate impacts of a contaminant spill. The program runs on almost any personal computer.

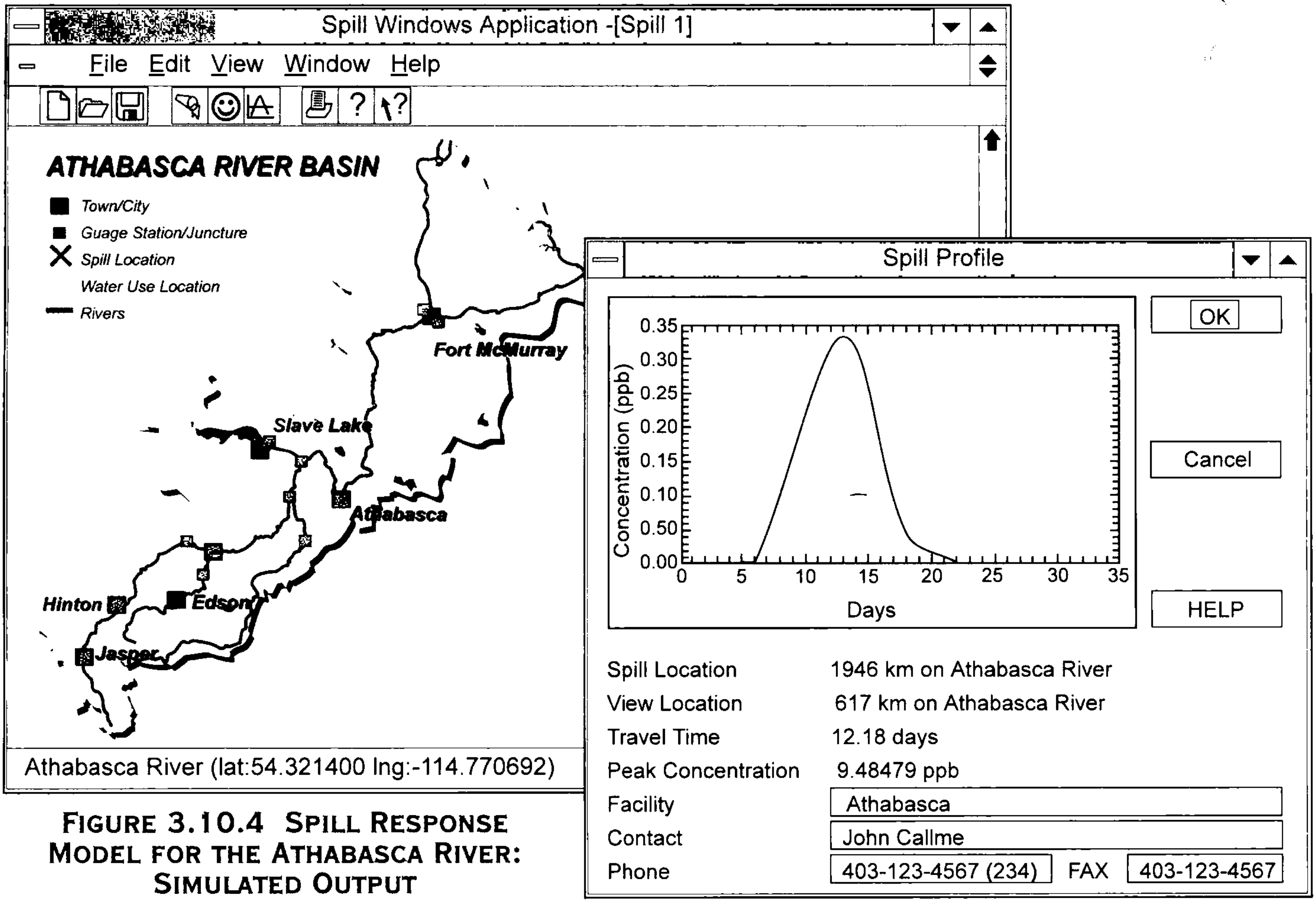


FIGURE 3.10.4 SPILL RESPONSE MODEL FOR THE ATHABASCA RIVER: SIMULATED OUTPUT

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Armstrong, T.F., Stanley, S.J. and D.W. Smith. 1995. *Assessment of Non-Conventional Drinking Water in the Northern River Basins.* Northern River Basins Study Technical Report No. 116.

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World Health Organization. 1993. *Guidelines for Drinking Water Quality. Volume 1: Recommendations*. 2nd ed. Geneva. 188 pp.

3.11 Ecosystem Health

Related NRBS Questions:

13. a) What predictive tools are required to determine the cumulative effects of man-made discharges on the water and aquatic environment?
    b) What are the cumulative effects of man-made discharges on the water and the environment?
14. What long-term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems? These programs must ensure that all stakeholders have the opportunity for input.

Introduction

The traditional approach to environmental management focuses on reducing levels of man-made chemicals to "safe" environmental levels. This "end-of-pipe" strategy has proven effective in reducing contaminant emissions from industries, municipalities and other point sources, but fails to recognize the inherent complexity of ecosystems. Each system, whether it be a small northern river or a large lake, is fundamentally unique and will react to environmental stressors in a distinctive manner. Furthermore, the human residents of the ecosystem have different needs and priorities. Consequently, what may be "safe" for a river in Ontario may constitute a problem in Alberta's northern rivers.

The ecosystem approach to environmental management has grown out of this need to recognize the complex interactions that occur within individual systems. It has three general characteristics:

- ❑ it emphasizes the need to collect and synthesize information on ecosystem structure and function;
- ❑ it recognizes that different levels within the ecosystem are interrelated and interdependent; and
- ❑ it necessitates management strategies that are ecological, anticipatory and ethical (adapted from Christie *et al.* 1986).

The concept of humanity as part of the ecosystem, not separate from it, is a vital underlying principle of the ecosystem approach. This means that the health, activities and concerns of local stakeholders should be viewed as characteristics of the ecosystem in which they live. It also means that stakeholders must be included in the decisions that affect their environment.

While the ecosystem approach represents a major philosophical advance in environmental management, it proves difficult to implement on a practical level. Implicit in the concept is the desire to attain and maintain the ecosystem at a particular level of function or "health." But what constitutes a healthy ecosystem and how can scientists determine when this state is achieved? Working within the context of the northern river basins, the Synthesis and Modelling Component developed a practical framework for assessing and monitoring ecosystem health.

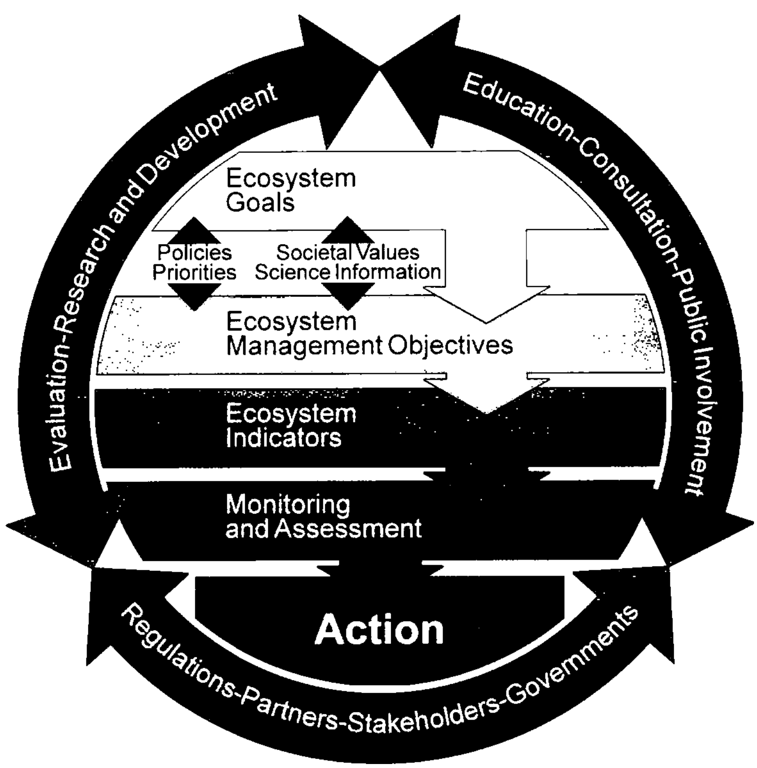
A great deal of effort has gone into defining the term "ecosystem health." Unfortunately, a precise and practical definition of both "ecosystem" and "health" continues to elude environmental managers.

It is generally accepted that an ecosystem is defined by the interaction between living organisms (including humans) and their physical environment. But it is difficult to define the absolute boundaries of an ecosystem. All ecosystems are "open" except the global ecosystem that treats the world as a whole. Is a river an ecosystem? An island? A forest? The answer to all of these questions is yes. What defines an ecosystem is largely a question of scale. Rather than defining the border of an ecosystem in absolute terms, it is more important to realize that all imposed boundaries will be arbitrary. In practical terms, these borders may be influenced by the geographic magnitude of the problem, the availability of resources and political boundaries. Within the NRBS, for instance, the ecosystem is defined as the Alberta and Northwest Territories portions of the Peace, Athabasca and Slave river mainstems. As part of this practical definition, one must recognize that social, economic and ecological conditions outside of these borders may influence conditions within the ecosystem.

A precise definition of health is equally elusive. Once again, NRBS researchers propose that a single, all-encompassing definition may not be necessary. Instead, a more practical approach is proposed — one that recognizes that the perception of health will vary with each ecosystem and over time. This strategy proposes that the desired structure and function of the ecosystem being managed will arise through a process that combines the best available scientific knowledge with societal expectations and concerns.

Using this practical approach, NRBS scientists have developed a framework for monitoring and assessing ecosystem health. This process will help researchers and managers to decide what needs to be monitored and for what reason. It also provides a mechanism for measuring the combined effect of multiple environmental stressors on an ecosystem, otherwise known as cumulative effects. There are four general steps in the framework (Figure 3.11.1):

Fig. 3.11.1 Integrated Monitoring Framework



Step 1: Identify ecosystem goals.

In the first step, a group of stakeholders, armed with the best available scientific information, begin to describe what they want from the ecosystem — they define what constitutes "ecosystem health" with regard to their specific situation. The stakeholders in each case will include public representatives, special interest groups, industry and all levels of government. One example of an ecosystem goal might be "We want to eat the fish."

Step 2: Develop specific management objectives.

Once the goals are defined, they must be further refined into a specific management strategy. This general action plan describes what information is required to address the situation. Using the previous example, a management strategy would outline what general information would signify that the fish are healthy and abundant. Knowledge of current monitoring and regulatory requirements may influence the strategy.

Step 3: Select appropriate ecosystem indicators.

The management strategy leads quite naturally into the choice of specific indicators — those aspects of the ecosystem that can be monitored to reveal its ongoing status. The indicators can be chemical, biological or sociological depending upon the situation. A good indicator will provide information that is relevant to a number of stakeholder concerns.

Step 4: Monitor and assess the state of the chosen indicators.

An effective monitoring program will keep tabs on the indicators and report back to the stakeholders on the state of ecosystem health.

Step 5: Take appropriate action.

Information generated through this process will be used to guide environmental planning and management decisions. It will also feed into new or refined ecosystem goals.

It is important to realize that this process is not a "one-way street." Quite the opposite, the framework is designed to be a dynamic and iterative process that can respond to changing societal priorities, new scientific information, evolving environmental regulations and other issues.

One of the key strengths of this approach is that it provides a mechanism for making environmental decisions that fall completely outside the realms of science. Science can analyze or predict the consequences of specific management decisions and can propose cost-effective solutions to environmental problems, but it cannot make societal decisions regarding the future direction of the ecosystem. Within the northern river basins, for instance, science may be able to predict the consequences of pulp mill effluent on the aquatic environment under several different development scenarios, but it cannot decide if another pulp mill should be built. These issues must remain the responsibility of the public stakeholders within the particular system.

It can be argued that the Northern River Basins Study has followed this framework to some degree in the design of the science program. Through the 16 guiding questions, the stakeholders on the Study Board took the first step towards defining their goals and priorities for the northern river basins. The science program then enacted a strategy to answer these questions and has proposed a suite of indicators to evaluate aquatic ecosystem health and cumulative effects. The specific indicators are listed in the technical synthesis report cited at the end of this section.

IMPLEMENTING AN INTEGRATED ECOSYSTEM MONITORING PROGRAM

The framework represents a theoretical system for assessing and monitoring ecosystem health. Currently, however, there is no administrative body or strategy within the basins to organize such an endeavour. Recognizing this challenge, individuals from the Synthesis and Modelling Component propose the formation of an Integrated Ecosystem Monitoring Committee.

A few responsibilities of such a committee might be to:

- ❑ play a lead role in coordinating monitoring efforts within the basins;
- ❑ maintain a common, standardized inventory of basins' issues, monitoring and research;
- ❑ exploit opportunities to improve monitoring and research efficiency;
- ❑ standardize monitoring protocols;
- ❑ provide guidance to monitoring and regulatory agencies concerning the consequences of monitoring findings;
- ❑ report to government and public stakeholders on monitoring and research activities; and
- ❑ integrate stakeholder concerns regarding priorities, findings and required actions.

A small independent panel of scientific experts from a variety of fields must be established to guide the Committee on technical matters. The Committee must also consider opportunities whereby communities can participate in monitoring activities. Two opportunities exist. First, the membership should include representatives from the community sector. Second, consideration should be given to incorporating volunteers within the notion of community-based monitoring. Harnessing the enthusiasm of volunteers serves two purposes: it promotes a more cost-effective monitoring program and it involves communities in activities that affect their environment.

RELEVANT DOCUMENTS

NRBS Synthesis Reports

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3.12 MODELLING

Related NRBS Questions:

13. a) What predictive tools are required to determine the cumulative effects of man-made discharges on the water and aquatic environment?
    b) What are the cumulative effects of man-made discharges on the water and the environment?
14. What long-term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems? These programs must ensure that all stakeholders have the opportunity for input.

INTRODUCTION

The Northern River Basins Study is one of the first integrated research endeavours to assess the cumulative impact of a broad range of industrial and municipal discharges on the water quality in large northern rivers. As such, the Study faces scientific challenges that might not be experienced in more southerly areas.

Environmental modelling in the Peace, Athabasca and Slave rivers is a scientific challenge because these systems are very large, highly complex and experience dramatic seasonal temperature fluctuations. To further complicate matters, there is very little information on these systems upon which to base modelling efforts. Much of the background information related to water quantity and quality modelling is based on small, southern river systems possessing different physical, chemical and biological characteristics that may not be applicable to large northern rivers.

Shortly after the Study began, a modelling workshop considered the merits of constructing a comprehensive simulation model of the northern river ecosystems. The techniques of building ecosystem models are well known but problems of scale in space and time pose major challenges for collecting sufficient data for calibration. For example, sedimentation processes take place over long periods of time and great distances. In contrast, many plants and animals live for only a few years, microorganisms only a matter of days or hours, and the effects of human activities occur on very local scales.

Splicing together various sub-models to make a comprehensive model is feasible, but usually results in questionable notions of how natural ecosystems function. In brief, current state-of-the-art ecosystem modelling is not yet adequate for modelling river ecosystems. Workshop participants decided that NRBS modelling needs would be better met with sub-models that addressed individual processes, with no attempt to assemble them into an all-encompassing ecosystem model.

What follows is a brief description of the various sub-models developed within the NRBS for predicting water quality, quantity and ecosystem health within the northern river basins. The models fall into three general categories:

- ❑ ***Water quantity modelling describing flow-related processes:*** These one and two-dimensional flow models developed by the Hydrology Component can be used to better predict the flow regimes in these river basins and provide an improved foundation to assess contaminant transport and fate. In addition, the models developed for the Peace River system can be used to better assess the potential effects of flow changes and variability.

- ❑ ***Water quality modelling describing the fate of chemicals in the physical environment:*** Several models developed by the Nutrients and Contaminants components describe the fate of various chemicals in the northern rivers. The Nutrients Component assessed a variety of modelling approaches and developed improved modelling algorithms to predict dissolved oxygen levels in the Athabasca River. The Contaminants Component also developed a contaminant fate model for a specific reach of the Athabasca River that predicts contaminant concentrations in water and sediments downstream from point sources.

- ❑ ***Food chain modelling describing contaminant fate and concentrations:*** The Contaminants Component developed an algorithm to predict contaminant fate and biomagnification in the aquatic food chain. The Food Chain Component provided important insights describing the actual food chains in these river systems, thereby providing additional information on potential routes of contaminant exposure.

This section evaluates the progress made by NRBS modelling endeavours.

NRBS MODELS

A brief description of NRBS models, their usefulness and their contribution to modelling northern rivers is given below.

Dissolved Oxygen
This model evaluates the influence of oxygen-demanding substances and river processes on oxygen production and consumption in the water column and builds upon the Dissolved Oxygen Stochastic (DOSTOC) model developed by Alberta Environmental Protection. This relatively simple model requires very few data compared to more complex approaches, allowing researchers to incorporate data that arose entirely within the northern river basins. Model results were then tested against measured dissolved oxygen changes in the Athabasca River.

The model was relatively successful in predicting large-scale trends in average oxygen concentrations for the Athabasca River, but was unable to capture local oxygen sags downstream of some pulp mills during the 1988-1989 period. This may have been caused by large and erratic loadings of oxygen-demanding substances or limited information regarding tributary and sewage treatment plant loadings.

In addition to DOSTOC, statistical models were developed that describe how oxygen concentrations decline in relation to distance along the Athabasca River from Hinton to Grand Rapids and from there to Lake Athabasca for the years 1988 to 1993.

Both the statistical and DOSTOC models are currently at the stage of verification and application. The Study has made considerable progress with regard to dissolved oxygen. DOSTOC may not be as complex as more sophisticated models, but it provides a simple and reliable framework for predicting dissolved oxygen changes and levels over relatively large reaches of the Athabasca River. It is also a useful tool for evaluating understanding of processes that influence dissolved oxygen concentrations in northern rivers.

Contaminant Fate
The contaminant fate model builds upon the Water Quality Analysis Simulation Program (WASP) developed by the U.S. Environmental Protection Agency. Using WASP, NRBS researchers were able to model the fate and transport of a variety of organic chemicals within the Athabasca and Wapiti / Smoky river systems. The modelling effort focussed on seven contaminants associated with pulp mill effluent.

The model was designed to describe what chemical reactions occur when these contaminants enter the aquatic environment and where they end up within the ecosystem (i.e., bed sediments, water column, etc.) This model is extremely complex in comparison with the relatively simple DOSTOC described earlier. As a result, the model "consumed" all of the information available for the northern rivers and demanded more. Literature values for certain water quality variables had to be adapted for use in the northern rivers. There wasn't enough "leftover" data to evaluate the applicability of these values in northern rivers or to fully test the accuracy of model predictions.

It is difficult to summarize all the results for such a sophisticated model. WASP was much better at predicting the fate and transport of one organic contaminant (2,3,7,8 TCDF) for which there are well defined fate constants. The model was able to reliably simulate the distribution and fate of 2,3,7,8 TCDF in all compartments of the aquatic environment (i.e., water column, suspended sediments and bed sediments). It could also predict levels of the other six compounds in the water column, as long as industrial loadings are well defined. However, the model consistently overestimates levels of these six compounds in bed sediments of the Wapiti / Smoky river system.

In summary, WASP is currently at various stages of development. The model was calibrated for 2,3,7,8 TCDF, although the calibration requires a more thorough assessment. Other elements of the model are still in the formulation stage.

Further progress on this model is hampered by the lack of available information. Researchers had to contend with a weak initial database and uncertainties regarding chemical loadings into the river systems. Also, there was very little information regarding the behaviour of many of the chemical species in the environmental conditions of the northern rivers. Given these challenges, the NRBS made considerable progress in model development for the transport and fate of contaminants. However, more research and calibration is necessary for this model to have useful applications in the northern river basins.

Contaminant Distribution in the Food Chain
The food chain model was designed to simulate the bioaccumulation of organic contaminants within three fundamental components of the food chain: bottom feeding invertebrates, benthic invertebrates and fish. It also identifies the primary source of contaminant exposure for these organisms.

The model was designed to take WASP one step further to predict how environmental levels of contaminants accumulate in the food chain. At this stage of development, it is questionable whether the untested WASP results can be used in this model to produce reliable, accurate predictions.

Six of the seven chemical compounds used in WASP were simulated using the food chain model. Once again, the most reliable results were generated for 2,3,7,8 TCDF. Still, the model tends to overestimate levels of most chemicals when compared to measured levels of contaminants in these organisms.

In summary, the model proceeded to the calibration stage. However, the significant lack-of-fit between the model output and observed values suggests that considerable work is still required to evaluate the reasons that the model failed. It may be that the model fails to take into account the variability of contaminant concentrations or the variation in organisms within and among locations. In particular, more information is required regarding the validity of the food-web configuration used in the model and the spatial movements of fish.

Water Quantity and Hydrologic Processes
Several models were developed or refined by the Hydrology Component of the NRBS. Collectively, these models provided a basis for evaluating the effects of flow regulation the Peace and Athabasca basins. In addition, components of these models provided an improved foundation to assess the transport and fate of contaminants.

A one-dimensional flow model was developed specifically for the Peace and Slave river systems. This model was developed to serve a number of impact-related studies initiated by the NRBS assessing the effects of flow regulation by the W.A.C. Bennett Dam on the downstream aquatic ecosystems of the Peace and Slave Rivers. This model reproduces both regulated and naturalized flows for the rivers and, unlike existing hydrologic models for the Peace River, reproduces discharges at any point along the river. At locations where detailed channel geometry was available, the model also provides accurate estimates of stage and mean channel velocity.

As this model was being developed in tandem with other NRBS studies, the total benefits of the model were not fully utilized during the NRBS. The model was applied to provide "time-of-travel" estimates in the analysis of spring break-up conditions on the lower Peace River adjacent to the Peace-Athabasca Delta. Future application of the model could include linkages with evaluating and quantifying morphologic changes along the Peace River and in the Slave River Delta. The model also has applications in meso-scale evaluations of aquatic habitat using low level multi-spectral imagery (as was done in the NRBS).

Several other models were utilized by the Hydrology and Other Uses components to address Study Board question #10. To apply the one-dimensional hydraulic model to the Peace and Slave rivers, a geometric model had to be developed. Although this model was designed specifically for hydraulic modelling, a considerable amount of cross-sectional data was used. The actual cross-section sites were documented, recognizing the future value of this geometric database. Pre-existing "hydraulic geometry" models were also applied to assess channel morphology on the Peace River and in the Slave River Delta. A sediment-based time scale adjustment model was also utilized to estimate how long before the regulated regime will taketo come to equilibrium. Evaluation of the hydrometeorlogical conditions controlling ice-jam floods on the Peace River near the Peace-Athabasca Delta required the use of various empirically and physically based models.

SUMMARY

The ability to ascertain the impacts of development on the aquatic ecosystem is actually a two-stage process:

- ❑ *Stage one models* describe the environmental changes caused by human influences (e.g., the distribution and fate of industrial chemicals within the aquatic environment, and their effects on water quality conditions).
- ❑ *Stage two models* predict how these environmental changes affect organisms that rely on the aquatic ecosystem (e.g., changes in the growth, reproduction, mortality and distribution of specific species).

Models developed within the NRBS generally fall within the stage one category. The scientific rationale behind this position is justifiable, given the lack of information that existed in the basins prior to the Study. Given this challenge, the NRBS made considerable progress in the development of predictive tools in some areas, and laid a scientific foundation in other areas for future modelling efforts. Knowledge generated within the Study regarding the impacts of human development on environmental conditions must now be used to predict the effects of these changes on living organisms.

RELEVANT DOCUMENTS

Primary NRBS Technical Report

McCauley, E. 1996. *A Review and Evaluation of Water Quality and Quantity Models Used Under the Northern River Basins Study*. Northern River Basins Study Technical Report No. 82.

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3.13 HUMAN HEALTH

INTRODUCTION

When compared to other countries, the northern river basins environment has not generally placed residents at great risk to their health. However, research within the Traditional Knowledge Component reveal that a substantial proportion of the local people are concerned about the subtle link between the state of their environment and diseases such as cancer, diabetes, heart problems, diarrhea, asthma, and other health problems in their communities.

According to a 1988 Environment Canada study, the Canadian public considered the environment to be first and foremost a human health issue, although concern for plant and animal life was also very high. A majority believed that pollution was affecting their family's health and more than 90 per cent believed that a number of environmental hazards were causing serious health problems. The respondents were particularly concerned about chemicals in water and air, and about protecting drinking water supplies.

The preoccupation with environmental health issues has not changed over the past decade. As with other Canadians, northern river basins residents now realize that health and environmental quality are inseparable. The top health-related environmental issues that were repeatedly raised during the Study's community gatherings, surveys, scientific forums and individual discussions include water and air pollution, contaminants and drinking water quality. In its simplest form, the recurring questions *"Can we eat the fish?"*, *"Can we drink the water?"*, *"Can we breathe the air?"*, *"Can we use the land?"* prompted the Study Board to establish the Human Health Committee to champion our understanding of health and the environment.

One of the committee's major tasks was to identify environmental issues and human health concerns and ensure that they are thoroughly examined. Another task was to initiate a study of health status in the Alberta portion of the Study area. Recognizing the importance of the human health concerns, the Minister of Health launched the Northern River Basins Human Health Monitoring Program on October 28, 1994. The results from this two-year, $300 000 companion study are expected by late 1996.

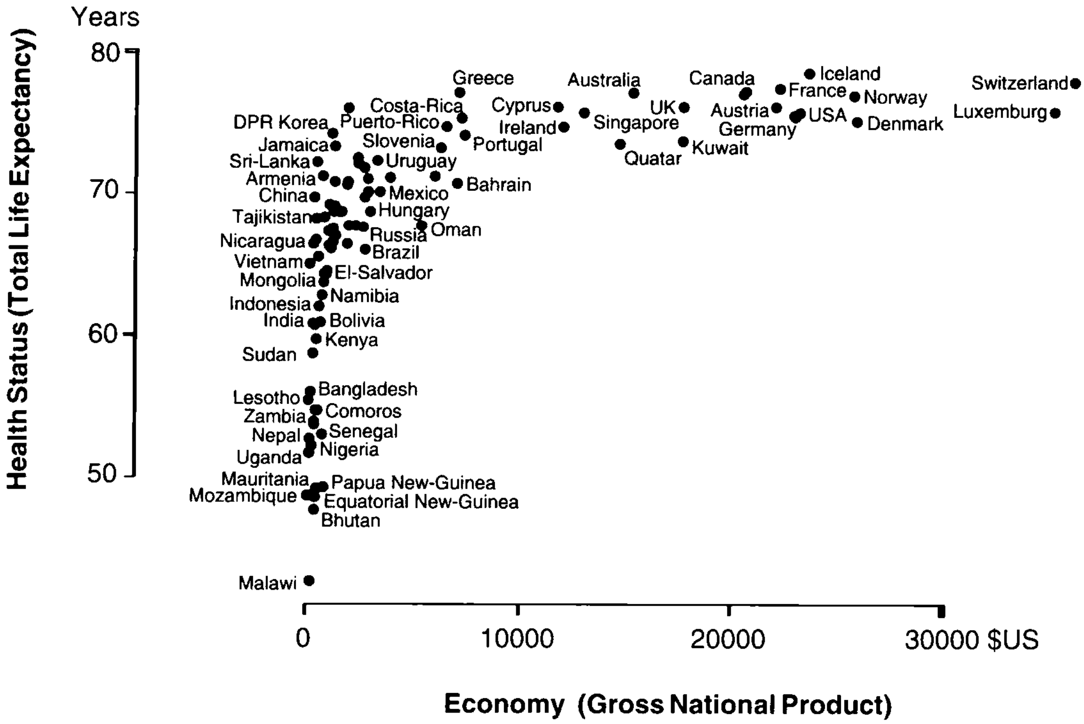
The first phase of the monitoring program will seek answers in three major areas represented by environmental stressors, human exposure, and health status. In the first area, that of environmental factors, the study will attempt to review chemical, physical and biological agents from a human health perspective. These will be prioritized based on their relative importance. In the second area, that of human exposure, the scientists will assess potential pathways of exposure such as drinking water, consuming fish and breathing the air. Third, disease rates will be analyzed to identify linkages, if any, between the health status of the population and environmental determinants.

GENERAL HEALTH

Economic development has dramatically improved the quality of people's drinking water, nutrition, housing, clothing and general sanitation. As shown in Figure 3.13.1, a strong relationship exists between economy and health. People in developed countries experience alonger life span than those who live in less developed nations. Over the past 70 years, development contributed to the significant increase in the life expectancy of all Albertans (Figure 3.13.2). Today, there are small differences in the regional life expectancies. People living in northern Alberta have a slightly shorter life expectancy than those living in central and southern Alberta (Figure 3.13.3).

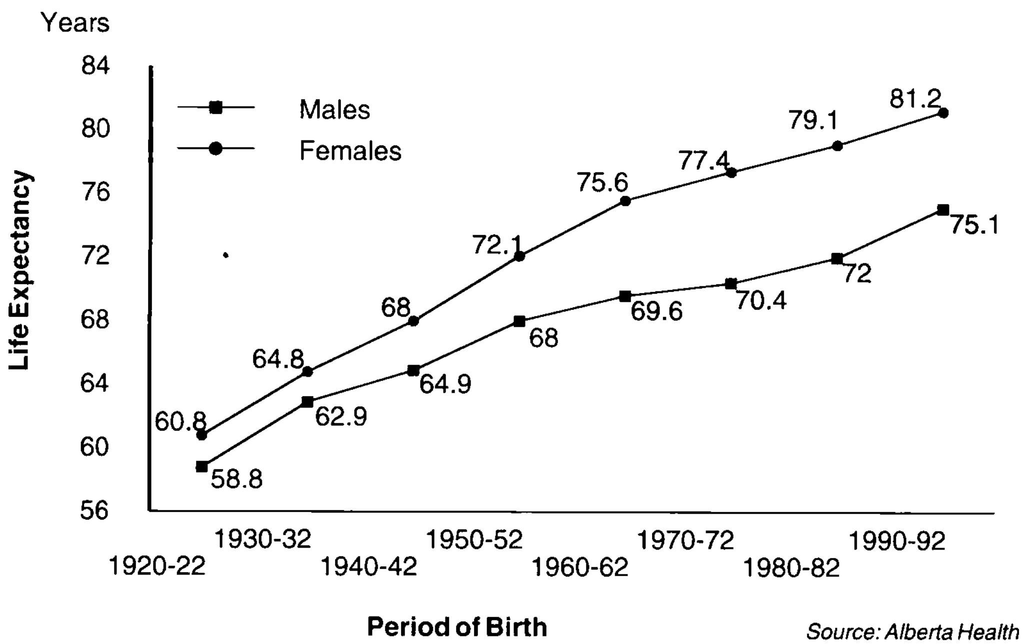
Although life expectancy is steadily increasing, accidents, cancer, suicide, heart disease, stroke and respiratory disease remain the major causes of premature death in Alberta. Loss of life at an early age is reflected by the potential years of life lost (Figure 3.13.4). Many of the concerns raised by northern river basins residents are also found on

Fig. 3.13.1 Economy and Health Status (Selected WHO Member Countries, 1991-1993)



Source: World Health Organization

Fig. 3.13.2 Study Area Life Expectancy: An Historical Perspective



Source: Alberta Health

this list. Not all major causes of death have close links with the environment, but some do. In particular, certain types of cancer are known to be partially linked to environmental factors. Lifestyle choices such as drinking and smoking, along with genetic influences are among other important contributing factors in the causes of death.

Death in the first year of life or infant mortality is a population health indicator. Infant mortality is related to prenatal care, the mother's health, access to health care and congenital conditions or diseases. Slight regional differences may result both from the small number of infant deaths and the small number of babies born. The infant mortality in the seven northern Alberta health regions is illustrated in Figure 3.13.5.

Birth weight is a health indicator of newborn babies. Low birth weight babies are more likely to have health problems, developmental delays, learning and behavioral differences. The proportion of low birth weight babies in the seven northern Alberta health regions is illustrated in Figure 3.13.6.

In a recent Alberta survey on health, people were asked to rate their health status compared with others of their age. The Traditional Knowledge Component also conducted a survey in selected northern communities, asking respondents to rate their health on a scale of one to five. A comparison between the two studies shows that approximately the same proportion of respondents rated their health as being "excellent" (Figure 3.13.7). However, a larger proportion of the northern residents reported their health "somewhat poor" (fair) and "poor." Such regional differences in self-reported health status may result from a combination of health determinants including the economic and social environment, physical environment, personal health practices, individual capacity and coping skills, and health services.

FIG. 3.13.3 STUDY AREA LIFE EXPECTANCY: REGIONAL DIFFERENCES (1990-92)

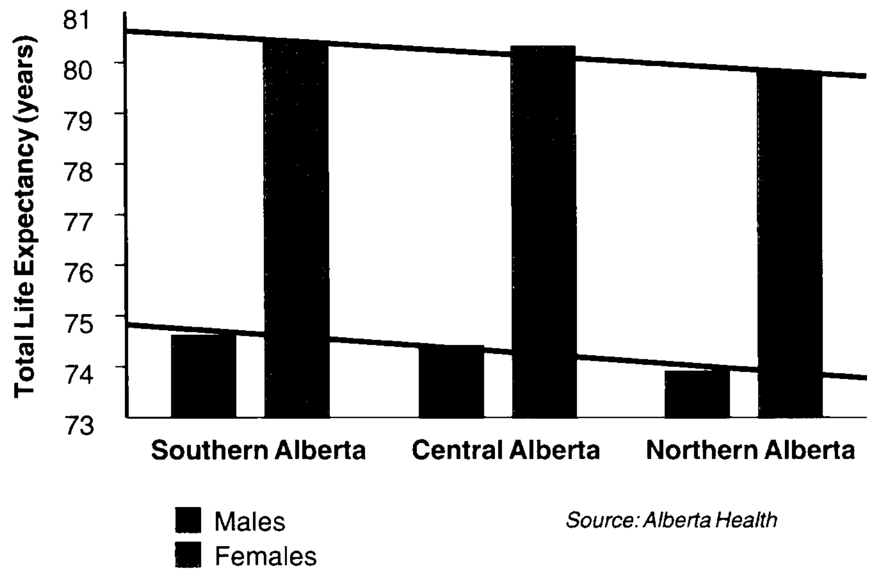
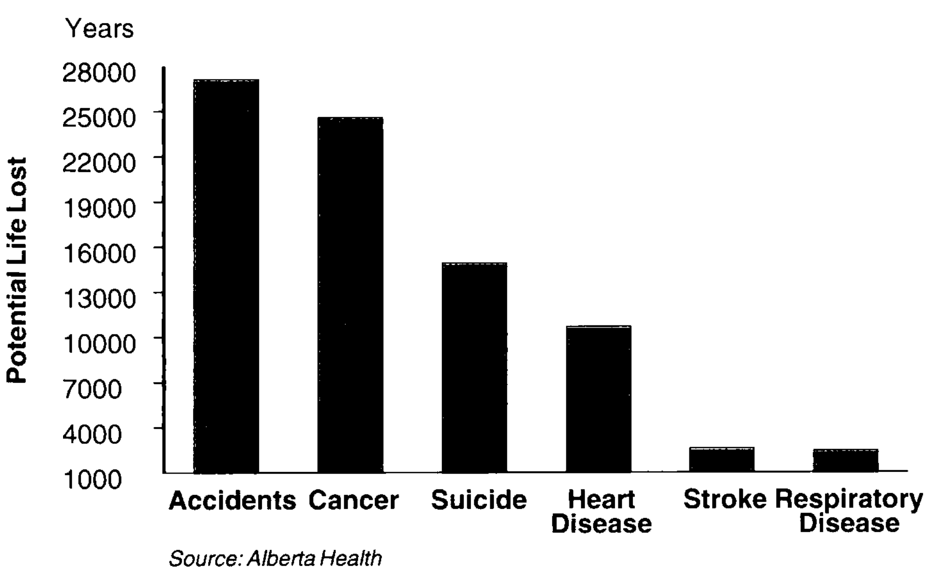


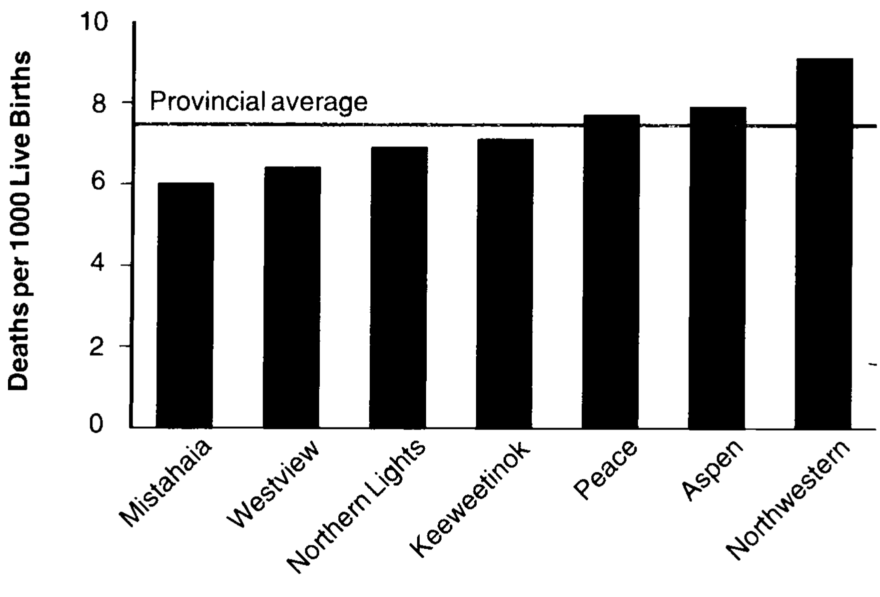
FIG. 3.13.4 MAJOR CAUSES OF PREMATURE DEATHS IN ALBERTA (1992)



CONTAMINANTS IN FISH

Safe food and drinking water supplies are essential to protect human health. While food and drinking water sustain us, they are usually the major route for contaminants to enter our bodies. People are exposed to contaminants mainly through contaminated food, such as fish, meats, poultry, eggs, milk and dairy products. The presence of contaminants in the food chain is a concern for many local people in

FIG. 3.13.5 INFANT MORTALITY RATES IN NORTHERN ALBERTA: REGIONAL DIFFERENCES (1993-1994)



Source: Alberta Health

the Study area who rely extensively on traditional foods for subsistence.

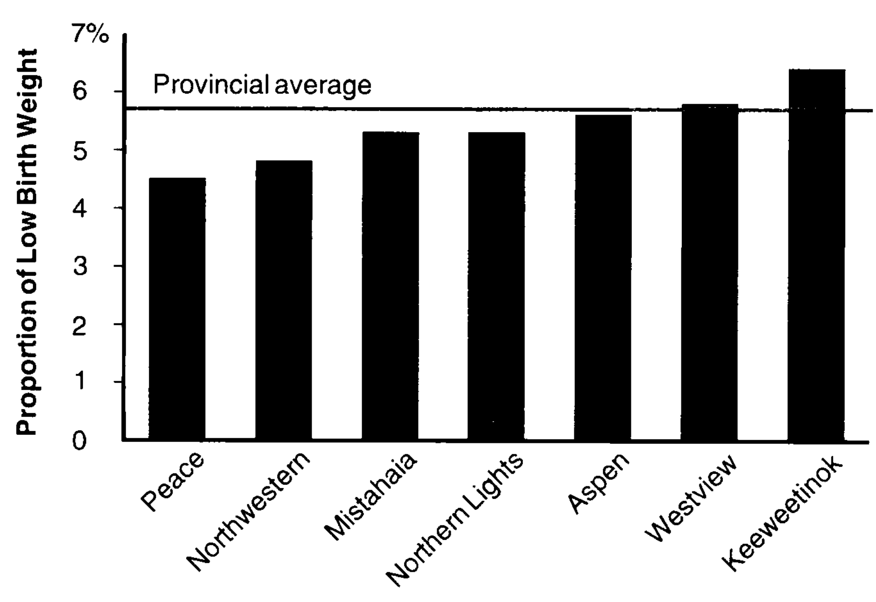
During the Study, over 3 000 fish representing 25 species were submitted for various chemical analyses by the NRBS scientists. Most of the analyses (91 per cent) were for six species:burbot, mountain whitefish, longnose sucker, northern pike, walleye and goldeye.

Computerized databases required by an in-depth human health risk assessment are currently being developed. While an extensive review of contaminants in fish is not yet complete, a preliminary assessment of these data indicates that mercury and methylmercury, 2,3,7,8-TCDD and 2,3,7,8-TCDF, and toxaphene should be reviewed from a human health perspective. Other contaminants such as PCBs, chlorinated phenolics and radionuclides were generally at low levels, within the human health consumption guidelines.

MERCURY

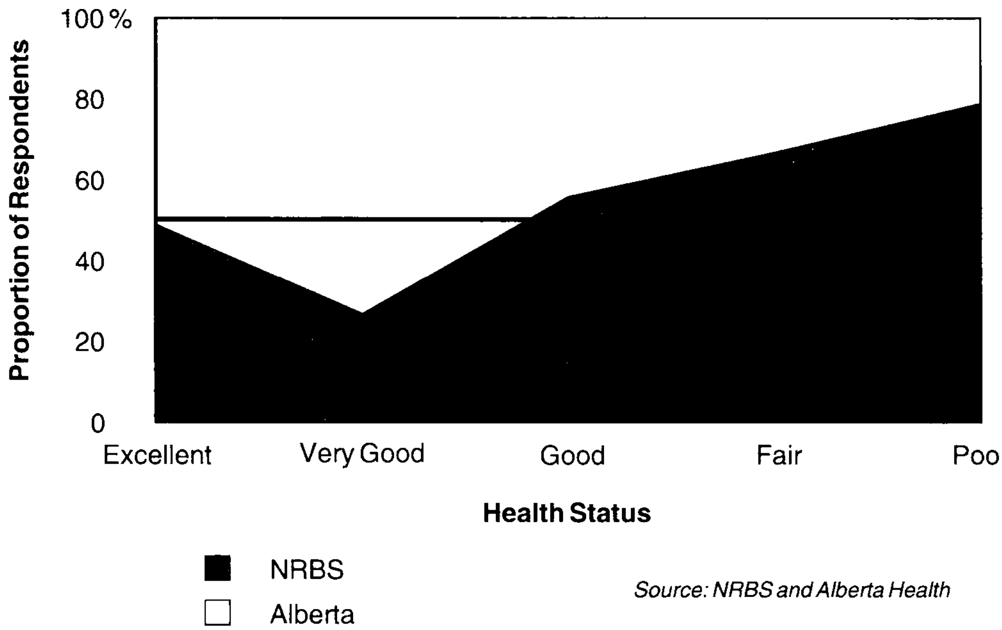
People are exposed to mercury largely through the food chain (e.g., by consuming mercury-contaminated fish). Organic mercury (methylmercury) is more toxic than the inorganic (metallic mercury). When methylmercury is ingested, it rapidly enters the bloodstream and is distributed throughout the body. Certain organs, particularly the liver and kidneys, accumulate more of it than others. Mercury is slowly accumulated in the brain where in sufficiently high doses it affects the brain's sensory, visual, auditory and coordinating functions. A developing fetus may be affected in many ways; possible effects include retarded physical growth and coordination, and cerebral palsy as well as delayed development of intellect and behaviour.

FIG. 3.13.6 LOW BIRTH WEIGHT IN NORTHERN ALBERTA: REGIONAL DIFFERENCES (1993-1994)



Source: Alberta Health

FIG. 3.13.7 PERCEIVED HEALTH STATUS: COMPARISON OF SELECTED NORTHERN COMMUNITIES AND ALBERTA



Source: NRBS and Alberta Health

A few initial observations on mercury with relevance for human health are:

- mercury was found in fillets or liver of all fish species sampled in the Athabasca, Peace and Slave river systems;
- levels in fish tissue are relatively stable since the mid-1980s;
- levels tend to be highest in predatory fish (e.g., pike, walleye, goldeye, pike and burbot) at the top of the food chain;
- concentrations in walleye vary among geographic sites with an increasing trend toward the mouth of the Athabasca and Peace rivers; and
- levels in some fish species exceeded the Health Canada guideline limit for human consumption.

Existing fish consumption restrictions in the Study area extend to walleye in the mainstem Athabasca river. From a health perspective, it is generally recommended that a balance be found between traditional foods, which can provide an excellent source of protein in the form of fish, and the potential danger to health due to mercury. Certain types of fish with generally lower levels of mercury, such as suckers and whitefish, may be favoured over those with high levels, such as walleye, pike, goldeye and burbot. Pregnant women and children under the age of 15 should not consume mercury-contaminated fish.

The observed mercury levels along the rivers, fish movements, fish type and the dietary patterns of the local people are important factors to be considered in the development of new, health-based fish consumption advisories. Considering the significant geographic variation of mercury in fish and the types of contaminated fish, the applicability of the current health advisories and the geographic boundaries as well as the fish species should be re-evaluated and adjusted based on the new information generated by the NRBS.

DIOXINS AND FURANS

Wastewater from pulp and paper mills contains many potentially hazardous chemicals. While dioxins and furans can originate from natural sources such as forest fires, most are released in the environment by pulp and paper mills that use chlorine bleaching, combustion sources such as incinerators, burning wood and motor vehicles. They have been classified as "toxic" to health and the environment under the *Canadian Environmental Protection Act*.

Much of the health concern about dioxins and furans stems from the result of animal toxicity tests. Animals exposed to 2,3,7,8-TCDD, the most toxic of the dioxins and furans, experienced weight loss, skin disorders, impaired liver function, and impaired reproduction including birth defects and cancer. It is difficult to assess the human health effects of dioxins and furans. It does appear, however, that effects on humans are much more limited than those on animals. The human health effects most consistently observed in occupational exposure settings are chloracne and other skin problems, as well as effects on the liver, immune system and behaviour.

People are exposed to dioxins and furans mainly through contaminated food, such as fish, meats, poultry, eggs, milk and dairy products. Air, soil, water and consumer products are minimal contributors to exposure.

Some general observations on dioxins and furans with relevance for human health are:

- highest dioxin and furan levels on the Athabasca River were found in 1992, within 50 km downstream from the town of Hinton (levels returned to control values within 115 km);
- highest levels on the Peace River were measured in 1992 on the Wapiti River near the town of Grande Prairie and at the confluence of Smoky and Peace rivers;
- significantly higher levels were observed in mountain whitefish than longnose suckers;
- concentrations in fish vary among geographic locations with a decreasing trend toward the mouth of the Athabasca and Peace rivers;
- levels have declined substantially relative to the late-1980s; and
- levels in burbot livers at two sampling sites nearest to Grande Prairie exceeded the Health Canada limit for human consumption.

Existing fish consumption restrictions for dioxins and furans extend to the upper reaches of the Peace and Athabasca river basins. Bull trout, burbot and mountain whitefish are affected in the Athabasca (upstream of Whitecourt, Iron Point and Fort Assiniboine), Berland, Wildhay and McLeod rivers. Burbot and mountain whitefish are contaminated in the Wapiti, Cutbank, Kakwa, Smoky, Little Smoky and Simonette rivers. From a health perspective, the current advisory recommends that only the fillet portions should be eaten; organs such as liver should be discarded. In the Athabasca River drainage, mountain whitefish should be limited to one meal per week. In the Peace river drainage, mountain whitefish should not be eaten at all.

Considering the decreasing trends of dioxins and furans in fish and their geographic variation, the applicability of the existing health advisories and the geographic boundaries should be re-evaluated and adjusted based on the newly available information.

TOXAPHENE

Toxaphene is an organochlorine insecticide. This group of compounds also includes DDT, chlordane and lindane. Because of their particular structure, the organochlorines do not break down easily and therefore remain in the environment for a long time. As a result they have the tendency to accumulate in the food chain, potentially resulting in health risks in humans.

A total of 571 tissue samples were analyzed for toxaphene using a detection limit of 0.05 ppm or 0.01 ppm. Among the samples analyzed using the higher detection limit, 95 per cent of the samples were below the detection limit. Only five per cent of the tissue samples were above the limit. All of the walleye, goldeye and lake whitefish tissue samples were below 0.05 ppm. Burbot, mountain whitefish and pike accounted for all the positive samples. When using the 0.01 ppm detection limit, approximately 16 per cent of the samples were above the detection limit. Mountain whitefish accounted for most of the positive samples followed by the longnose sucker and burbot.

There are currently no fish consumption restrictions for toxaphene in Alberta, but the Government of the Northwest Territories health authorities have issued a cautionary note regarding burbot liver taken from the Slave River.

Related Documents

NRBS Synthesis Reports

Gabos, S. 1996. *A Review of Population Health Status in Northern Alberta.* Northern River Basins Study Synthesis Report No. 6.

Flett, L., Bill, L., Crozier, J. and D. Surrendi. 1996. *A Report of Wisdom Synthesized from the Traditional Knowledge Component Studies*. Northern River Basins Study Synthesis Report No. 12.

Other Relevant Documents

Alberta Health. 1995. *Results of a Public Survey on Health and the Health System in Alberta*. Edmonton, Alberta.

Environment Canada. 1988. *Public Opinion and the Environment*. Ottawa, Ontario.

Health and Welfare Canada. 1991. *Pulp and Paper Mill Effluent: Issues*. Health Protection Branch. Ottawa, Ontario.

Health and Welfare Canada. 1990. *Mercury, Fish and You. Mercury Questions and Answers.* Medical Services Branch. Ottawa, Ontario.

Hum, L.C. and R. Semenciw. 1991. *Mortality Patterns in Canada, 1988*. Chronic Diseases in Canada.

Wheatley, B. and S. Paradis. 1995. Exposure of Canadian Aboriginal peoples to methylmercury. *Water, Air and Soil Pollution*. **80**: 3-11.

3.14 CUMULATIVE EFFECTS

INTRODUCTION

"Cumulative effects" is the phrase used to describe the additive and interactive effects of stressors acting at different temporal and geographic scales within the ecosystem. Within the northern river basins, the study of cumulative effects is complicated by a number of factors, such as the size of the basins, the meagre amount of information related to large northern rivers, the variety of environmental stressors and their complex interactions among individual stressors within the ecosystem. This section highlights the cumulative effects of development in the northern river basins and discusses their ramifications with regard to ecosystem health and continued human use of aquatic resources. A more thorough examination of this topic can be found in the NRBS synthesis report No. 11, entitled *"Cumulative Impacts within the Northern River Basins."*

ECOSYSTEM HEALTH

In this report, cumulative effects are categorized into several key issues relating to ecosystem health: the effects of chemicals, changes to flow regimes, the effects of nutrients and dissolved oxygen, the health of aquatic biota, and effects and implications for human populations.

Cumulative Effects of Chemicals

Major findings related to cumulative effects of chemicals are illustrated in Figure 3.14.1. A priority of NRBS research was to collect information regarding levels of organochlorines and other contaminants in the aquatic environment. Environmental concentrations of chlorinated organic compounds, such as dioxins, furans, chlorinated resin acids, and chlorophenols, have declined overall since the late 1980s, but are still found in detectable levels in sediments and fish in the basin. Traces of pulp mill-related compounds in sediments from Great Slave Lake confirm that these compounds are transported great distances downstream.

The reductions are partly due to improved mill technologies that have reduced effluent loadings of certain contaminants, especially organochlorine contaminants. Environmental processes have also influenced the distribution of contaminants within the ecosystem; for instance, the annual influx of sediment tends to bury previously contaminated sediments.

Generally, highest concentrations of chlorinated compounds still tend to occur in reaches immediately below pulp mill effluent inputs. The highest levels of organochlorine compounds (dioxins and furans) associated with sediments and aquatic life were measured in the reach between Hinton and the Emerson Lakes sampling site on the upper Athabasca River. Levels of specific contaminants in sediments from this reach exceed guidelines developed by the Canadian Council of Ministers of the Environment. Higher frequencies of physical abnormalities in aquatic invertebrates confirm that this reach of the Athabasca River has been subjected to the cumulative effects of development.

Research has confirmed that the atmosphere is a source of contaminants (including PCBs) However, the variation in PCB concentrations across the basins suggests the existence of additional point-sources. Higher PCB levels in burbot were found in the Wapiti / Smoky rivers, the Peace River and the Athabasca River downstream of Hinton and Whitecourt. Elevated PCB levels in sediments were found in the Wapiti / Smoky rivers and in the Peace River upstream of the Smoky River confluence.

Higher PCB concentrations in some reaches of the Wapiti / Smoky and Athabasca river basins may be related to point-source inputs into the environment, such as those occurring from spills. In three locations within the Peace River drainage, observed levels of PCBs in burbot doubled between 1992 and 1994. The reason for this is unclear, but deserves further investigation. Higher PCB concentrations in some fish species may be partly related to different eating habits.

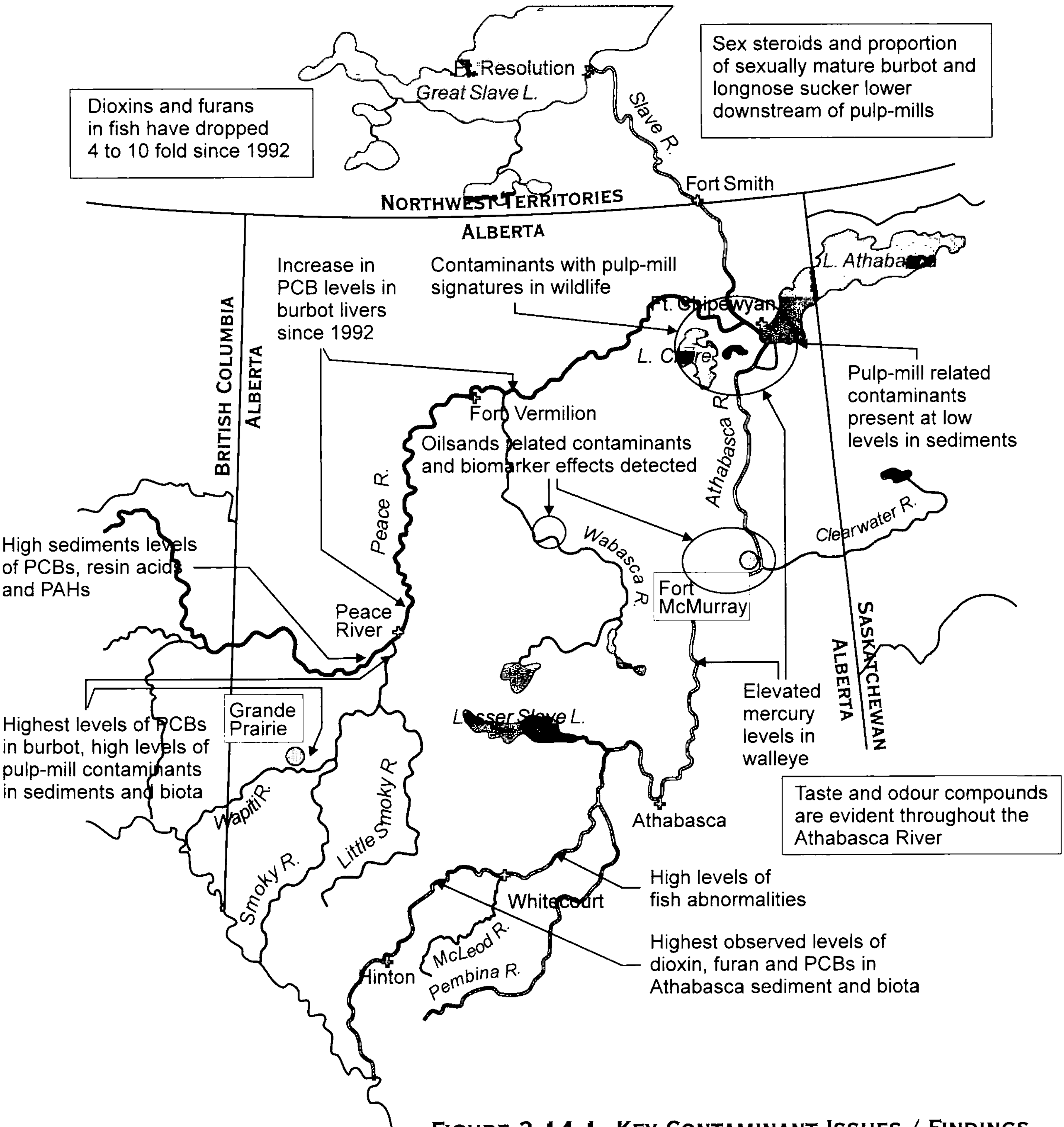


FIGURE 3.14.1 KEY CONTAMINANT ISSUES / FINDINGS

Mercury contamination of fish is a concern among basin residents. In contrast to the downward trend of organochlorine contaminants, mercury concentrations in sediments and fish tissues throughout the basins has not changed since the late 1980s. However, one concern relates to walleye, which sometimes exceed Health Canada mercury guidelines in the lower Athabasca. Existing fish consumption restrictions in the Study area extend to walleye in the mainstem Athabasca River.

Current health advisories for all fish species should be re-evaluated and adjusted based on fish consumption patterns within the basins. For more information related to mercury and fish consumption refer to Section 3.13.

Cumulative Effects of Hydrology and Climate
Major findings related to the cumulative effects of hydrology and climate change are illustrated in Figure 3.14.2. NRBS research has furthered knowledge of how flow regulation has changed the natural river flow of the Peace River system. A detailed discussion of these changes is found in Section 3.5 of this report. To summarize, within the Peace River:

- peak spring flows have decreased and occur later;
- summer flows have decreased;
- winter flows have increased;
- ice is weaker, coarser and forms later; and
- tributary flows are now more important to maintaining summer flows.

Many of these effects are dampened with distance from the Bennett Dam in British Columbia. These alterations, combined with climate variability, have had a dramatic impact on the ecology of the Peace basin, including drying of the Peace-Athabasca Delta perched basins, changes to vegetation of wildlife, and alterations to the geomorphology of the mainstem Peace River. Further information regarding the impact of the Bennett Dam can be found in Section 3.5.

On a human scale, one of the cumulative impacts of these changes is related to residents' lifestyles. Residents contacted by the Traditional Knowledge Component reveal that traditional basin residents rely on the rivers for their culture and lifestyle (Section 3.4). Not surprisingly, these hydrological changes have had a pronounced affect on their perceptions of ecosystem health and their quality of life, and have caused them to change their use of the basin resources.

Many of the perceptions and commonly held beliefs of basins residents regarding the state of the basins ecosystem were corroborated by NRBS research. Some of these observations include reduced flooding in the Peace-Athabasca Delta, changes in sediment patterns along the Peace River, increased turbidity in certain river reaches and alterations to aquatic and nearshore habitats.

Cumulative Effects of Nutrient Addition and Dissolved Oxygen
Zones of concern for nutrients and dissolved oxygen are illustrated in Figure 3.14.3. Nutrient discharges into the northern rivers have been shown to enrich aquatic communities immediately downstream of point sources, such as pulp mills and municipalities (see Section 3.7). Currently, the cumulative effect appears to be primarily aesthetic — related to an increase in the amount of algae in reaches immediately downstream of nutrient discharges.

During winter, dissolved oxygen levels tend to decrease naturally along the length of ice covered rivers such as the Wapiti / Smoky and Athabasca rivers. In addition, there are noticeable "sags" below major effluent discharges from communities and certain pulp mills. Oxygen concerns exist in the Athabasca River upstream of Grand Rapids, and in the Wapiti / Smoky river system downstream of Grande Prairie to the confluence of the Peace and Smoky rivers (see Section 3.8 for further detail). In these areas, the number of developments, combined with ice cover, significantly reduces winter dissolved oxygen levels in specific reaches. The Wapiti / Smoky system has lower flows and the oxygen depletion is much greater than in the affected Athabasca River reaches.

Pulp mills are one of the larger man-made sources of oxygen-demanding substances being directed to the aquatic ecosystem. To reduce their discharge of these substances, pulp mills will often add nutrients to improve their effluent treatment process. These nutrients are intended to enhance bacterial breakdown of organic compounds in the effluent prior to its release into the environment. In such cases, any excess nutrients enter the aquatic environment and further enhance aquatic productivity, which can contribute to the use of dissolved oxygen in the aquatic environment.

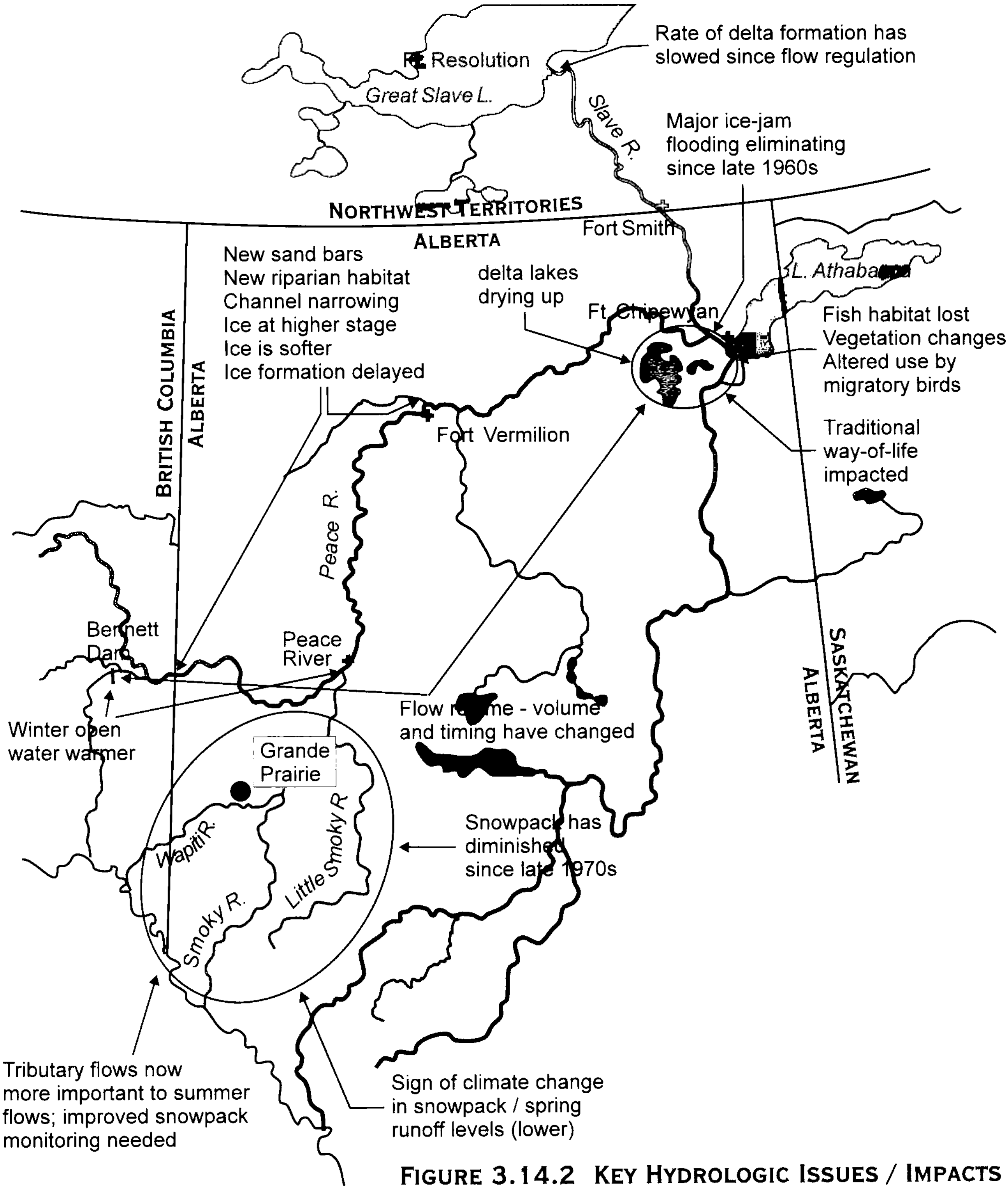


FIGURE 3.14.2 KEY HYDROLOGIC ISSUES / IMPACTS (PEACE AND SLAVE RIVER BASINS ONLY)

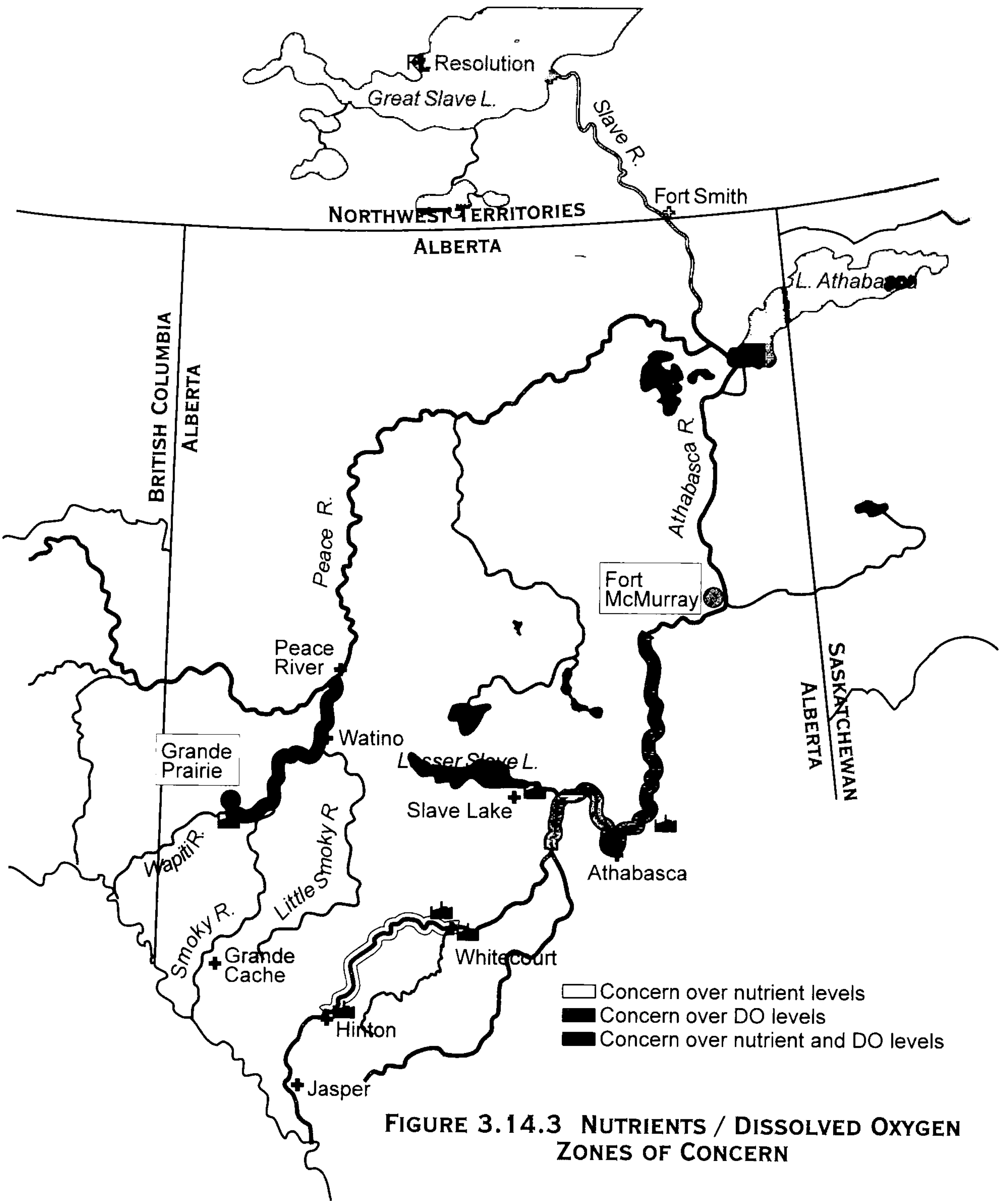


FIGURE 3.14.3 NUTRIENTS / DISSOLVED OXYGEN ZONES OF CONCERN

The cumulative effect of continued or increased nutrient loadings to these systems is currently unknown and requires further investigation.

Health of Aquatic Biota

Several independent NRBS investigations confirm that some fish in certain areas of the northern river basins are being affected by the cumulative effects of development discharges to the aquatic ecosystem. Traditional peoples have expressed a concern over the observed decline in the quantity and quality of fish from the lower Peace and Athabasca rivers, the Peace-Athabasca Delta and the Slave River. The cause for these changes remains largely unknown.

Using a suite of biomarkers, NRBS researchers determined that some fish in select river reaches are exhibiting signs of environmental stress (see Section 3.9). Certain fish captured downstream of pulp mills displayed higher frequencies of physical abnormalities (i.e., scars, lesions, tumours, etc.) and depressed levels of sex hormones. There were also higher numbers of sexually immature fish captured immediately downstream of pulp mills. The oil sands regions located near Fort McMurray in the Athabasca River and in the Wabasca River are also sites where fish are exhibiting signs of stress. It should be noted, however, that NRBS biomarker research is currently insufficient to fully describe the nature and extent of these problems. Further research is required to understand the link between biomarker responses in individual fish and population / community level effects.

A critical knowledge gap exists with regard to the availability of fish habitat, particularly in the mainstem rivers. Fish habitat in the delta regions has also been affected by changes in flow patterns and flooding frequency. These changes have greatly reduced the availability of spawning habitat for spring spawning fish and have physically isolated certain lakes and streams within the Peace-Athabasca Delta. These flow regulation effects may also be true for the Peace River.

NRBS studies show that fish species spawn in tributaries and the mainstem rivers. They are most vulnerable to point source pollution on the mainstem systems where industry and municipalities are dominant. One critical feature of mainstem river habitat is the availability of sufficient levels of dissolved oxygen. Since low dissolved oxygen levels can impair the development and survival of fish and other aquatic organisms, it is imperative to ensure that human activities do not critically reduce these levels within the river, particularly during the winter.

As with fish, benthic invertebrates are sensitive to pulp mill effluent and municipal discharges. There is evidence that nutrients in pulp mill and municipal effluent are enhancing the density of invertebrates that inhabit substrates downstream of the mills — a common enrichment response. While on a basin-wide scale substrate quality appears to be acceptable, there is some evidence indicating that the Athabasca River reach between Hinton and Whitecourt is ecologically impacted. Deformities in fish occur naturally, but NRBS studies found a slightly higher than the normal incidence of deformities immediately downstream of pulp mills in this reach. Incidences of deformities returned to normal as the river progressed downstream.

Cumulative Effects and Implications to Human Use

The NRBS generated information on topics that may be related to human health, such as drinking water quality. Furthermore, the Other Uses and Traditional Knowledge components have collected a large amount of information regarding human perceptions, values and concerns with regard to the environment, as well as their use of basin resources now and into the future. Generally speaking, other scientific findings within the NRBS have served to confirm many commonly held beliefs by basins residents regarding the quality of the basins' ecosystem.

The large majority of residents received high quality drinking water from municipal treatment facilities. However, NRBS studies found several instances where the quality of treated water from small facilities failed to meet guidelines (see Section 3.10). A number of these facilities failed to meet guidelines for turbidity or microbial content. In addition, a small number of facilities exceeded guidelines for trihalomethanes — by-products of chlorine disinfection.

Industrial contaminants in drinking water do not appear to be a public health issue at this time. However, some residents believe that waters downstream of pulp mills are tainted with effluent. NRBS has confirmed that tainting substances can be chemically detected hundreds of kilometres below point sources. However, concerns regarding these substances are primarily aesthetic, and levels of these compounds have decreased due to improved pulp mill technologies on the Athabasca River. Less is known on the topic of fish tainting. Anecdotal evidence suggests that fish are tainted downstream of pulp mills and in the oil sands region near Fort McMurray. Research has been unable to identify the specific tainting compounds.

Communities situated on the lower Peace, Athabasca, and Slave rivers insist that they are on the receiving end of pollution originating from upstream developments or industrial plants. The distance that contaminants travel downstream is a function of their specific chemical and physical characteristics within water. Traces of contaminants that are commonly associated with pulp mills can be found as far downstream as Great Slave Lake.

Some aboriginal people have expressed concern regarding the quality and quantity of fish and wildlife they consume and how these species may be affected by contaminant exposure. Levels of mercury, dioxins and furans were usually at barely detectable or non-detectable levels in wild foods, including fish, waterfowl, muskrats and mink. One exception exists in the lower Athabasca River, where mercury levels in walleye often exceeded Health Canada guidelines. Fish consumption advisories are currently in place in this region.

At present, there is no information that allows the NRBS to comment on long-term implications to either human or ecological health caused by long exposure to low levels of contaminants. A companion study to the NRBS (the Alberta Northern River Basins Human Health Study) will shed further light on health-related issues in the basins.

SUMMARY OF CUMULATIVE EFFECTS BY RIVER REACH

As shown in the Key Findings and Cumulative Effects Assessment sections of this report, cumulative environmental effects manifest themselves at a variety of spatial, temporal, and organizational scales within the ecosystem. Although it is important not to lose sight of cumulative effects occurring at a basin-wide level and the inter-relatedness among river reaches, we now summarize our understanding of cumulative impacts on a reach-by-reach basis. This approach provides the opportunity to focus on characteristics which are unique to reaches and identify related management considerations. A summary of scientific findings is provided, as is a social perspective which was developed from input obtained at community gatherings, science fora, and through the household and traditional knowledge surveys. In addition to the individual reach profiles, a basin-wide profile is included to highlight those factors that apply throughout the basins.

While this summary is inclusive of NRBS and companion investigations, we remind the reader that investigation of some facets of the ecosystem including: climate change, agriculture practices, forestry management, biodiversity and human health were beyond the scope of this study. While these issues were not investigated directly, they will almost certainly have implications for cumulative effects within the basins and should not be ignored in any future ecosystem management program.

As well, because of the higher level of industrial pressure, primarily existing pulp mills, the NRBS science program placed a greater emphasis on the Athabasca River than on the Peace and Slave rivers. The reader is therefore cautioned that not all issues were equally investigated in all reaches, and this reflects perceived impact priorities at the outset of NRBS. Issues not investigated (e.g., nutrient enrichment studies on the Peace River), should not be interpreted to mean that these issues are not important, rather they reflect the research and funding priorities of the NRBS.

Figure 3.14.4 summarizes overall cumulative effects with the northern river basins on a reach-specific basis. This figure provides a mechanism for illustrating priority areas for environmental management and identifies issues of concern based on a weight-of-evidence approach. Within each reach a histogram, consisting of five stacked boxes, is provided. Each box represents one of the five major issues in the basins (i.e., dissolved oxygen, nutrient enrichment, hydrologic regime, human health implications and contaminants) and the shading of the box reflects the level of concern for that issue in that reach. A completely dark box indicates significant concern and a need for action. A partially shaded box indicates caution and a need for ongoing monitoring and / or further investigation. A clear box indicates that, based on current information, the issue is of minimal concern. In most cases ongoing routine monitoring should be adequate for those issues designated as being of minimal concern; however, further investigation may result in a change in designation for some of these issues.

The purpose of Figure 3.14.4 is to provide a general overview of cumulative effects in these basins. A more detailed description of these effects is provided on a reach-by reach basis in the following section. The histograms presented in Figure 3.14.4 are provided again in this section along with the criteria and rationale used to determine the levels of cumulative effects concern.

BASIN-WIDE

Scientific Summary

The basin-wide fish surveys and other fish collections by NRBS have confirmed that dioxins and furans occur in the food web at low levels across the basins, relative to other areas in Canada. The highest detection frequencies for all 2,3,7,8-substituted dioxin / furan congeners were observed immediately downstream of bleached kraft mills.

NRBS corroborates other investigations which have reported a recent decline in concentrations of dioxins and furans in fish, commensurate with improvements in pulp mill treatment technologies. Although there is evidence of PCB contamination in both the Athabasca and Peace river systems, PCDD/Fs, rather than PCBs or organochlorine pesticides, are the chemicals of concern for human exposure. Levels of TCDD and TCDF, the major contributors to toxicological concerns in these groups of compounds, are expected to decline further because of technology improvements. Low level contribution of several contaminants from the atmosphere have been demonstrated by NRBS. Fish health investigations have raised concerns about exposure of fish to contaminants, hormone disruptors and delayed sexual maturation. The vulnerability of fish to anthropogenic contaminants remains uncertain because of the general deficiency of information on fish ecology within the basins. However, the level of knowledge for larger fish in the Slave River basin is good.

Natural sources and processes contribute to some of the perceived environmental problems (e.g., mercury levels in fish, eutrophication, low dissolved oxygen, taste and odour of drinking water, hydrocarbons and turbidity). The primary human health concerns related to contaminants need to be assessed by health authorities, and include dioxins, furans and mercury in fish, and trihalomethanes and bacteria / pathogens in treated drinking water (especially in communities of less than 500). Dietary information (e.g., fish consumption) obtained as part of NRBS should be useful in reviewing health implications. Science findings to date do not establish thresholds related to ecosystem health or to pollution loadings. There is a lack of long-term monitoring data related to contaminants in edible fish tissue.

Enrichment of river reaches below pulp mill and municipal sources is observable and quantifiable. It is recommended that nutrient regulations should be developed which are ecosystem based, not technology based.

Hydrologic regimes influence the state of aquatic ecosystems. The ecology of the Peace and Slave river delta systems are particularly vulnerable on account of the Bennett Dam. The quality of the Athabasca River ecosystem, although not influenced significantly by river impoundments, is highly influenced by natural variability of flows coupled with the use of the river for handling treated effluent. Climate variability is potentially a factor in explaining some of the water issues in the deltas but more research is required to expand on the NRBS findings.

The ecological knowledge of traditional peoples is highly relevant and valuable to understanding the behaviour and distribution of wildlife, ecosystem

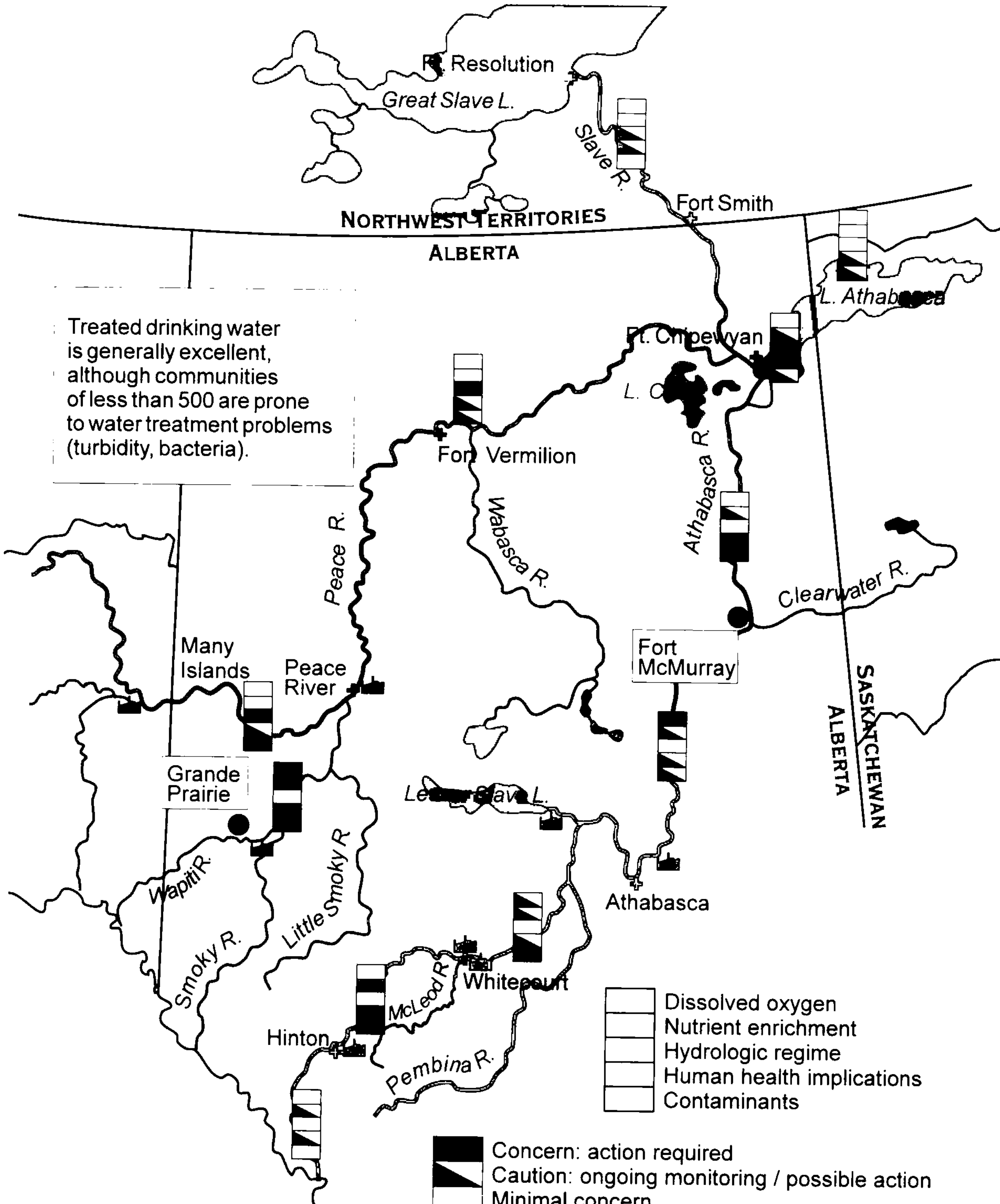


FIGURE 3.14.4 SUMMARY OF CUMULATIVE ENVIRONMENTAL EFFECTS

functions and ecosystem responses over space and time. Current monitoring in the basins is not designed to address cumulative effects assessment needs. There remain inconsistencies across agencies with regard to scientific design, collection-analysis-data handling / storage and reporting protocols that would benefit from coordination, integration and standardization.

Societal Perspective

Overall, the public recognizes the high quality of water within the northern river basins and their uniqueness relative to other areas of Canada and the world. For this reason, the public favour tight controls to protect this asset over the long-term. They are, however, concerned about the contaminants from industries and they frequently perceive fish and water to be unsafe to consume. Fish are a valued resource of the basins. As indicators of ecosystem integrity, society has indicated the need to protect fish health, population, distribution, migration and spawning behaviour and critical habitat. The public surveys of NRBS clearly reflect a need for public involvement in the decision-making affecting the sustainability of the basins' resources as well as a role in the monitoring of ecosystem health. There appears to be a general lack of public trust for industries to self-regulate and conduct their own monitoring. Management philosophies of no further degradation and zero discharge frequently surfaced in community discussions.

Key Management Considerations Applicable to all Basins

- Adoption and application of risk assessment approaches to pollution prevention and ecosystem protection
- Reach-specific aquatic ecosystem guidelines to guide pollution prevention including regulatory control of nutrients
- Effects of persistent low and bioaccumulative dioxins, furans and mercury in fish throughout the basins
- Quantification of natural versus man-made sources of contaminants
- Non-point source pollution: land use, landfills, and atmospheric deposition of remotely derived contaminants
- Effectiveness of drinking water treatment systems in small communities
- Biology and lifecyle of fish species and critical habitats
- Public consultation, involvement and education, information management, and multi-agency coordinated monitoring

ATHABASCA RIVER: ATHABASCA FALLS TO HINTON

Scientific Summary

Dissolved Oxygen		Naturally high
Nutrients		Enrichment is evident immediately below the town of Jasper
Hydrologic Regime		Natural flow conditions; effect of deforestation outside the park is unknown
Health Implications		Human health guidelines for fish consumption may be exceeded
Contaminants		Dioxins, furans and mercury in fish

The Athabasca River between Athabasca Falls and Hinton reflects a unique river / tributary system (e.g., Snaring, Snake-Indian, Rocky rivers) which is vitally important to the survival of the remnant pygmy whitefish population and the spawning movement of mountain whitefish, bull trout, and lake whitefish. Because of large populations of mountain whitefish that spawn in these areas, major habitat disruptions could have significant impacts on these species. NRBS has reported that lake whitefish likely spawn on the mainstem in the area upstream of Jasper Lake.

Fish containing contaminants associated with downstream developments are known to seasonally frequent the waters of Jasper National Park. Sources of pollution in this reach are mainly municipal. Nutrient enrichment below the townsite of Jasper is readily evident in the river by the increased abundance of algae, the main impact of which appears to be on the aesthetic / recreational value of the river. The potential effects of contaminants from landfill sites have not been investigated nor have the effects of deforestation.

Societal Perspective
Public views expressed at community gatherings, science fora, past public hearings, and views expressed by the Study Board members would suggest that this reach is generally viewed as being pristine and deserving of a high level of protection. The presence of a National Park in the headwaters of the river is seen as providing a high level of protection by virtue of its non-degradation policies.

Key Management Considerations Unique to Reach
- Fish spawning habitat and protection of fish stocks aggregating near mouths of tributaries
- Threatened populations of pygmy whitefish and bull trout
- Ecological effects of Jasper townsite effluent and of active and abandoned landfill sites
- Land clearing downstream of Jasper Park and its interactions with the aquatic ecosystem including flow regimes

ATHABASCA RIVER: HINTON TO WHITECOURT

Scientific Summary

Dissolved Oxygen	Naturally high although a sag occurs immediately below Hinton in certain low flow years
Nutrients	Non-limiting: Enrichment evident immediately below Hinton
Hydrologic Regime	Natural regime; influence of deforestation is unknown
Health Implications	Consumption of fish (mercury, dioxins / furans); drinking water taste and odour
Contaminants	Contaminant levels in sediment / biota; fish abnormalities; depressed sex steroids / delayed maturation

The quality of water entering this reach is generally excellent (natural) but deteriorates upon receiving effluent from the town of Hinton and the Weldwood of Canada Ltd. pulp mill. With the addition of the Hinton combined effluent (HCE), there is evidence immediately downstream of nutrient enrichment in the benthic community, but no evidence in this community of acute toxicological effects; certain contaminants (e.g., dioxins, furans, PCBs and mercury) are bioaccumulated in the aquatic food chain. Depressed steroids in fish have been observed as having, what appears to be, an abnormally high ratio of sexually immature to mature fish.

The highest levels of contaminants in sediments of the Athabasca River exist in this reach, specifically below the pulp mill to below Emerson Lakes. The HCE was found (1992 / 93) to have the highest levels of TCDD/F of any effluent sampled on the Athabasca River. All mean levels of TCDD (and their toxic equivalents) in fish muscle or liver were below the Health Canada limit for commercial fish sale. A few individual fish tissues, mainly burbot liver, downstream of Hinton, exceeded the 20 $pg \cdot g^{-1}$ guideline.

Tainting compounds (chlorophenolics) are introduced by the effluent, and affect the palatability of water. In 1992 / 1993, odour causing compounds from Hinton were detected 1 200 km downstream indicating the large spatial influence of the effluent. In the 1994 survey, Hinton-related odours, although present, were not distinguishable from other influences such as from Alberta Newsprint and Millar Western pulp mills at Whitecourt.

Biomarkers, bioindicators and gross pathology indicate sub-lethal influence of contaminants in this reach. The frequency of deformity is above background in the chironomid community below Hinton. Relative to elsewhere in Canada, this reach is considered to be lightly impacted by contaminants but the implications of long-term exposure to sub-lethal concentrations is still unknown.

Although dissolved oxygen is not an issue in the reach, the cumulative effect of the HCE and sources in the next river reach combine to become an issue further downstream. As with all mills, there is a concern that mill effluent can, under extreme hydrologic conditions of low flows and high summer temperatures or winter ice cover, deplete oxygen to levels where the instream and / or streambed dissolved oxygen levels may threaten various life stages of fish and other biota.

Societal Perspective

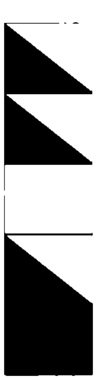
Public input at community gatherings, science fora, past hearings, and household surveys suggest that this reach is generally viewed as being impacted by the HCE. Public opinion seems to favour tighter effluent regulation and monitoring and public views have included philosophies of zero discharge and "capping" of pollution loads. To many, no level of dioxins and furans is acceptable in effluent or the environment and the quality of the system is worth protecting from further degradation. Particular concern has been expressed about high levels of phosphorus from the HCE and the need for reduction to protect river water quality. The McLeod River has been identified as a water quality concern due to sewage effluent releases. Other concerns include: scum on surface water, garbage dumping along the river, pesticides, forestry (clear cutting) impacts, point source controls, impacts on song birds, use of chlorine, handling of toxic wastes, contamination of wildlife, and safety of drinking water.

Key Management Considerations Unique to Reach

- Land clearing (forestry and agriculture) and aquatic ecosystem interaction
- Nutrient enrichment from Hinton to Whitecourt
- Contaminants (organochlorines) and others in fish and macroinvertebrates
- Ecological implications of low flows under ice, coupled with effluent loadings
- Health of aquatic life
- Fish use of critical habitat in tributaries (e.g., McLeod River)
- Influence of HCE effluent on river sediment processes

ATHABASCA RIVER: WHITECOURT TO ATHABASCA

Scientific Summary



Dissolved Oxygen	Oxygen sag below Whitecourt in some years
Nutrients	Non-limiting to confluence with Lesser Slave; trophic enrichment below Whitecourt
Hydrologic Regime	Natural regime; effect of deforestation is unknown
Health Implications	Human health guidelines for consumption of fish may be exceeded; drinking water taste and odour
Contaminants	Levels in fish and sediment; depressed sex steroids; incidence of fish abnormalities

The Athabasca River has naturally occurring low flows and low oxygen levels under ice conditions. The loading of organic wastes to the river are known to further reduce oxygen levels. Oxygen sags have been recorded under ice conditions immediately below Millar Western at Whitecourt. Since 1989, the minimum winter dissolved oxygen levels appear to have not fallen below 6.8 mg/L. A concern is the progressive longitudinal downstream decline in dissolved oxygen in the river until it is enhanced by the entry of the Lesser Slave River. The minimum mid water column level indicates that the oxygen level at the sediment-water interface could be as low as 4 mg/L. In order to ensure the survival of fish eggs and other biota, this level should not fall below 3 mg/L. The Pembina River displays naturally low oxygen levels during the winter and summer. Ground water is important to the base flow of the Pembina River.

The benthic community downstream of the town of Whitecourt is reflective of nutrient enrichment. The pulp mill practice of adding phosphate to encourage biological breakdown of organic wastes prior to release into the river should be reviewed and controlled.

Coal development on the upper Pembina River was not investigated; fish collected from the lower Pembina River show unusually high metallothionein induction indicating possible exposure to metals in this system. Optimal mountain whitefish spawning habitat exists in this reach. Fish health is suspect in this reach based on a high incidence of abnormalities below Whitecourt pointing to the need for in-depth investigations of the causes. Levels of dioxins, furans, PCBs, chlorinated resins acids and chlorophenols in fish and / or sediments are lower than in the reach immediately upstream but tend to be highest below Whitecourt. None of the contaminants investigated were detected at levels thought to cause acute toxicology in aquatic life. Taste and odour compounds in the river improve longitudinally throughout this reach.

Societal Perspective

Statements of concern from the public relate to issues arising during the AlPac hearings including: dissolved oxygen requirements of fish; fish quality and health; nutrient enrichment; dioxins and furans; drinking water quality; land use impacts; etc. Members of the public have identified the Pembina River as having nutrient, turbidity and dissolved oxygen problems. Other concerns include: deforestation effects on water quality, drainage of muskegs and wetlands, long-term monitoring, edibility of fish, quality of fish, mink and other wildlife, abundance of fish, spills, sewage discharges, and effluent treatment.

Key Management Considerations Unique to the Reach

- Ecological effects (e.g., nutrient enrichment) caused by discharges from municipalities and pulp mills
- Management of dissolved oxygen levels (Whitecourt to Grand Rapids)
- Organochlorine compounds: dioxins, furans, chlorinated phenolics, resin acids and PCBs
- Health of aquatic life (e.g., abnormalities, depressed sex steroids, etc.) and use of the mainstem system by fall spawners downstream of Whitecourt
- Deforestation and its influence on hydrologic regimes and fish habitat

ATHABASCA RIVER: ATHABASCA TO FORT MCMURRAY

Scientific Summary

Dissolved Oxygen	Low winter dissolved oxygen; longitudinal decline in DO
Nutrients	Localized nutrient enrichment
Hydrologic Regime	Natural regime; effect of deforestation is unknown
Health Implications	Human health consumption guidelines for some fish exceeded; drinking water taste and odour
Contaminants	Naturally occurring hydrocarbons; mercury in fish; dioxins in municipal effluent

This reach includes the AlPac pulp mill near the town of Athabasca. Dissolved oxygen levels sag below the town of Athabasca and conditions in this reach likely reflect the cumulative organic loading from upstream sources. Based on NRBS research, it is recommended that the provincial water quality objective for dissolved oxygen be increased to provide a greater safety margin for the protection of aquatic life.

The influence of oil sands deposits begin to show in this reach with the natural occurrence of PAHs and other organic compounds. Overall, concentration of organochlorine contaminants in sediments and biota decline throughout this reach relative to upstream sites.

Mercury was detected in all fish however the levels were highest in the larger-older fish, particularly walleye, a predator known to accumulate this contaminant. These results corroborate those which lead to the existing fish consumption advisories. The highest level observed was in walleye collected from above Grand Rapids.

Taste and odour compounds are evident in this reach originating from upstream pulp mills and possibly enhanced by municipal wastes. The synergistic effects of these and oil sands hydrocarbons remain unknown.

Critical spawning habitat for fish exists in the vicinity of Mountain and Cascade rapids upstream of Fort McMurray. Upwards of 1 000 000 lake whitefish (fall spawners) and large numbers of longnose suckers (spring spawners) that originate from Lake Athabasca spawn in this area. Walleye are also believed to spawn in this reach. Reaeration of the river by Grand Rapids significantly improves the instream dissolved oxygen levels thus providing optimal conditions for whitefish egg development.

Societal Perspective
Statements of concern from the public relate to issues arising during the AlPac hearings including: dissolved oxygen requirements of fish; fish quality and health; nutrient enrichment; dioxins and furans; drinking water quality; and land use impacts.

Key Management Considerations Unique to the Reach

- Ecological effects of discharges from municipalities and pulp mills
- Nutrients enrichment below Athabasca
- Management of dissolved oxygen levels
- Organochlorine compounds: dioxins, furans, chlorinated phenolics, resin acids and PCBs
- Health of aquatic life
- Natural and anthropogenic loading of hydrocarbons
- Taste and odour producing compounds (fish and drinking water)
- Guidelines for human consumption of fish

ATHABASCA RIVER: FORT MCMURRAY TO PEACE-ATHABASCA DELTA

Scientific Summary

Dissolved Oxygen	Natural
Nutrients	Localized enrichment below Ft. McMurray
Hydrologic Regime	Natural regime; effect of deforestation is unknown
Health Implications	Human health consumption guidelines for some fish exceeded; taste and odour in drinking water
Contaminants	Highest MFO induction; naturally occurring organics

This reach includes the massive oil sand complexes and the municipal effluent from Fort McMurray. Natural hydrocarbon seeps are evident along the Athabasca River and contribute PAHs and other hydrocarbons to the river. The effect of these hydrocarbons on the ecosystem have not been extensively investigated but NRBS has obtained presumptive evidence that suggests that naturally occurring substances may be responsible for the MFO inductions in fish. The Clearwater and Steepbank rivers also provided evidence of MFO induction. Further investigations into the causes of induction and its implications are required. Of the chemi-thermomechanical pulp mill and sewage treatment plant effluent, the Fort McMurray effluent is the largest source of PCDD/Fs, based on concentration and discharge to the entire river during a one-time sampling in April 1993.

These same oil sands sources with their associated metals may also be linked to higher metallothionein in the lower Athabasca River and this requires investigation as well. Recent evidence submitted by Suncor indicates that the cause of mercury contamination of the Athabasca River benthic community has been remediated. Preliminary benthic invertebrate data, also provided by Suncor, suggest that the problem has been cleaned up. NRBS did not investigate mercury levels in benthos in this reach. Mercury levels are high in large walleye in this reach of the Athabasca River. Human consumption advisories are in effect.

Nutrient enrichment is apparent in the benthic community immediately below Fort McMurray reflecting the addition of the municipal effluent. Unlike the two reaches immediately upstream, dissolved oxygen is not an issue in this reach. The Clearwater River influences the flow and quality of the Athabasca River. NRBS research has confirmed that the Clearwater River and the municipal discharge from Fort McMurray contribute to increased productivity in the Athabasca River.

Taste and odour compounds are evident in this reach originating from upstream pulp mills. The synergistic effects of these and oil sands hydrocarbons remain unknown.

Societal Perspective
At public gatherings, science fora and through surveys, statements of public concerns included: the lack of involvement of traditional knowledge in decision making and local people in monitoring; pulp mills are contaminating and fouling our fish and drinking water; oil sands developments are affecting wildlife; fish populations have declined; river looks dirtier and there are more weeds now; applicability of consumption guidelines for fish containing high levels of mercury; little or no warning provided to downstream interests when spills occur; effects of contaminants on human health and way-of-life.

Other concerns expressed include: safety of tailing ponds and leachates, presence of carcinogens and linkages to human health, fish health and quality, drinking water quality, turbidity, taste and odour, hydrocarbon seeps, uncertainty in cumulative impacts and reliability of industry data. The Clearwater River is perceived as having become polluted in recent years and contains high levels of nutrients. Non-point source pollution was raised as regards the Clearwater River. Spill notification times and responses are a concern to citizens.

Key Management Considerations Unique to Reach
- Pollution prevention in light of downstream interests and cumulative effects
- Naturally occurring hydrocarbons and metals
- Nutrient management
- Health of aquatic life
- Long term management of oil sands tailing ponds, oil sands operational emissions and expanding operations
- Spill response: Timely response in reporting of municipal and industrial spills to downstream interests
- Wetland drainage and deforestation effects
- Tainted fish and drinking water

Scientific Summary	
Dissolved Oxygen	Natural
Nutrients	Some anecdotal evidence of enrichment in shallow open water
Hydrologic Regime	Significantly impacts: drying of delta lakes; habitat loss; water levels
Health Implications	Fish consumption guidelines relevant to locals (mercury); way-of-life
Contaminants	Contamination from remote sources in fish and sediments; depressed sex steroids

Science has demonstrated significant ecological changes in this area during the last two decades. Drying of the delta is related to the Bennett Dam and it is hypothesized that this may be exacerbated by climate variability. Ecological changes in the delta have resulted in impacts on fisheries habitat, fish movement and spawning behaviour, changes in waterfowl migration routes, decline in populations of ungulates, muskrats and other wildlife, and changes to way-of-life of people living in the delta.

The PAD supports abundant fish populations of a number of species (walleye, northern pike, lake whitefish and goldeye) and a commercial fisheries operation. A subsistence fishery exists in the delta. Critical spawning areas are: Mamawi, Claire and Richardson lakes. Spawning does occur throughout the delta.

Contaminants such as dioxins, furans and mercury exist in burbot liver and the muscle and liver of other fish species. Levels need to be assessed relative to the unique dietary intake of aboriginal people. Radionuclide research confirms the fish collected at the delta and west end of Lake Athabasca have not been contaminated by mining operations in the basin.

Biological, sediment and water transport processes move contaminants from the headwaters of the basins to the delta. When the sediment contaminants reach the delta they become dispersed through particle size partitioning processes and are deposited throughout the delta, Lake Athabasca and / or transported into the Slave River system. Deep core investigations have confirmed this and the "dilution" effect of these processes. NRBS has confirmed that pulp mill contaminants have reached the perched basins. Weak PCDD/F signatures were evident in muskrat and canvasback ducks collected from perched lakes and Flour Bay. Health Canada reviewed the NRBS mammal and waterfowl contaminant data and concluded that consumption of these muskrats and canvasback ducks would not pose a hazard to humans.

Societal Perspective

At public gatherings, science fora and through surveys, statements of public concerns included: pulp mills are contaminating and fouling our fish, increasing abnormalities in fish, and affecting wildlife, vegetation and drinking water; oil sands developments are affecting wildlife; uranium mining; fish populations have declined; spawning beds have dried up and migration patterns affected through infilling of channels; fish nets are now covered with weeds; applicability of consumption guidelines for fish containing high levels of mercury; little or no warning provided to downstream interests when spills occur; and effects of contaminants on human health and way-of-life. Major concerns were expressed related to the effects of the Bennett Dam including the loss of a way-of-life. Several elders noted that their concerns and views seem to be often ignored and they recommend that traditional knowledge be incorporated into decision-making related to resource management and approval of developments.

Key Management Considerations Unique to Reach

- Options for enhancing ice dams and delta flooding
- Delta ecosystem response to flow regulation
- Way-of-life impacted (cultural, spiritual, economic, trapping / hunting)
- Declining wildlife and fish populations
- Fish quality and health; non-conventional drinking water treatment
- Public information, timely response and reporting of spills

ATHABASCA RIVER: LAKE ATHABASCA

Scientific Summary

Dissolved Oxygen		Natural
Nutrients		Cores reflect evolution of basin; traditional knowledge provides anecdotal evidence of increases in algae
Hydrologic Regime		No issues identified
Health Implications		None identified; vigilance required at west end of lake as regards consumption guidelines
Contaminants		Pulp mill signature in sediments; declining radionuclides

Lake Athabasca traps some of the sediments which move through the Athabasca River system. Sediments also deposit directly in the delta and / or move into the Slave River system and Great Slave Lake. Investigations have confirmed that pulp mill contaminants have reached the lake over very long time periods. Concentrations are close to the analytical detection limits, organochlorine contaminants in fish are near reference levels. Atmospherically derived contaminants are apparent in the cores as are PAHs originating with forest fires and hydrocarbon development. Some fish from the lake have high concentrations of mercury. A survey of subsistence fish in 1994 / 1995 indicated that mercury in burbot, walleye and pike are below the commercial guideline of 0.5 mg/kg (parts per million). Given the subsistence use of fish from the lake, the Alberta consumption advisories should be reviewed for relevancy to the traditional peoples.

Radionuclide concentrations in fish are well within the guidelines provided by Health Canada. There is evidence of radionuclides moving out into Lake Athabasca at the east end of the lake from the Gunnar mine site although this has diminished in recent years due to lower mining activity and controls. Ongoing and increased mining in response to international pressures is a significant concern of the people who live along the shores of the lake and downstream in the Northwest Territories.

Fish health assessments were not undertaken on fish from the lake. However, local people and commercial fisherman report fish abnormalities (external and internal) which should be investigated further.

Societal Perspective

People from the delta area have expressed fears that the lake is vulnerable to contaminants from uranium mining, pulp mill developments, oil sands and other pollution sources. Commercial fisherman have noted an increased incidence of poor quality fish (livers) but this has not been confirmed. Water quality is generally seen as vulnerable to industrial development and poorest at the mouth of the Athabasca River. There have been observations that fish nets are now becoming covered by algae and a perspective is, that this is man-induced pollution from upstream developments. Other concerns include: incomplete environmental impact assessments, atmospheric contaminants, contaminants in fish and most of the concerns noted for the delta.

Key Management Considerations Unique to Reach

- Remedial works in the delta and their effect on fish movement and habitat use
- Mining of uranium in the headwaters and the management of abandoned uranium mines
- Fisheries management: stock assessment
- Atmospheric deposition of contaminants
- Eutrophication of the west end of Lake Athabasca
- Relevancy of fish consumption guidelines to traditional peoples

PEACE RIVER: MANY ISLANDS TO CONFLUENCE WITH SMOKY RIVER

Scientific Summary

Dissolved Oxygen	No NRBS research was undertaken; natural conditions likely exist
Nutrients	No NRBS research was undertaken into nutrient enrichment
Hydrologic Regime	Radical changes: regime, ice, extremes, timing, sediment load, open winter areas
Health Implications	Human health consumption guidelines for fish (mercury, PCBs)
Contaminants	Mercury, PCBs, resin acids, PAHs, dioxins and furans in sediment / burbot higher than reference

An altered flow regime is an obvious consequence of the Bennett Dam. Winter flows tend to be higher than normal, summer flows and the spring peaks lower on average. Changes in channel geomorphology, aquatic vegetation and riparian habitat are evident throughout this reach and could take decades or centuries to "stabilize." The effect of open water winter conditions, higher winter water temperatures and geomorphological changes on fish, habitat use and on other biota have not been quantified. Snow pack and spring runoff in tributaries have been lower in recent years.

This section of the Peace River is of generally good water quality although there is some evidence of industrial contamination as determined by the presence of certain contaminants in sediments and fish. Levels of PCBs, resin acids, and PAHs are higher than reference locations in sediments above the confluence with Smoky River and in this area. PCB levels in the sediments exceed the interim Canadian sediment quality guidelines for the protection of aquatic life. The concentration of PCBs in burbot liver are an order of magnitude higher than found in burbot from the Wabasca River, a tributary to the Peace River but still well below PCB guidelines for the commercial sale of fish. The extent to which observed PCB levels in fish are a function of their concentration in the food web as opposed to point source release is unclear; however, the PCB data should be reviewed from the point of view of traditional life styles.

Levels of PCDD/Fs in sediments were low but detectable. The only sampling done for PCDD/Fs in fish was in 1994 when we tested burbot livers. All results were at or below the analytical detection limit. There are no data in this reach which could be used for assessing temporal trends in dioxins and furans.

Mercury levels in fish of this reach are generally lower than elsewhere in the basins with the occasional larger fish having levels which exceed the commercial health guidelines of Health Canada. There is no fish consumption advisory in effect for this part of the Peace River and our data (for mercury, dioxins, furans and toxaphene) would seem to corroborate that none is required.

The large river volume probably assimilates existing sources of nutrient and organic wastes effectively. NRBS did not investigate the effect of British Columbia pulp mills or municipalities on Peace River water quality. Dissolved oxygen levels are not an issue.

Unique fish and riparian habitats exist within the Many Islands area downstream to the Montagneu River although they are unstable and undergoing change with evolving shorelines and shifting and new sand bars as evident in the Many Islands area.

Societal Perspective
The Peace River is considered a valuable and precious resource. Flow regulation has been seen as self-serving to British Columbia with little consideration of the downstream ecosystem and human interests. Concerns have been expressed about the possibility of contaminants from British Columbia pulp mills and municipalities and mercury contamination of Peace River fish.

Key Management Considerations Unique to Reach
- Hydrologic regime and geomorphological responses
- Contaminant sources (PCBs, PAHs, resin acids and dioxins and furans) and levels in sediment and / or fish
- Transboundary river; pollution from British Columbia and high mercury in fish of Williston Lake
- Ecologically sensitive regulation of flows from the Bennett Dam
- Human consumption advisories
- Periodic monitoring of contaminants in fish

PEACE RIVER: CONFLUENCE OF SMOKY RIVER TO RIVIÈRE DES ROCHERS

Scientific Summary

Dissolved Oxygen	Natural
Nutrients	Information is lacking although localized enrichment is evident
Hydrologic Regime	Radical changes: regime, ice, extremes, timing, sediment load, channel / riparian changes
Health Implications	Fish consumption guidelines (mercury and PCDD/F)
Contaminants	Depressed sex steroids, pulp mill contaminants, PCBs

The most dominant stressor affecting the entire length of the Peace River is flow regulation by the Bennett Dam. Although hydrologic effects are attenuated downstream, there is concern related to reduced flooding of the Peace-Athabasca Delta. There is preliminary evidence that climate variability may be an important factor in explaining reduced tributary runoff in the upper basin and drying of delta lakes.

The large water volume and high sediment load in the Peace River dilutes the contaminants discharged from pulp mills and municipalities. There is evidence of trace contaminants (PAHs and chlorophenolics) in sediments with tetrachlorodibenzo-p-dioxin (TCDD) levels below detection. Increases in chlorinated resin acids were not seen below Daishowa although total resin acids are as high in this reach as on the Athabasca River at Emerson Lakes. PCB levels doubled in fish from the Peace River near Notikewin, and near Ft. Vermilion between 1992 and 1994. Tetra-chlorodibenzodioxins and furans (TCDD/F) have decreased in burbot livers since 1992. Nutrient enrichment was not investigated by NRBS in the reach.

Dissolved oxygen is not an issue. Depressed sex steroid levels (based on basin-wide analysis of near field sampling stations) occur in burbot and longnose sucker below pulp mills relative to reference samples and coupled with a low ratio of mature to immature fish is worthy of management follow-up. The levels of TCDD/Fs in fish have decreased by 50-80 per cent since 1992, probably as a result of technology improvements.

The effects of agriculture on the Peace River or its tributaries has not been investigated. Examining the potential for non-point source pollution, NRBS scientists have noted that agriculture and forestry operations may be important considerations in the long-term management of the system. The oil sands which intersect the Peace River have not been found to cause any unusual water quality or ecosystem health effects. However, elevated levels of MFO induction in burbot collected in the Wabasca River are suggestive of natural contamination from oil sands seepage.

This reach is critical winter habitat for goldeye which spend the spring and summer in the lower Athabasca River within Wood Buffalo National Park. Goldeye are the dominant fish species in this reach with an estimated population of one million.

High level of free retinoids in burbot from the lower portion of this river reach suggests physiological stress but the cause is unknown.

Societal Perspective

The public fears river degradation by pulp mills, forestry, agriculture, mining, oil and gas, and municipal wastes. Frequent observations were made about past spills related to PCBs and other substances on the Smoky and Wapiti systems which may impact the Peace River. Observations of fiber, foam, odours, and tainted drinking water have been associated with pulp mills. Increased sediment and dirty ice, likely caused by increased winter flows, leaves an impression of degraded water quality. Changes in wildlife and fish populations are perceived to be linked to development on the river. Apparently uncontrolled agricultural activity, especially the clearing of land right down to the water's edge is a growing concern. Land clearing for forestry is increasing in the tributary watersheds (Notikewin, Cadotte, Buffalo, Wolverine, Ponton, Wabasca and Mikkwa) with concerns expressed about water quality and vulnerability of fish habitat.

Key Management Considerations Unique to Reach

- Flood management and safety of property and humans
- Ecological changes in the river channel
- Ice formation, quality and timing
- Agricultural land use; interaction with aquatic ecosystems
- Effects of deforestation
- Health and quality of fish and fish habitat
- Information on nutrient enrichment is lacking
- Options for enhancing ice dam formation and delta flooding
- Depression of sex steroids and increased incidence of immature fish

SMOKY-WAPITI RIVERS

Scientific Summary

Dissolved Oxygen	High rate of decline in short river length
Nutrients	Non-limiting except in lower Smoky where nitrogen-limited; enrichment below pulp mill / Grande Prairie
Hydrologic Regime	Recent decrease runoff due to climate variability
Health Implications	Human consumption of fish
Contaminants	PCDD/Fs, PCBs, fish deformities, depressed sex steroids, delayed fish maturation

Based on the weight-of-evidence approach, the Wapiti / Smoky river system is currently the most heavily stressed in the northern river basins. Issues of concern include high levels of nutrient addition from the city of Grande Prairie and the Weyerhaeuser pulp mill, sharp declines in under-ice dissolved oxygen, and high PCB concentrations in sediment and fish. The extent to which observed

PCB levels in fish are a function of their concentration in the food web as opposed to point source release is unclear. Whatever the factors responsible for these PCB levels, the issue clearly requires further investigation. Concerns relate to the rapid decrease in the river system's capacity to assimilate further organic wastes without implications to fish (dissolved oxygen) and long-term eutrophication on this system.

Twenty-three per cent of annual TP loading in the Wapiti River is from Grande Prairie and Weyerhaeuser and is in excess of 40 per cent during low flow periods. The proportion of bio-available phosphorus in these effluent is higher than in the receiving water. Recent decreases in basin runoff related to decreased snowpack would further exacerbate the effect of nutrient / contaminant additions to the rivers.

Contaminants related to dioxins, furans, PCBs and chlorophenolics are present in sediment, water and / or fish.

Unexplained doubling of PCB levels in fish occurred between 1992 and 1994 on the Wapiti River. TCDD/Fs in biota appear to have declined by a factor of 10 since 1992 but are still relatively high relative to other locations in the basins. Depressed sex steroids coupled with an apparent anomalously high ratio of sexually immature fish (burbot and longnose suckers), and a higher than normal incidence of fish deformities below the mill give cause for concern and the need for further research. Although pulp mill effluent may have affected the reproductive ecology of individual fish, there is no evidence yet that populations have been affected.

These small river systems provide critical spawning habitat for several fish species and therefore are particularly vulnerable to pulp mill and municipal wastes.

NRBS has determined that variability in precipitation and winter snow pack has played a significant role in influencing observed levels of spring runoff in these tributaries to the Peace River. This has important implications for several areas of water management including flood forecasting and control, water licensing and apportionment, instream flow needs, pollution control and water quality.

Societal Perspective

Public statements about the state of the resource in this system include perceived impacts from coal mining (dust), power generation (transformers: PCBs), red snow, spills, deformed fish, air quality associated with oil and gas field flaring, aesthetics (such as foam, wood chips, and odours) and fish and water tainting.

Key Management Considerations Unique to Reach

- Highest levels (on lower Wapiti) of dioxins, furans, PCBs and chlorophenols in sediments, fish and /
- or water of the Peace drainage
- Relative to river discharge the Wapiti-Smoky systems are most heavily impacted in the basins
- (dissolved oxygen, nutrient enrichment)
- Fish health, reproductive ecology and exposure to pulp mill effluent
- Pollution loading relative to naturally occurring low flows
- Forestry management and land clearing relative to water quality

SLAVE RIVER: RIVIÈRE DES ROCHERS TO (INCLUDING) SLAVE DELTA

Scientific Summary

Dissolved Oxygen	Not investigated but natural regime expected to exist
Nutrients	Likely natural but not investigated; algae apparent on submerged rocks at Rapids of the Drowned
Hydrologic Regime	Modified: higher winter flows and sediment loads, reduced peak flows, possible impacts on delta
Health Implications	Fish consumption guidelines linked to dietary intake; non-conventional treatment of drinking water
Contaminants	Atmospheric sources; metallothionein, pulp mill signatures

Flow alterations in the Slave River may have implications to fish movement, distributions and the state of the delta. NRBS did not conduct in-depth investigations of the flow regulations effects on Slave River Delta ecology. Impacts of the flow regulation are therefore not adequately described except as related to understanding the hydrologic regime of the river itself. Research is needed to assess the state of the delta and its vulnerability to upstream flow regulations. Increased suspended sediment has been observed during winter with the higher than normal flows.

The Rapids of the Drowned to Cunningham Landing is critical spawning habitat for inconnu and lake whitefish as is the lower-middle reach between Pointe Ennuyeuse and Grand Detour where inconnu spawn. The Slave River Delta is known to be a spawning and rearing habitat for burbot and northern pike.

Although contaminants (e.g., PCDD/F) have only been detected in fish (e.g., burbot) and lake sediments at or near analytical detection limits, this indicates upstream sources are beginning to show their presence many hundreds of kilometers downstream. Atmospheric sources of contaminants are implicated. Further research is needed to explain the cause and the significance of these findings.

Fish health apparently remains exceptional throughout this reach. A "recommendation" by the Northwest Territories Government, similar in nature to the Alberta consumption advisories, exist for fish taken from the Slave River because of toxaphene. Due to analytical difficulties, NRBS data could not corroborate the toxaphene issue for fish from the Slave River.

We heard from the people that wide use is made of drinking water using non-conventional treatment. Particular concern relates to the practice of using untreated water in back country locations and the possible consequences.

Societal Perspective

Local people have indicated concerns related to: long-term sustainability of the white pelican colony; waste from Fort Smith, enhanced algal growth at the Rapids of the Drowned, increased turbidity in the winter, drinking water quality, buried landfill leachates, water level fluctuations, declining wildlife populations and fish quality.

Key Management Considerations Unique to Reach

- Habitat protection; Fisheries management fish biology
- Ecological effects of flow regulation on the Slave Delta
- Contaminant (metals, toxaphene) in fish
- Human consumption guidelines relative to fish muscle and livers
- Transboundary river

RELEVANT DOCUMENTS

Primary NRBS Synthesis Report

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NRBS Technical Reports

Alke, E. 1995. *Executive Summary of a Workshop on the Impacts of Land Clearing on the Hydrologic and Aquatic Resources of Boreal Forests in Alberta, November 18 and 19, 1994.* Northern River Basins Study Technical Report No. 63.

Cash, K. 1996. *Benthic Macroinvertebrate and Fish Community Structure Within the Northern River Basins: An Assessment of Their Utility in Biomonitoring.* Northern River Basins Study Technical Report No. 123.

Cohen, S.J. 1995. *The Potential Effects of Climate Change in the Peace, Athabasca and Slave River Basins: A Discussion Paper.* Northern River Basins Study Technical Report No. 65.

Donald, D.B. *et al.* 1996. *Indicators of Ecosystem Integrity: Peace-Athabasca Delta.* Northern River Basins Study Technical Report No. 107.

Hudson, E. 1996. *Climate of the Northern River Basins.* Northern River Basins Study Technical Report No. 124.

McDonald, K. 1996. *Analysis of Back Trajectories: Identification of Air Pathways.* Northern River Basins Study Technical Report No. 109.

4.0 STUDY BOARD RECOMMENDATIONS

4.1 INTRODUCTION

In preparing its recommendations, the NRBS Board began by confirming its shared vision that the northern river basins should be wisely managed for the future. It was a vision that recognized the totality of the basins as an ecological unit, where the standards and regulation of the use of the waters are continually being challenged, where both the latest research and monitoring are essential, and where the basin residents and stakeholders provide an important resource. To reach its conclusions, the Board spent much time preparing discussion papers, convening workshops, holding internal discussion sessions and calling on advice from members of the public. It was not easy to reach common agreement; the Board comprised very diverse but representative interests, and divergent viewpoints frequently had to be reconciled. In the end, large areas of common ground were developed.

The Board recommendations depended heavily on the basic and applied research results brought to conclusion by the science component group leaders. It took special note of findings about societal values and opinions. As a result, the Board has prepared the following recommendations for which much of the rationale is to be found in the project reports, synthesis reports, proceedings of Board meetings and its discussions. Throughout the process, the Board obtained input from the extensive program of public participation and arranged a final round of community workshops immediately prior to the completion of this report (see Section 6.0). The many contributions of basin residents are gratefully acknowledged.

Except where otherwise noted, the Board's recommendations as presented in this report have the substantial or unanimous support of the Board members. In some instances, individual Board members who disagreed in some way with a recommendation have chosen to have their dissent from the majority position recorded in writing, to help the reader's perspective.

In taking a position on the Board's recommendations, Board members were applying their best judgement and acting in their individual right as Board members. Their positions on the Board's recommendations do not necessarily indicate support or lack thereof on the part of the organizations from which Board members were drawn.

4.2 Basin Management

The scientific findings of several Study components have direct bearing on water resource management in the northern rivers. Thus, studies completed on nutrients and dissolved oxygen have implications for regulations. Contaminant studies also call into question the adequacy of present measures to protect water quality. The quality of drinking water took the Study somewhat far afield from the mainstem river systems but this was necessary to answer the question that the residents wished to have answered: is the water safe to drink?

Early in its work, the Board decided not to expend some of its limited budget on studies of land use within the basins. The primary focus of field and laboratory studies centred on the aquatic ecosystems, and virtually all of the research projects focused on aquatic environments. But land use issues kept cropping up at community gatherings, at meetings of the Science Advisory Committee and in discussions of the component group leaders. Workshops were organized on land use policies and forestry practices and a number of recent reviews were provided to Board and staff members. Many of the Board members had a wealth of experience and expert knowledge which assisted Board discussions.

In consequence of their sustained interest in the inter-relationship between land use and water resource management, the Board developed several recommendations concerned with government policies and proposed legislation. The result is a diverse group of recommendations, but all relate to the activities in the basins and their impact on the residents and the rivers.

Recommendation 1, Basin Management

Preamble

During the public consultation process, the Board encountered concerns about the nature and extent of effluent from municipal, industrial and other sources. Some representatives from the public-at-large and interest groups called for a reduction of these effluents within the basin, and, in some cases, for the elimination of pollutants introduced through human activity.

While public attention was often focused upon concerns relating to toxic substances emitted by point sources, scientists have expressed parallel concerns over nutrient additions and associated runoff of biocides and heavy metals from large water reservoirs and lands disturbed by agriculture, forestry and industrial activities.

The Board was encouraged by the findings of the science research that over the course of the Study, the concentrations of certain organochlorines (notably dioxins and furans) decreased. However, these contaminants are still found in detectable amounts in sediments and fish tissue samples across the basins. Also of note, were PCB levels found in some reaches of the northern rivers. Other research results indicate that fish within the basins have been exposed to toxic contaminants and may be responding in a variety of ways. Lesions and other abnormalities in the fish populations were also noted at some locations at higher levels than occur naturally. In some cases, changes to the aquatic ecosystem through the addition of nutrients were also cause for concern. This concern is based largely on the implications for instream productivity, dissolved oxygen and benthic community structure.

Traditional knowledge reinforced the science findings with observations of lesions and other abnormalities in the fish populations. Fish populations are said to be far less abundant than they once were. It was stated that some fish that are caught do not taste or smell as they should and that the rivers are less clean than they once were.

Opinions of some respondents to the householder and stakeholder survey were reinforced by comments of some people attending community gatherings and workshops. They told the Board of their strong support for the concept that "zero discharge" of substances or waste into the environment should be the objective of environmental management strategies.

Taken literally, "zero discharge" would be difficult to achieve. For example, eliminating discharges directly into the rivers could result in discharge to the land or air. As it stands now, some pollution comes to the northern basins from far afield, from North America, Europe and Asia. Airborne contaminants such as mercury, PCBs, pesticides, dioxins and furans, as well as radioactive isotopes are imported to the basins. Local airborne sources may also contribute to stream pollution directly and indirectly through drainage from the land. The disposal of wastes directly in landfill may similarly mean that contaminants that originally came from point sources become more widely dispersed, seeping into the streams as non-point sources. Other non-point sources, such as agricultural drainage containing pesticides and fertilizers, are equally difficult to assess and control.

However, understood within the broader principle of pollution prevention, zero discharge may be one of the ways to reduce the deposition of unwanted substances or waste into the environment. The pollution prevention principle requires the elimination or virtual elimination of the generation, use and discharge of persistent toxic substances that tend to bioaccumulate in the environment. It also requires significant reduction in or the virtual elimination of deposits of all other forms of waste into the environment.

Conclusion

The Board supports the fundamental principle of pollution prevention. Science and traditional knowledge findings, together with public input, all indicate that action is required to address the presence and effect of contaminants and nutrients generally, and particularly in some reaches of the rivers. In some instances, the Study's findings are preliminary and further study may be required to fully answer the questions raised. However, the weight of evidence justifies a precautionary approach.

The Board recommends that:

1. **Regulatory agencies for the northern rivers declare and implement, through law, policy and practice, pollution prevention, including but not limited to zero discharge, as a primary environmental objective and as an important component of sustainable development.**

2. **For contaminants;**
    a) **The objective be achieved within ten years for persistent toxic substances, to eliminate their use, generation or discharge with respect to the northern rivers.**
    b) **Implementation begin by "capping" direct loadings into the rivers of persistent toxic substances at 1996 levels.**
    c) **An open, credible process be employed to: (i) identify substances or test for substances within the category; (ii) develop a timetable for a step down to elimination; and (iii) determine ways in which the step down may be achieved. This should be accomplished with reference to the definition of persistent toxic substances and process contained in the Environment Canada Toxic Substances Management Policy (June 1995).**

3. For nutrients;
   a) The objective be achieved within a reasonable period of time for nutrients, to eliminate or substantially reduce their discharge to the northern rivers, consistent with environmental management objectives.
   b) Implementation begin by "capping" direct nutrient loadings into specific reaches of the rivers, as indicated by the Study's findings.
   c) An open, credible process be employed to: (i) identify environmental management objectives with respect to nutrients; and (ii) develop a plan to reach those environmental management objectives.
4. For other wastes;
   a) The objective be achieved within a reasonable period of time for other wastes, to eliminate or substantially reduce their discharge to the northern rivers.
   b) An open, credible process be employed to develop a plan for achieving waste reduction or elimination.

5. Regarding international agreements;
   a) The Government of Canada should vigorously pursue the development of international agreements, treaties or protocols consistent with the elimination or reduction of the use, generation or discharge of airborne pollutants.

6. And with respect to performance evaluation;
   a) The Ministers and their governments make a report to the public in 5 years (after this Study) on the progress achieved in implementing these recommendations.

Dissenting Views

Recommendations 1-1, 1-3, 1-4, and 1-6 carried the substantial support of the Board. With regard to Recommendation 1-2, some members viewed the ten-year time limit as being unreasonably short. With regard to Recommendation 1-5, some members viewed international affairs as being beyond the scope of the NRBS.

Some dissenting members argued as follows:

> *"Recommendation 1-1. For the NRBS Board to place a recommendation in its report for zero discharge would in, our opinion, be irresponsible as such a recommendation is an impossible illusion and we feel it is irresponsible to make recommendations that are impossible to achieve.*
>
> *"Recommendation 1-2. The placing of a cap on effluent discharges would have enormous implications for municipal expansions, economic development initiatives and for other areas such as agriculture. Such a recommendation would be devastating for economic development in northern Alberta and would, in our opinion, be extremely presumptuous on the part of the NRBS Board. There are a number of industrial projects in planning stages at this time, some of which are in fact covered by signed agreements with the Government of Alberta. There are processes in place to assess new projects from every perspective, including strong environmental assessments, and these are the processes by which new industrial projects should be judged. For the NRBS Board to forward a recommendation to the Ministers that would eliminate such projects, before any review process, would not be responsible.*
>
> *"Recommendation 1-3. Our dissenting position with this recommendation pertains to the elimination, or the far-reaching capping, of all nutrients from discharges. This recommendation has enormous potential cost implications for all municipalities in the northern river basin area. It is our understanding that some recommendations on nutrient discharges may be forthcoming from Alberta Environmental Protection in the future, pertaining to tertiary treatment of waste water in larger municipalities. The [Board's] recommendation, as written, does not exclude any municipal waste water treatment facility and, as such, is not acceptable.*
>
> *"Recommendation 1-4. We oppose this recommendation because it refers to elimination of the discharge of other wastes. We have absolutely no objection to the term 'reduction' of other wastes, but, as noted in our objection to the*

previous recommendation, we do not believe that zero discharge is a possible objective."

In place of the Board's recommendations, these Board members offer the following alternative, that:

> *"The regulatory agencies within the northern river basins set, as an objective, the on-going reduction of emission of contaminants, nutrients, and oxygen demanding materials that are determined to have detrimental impacts on river systems and/or human health;*
>
> *"Methods of discharging effluents be continually improved and upgraded, as technology allows, with reasonable environmental and economic considerations;*
>
> *"On those reaches of rivers that have been determined to bear excessive effluent loading, a policy of no further loading be established with a future program of staged reduction of effluent discharge."*

The above dissenting opinions and recommendations were submitted by the Board members, Mayor Michael Procter and Councillor Diane Slater.

Another Board member expressed the following view:

> *"It is not reasonable to specify a ten-year period for the elimination of "persistent toxic substances". The timetable must be site specific. The reasons are obvious — technology status, business constraints, and substance differences. This may also inhibit the development of more cost-effective technology. It may be more appropriate to use regulatory means at the licensing level to deal with time-tables."*

A further dissenting view was expressed by another Board member with regard to the time line set for eliminating the use, generation and discharge of persistent toxic substances recommended in Recommendation 1-2:

> *"The technology does not now exist to enable this time limit to be met without placing a huge economic burden on the existing industry and creating related spin-off effects on the citizens of the region. (For example, as a minimum it would require change in TCF technology, even though the zero effects are not proven.) There will be ways to eliminate the substances used or produced by these technologies, but not in the time frame indicated."*

RECOMMENDATION 2, BASIN MANAGEMENT

Preamble

Oxygen is required by aquatic organisms to survive, grow and reproduce. Dissolved oxygen in water can be depleted during winter as a result of oxidation of organic matter (decomposition) during the time of year when ice and snow cover prevent replenishment by photosynthesis and reaeration. The sources of organic matter that contribute to under ice water column and sediment oxygen demand (SOD) include terrestrial leaf-litter, suspended solids in pulp mill and municipal effluent, and elevated levels of algal growth in nutrient enriched reaches of the rivers. Wastewater effluent may also have significant levels of biochemical oxygen demand (BOD). Continuous winter dissolved oxygen monitoring and winter dissolved oxygen surveys on the Athabasca River have shown that levels have stayed above 6.5 mg/L at the two low points upstream of Smith, Alberta and upstream of Grand Rapids since 1989. Pulp mill BOD discharges presently exist at less than half of their licensed limits and are not as dominant a factor in determining winter dissolved oxygen as they probably were during the 1960s. Under present conditions BOD, SOD, headwater and tributary dissolved oxygen inputs, mainstem flows, and reaeration at variable open water leads, all appear to be important influences on winter dissolved oxygen.

Laboratory studies on effects of lowered dissolved oxygen levels (3 mg/L) at low temperatures (2-3^{0}C) showed that mountain whitefish eggs took longer to hatch and bull trout alevins were less well developed than at higher dissolved oxygen concentrations. The commonly occurring mayfly in the northern rivers (*Baetis tricaudatus*) was also found to have decreased survival and reduced feeding rates at a dissolved oxygen concentration of 5 mg/L. Given that mayflies and the early life stages of fish live at or in the surface layers of the riverbed and that dissolved oxygen concentrations can differ by 3 mg/L between the water column and the water in the sediments of the riverbed, dissolved oxygen concentrations in the Athabasca River could already be at levels that could have chronic effects on these animals at localized sites.

Additions of nutrients such as nitrogen and phosphorus stimulate plant growth which in turn contributes to oxygen deficiencies under winter ice. Effects of this kind are negligible in the mainstems of the Peace and Slave rivers but in the Athabasca and in the Wapiti / Smoky systems, pulp mill and municipal effluent cause biological enrichment. Many organisms, including fish may grow faster and have higher rates of survival. Nutrient additions are thus a mixed blessing, since moderate additions can increase the growth of aquatic insects and fish but excessive enrichment can substantially degrade water quality and the aesthetics of rivers.

In the long term, nutrient enrichment is cumulative. Nitrogen and phosphorus recycle in ecosystems. In consequence, the initial impact of nutrient additions may extend for only a few kilometres downstream from a point source, but subsequently the effect may be observed much further downstream. While the effect of a point source is quickly dampened as the nutrients become chemically locked in sediments or become incorporated in plants and animals, the release of nutrients from sediments that are disturbed or from decomposing plants and animals can extend nutrient impacts far down stream.

Conclusion

The adherence to strict uniform wastewater treatment design standards for all municipalities, without regard for the fish habitat and existing dissolved oxygen problems in downstream reaches, may be inadequate to protect these reaches and may also unduly penalize some communities situated on larger, well-oxygenated reaches. The Board concludes that governments must examine the concept and implementation of reach-specific water quality objectives to protect sensitive fish habitat and spawning areas while taking into account nutrient and contaminant loadings to the river.

This implies a need to achieve a better understanding of the dissolved oxygen requirements of various fish species and other aquatic organisms in the northern rivers under ice cover winter conditions.

The Board is not satisfied that present regulation of nutrient additions is adequate for controlling their environmental effects in many locations in the basins. As cities and agricultural activities grow and as new industrial facilities come online, nutrient effluents may constitute a worsening long-term threat to the ecosystem. Effluent standards for municipalities should be based on providing a good general level of treatment supplemented by additional (tertiary) treatments as necessary to protect downstream fish habitat and maintain dissolved oxygen levels. Standard reporting requirements for water quality parameters and flow rates should be in place. Correction of these and other deficiencies would ensure better control of nutrient rich effluent from municipal sewage treatment plants and pulp mills and would facilitate assessment of long-term consequences of nutrient additions.

The Board recommends that:

1. **The Governments of Alberta and Canada initiate and complete the necessary studies to determine the winter dissolved oxygen requirement for fish and other aquatic species as per the CCME Guideline Protocol, and subsequently assess the oxygen requirements for the organisms in the various reaches of the northern rivers.**

2. **Alberta adopt the CCME Dissolved Oxygen Guideline of 6.5 mg/L as an overall provincial approach in making decisions on future development proposals.**

3. **Throughout the basin, nutrient and biological oxygen demand monitoring be improved, especially for municipal sewage treatment facilities and some pulp mills. Standards for Quality Assurance / Quality Control requirements be enhanced for existing and future effluent licences and permits. These data be logged in a central database and linked to provincial water quality data.**

4. **Phosphorus concentrations in pulp mill effluents be reduced to minimal levels. Alberta Environmental Protection require pulp mills to monitor and assess their operations to ensure that phosphorus additions are not in excess of what is needed to minimize BOD of effluent.**

5. **Municipal sewage effluent may require tertiary treatment to reduce phosphorus additions at certain locations. The Board recognizes the significant cost implications but emphasizes the importance of reducing phosphorus inputs over the long-term. Particular attention is drawn to the Wapiti / Smoky system at Grande Prairie, and to the inadequately treated municipal sewage entering the upper Athabasca River from the town of Jasper in Jasper National Park.**

RECOMMENDATION 3, BASIN MANAGEMENT

Preamble

Uppermost in the concerns of northern residents is whether the water is safe to drink and the fish are safe to eat. The Board's drinking water study went far afield from the mainstems of the rivers and their tributaries, examining the quality of water that people actually drink from a variety of sources. There are 122 drinking water treatment and supply facilities in Alberta that are regulated by the federal and provincial governments. These facilities serve a population of approximately 173 300. Thirty-seven of these facilities serve a population of approximately 151 400. The remaining 21 900 people are located in 85 communities with less than 500 population each.

Studies determined that the risks stem primarily from the consumption of water from unregulated or non-conventional supplies and in some communities with less than 500 population. The risks arise primarily from microbial contamination that poses an immediate health risk, as compared to chemical parameters which are usually only a concern in the context of a lifetime of exposure.

Information on water treatment facilities in the Northwest Territories was not included in the assessment.

Conclusion

The problems in smaller communities are often related to the operation of plants because facility owners do not make use of existing operator training, certification and assistance programs. Facility owners must be educated so that water treatment becomes a priority. The facilities must be given adequate attention and resources. There is a need to continue enforcement of water quality guidelines and promote standardized water delivery and storage practices. Drinking water quality monitoring requires improvement. There is a need to provide public education on safe use of naturally found water.

The Board recommends that:

1. **The federal, provincial and territorial governments increase their efforts in the smaller communities to educate facility owners regarding the need to properly operate the water treatment facilities including the use of the existing programs for operator training, certification and assistance.**

2. **The federal, provincial and territorial governments ensure that there are adequate treatment facilities, equipment and operating standards for their constituents.**

Recommendation 4, Basin Management

Preamble
The integration of water quality and water quantity is essential for sophisticated water management. Their separation in Alberta government legislation is unfortunate. The impact of effluent on river ecosystems depends not only on the substances they contain but as well on how rapidly effluents are diluted. The Water Management Advisory Committee, during its public meetings, received many comments on this subject stressing the need for "strong, visible coordination or links" between the new *Water Act* and the *Environmental Protection and Enhancement Act*".

Conclusion
Aside from provisions for referral, the proposed new Act is silent on the subject of the coordination of quantity and quality. Water management plans may involve cooperation with "government agencies and other government departments" that could include Alberta Environmental Protection but the key issue of integrating water quality and quantity considerations is not specifically nor adequately addressed.

The Board recommends that:

1. **The proposed Alberta Water Act make specific provision for the integration of water quantity and water quality planning and administration.**

Recommendation 5, Basin Management

Preamble
Adequate levels of flow are necessary for the protection of stream and riparian biota, for aesthetic reasons, and the pursuit of stream-based recreation. Ensuring those flow levels is commonly recognized as being consistent with balanced use of water resources. There are many administrative ways to secure these instream flow needs (IFNs), among which is the provision in the proposed new *Alberta Water Act* for the government to apply for a licence. The Act does not make clear what might motivate the Alberta government to apply for a licence but presumably, strong representations from residents and users could be influential in determining government actions. Proactive steps from within government might lead to a more consistent approach.

Conclusions
The Board is of the view that the Alberta government should play an active role in setting aside stream flows for protection of aquatic habitat. A positive proactive program with consistent criteria would best serve the public interest.

The Board recommends that:

1. **The government of Alberta provide leadership in water management planning incorporating, as a first priority in the water management process, instream flow needs for ecological purposes in the northern rivers and their tributaries within the province.**

Recommendation 6, Basin Management

Preamble
Inspection and enforcement of regulations concerning water quality and water quantity are essential for wise use of water resources. Until recent decades, competition for water has not been intense. With progressively greater settlement and industrial activity there has been a commensurate requirement for closer control of water uses. Many licences provide for more water than is needed. Some people believe that some licences provide for much less than is taken. The proposed new *Alberta Water Act* contains an arsenal of provisions for inspecting and enforcing water quantity that should be used fully.

The same may be said for the provisions of the *Alberta Environmental Protection and Enhancement Act* with respect to inspection and enforcement of licensing provisions for effluent discharges. Without rigorous inspection and enforcement the purpose of legislation may be frustrated.

Conclusion

In the course of its public meetings throughout the basins, the Board heard strongly expressed views about the ineffectiveness of current inspection and enforcement activities. Public concern about the adequacy of inspection and enforcement were echoed in the Board's survey of basin residents. It is evidently perceived that much could be done to address these concerns.

The perceptions may not necessarily accord with realities, in which case there is need for better communication with the public. On the other hand, concerned members of the public should do everything reasonably possible to determine whether the facts support their perceptions. This might be achieved in part by applying for information under the Freedom of Information Act. In any event, the Board feels there is room for improvement in the areas of inspection and enforcement of water licence legislation.

The Board recommends that:

1. **Jurisdictions of the northern river basins strengthen and publicize inspection and enforcement activities with respect to protection of water quantity and quality.**

RECOMMENDATION 7, BASIN MANAGEMENT

Preamble

The Peace-Athabasca Delta has been slowly drying up since the Bennett Dam was completed over 20 years ago. Regulation of the Peace River flow at the Bennett Dam has been held partially responsible because spring and summer flows are lower and winter flows higher. The effect of the Bennett Dam has been exacerbated by relatively dry climate conditions over the past two decades. Rock filled weirs, constructed in the 1970s, have restored summer water levels and reduced their seasonal amplitude, but have not reflooded many of the perched basins — the areas that have experienced the most drying. For these basins, a large-scale flooding of the Peace River is required.

Several measures could be taken to reflood all or part of the delta periodically. Variable height control structures that allow water in but not out of lower basins have been used on an experimental basis in the past with some success, but problems with ownership and responsibility must be addressed. The method deserves further attention and though it would affect only limited areas it would provide valuable information on the response of vegetation to flooding. Hydraulic pumps have been suggested for flooding perched basins above the main flow network but for larger scale flooding, the construction of an ice dam near Quatre Fourches Dog Camp is probably needed. An attempt in 1994 / 95 was hampered by winter decreases in flow related to operation of the Bennett Dam. Future attempts should be preceded by understandings with B.C. Hydro.

Complete restoration of periodic flooding of the higher perched basins is only feasible with an ice dam on the Peace River, perhaps with ice thickness enhanced using spray ice techniques. This method will probably only work in years when high tributary flow is augmented by increased releases from the Bennett Dam. Monitoring the snow pack of tributary basins is essential for precise forecasting of the likelihood of favourable conditions for flooding. Present monitoring of the Wabasca River basin is inadequate and further refinement of Smoky River basin monitoring would be desirable. The creation of ice jams using "thermo-siphons" as initiators was suggested in the early 1970s and is worth consideration. Reopening a connection from the Peace River to the creeks that drain into Lake Claire would facilitate flooding and a connection via the Claire River has recently been opened.

Reclamation of the delta is of great importance to residents of the area. Production of waterfowl, muskrats, fish and bison depends on returning the delta to its former state. The way of life for delta residents depends in turn on restoration of its flooding from time to time (see the Traditional Knowledge synthesis report).

Conclusions

The Board was pleased that projects of the Study and those of the Peace-Athabasca Delta Committee could be undertaken closely together and that the Science Advisory Committee's services were available for both.

The Board concludes that enough is now known of the mechanisms responsible for flooding of the delta to make attempts to partially or fully return the delta to its natural condition of periodic flooding. The Board's studies, both scientific and traditional knowledge, have demonstrated conclusively that the flow regulation and operation of the Bennett Dam on the Peace River has altered the aquatic ecosystem to a large extent throughout the basin. Mitigation of these impacts in the absence of a natural flow regime has proven to be extremely difficult in the one area of the basin where attempts have been made (Peace-Athabasca Delta). Many other areas, habitat types and specific reaches remain with unchallenged and dramatic impacts from the alterations to the natural flow pattern. The causes are complex, including possible factors such as climate change, and no results can be guaranteed. However, some modification of regulation of discharge from the Bennett Dam in late winter and spring, combined with high tributary flows, could be an element of major remedial plans.

Downstream effects and conditions as a result of development are important and must be considered in any development. Where effects result, the cost of mitigation and remediation strategies should be factored into the development.

For all reclamation schemes, public consultation with residents of the region is essential. They not only have a lot at stake, but are very knowledgeable about the complexities of the delta and its history of flooding. Moreover, they may feel that the future of the delta may not necessarily be designed to mimic the past; other land use options are available.

The Board recommends that:

1. **The governments of Canada, Alberta and British Columbia implement an action plan for reclamation of the Peace-Athabasca Delta, the plan to include provisions for environmental impact assessment and public consultation with delta residents and with those that might be affected downstream, such as at the Slave River Delta.**

   The plan may also include full-scale delta flooding requiring modification of the flow from the Bennett Dam, which may mean possible impacts along the Peace River, notably at the town of Peace River. It may also result in denial of any additional hydroelectric development in either British Columbia, Alberta or the Northwest Territories if it has impacts on reclamation of the delta.

2. **As a principle for any future negotiations on mitigation of the impacts of the Bennett Dam, that the dam's operating regime be modified to help rehabilitate the Peace-Athabasca Delta and the riparian and aquatic conditions of the Peace River system. Further, that economic considerations of power production from this industry should not take precedence over the environmental stability and natural ecosystem of the Peace River, Peace-Athabasca Delta, Slave River and Delta and the Mackenzie River system.**

Dissenting Views

A dissenting view was expressed by a Board member:

> *"It would be impossible to restore pre-regulation flow patterns to the Peace River without the removal of the W.A.C. Bennett Dam and the second dam that is downstream of the Bennett Dam. Further, it is very important that the level of the Peace River, at the Town of Peace River, freezes over at a reasonably high level to ensure that the ice cover is not broken up during later, higher power generation periods. It is not reasonable to expect that B.C. Hydro would agree to eliminating power generation during their peak demand months of December, January, February, March and April. An*

additional issue is; How would the storage capacity of Williston Lake respond to the substantial reduction of discharge of water during the winter months?

Recommendation 8, Basin Management

Preamble

Rivers are integrators of natural factors and of human activities in the basins they drain. The fate of river ecosystems is critically dependent on what happens on land. The Study Board was frequently encouraged at its hearings to engage in studies of land management but was reluctant to go far afield from its mandate. Nevertheless, the Board repeatedly acknowledged the need for better understanding of the effect of land use patterns on the northern river systems.

In addition, the Board devoted some time in its various discussions to a few issues of land use management of particular relevance to the northern rivers, such as land clearing for agriculture and clear cutting in forestry. The Board noted in its discussions that legislation to ensure integration and coordination of land use management planning and water management planning is not in place for the northern river basins under current territorial or provincial legislation. The proposed new *Alberta Water Act* does not make explicit provision for the integration or coordination of land use and water management planning. Moreover, the June 1995 repeal of the *Alberta Planning Act* and subsequent changes to the *Municipal Government Act* have eliminated the role of regional land use planning in Alberta. Such integration and coordination as does occur at present is in the hands of an interdepartmental committee. Surprisingly, the solitudes of land use management and water use management persist despite widespread awareness of their interdependence. For example, the recently released *Alberta Forest Conservation Strategy* makes virtually no mention of the impact of forest management practices on the quality or quantity of water in streams and rivers or their effects on river ecosystems.

Northern Alberta has undergone significant development in the past few decades and there are prospects for further economic growth in the coming years. Extraction of oil from oil sands could significantly increase, forest harvesting and forest products manufacturing will probably increase, and agricultural land clearing will continue. Together with other developments, these activities will entrain increases in population and recreational uses of the region all with potential impacts on the northern rivers. These changes will take place during a period of world wide climate change in which the effects on the northern river basins area could be potentially greater than elsewhere in North America.

Conclusions

The Board wants to ensure that land use planning and water use planning are sufficiently integrated so as to ensure wise long term management of the natural resources of the northern river basins. This view is strongly supported by those who live in the basins.

The Northern River Basins Study was aimed at the waterways of the north. The Board recognized that the long-term effects of forestry, agriculture, oil and gas development and other land clearing in the Athabasca, Peace and Slave Basins are inadequately known and that these activities may have profound consequences for the aquatic ecosystem.

But the Board also realized that to undertake a detailed and comprehensive review of land use practices was beyond its time frame and resources. The necessary understanding can only be gained by the sustained and coordinated attention of the responsible government agencies.

The Board noted that several studies have been initiated over the past five years on various aspects of the impact of forest management practices on hydrology and other environmental concerns. It is important that the findings of these studies should be quickly incorporated into basin management planning.

The Board recommends that:

1. **Formal arrangements be made to ensure that land use planning and water use planning are integrated as basin management planning throughout the northern river basins;**

   a) **the effects on surface waters and the mainstem rivers of agriculture, forestry, oil and gas activities and other land clearing be reviewed on a continuing and comprehensive basis;**
   b) **all aspects of land use activities be scrutinized including land clearing, road building, channelization, revegetation, use of fertilizers and biocides and waste disposal;**
   c) **attention be given to groundwater levels, flow patterns in tributary streams and the integrity of fish spawning areas; and**
   d) **compounding effects of potential climate change and of atmospheric sources of contaminants be considered as important elements of context.**

RECOMMENDATION 9, BASIN MANAGEMENT

Preamble

Water shortages are frequently foreseen as likely causes of national and international discord in the 21st century. Schemes for longer scale transfers of water from one region to another will be proposed, some of which may well be resurrections of schemes that have been proposed in the present century. There is a public fear, expressed through the householder survey and the Board's public consultations, that the waters of the northern river basins may be attractive for major diversions. With the likelihood of climate change their flow may be reduced at the same time as schemes for their diversion proliferate. The potential ecological impact of major diversions from the northern rivers could also have serious ecological and societal consequences.

Conclusions

The Board is strongly of the view that major diversions from the northern rivers should not be permitted.

The Board recommends that:

1. **The governments of Canada, the Northwest Territories, Alberta, British Columbia and Saskatchewan exercise their legislative powers to the fullest in preventing major diversions of basin water outside of the northern river basins.**

4.3 REACH-SPECIFIC ISSUES

Certain recommendations address specific reaches of the rivers, where the Study has identified issues of immediate and pressing concern. These recommendations, although they may also relate to basin management, monitoring or research, are presented together here for ease of reference.

RECOMMENDATION 10, REACH-SPECIFIC ISSUES

Preamble

In assembling the information on a variety of contaminants and their possible effects, the NRBS studies have identified three particular areas as worthy of special attention.

Based on the weight of evidence approach, the Wapiti / Smoky river system is currently the most heavily stressed in the northern river basins. Issues of concern include high levels of nutrient addition from the City of Grande Prairie and the Weyerhaeuser pulp mill, sharp declines in under-ice dissolved oxygen, and the high PCB loadings in sediment and fish. Dioxin and furan concentrations in biota have declined since 1992, but remain among the highest observed in the basins. When reduction in winter snow pack and subsequent declines in discharge levels occur, this serves to further concentrate contaminants and nutrients in the system. Prevention of further deterioration should be a priority for management authorities, as should be the remediation of an already stressed aquatic ecosystem. These tributary systems are small and relatively shallow, provide critical fish spawning habitat and are therefore particularly vulnerable to the effects of pulp mill and municipal wastes.

NRBS studies consistently found that fish in the Slave River Delta were large and in good condition. However, these same populations also exhibited elevated biomarker responses (e.g., metallothionein). Although NRBS has obtained evidence that pulp mill contaminants are deposited in the delta and Great Slave Lake, observed levels are currently low and the actual exposure of these fish to contaminants, either from Great Slave Lake or from upstream sources remains unknown.

Recent improvements in process technology at the Hinton pulp mills have reduced levels of persistent organochlorine contaminants entering the environment. This improvement is reflected by declines in measured levels of certain contaminants (e.g., dioxins and furans) in sediment and biota. However, NRBS has identified contaminant-related concerns in the Emerson Lakes area below Hinton and has recorded a high incidence of fish abnormalities below Whitecourt. In addition, nutrient discharges from the Weldwood mill have resulted in "nuisance" growth of algae for up to 30 kilometres downstream of Hinton. Improvements in pulp mill technology may serve to reduce these impacts, but given current conditions in this reach, monitoring should be particularly vigilant.

Conclusion
The Board has reviewed the reach specific findings of Synthesis Report #11 and draws particular attention to concerns for these three regions of the basins.

The Board recommends that:

1. **The Ministers direct action to be undertaken to protect the Smoky and Wapiti Rivers from further dissolved oxygen, nutrient and contaminant stress, and undertake to develop and apply reach-specific guidelines and associated regulatory requirements relevant to the small size of these rivers.**

2. **Fish contamination and fish health effects be assessed for the populations of fish in the Slave River Delta ecosystem.**

3. **Monitoring activity be intensified in the reach of the Athabasca River from Hinton to below Whitecourt.**

4.4 Monitoring

Adequate protection of a river ecosystem requires keeping track of ambient conditions and of what is going into the river, what impact it has on the organisms that live in the river and what effects there may be on humans who drink the water or rely on the river for food. The synthesis reports contain many specific recommendations for monitoring which will be of interest to research and management specialists. The policy recommendations which follow this introduction are directed to the attention of water resource managers.

Monitoring is undertaken for a variety of reasons. Effluent monitoring, keeping track of what goes into a river from point sources such as industrial operations or municipal sewage discharges, is relatively straight forward. Alberta Environmental Protection has a comprehensive set of standards, requirements and procedures for point source monitoring by licensed facilities. Quality assurance and quality control measures should be rigorous, should address issues of sampling, laboratory analysis and data processing and the science should be overseen independently.

Monitoring of ambient water quality enables assessment of the combined effects of point and non-point sources as well as changes arising from natural causes. Environment Canada has eight active monthly water quality monitoring stations in the Peace, Athabasca and Slave basins. Alberta Environmental Protection has a network of 20, designed to undertake investigations in the vicinity of major industrial developments and conducts special surveys where potential problems are apprehended. British Columbia operates a single monitoring station on the Peace.

Alberta Environmental Protection has an extensive set of standards and monitoring requirements for industrial and municipal facilities. The frequency of monitoring depends, among other things, on the type of treatment process, retention time, environmental significance of substances being released, the need for baseline information, cost in relation to capabilities of the discharger and the benefits obtained and the compliance history. Monitoring requirements can be modified if circumstances so dictate. The federal government's involvement in monitoring is focused on scientific and technical leadership for monitoring methodology and on the design of data base systems to support monitoring programs of national interest. The federal, provincial and territorial governments are currently engaged in harmonization discussions and have developed a draft *Environmental Management Framework Agreement (EMFA)*. It addresses, among other topics, the proposed roles of each government in monitoring. The Study Board supports the intent of these discussions.

Monitoring of water quantity, flow or discharge touches on all aspects of water use and is thus of central significance to water management. After an initial survey, a gauge to measure the river level may be sufficient for estimating discharge. Recalibration of the relation between gauge height and discharge is necessary periodically to account for changes in the river cross section. The federal government has played a leading role in monitoring flows in major river systems in Canada, a role which is currently being reviewed. The Study Board views close cooperation between the federal and provincial governments as desirable.

Time series of available hydrologic data are relatively short for the northern rivers. They do not provide an adequate basis for projecting hydrological characteristics that are relevant to such matters as water quality, flood control and sediment transport. The prospects of climate change heighten the need for monitoring of flows.

Environmental impact monitoring is a logical sequel to environmental impact assessment. In conformance with a federal government proposal, the Province of Alberta is currently implementing the pulp mill Environmental Effects Monitoring (EEM) program, which involves characterizing the effluent, describing the plume at various levels of flow, and monitoring the environmental impacts of the effluent. Quality assurance and quality control measures are necessary for field sampling methods as well as for laboratory analyses and data analysis.

The EEM program is designed to be undertaken by industry on a three-year cycle. Each EEM proposal is reviewed by a team of experts with representation from Environment Canada, Alberta Environmental Protection, and Fisheries and Oceans Canada. While the Administrative Agreement signed under the *Fisheries Act* designated the Province to take the lead in coordinating the EEM, neither the study proposal nor the review team participation will be altered. The province will serve as the one-window contact and coordination body.

This delegation to industry would not address cumulative effects, nor would it gain universal public confidence as providing independent assessments of environmental impact.

Methodologies of environmental impact assessment are continually being refined. Every effort should be made to standardize methods and to develop techniques for detection of long term trends in abundance and health of plants and animals. This is a particular problem for the northern rivers that are much less known than those that are southerly. A strategy for monitoring should be developed that spells out the details of methodology including the frequency with which various measurements should be made and the possibility of "pulsed" monitoring with intensive studies at intervals of several years.

The number of substances entering the northern rivers from effluent discharges is very large.

Municipal effluent alone contain the wide variety of things that are used in every day life, ranging from paint remover to birth control pills. Industrial effluents have an equally wide variety of organic and inorganic constituents that includes the residues of chemicals used in processes and the products of their interaction with substrate materials such as wood. Treatment reduces some of these effluent materials but what is discharged still bears a "fingerprint" of its source of origin. A river receiving several effluents gains a composite fingerprint. Only a small proportion of the substances involved may be identified but their molecular weights will show up in the output chart of a mass spectrometer, like individual peaks of a mountain range, a sort of fingerprint of what a sample contains. This technique, known as broad spectrum analysis is currently used by Alberta Environmental Protection. Its further development has been pioneered by the Study. Broad spectrum analysis is an effective tool for comprehensive assessment of the contents in effluent and ambient water. This technique has potential for enabling detection of changes in effluent loadings and rapid identification of their specific sources.

Public participation in monitoring has been practiced in some jurisdictions in the United States and was advocated in representations to the Study Board. The objectives of volunteer monitoring programs include acquisition of local knowledge, public education, the provision of data for water quality and impact assessment and an enhanced public auditing function. The quality of the data determine the uses to which they can be put. For some measurements field sampling methods are technically demanding in both equipment and expertise and are probably best attempted by volunteers only after specialized training. But most routines are readily handled after brief training and can provide valuable supplementary information to government agency monitoring programs. The values of public involvement are self evident both for the volunteers and those with whom they associate. Whether the data collected by volunteers is sufficient for watchdog purposes depends on the quality and quantity of the data and how systematically they are collected. The Study Board endorses the concept of public participation in monitoring.

RECOMMENDATION 11, MONITORING

Preamble

Monitoring is undertaken by several interests: industrial, municipal, provincial, territorial, federal and in the course of research projects by university and other researchers. To gain a comprehensive picture of what is going into the rivers and what effects it has on the physical, chemical and biological characteristics of the rivers requires the assemblage of a diverse package of information. There are inconsistencies in the quality of data, and in their methods of analysis and archiving. For purposes of cumulative assessment, some parameters are measured at intervals that are too infrequent, others are measured more often than is necessary, or to a degree of precision that is not warranted, still others that should be measured are not measured. The various shortcomings of the various monitoring activities have arisen in part because events have overtaken them. New philosophies of ecosystem assessment together with new technologies and new understandings require that the approach to monitoring should be dynamic, evolving to meet changing circumstances. Moreover, as the requirements for more and better monitoring expand, the value of coordination of efforts is increasingly apparent. Similarly, greater consistency in the software used to record monitoring data is necessary if data from different sources are to be readily accessed and compared.

Monitoring is central to the allaying of public concerns about whether it is safe "to drink the water and eat the fish". Monitoring must be seen to be efficient, effective and rigorous, and that can be seen to be doing impartial assessments using state-of-the-art science and technology. Recent research on assessment of environmental impacts on rivers has emphasized the necessity of holistic ecosystem approaches. Water quality and effluent emission standards are at best only an indirect measure of what the biological effects may be of discharging effluent. Much better indicators are the plants and animals themselves and the properties of the ecosystem of which they are constituent parts.

The Board is also of the view that the time has come to follow the lead of other jurisdictions in involving the public in monitoring, perhaps on a modest basis as a start, as well as ensuring unfettered public access to monitoring information. To be credible, monitoring by volunteers must be well managed and technically adequate. Meaning well is not enough.

The importance of ongoing research in support of monitoring cannot be over emphasized. The technologies of industrial operations evolve continuously. Research elsewhere in the world creates awareness for monitoring of substances not previously known to have environmental effects. New techniques of analysis bring greater sophistication to data interpretation.

In Canada the leading roles for research related to monitoring have been played by the federal government laboratories with some participation by universities and by industrial associations such as the Pulp and Paper Research Institute of Canada (PAPRICAN). These have been successful national arrangements and should be continued, placing emphasis on maintenance of the strengths of federal government laboratories.

Conclusion

The Board has heard many comments on the subject of monitoring and is aware of current "harmonization" discussions between the federal and provincial governments. The Board has considered various options for rationalizing and improving monitoring including the establishment of a "completely independent" agency such as the Clean Air Strategic Alliance (CASA). It is the view of the Board that the best approach is to ensure that current monitoring efforts are coordinated, on an ongoing basis, and assessed for adequacy. Consistent with the principles it has espoused, the Board is convinced of the importance of an ecosystem approach to monitoring with all that is implied.

The Board has been conscious of the importance of first class scientific advice in the interpretation of monitoring data and fully recognizes the need for research guidance in the continuing evolution of monitoring techniques. Collaboration among the various agencies is much to be desired as a means of ensuring relevance and excellence at least cost.

The Board recommends that:

1. **The Alberta and Northwest Territories Governments invite representatives of the governments of Canada, British Columbia and Saskatchewan, municipalities, industry, universities, First Nations and other agencies involved in monitoring activities, in consultation with an advisory committee involving members of all stakeholder groups concerned with or affected by monitoring activities, to participate in an Integrated Ecosystem Monitoring Committee (IEMC). The role of the IEMC would be to coordinate and oversee technical and scientific aspects of water quality, water quantity and biota monitoring in the northern river basins to ensure minimal duplication of effort and greatest collective efficiency. The IEMC would adopt an ecosystem approach to environmental monitoring (see Synthesis Report #10).**

Among its activities the IEMC would:

- a) **evaluate and standardize protocols for design of data collection and management, quality assurance / control and data analysis, giving particular attention to the frequency of monitoring for various contaminants in fish and sediments;**
- b) **establish a standardized database for the basins;**
- c) **recruit and oversee volunteer organizations and individuals into the monitoring activities providing orientation and training as required;**
- d) **establish a small independent panel of experts on the technical aspects of monitoring to advise the IEMC on its program implementation, data interpretation and scientific recommendations; and**
- e) **play a lead role in setting the research agenda for the northern river basins as it relates directly to monitoring of effluent discharges and their individual, synergistic and cumulative effects.**

Preamble

The presence of contaminants in the food chain including fish is a concern for many local residents of the northern river basins who rely extensively on traditional foods for subsistence.

For the various Study projects, a large number of environmental samples and fish samples was subject to various chemical analysis. While, in general contaminant levels do not constitute an immediate health problem, a review of the findings indicates that there are opportunities for various contaminants to enter the food chain that leads to the dining tables of northern residents. Such contaminants include dioxins, furans, toxaphene and mercury. The daily intake of these compounds may be limited by fish consumption advisories in some reaches of the river systems, but based on current knowledge, intake is low and appears to be without appreciable risk to health.

Of all of the contaminants found in the northern rivers, none is of more widespread concern to human health than mercury. Most of the mercury is of natural origin, augmented by contributions from the atmosphere at a rate of roughly one per cent each year. Large reservoirs behind dams, such as the Williston Reservoir, flood soils and produce quantities of methylated mercury for many years after they are first filled.

At several places in the Peace and Athabasca systems concentrations of mercury in filets or livers of predatory fishes (e.g., pike, walleye, burbot and bull trout) approach or exceed national standards (e.g., Williston Lake, western end of Lake Athabasca and the lower Athabasca River). Appropriate health advisory warnings have been posted. The risks of mercury poisoning are proportional to the rate at which fish are consumed as well as to the content of mercury in the fish and to what part of the fish is eaten. Fish livers concentrate mercury as well as other contaminants because the liver is the detoxification centre of the body.

In general, mercury levels are at levels that are not a threat to human health for the great majority of fish eaters, but for the few heavy consumers in localized areas there could conceivably be problems. In the future if mercury levels continue to rise from atmospheric fallout, the threat to human health will increase.

Traditionally, fish consumption guidelines have been defined by first establishing an experimental threshold in animals. A fraction of the threshold concentration obtained by applying a large safety factor is then denoted as the standard. From a human health perspective, however, it is important that a balance be found between eating fish, which provides an excellent source of protein, and the potential danger to health due to contaminants. Factors such as, the movement of fish, the geographic variation of concentrations, the types of fish contaminated, trends of concentrations over time, to mention just a few, also have to be considered in developing and reassessing fish consumption advisories.

Conclusion

The Board noted the existence of fish consumption advisories in various reaches of the Peace-Athabasca-Slave rivers system. There is a need to review existing advisories in the light of the new information about contaminants in fish and for the development of new, human health based policies, standards and guidelines.

The Board recommends that:

1. **Alberta Health, Alberta Environmental Protection and Northwest Territories Health and Social Services, together with Health Canada and First Nations Health Authorities be charged with the responsibility of leading and coordinating the development of new, human health based fish consumption policies, standards and guidelines for the Northern River Basins. This will require close collaboration and cooperation with other provincial, territorial and federal agencies, to rationalize and harmonize the extent of advisories across administrative boundaries. The process should build on the data and information generated by periodic surveys of fish contaminants. An improved mechanism should include the timely interpretation of findings, dissemination of information in a meaningful and culturally sensitive fashion, and contemporary population health risk assessment, risk management and risk communication concepts.**

4.5 RESEARCH

The synthesis reports prepared by the various study components are appended to this report of the Study Board. They contain a substantial number of detailed recommendations that are drawn to the attention of research specialists and resource managers. All good research reports conclude with a list of suggestions for future research, which is as it should be. But in the case of the northern river basins the needs for future research also reflect the size and length of the rivers and their northern location — factors that contribute to a dearth of previous studies. When the NRBS program was conceived it was with the aim of "plugging gaps" in knowledge of the rivers. Many of the gaps have now been filled. At the same time, many new gaps have been identified. Research on the northern rivers must be continued. Research lights the way to the realization of new problems and new opportunities.

The Board views the future for research on the northern rivers as very important. If the rivers are to receive the attention they need to ensure their wise management, they must be given high priority in the research agendas of all levels of government. The recommendations that follow are presented with an appropriate sense of urgency.

RECOMMENDATION 13, RESEARCH

Preamble

Concentrations of polychlorinated biphenyls (PCBs) are generally absent or low in the northern rivers but some concentrations observed in burbot from the Peace River system (Wapiti River near Grande Prairie and from the Peace River upstream of its confluence with the Smoky) and the Athabasca River below Hinton were relatively high. PCB concentrations in Wapiti River burbot almost doubled between 1992 and 1994. A few kilometres upstream of the Peace-Smoky River confluence a relatively high concentration was observed in deposited sediments. The relative abundance of different kinds of PCBs was not the same in fish at the Wapiti and Peace River sampling locations, suggesting the burbot on these systems may have been exposed to different sources of PCBs.

Conclusion

These various findings warrant a special follow-up study to identify the sources of the PCBs in the Wapiti, Smoky, Peace and Athabasca river systems.

The Board recommends that:

1. **The Ministers direct further investigation to be undertaken into defining the extent of PCB contamination and their sources in the Wapiti, Smoky, Peace and Athabasca river systems.**

RECOMMENDATION 14, RESEARCH

Preamble

Prior to the Northern River Basins Study, knowledge of the northern rivers was fragmented and incomplete. Some of the major accomplishments of the Study have been to assemble available information, augment the database by filling in gaps and summarize the present state of knowledge of the northern river basins. Much remains to be learned.

Collaboration among the various research sectors has been a notable feature of the Study, building on a modern trend to collaboration as a means of achieving both efficiency and effectiveness. The experience of the Study has underlined that the various levels of government, the First Nations, the universities, industry and the concerned local public have different perspectives on research needs. Their collaboration has helped ensure both quality and relevance.

Conclusions

The Board concludes that to best serve the purposes of management, further research on the northern river basins should be given high priority and the process of synthesis of findings should continue. Particular attention should be given to follow-up on the research recommendations contained in the synthesis reports.

The Board recommends that:

1. **The Ministers, for a five-year period following completion of the Northern River Basins Study, report annually on the progress of implementing the research and management recommendations of this Report to the Ministers and the synthesis reports; that the annual summaries clearly describe the results of the ongoing research and management initiatives; and that the report be made available to the general public.**

RECOMMENDATIONS 15, RESEARCH

Preamble

The effects on fish and aquatic organisms of various stresses to which they are exposed may be greater when they are exposed to more than one source of stress at the same time. Thus, a contaminant may have greater effect when dissolved oxygen concentrations are low or, the combination of two different contaminants in effluent may be harmful although neither may be above acceptable individual limits. Fish may thus show signs of possible effects resulting from simultaneous exposure to a variety of stressors. Organochlorine contaminants arising from pulp mill operations have declined in fishes and sediments in the river basins, probably reflecting a switch from chlorine to chlorine dioxide bleaching. Nonetheless, the study observed sex hormone depressions and increased numbers of sexually immature fish collected in reaches immediately below pulp mills. In addition, fish from some reaches in the northern river basins exhibited heightened incidence of lesions and tumours.

Conclusion

For the northern river basins the scientific evidence for cumulative effects is fragmented and the database is currently insufficient to clearly define the nature and extent of the problems. Nevertheless, the Board is satisfied that the weight of evidence is sufficient to raise concerns that the cumulative effect of various stressors in some reaches of the Athabasca and Peace rivers could be resulting in harmful effects on fish populations. A variety of contaminants in the basins may impair reproductive success of fishes. The possible occurrence of these effects in the northern rivers is a source of concern to the Board and underlines the need for great caution in management decisions for the rivers.

The Board recommends that:

1. **The Ministers initiate an intensive and comprehensive study of endocrine disruption and reproductive biology of fishes throughout the basins, and the implications for the fish populations and the integrity of the aquatic ecosystems.**

2. **The Ministers initiate a complementary study to assess the increased incidence of fish abnormalities in reaches immediately below pulp mills.**

RECOMMENDATION 16, RESEARCH

Preamble

Both oil sands development and natural exposure to oil sands deposits may result in concentrations of hydrocarbons and other substances that cause stress to fishes. Assessment of the effects of oil sands development is accordingly complex. Further complications may arise from additions of municipal effluent discharges in the vicinity, such as Fort McMurray, and from nutrient-rich tributaries such as the Clearwater and Steepbank rivers. Levels of stress were observed in fish from the Wabasca River. It needs to be determined if this stress is due in part to natural exposure to oil sands deposits.

It is expected that oil sands production (which currently accounts for 16 per cent of Canada's total oil production) will increase by approximately 60 per cent between 1994 and 2008.

Conclusion

Further development of oil sands deposits is imminent. A better understanding of stresses induced from natural causes and from human activities is needed especially at certain reaches of the northern rivers which may be most affected.

The Board recommends that:

1. **The Ministers draw on such expertise as necessary to undertake research on the effects on aquatic biota of exposure to substances arising from oil sands, both naturally and as a result of oil sands industry development, giving particular attention to establishing monitoring requirements.**

RECOMMENDATION 17, RESEARCH

Preamble

In the past decade, changes in the Slave River Delta have been observed both by the residents and by scientific investigators. Some of the changes might be attributed to the regulation of the Peace River by the Bennett Dam. At the same time, the inflow to Great Slave Lake from other tributaries has been lower than in previous decades and lake levels have been falling with potential impact on the ecological and physical conditions of the Slave Delta. The possible causes of change include not only the water levels but changes in sediment transport in the Slave River for which, at present, there is not sufficient data or understanding. Possible linkages to sediment transport and deposition processes in the Peace-Athabasca Delta add a further dimension of potential complexity.

Great Slave Lake is receiving contaminants from Slave River sediments as well as from airborne and local sources. The subsequent distribution of contaminants is largely dependent on the physical circulation of the lake, which has yet to be described. Since the work of Rawson in the 1940s, which described the limnology in broad terms, there has been no systematic study of physical circulation in the lake. In consequence, the fate of contaminants entering and leaving the lake is not known.

Conclusion

The Board recognizes that the changes to the Slave River Delta may be related to flow interventions upstream that may have had serious effects on wildlife and the people who depend on it. A better understanding of the causes for the physical changes to the delta is necessary to determine the extent to which the Bennett Dam is responsible.

The Board has noted that residents of the Great Slave Lake region are concerned that the lake could become a repository for an increasing load of persistent contaminants. An understanding of the physical circulation of the lake is a critical first stop in addressing these concerns. Despite being one of Canada's largest lakes, relatively little scientific understanding yet exists of Great Slave Lake.

The Board recommends that:

1. **A study be undertaken by the federal and territorial governments to determine the causes for physical changes in the Slave River Delta and their environmental impact. Elements of the study would include:**
   a) **history of the delta;**
   b) **recent changes to the delta, including erosion and deposition processes;**
   c) **the influence of lake levels and shore processes related to wind, waves, current and ice conditions; and**
   d) **evaluation of the effects of the Bennett Dam, climatic factors and other natural causes on recent changes to the delta.**

The Board further recommends that:

2. **The federal and Northwest Territories governments undertake a study of the limnology of Great Slave Lake with emphasis on sediment deposition and contaminant distribution.**

RECOMMENDATION 18, RESEARCH

Preamble

A continuing program of research is an essential element of natural resource management. Because natural resources are in large part publicly owned and managed, the burden of responsibility for research falls primarily on government and secondarily on industry. The Study has relied very heavily on government personnel in the planning and implementation of its research program. Universities have made significant contributions and the Board has noted with interest the award of a National Centre of Excellence project, led by the University of Alberta, on boreal forest management. More intersectional projects of this kind are much to be desired for the northern rivers.

During the course of the Study, the Board was vividly aware of the cutbacks in government expenditures because of their impact on the Board's program. Federal government cuts were particularly severe in their inland waters and inland fisheries activities. Provincial government cuts meant a significantly reduced wherewithal to address northern basin issues. The fact that the Study was completed more or less on time and on budget is a testimony in large part to the dedication and commitment of the scientists, particularly the Science staff of the Study and the component group leaders.

Conclusion

The Board is greatly concerned that the future management of the basins will not have resources of the same strength on which to draw. The future of the basins will be at risk because of a lack of scientific expertise to adequately monitor the rivers and do research to identify the causes of problems and how they might be resolved. Research is an essential component of management. To fulfil their responsibility for stewardship and management of the northern river basins, governments must develop and maintain leading edge expertise in the agencies charged with monitoring the environment.

The Board recommends that:

1. **Federal, provincial and territorial governments give priority to ensuring that scientific resources (including personnel) be maintained at levels necessary for long term protection of the northern rivers and that the national granting councils provide increased funding for the support of multi-sectoral sponsored research on environmental problems through their various partnership programs.**

RECOMMENDATION 19, RESEARCH

Preamble

Many residents of the northern river basins rely heavily on fish as a staple food source. In recent years, the abundance of fish is believed to be declining and is a source of increasing concern to the many who fish for domestic purposes and those who fish commercially.

Numerous fish species of the northern rivers undertake extensive migrations both in the rivers and to and from the large lakes. In consequence, assessment of the capacity of the fish stocks to support fishing must involve the whole network of lakes and streams of the basin. For example, the Slave River is extensively used by fish from Great Slave Lake, fish from the western end of Lake Athabasca move extensively through the lakes of the delta and into the Peace and Athabasca rivers.

Some assessments of the status of the various stocks of commercially important species have been undertaken at intervals since the 1940s, but no attempt has been made to synthesize data from the lakes and rivers for a comprehensive assessment. Such an assessment perhaps should have been attempted by the Study but other priorities took precedence.

Conclusion

The Board heard several representations from commercial fishermen in northern communities. While most were concerned with the quality of fish, concern was also expressed for declines in abundance.

Available data is probably sufficient for a preliminary assessment of the status of fish stocks in the major lakes and to a lesser extent the northern rivers to which they are connected. The Great Slave Lake Advisory Committee which is representative of users, has established priorities and work is currently proceeding on Slave River / Great Slave Lake inconnu and Great Slave Lake whitefish. Nevertheless, the Board is concerned to have a status report on fish stocks in the Slave River Basin and Great Slave Lake, in support of sustained use.

The Board recommends that:

1. **The governments of Canada, Alberta and the Northwest Territories prepare a comprehensive review of the use, condition and sustainability of fish stocks in the Slave River basin and Great Slave Lake that are used for domestic and commercial purposes.**

4.6 Public Participation

The Northern River Basins Study Board considers its program of public participation as one of the Study's greatest accomplishments. At the outset, many residents of the northern river basins expressed concern that the Study would not be "open" in its interactions with the public. Soon after the Study's launch, the Board affirmed its intention to interact with members of the public in an open and meaningful manner, to the benefit of both the public and the Study. This two-way flow of information made it possible for the Study to modify its plans, programs and field work while keeping the public up to date on the ongoing process.

The structure of the Board helped ensure public input into the Study. Many members of the multi-stakeholder Board consulted on a regular basis with their respective constituents. This process facilitated input and interaction with members of the aboriginal, environmental, educational, industrial, health and agricultural communities.

The Board and staff met with a number of residents and stakeholder groups soon after the start of the Study to develop a program of public participation. The subsequent ongoing contact served as an important vehicle in facilitating open communication and effective interactions.

The Board early adopted a policy that all information, following proper scientific and Study Board scrutiny, would be released to the public, media, libraries, stakeholder groups and other interested parties in a timely manner.

The pursuit of a policy of public participation of openness and information is not for the faint of heart, but it results in a product of wide acceptance and reflects a collective wisdom.

Preamble

The Study adopted a number of measures to ensure interaction with residents of the river basins and other interested parties, including:

1. Study Board Meeting Venues:
The Study Board held its bi-monthly regular meetings in communities throughout the river basins. The public was invited to attend and participate in these meetings.

2. Community Gatherings
The evening prior to most Study Board meetings, a Community Gathering was held. Members of the local community were invited and encouraged to express in an "open microphone setting" comments, concerns and suggestions, providing the Board with information on local issues and perspectives. In turn, science directors and other individuals made presentations on local and regional scientific matters.

3. Science Forums:
The Study held annual Science Forums which provided members of the public an opportunity to review and comment on science plans and work to date. At these forums, Study scientists shared scientific results and answered questions.

4. Trade Shows:
The Study participated in numerous trade shows throughout the basins, providing important contact between Study Board members, staff and members of the public.

5. Widespread Information Availability:
The Study adopted a number of measures to ensure that the greatest number of residents would receive information relating to the Study and its progress. A toll free number to the Study Office was established. Copies of the Study's newsletters were regularly distributed to all residences within the Study area. Prior to each Study Board meeting, an information flyer and invitation was sent to all homes within a 100 kilometre radius of the meeting place.

6. Education:
The Study visited schools within the basins, to brief students and teachers on the Study goals and progress.

7. Meaningful Language:
Wherever possible, the Study attempted to explain its scientific progress and results in non-technical language. Wherever appropriate, information was communicated using Cree and / or Chipewyan language. A number of Cree and Chipewyan audio and video tapes were produced. A pictograph was also produced by an aboriginal artist depicting the interrelationship of environmental factors within the northern river basins. This pictograph entitled "Knowledge of the Mother" was reproduced and distributed in poster form.

Conclusion

Public input and participation, together with the open sharing of information resulted in a more effective Study. The Study is well known by basin residents and the findings of the Study will be received by a knowledgeable and better informed public audience.

The Board believes that public participation was successful because the Study structure allowed for changes, corrections and new directions based on public reaction and comment.

The Board feels strongly that public participation programs were successful because they respected local community structure, language and preferred methods of communications. Local leaders were consulted in the development of the programs. Wherever possible, local language was utilized, or translations provided. As well, special care was taken to respect the unique roles of written, visual and oral communication.

The Board also believes that the widest possible interests and points of view were represented in the public participation process. No member of the public should have felt excluded from participating in the study.

The Board recommends that:

1. **In light of the benefits to be gained through public involvement it is important that meaningful public participation be an integral part of the planning and development of future studies and their scientific programs by:**
   a) **adopting an open communications policy;**
   b) **allowing for modification based on public input;**
   c) **ensuring that regular meetings and public consultations occur in communities and venues in the study area;**
   d) **ensuring that consultations and meetings are conducted in a manner that reflects local community structure, language and preferred forms of communication; and**
   e) **providing access to all data, reports and documentation.**

RECOMMENDATION 21, PUBLIC PARTICIPATION

Preamble
A survey of basin residents was conducted to obtain information about the uses of the river basin by the residents and other stakeholders, and to assist the Board in forming its recommendations. The polling included questions about issues, approaches for correcting problems and opinions on safeguarding the value of the rivers to people. The survey provides a statistical benchmark for future comparisons.

Conclusions
The Board is aware of the potential value of such surveys and anticipates the value of a similar survey in the future. The survey should be statistically valid, and done independently and authoritatively. It should document public opinion, understanding and response to actions taken pursuant to the Northern River Basin Study.

The Board recommends that:

1. **A valid and representative sample survey be conducted five years hence to assess changes in the use of the river basins and in the perceptions and attitudes of residents, providing a means of comparing public perceptions with realities at that time and providing guidance for policy development.**

4.7 SUCCESSOR ORGANIZATION

RECOMMENDATION 22, NEW BODIES

Preamble
Early in its deliberations, the Board posed itself 16 questions of which the 16th was "What form of interjurisdictional body can be established insuring stakeholder participation for the ongoing protection and use of the river basins?" After extensive discussion and debate the Board appreciated that the question had many dimensions, but a clear need emerged for a mechanism or structure by which the work started by the study can be continued and its results and benefits maximized. The argument for some new form of governance and advice turns on a couple of basic points. The currently prevailing wisdom, widely accepted in developed countries, is that "environment" and "economy" are central issues when contemplating change. Moreover, it is fundamental today to go beyond the basic steps of electing governments to involving resident societies and stakeholders directly in identifying their values for choosing directions in both the present and the future.

Environment
The Report to the Ministers recognizes the northern river basins as an ecological entity, and for its own sake and the sake of its residents, it must be dealt with as a whole. Thus because there are borders, there is strong reason for interjurisdictional cooperation.

First Nations' traditional relationship to the waters and the land in the northern river basins is ecologically based and must be protected, along with the interests of all other basin residents and beneficiaries.

There is a need for continued monitoring of the ecological conditions addressed by the Northern River Basins Study, and the regulations for river use must be under continual surveillance that is both adequate and scientifically up-to-date.

Continuing research is called for to follow up NRBS recommendations about knowledge gaps still remaining. In fact, the Northern Rivers should always be research subjects related to effective basin management and for scientific gains.

Some of the recommendations of the NRBS, if they are to be implemented, will require coordination by several agencies in the federal, provincial and territorial governments.

Economy
Expansion of present industry, proposals for new development and population growth will put real pressure on the northern rivers. An open, transparent public process is the best way to make the choices.

Coordination is needed among research, monitoring, management and legislative activities covering the northern river basins, and more than one government is involved.

Governments with parallel or overlapping mandates have to cooperate among jurisdictions if they find fiscally efficient and scientifically sound ways to rationalize existing or new functions. Dispute resolution mechanisms, including mediation, are needed for interjurisdictional issues.

Social Values
Throughout NRBS, there has been a strong indication of a lack of public confidence in the present way governments and industry are managing the northern rivers. A stakeholder and residents survey reports that the respondents think a new, ongoing inter-governmental and stakeholder committee should be established to protect the use of the river basins. The survey even suggested that this Committee should have many of the management functions now held by governments.

The basic link between the public interest and environment policy and management is still through elected governments, legislation and the public administration. However, existing structures that could deal with aspects of the follow-on from NRBS are not interjurisdictional in nature, nor do they include the full spectrum of stakeholder groups as well as government.

Public advice and participation in making developing policy, resource planning and making other decisions can be refined through involving interest groups, residents and other stakeholders. Mechanisms to effect this advice, participation and partnership should, in this contemporary society, supplement established practices.

Public understanding, and therefore the quality of public advice will be better if there is good public education, greater public awareness and free access to pertinent information. The public want a direct hand in this.

Finally, the development of a separate agency can be a natural extension, not only of the Northern River Basins Study, but also of other initiatives affecting the basins. Specifically, it could build upon the Mackenzie River Basin Committee master agreement.

Functions to be Addressed
Following the conclusion of NRBS, three distinct functions stand out for attention. There is need for:
a. a revised approach to basin management;
b. effective monitoring of human use of the rivers; and
c. an overseeing agency with direct public links, public reporting and capacity to judge the stewardship of aquatic resources.

Basin Management
A large part of the Northern River Basins Study was aimed at understanding the aquatic ecosystem, and linking it with human activity and river uses. While highly important, the aquatic ecosystem is only one part of the basin ecosystem and cannot be dealt with in isolation. An integral relationship exists between land use of all types, including forest harvesting, agriculture, municipal and industrial development, etc., and water quantity, quality and use. There have been, and are now, systems for managing the northern rivers, but throughout the Study and consistent with

modern thinking about environment and economy, the concern for river management has moved outward from the hands of regulators to be an issue with the wider public. This, plus 'whole basin' concepts, puts basin management to the forefront in a necessary government reordering.

The concept of 'whole basin' ecosystem management is not without challenges. In fact, the present system of jurisdictional ownership of water transmits consequences downstream, some of which are not wanted. Current First Nations agreements and proposals for co-management with government of river resources tend to be applied to distinct reaches of a river. This same approach could conceivably arise in other circumstances. A design for future management of the northern rivers, within the ecological overview will have to find ways to acknowledge local or regional circumstances.

Management decisions have to build on knowledge, so the management function clearly calls for research as a parallel activity. Whatever structure that is given the management functions for the basins will have to be able to identify, call for, or undertake the necessary studies.

Monitoring

Adequate protection of the northern rivers ecosystem requires keeping track of what goes into the rivers, what impact it has on river life, and what effects may be expected by those who drink the water or eat fish or other food from the rivers. The Study has amply demonstrated what may be for some self evident, that monitoring of the aquatic and riparian ecosystems is absolutely essential. It is a complex task, many elements of which are highly technical and dependent upon good science if they are to properly meet public standards and expectations. The monitoring systems that are in place will be improved by the results of the Study. The potential for creating new thinking and restructuring of river ecosystem monitoring is the message of separate recommendations. The adoption of these recommendations may require a structure or agency separate from what might be proposed for basin management and / or other forms of public scrutiny.

Overseeing Resource Stewardship

It is a separate function to review, make judgements and adjust the ways the Northern Rivers are being managed. It involves testing the standards, recommending revisions to the regulations, anticipating new developments, and ultimately, making the right decisions. At present, these functions are mainly in the hands of government agencies, governed by legislation. The Study has indicated that this approach should be stretched to be more inclusive of structured public participation in the task of overseeing resource stewardship. The benefit does not only come from better environmental behaviour but from better public education through free information flow and regular meetings with the public at large.

The evidence for these observations is, in part, the way NRBS itself conducted the Study with its unique Board composition and its extensive use of public meetings. The stakeholder and residents surveys support in every respect the above remarks. The advice that is being conveyed is that direct public links to an overseeing function are needed, and can best be effected by a separate agency created for that purpose.

Other Factors

First Nations

As recognized by NRBS, First Nations peoples living in the northern river basins have a unique and pre-existing relationship with the resources of basins. Any approach taken to following on from NRBS must provide for meaningful input and participation by First Nations peoples so that it protects their rights and interests. In this respect, co-operative management of the rivers is an important issue for First Nations residents. In both this and any other participation by First Nations in the management and overseeing process, First Nations expect to be invited on a government to government basis to participate. It is an approach that acknowledges First Nations cultural norms as to how input can be offered that is representative of First Nations peoples as a whole.

Funding

Recommendations for change inevitably involve questions of costs. NRBS did not, however, investigate the financial implications of the follow-on structures offered for consideration. There are, nevertheless some observations.

The means of funding any vehicle or process for follow on from NRBS should be tailored to the nature of the vehicle or process. It can be assumed that governments will resist proposals that duplicate or are redundant, open-ended, or lacking definition. Also it is likely that if existing funding can be redirected or reduced, it will be preferable to having to find new funds. Government funding for new functions in today's world will mean arguing for high priority within fixed budget limits, or seeking new partners like industry, municipalities, other interest groups and even public subscription or the capacity for charitable donations. Assessed on a rational basis, such as water consumption or effluent discharge permits, perhaps modified according to user, funds could be raised to contribute to the new post NRBS arrangement being recommended. The basic point is not to advance a particular scheme, but that there is an opportunity to be inventive. In this particular instance, it might be easier to try something new because it has local application, although it might be seen as a precedent by others.

Conclusion
The Board devoted considerable time to its deliberations on the question: *What should be the nature of a successor organization to NRBS?* In addition to background papers prepared by the Study staff, the Board commissioned a review of the possible alternative structures (Report No. 62). After Board discussions, an option was presented that involved a two-tiered board to provide interjurisdictional management on the one hand, and an overseeing function on the other (Report No. 84). Report No. 84 includes extensive background and rationale for the way in which the Study board has addressed Question 16. An alternative structure was advanced by a Board member proposing an independent council of residents, stakeholders and other interests that can demonstrate legitimate concerns to assume an overseeing and advisory role to press for proper stewardship of the rivers and the basin. Later, a small task force expanded the options and prepared the stage for final Board recommendations on Question 16.

Following debate, the Board concluded that the prior question, *"Do we need a new structure implied in Question 16?"* should be answered in the affirmative.

The Board recommends that:

1. **The Ministers co-operate to establish, on a suitable financial basis, such new bodies as are needed to meet the present and future concerns about the aquatic and riparian ecosystems of Northern River Basins.**

RECOMMENDATION 23, SUCCESSOR ORGANIZATION: RECOMMENDED STRUCTURE

Preamble
The Study Board examined and debated a broad range of possible organization structures that could be utilized to carry forth the work and recommendations of the NRBS after its term concludes. The Board then distilled these possibilities into seven distinct alternatives, as briefly described below. Each is described in more detail in Section 7.8, including remarks about possible advantages and concerns for each.

1. Northern River Basins Management Board
   Would have powers seconded to it by governments to perform much of the management function for the Basins. The exact sharing of powers is not defined absolutely, but the intent is to have a board that could indeed manage the northern rivers aquatic ecosystem.

2. Northern River Basins Environmental Board
   Would have power to conduct research, monitor as needed, and otherwise prepare itself to give well placed management advice to the governments.

3. Northern River Basins Advisory Board
   Would oversee the stewardship of the Basins. It would advise on policy, standards and practices that affect the northern rivers.

4. *Mackenzie River Basin Transboundary Waters Master Agreement* and Board
   The longstanding and almost concluded Agreement would be utilized to encompass in scope the Northern River Basins south of Great Slave Lake.

5. Two-Tier Board Structure
   One part would address management, and independent from the first, a second part would act as overseer of the work of the first, thereby serving as a public monitoring body.

6. Northern River Basins Stakeholder Council
   Would consist of members self selected by resident / stakeholder groups, with the aim of influencing government action in line with its goals for responsible basin management.

7. Alberta Northern River Basins Branch
   A "go it alone" proposition for Alberta, consolidating Alberta's responsibilities for the basins within a single branch of government, but excluding any direct interjurisdictional organization.

The first three options are for interjurisdictional, stand alone boards with graduated authority, descending in scope and power. The first two would appear to have the most potential to meet the public expectations identified by the Northern River Basins Study. Alternatives four, five and six all have potential, but each appears to be less than ideal for reasons noted in the accompanying comments (see Section 7.8). Alternative seven is simply a reorganization of Alberta's existing resources relative to the northern river basins, and assumes that Alberta would find it necessary to proceed independently of the other governments.

These alternatives have been developed to describe the range of options that may be available for dealing with the northern river basins after the NRBS concludes. While they have been given considerable thought, they are not presented as final answers. Whether one of them is adopted, or a variation is agreed to, they are intended to assist in guiding the governments to a viable solution that will meet the needs of the northern river basins and their residents.

Doing nothing to establish a process for follow-on from NRBS, that is, remaining with the status quo, is not considered to be an option as it would not meet any of the three essential needs that NRBS has identified; those of

1. ecosystem management;
2. improved ecosystem monitoring; and
3. watchdog role and public participation.

As can be seen from many of the recommendations of the Board, the public is not confident in the way things are being done now. The solution must include visible, ongoing public involvement, public access to information, and independence.

Conclusion

Having already recommended that the Ministers should establish some form of post-NRBS structure for the northern river basins, the Study Board urges that the *Mackenzie River Basin Transboundary Waters Master Agreement* be made final. The long time in negotiations notwithstanding, the Board is convinced that the Agreement is a good umbrella for overall management and wise use of the entire Mackenzie drainage, including the northern rivers. Beside its provision for sub-agreements in bilateral, transboundary situations; it closely resembles some of the options for northern rivers, and together they would give stronger purpose to those goals arising from NRBS. In particular, the Agreement calls for active participation of the provinces of British Columbia and Saskatchewan, something which has been effectively missing in NRBS but obviously necessary for total drainage basin strategies.

The Board recommends that:

1. **All reasonable efforts by the Ministers be directed to the earliest possible signing of the *Mackenzie River Basin Transboundary Waters Master Agreement*, and the establishment of that Board.**

General Conditions for Recommended Structures

The Study Board, reflecting its experience from NRBS, is concerned about the membership of any particular interjurisdictional board or panel that might be created for the Northern Rivers, and sees great value in a comprehensive group with different interests represented.

The Board recommends that:

2. **Membership of any new board or panel related to the affairs of the northern river basins be kept small but appointed to represent federal, provincial and territorial governments, First Nations, municipalities, industry, environmental interests, residents and other stakeholders without dominance by any one constituency or interest group.**

3. **The method of appointment for each member be acceptable to the constituency to be represented by the member.**

The Preferred Solution

In selecting a preferred structure to recommend, the Study Board was not unmindful of the existing systems through which governments and others were already performing many of the tasks related to conditions and use of water in the northern river basins. Recommending a new structure is based on evidence from the Study and the experience of the Board through the past five years. It is not necessarily intended to replace all that is now being done, but to supplement it by responding to new thinking and public awareness.

The Board expressed strong preference for the principles embodied in Alternative Structure No. 3, the Advisory Board, preferably accompanied by Alternative Structure No. 4, the *Mackenzie River Basin Transboundary Waters Master Agreement* as a good umbrella for overall management of the entire Mackenzie drainage. There was a strong sense that this structure needed to adopt some of the more "hands-on" management functions described in Alternative Structures No. 1 and 2, while recognizing the potential difficulty of governments agreeing to delegate their powers to an appointed body. There was some support for the representational features of the Stakeholder Council, Alternative No. 6.

Under the circumstances, the Study Board concluded that an advisory board, properly informed with power to direct research and monitoring activities, with a strong ability to influence governments, adequately supported and delivered by credible individuals in an open public arena could make major contributions to the well-being of the northern rivers and the people who live there.

The Board recommends that:

4. a) **An advisory board, to be called the Northern River Basins Board (NRBB), be created jointly by the governments of the jurisdictions covered by the northern river basins, to advise governments on matters related to the aquatic and riparian ecosystems of the northern river basins.**
   b) **The NRBB have within its mandate the responsibility to; (i) participate in the development of the governments' management policies and practices for the rivers, (ii) review and comment upon current and proposed conditions for the rivers, (iii) review and advise upon public knowledge and expectations concerning the aquatic ecosystem, and (iv) address other matters it deems relevant.**
   c) **The NRBB have its own secretariat, and be given adequate support to meet its mandate, and have the means to consult and involve public opinion.**
   d) **The NRBB gather input and feedback from the public, and be able to provide information to the public, on matters within its mandate.**
   e) **The NRBB be empowered to report directly to the responsible Ministers of the sponsoring governments on any matter within its mandate.**
   f) **The NRBB publish an annual report to the sponsoring governments and the public at large, detailing its work through the year and commenting on all issues within its mandate.**
   g) **The NRBB be compatible with and related to the *Mackenzie River Basin Transboundary Waters Master Agreement*, should that Agreement come into force.**

The Board further recommends that:

5. **If the NRBB is established as recommended, the Integrated Ecosystem Monitoring Committee (IEMC) as described in Monitoring Recommendation 11-1 should be closely linked to NRBB, possibly reporting to the NRBB.**

Dissenting Views

Strong dissenting views were expressed by some Board members with regard to Recommendation 23-4, reflecting a wide difference of opinion as to the best means of meeting the need. As stated by one Board member:

> *"There is need for NRBS follow-up activities to ensure recommendations are carried out. However, given the uncertainty of government (political) priorities, the availability of existing infrastructures (or committees), fiscal reality and poor definition of purpose, the recommendation of a specific organization is premature. It is sufficient to provide the range of options and the Board examination of post-NRBS needs."*

As stated by some Board members:

> *"The subject of creation of the NRBB is already covered by Recommendation 22."*

Addressing Recommendation 23 in light of Recommendation 22, another Board member added:

> *"The Board has clearly laid out the details of the management system and the requirements for consultation and the examination of the values that are important to the residents of the basins. These aspects of the system need to be implemented to the extent expected by those residents. The Board should recommend that the governments implement whatever systems and structures are required to meet the outcomes, not what those structures should be. If the Board feels the governments are the keepers of the resource, the Board should tell them how it should be managed. The Board should define the input and influence it wants to have regarding the future of the resource. The Board should require that the governments develop the systems and structures to accomplish the recommended results."*

RECOMMENDATION 24, TRANSITION

Preamble

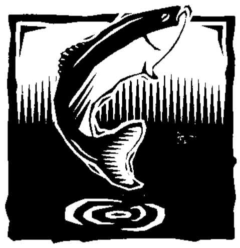
It will likely take some time for the Ministers to evaluate NRBS results and recommendations. However, the northern river basins are a dynamic ecosystem in which the conditions identified by the Study continue to persist and evolve. To ensure that nothing is lost in terms of what has been learned with regard to reach specific issues, basin management, monitoring, research, public confidence, etc., steps should be taken as soon as possible in anticipation of actions the Ministers may decide to take. At the same time, the Ministers will likely require an opportunity to determine how they may choose to coordinate their efforts in follow-up.

Conclusion

The Board anticipates that the Ministers may require a mechanism to bridge any possible gap between the completion of the NRBS and the establishment of any successor organization(s).

The Board recommends that:

1. **A steering committee be established by the governments of Canada, Alberta and Northwest Territories to facilitate a transition, by April 1, 1997, from the NRBS to other bodies with successor functions.**



5.0
First Nations / Métis Recommendations

5.1 Background and Board Position

The NRBS Board requested that its First Nations Committee (made up of First Nations members of the Board) address the issues arising from the Study that have specific significance for the First Nations peoples of the northern river basins.

The Northern River Basins Study Board received the First Nations / Métis Issues - Recommendations document from the Board's First Nations Committee. After a thorough review at the Board's Meeting No. 31, February 23, 1996, the Board agreed, by consensus:

a) that the document is the Committee's final report to the Board; and
b) to support all six of the Recommendations contained within the main body of the document.

The recommendations, as supported by the Board are:

1. Governments establish a committee, that will involve communities and other stakeholders, to consult, advise and implement resulting programs and projects which are the outcome of the recommendations from the Northern River Basins Study, so that the interests and rights of the First Nations / Métis are safeguarded and protected.

2. The governments develop a government to government relationship with First Nations / Métis governments concerning implementation of northern river basins strategies and recommendations.

3. An ecosystem management approach be used which includes all aspects of the watershed management and encompasses the commitment of First Nations / Métis people to the ecosystem approach.

4. Any future research programs developed or endorsed by the governments or research organizations be encouraged to focus on the integration of scientific and traditional knowledge within a First Nations / Métis research protocol.

5. The northern river research strategies endeavour to enable First Nations / Métis communities and governments to initiate and carry out scientific research which answers First Nations / Métis environmental questions about the northern river basins.

6. Governments commit to a cooperative and participatory thrust of future research in the northern river basins focusing on human health and its link to environmental contaminants or ecological change, and the cause and effect relationship of environmental contaminants or ecological change to the health of the communities and peoples involved; particular effort should be placed on the quality of water within the region encompassed by the Northern River Basins Study boundaries.

The Board appreciates the commitment and efforts of the Board's First Nations Committee members in bringing forward the attached document.

FIRST NATIONS/METIS ISSUES

RECOMMENDATIONS
TO THE
NORTHERN RIVER BASINS STUDY BOARD

by the First Nations Commitee
of the Northern River Basins Study Board

FIRST NATIONS/METIS ISSUES

RECOMMENDATIONS

The Northern River Basins Study represents an innovative advance in the way the voice of First Nations/Metis people living in the Study area was sought and incorporated into the Study results. The importance of traditional knowledge as a valid and credible basis for drawing conclusions about the state of the river basins is dealt with elsewhere in the Board's report. The methods used to incorporate First Nations/Metis people in the post-Study strategies and their continued involvement received considerable Board attention as well as attention from the Science Advisory Committee of the Study.

To address issues from the First Nations/Metis perspective, the Board established a First Nations Committee. The Committee used First Nations processes to formulate several strategic recommendations which it proposed to the Board. Underlying these recommendations is a recognition that effective involvement of First Nations/ Metis peoples calls for a somewhat different approach than involvement of the rest of the general public. Rather than step forward as individuals, First Nations/Metis people prefer to be involved in formal process (e.g. guidance and conduct of this Study, formal follow-up mechanisms that may result from this Study) through First Nations/Metis governments. Thus, the strategic recommendations formulated in good faith by the First Nations Committee must be endorsed by the First Nations/Metis governments through their formal governmental instruments. The collective responsibility of the First Nations/Metis governments takes precedence over individual representation.

WATER POLICIES AND PROGRAMS

The First Nations Committee of the Study Board believes that only by establishing permanent vehicles to provide input on water policies and programs will the opinions and experiences of the people most directly affected gain the influence they deserve. The Northern River Basins Study First Nations Committee, in consultation with First Nations and Metis Leadership, recommends that:

1. **Governments establish a Committee, that will involve communities and other stakeholders, to consult, advise and implement resulting programs and projects which are the outcome of the recommendations from the Northern River Basins Study, so that the interests and rights of the First Nations/Metis are safeguarded and protected.**

A specific proposal for the creation of a Regional River Basin Committee can be found in Attachment #1. The First Nations Committee of the Northern River Basins Study believes that specific policy instruments are available to the governments to establish this type of committee. For example, Part 1 of the Canada Water Act, is available to Environment Canada to establish a Regional River Basin Committee for the purpose of consultation, advice, coordination and implementation of water policies and programs, which also could be used to protect and safeguard First Nations/Metis interest and rights. The responsibility of the Government of Canada can be used from various Acts and laws to protect First Nations/Metis communities.

COOPERATIVE WATER MANAGEMENT AGREEMENTS

First Nations/Metis peoples comprise a significant portion of the total population of the Northern River Basins. As the major population, First Nations/Metis people prefer that any activity which affects their communities, be addressed by their own governing structures. Water management agreements are a good example of these activities. A water management plan will impact on the communities both collectively and individually. The

Northern River Basin Study First Nations Committee, in consultation with First Nations and Metis Leadership, recommends that:

2. **The governments develop a government to government relationship with First Nations/Metis governments concerning implementation of Northern River Basins Strategies and Recommendations.**

The First Nations Committee of the Study Board believe that Alberta Environmental Protection could propose a change to the Draft "Alberta Water Act". This amendment would facilitate the development of a government to government relationship for cooperative water management. The proposed amendment would deal with the definition of " other levels of government". A suggested change of text would include First Nations/Metis governments.

BASIN ECOSYSTEM MANAGEMENT APPROACH

The Northern River Basins Study, through its reports and recommendations, strongly recommends that a comprehensive ecosystem management approach be taken in any future planning or management of the Northern River Basins. The agreement for an ecosystem management approach needs to reflect regional approaches in their implementation and their scope of control. Regional representation would provide a means to more effectively address local issues and involve local participation within their specific regions; however, these regional authorities would work in conjunction with the Basinwide approach. The Northern River Basins Study First Nations Committee, in consultation with First Nations and Metis Leadership, recommends that:

3. **An ecosystem management approach be used which includes all aspects of the watershed management and encompasses the commitment of First Nations/ Metis people to the ecosystem approach.**

The First Nations Committee of the Study Board believes that regional and local knowledge of the system can be effectively used by the Basinwide approach. Individual sub-basins, reaches or localities could be represented as principles of the Basinwide agreements. These principles could independently research and investigate their communities needs, while coordinating their activities with the larger approach. The Little Red River Cree Nation, Tall-Cree First Nation and Government of Alberta Agreement could be utilized as a demonstration of a principles approach to ecosystem management.

The First Nations Committee of the Study Board would also like to emphasize that an ecosystem approach is necessarily holistic in scope. It is inevitably more complex than dealing only with aquatic and riparian elements of the ecosystem. Whatever occurs on lands, in forests and in the air over the basin will have direct consequences for the Northern River Basins. Only through addressing all elements of the ecosystem will we be able to understand and manage the system. The Northern River Basins Study, while an excellent effort, is only the start of a much larger process. The First Nations/Metis people are ready, willing and able to assist with this effort.

INTEGRATION OF TRADITIONAL KNOWLEDGE

Traditional Knowledge has proven to be an important and vital component of the Study, which compliments modern science. Scientists and people involved with the Northern River Basins Study have discovered that traditional knowledge can be effectively used to enhance scientific investigation by adding both knowledge and values. Traditional knowledge was used to design scientific research programs and projects, for example: The Geographic Information Systems Program, and Fish Sampling Sites for the Fisheries projects. Traditional knowledge offered the only information and data on the conditions of the Basins before modern records were kept. The traditional knowledge of the people of the Northern River Basins have proven to be important at all levels of decision making. The Northern River Basins Study First Nations Committee, in consultation with First Nations and Metis Leadership, recommends that:

4. **Any future research programs developed or endorsed by the governments or research organizations be encouraged to focus on the integration of scientific and traditional knowledge within a First Nations/Metis research protocols.**

The recognition of the value of traditional knowledge is not enough in and of itself. As a means of ensuring that traditional knowledge plays an effective role, First Nations/Metis communities must also have the capability to carry out research which interests their respective communities. This research will enhance each community's knowledge base, and provide a method to teach traditional knowledge as well as provide an educational venue in the community. The Northern River Basin Study First Nations Committee, in consultation with First Nations and Metis Leadership, recommends that :

5. **The Northern River research strategies endeavour to enable First Nations/ Metis communities and governments to initiate and carry out scientific research which answers First Nations/Metis environmental questions about the Northern River Basins.**

HUMAN HEALTH

As a result of the traditional knowledge obtained by the Northern River Basins Study Traditional Knowledge Component in 10 communities in the northern river basins, community health has been identified as a major concern of all these communities. The concerns expressed by First Nations/Metis peoples are of an holistic nature encompassing such matters as the effect of environmental change on the physical, spiritual, and socio-cultural health of their communities and the individuals living in the Basins.

The research conducted in the Traditional Knowledge Component of the Northern River Basins Study assisted greatly in identifying some of the basic issues related to this important area, but a great deal more research needs to be done to refine our understanding of these issues and develop the actions necessary to remedy problems when they are identified. The Northern River Basins Study First Nations Committee, in consultation with First Nations and Metis Leadership, recommends that:

6. **Governments commit to a cooperative and participatory thrust of future research in the northern river basins focusing on human health and its link to environmental contaminants or ecological change, and the cause and effect relationship of environmental contaminants or ecological change to the health of the communities and peoples involved; particular effort should be placed on the quality of water within the region encompassed by the Northern River Basins Study boundaries.**

ATTACHMENT #1

A PROPOSAL FOR THE CREATION OF A REGIONAL RIVER BASIN COMMITTEE

Respectfully Submitted to

The Honourable Ty Lund
Minister of Environmental Protection
Government of Alberta

and

The Honourable Sergio Marchi
Minister of the Environment
Government of Canada

from

The First Nations and Metis Leaders
from the Region Encompassed by
the Northern River Basins Study

February 6, 1996

A Proposal
for the Creation of a
Regional River Basin Committee

1.0 BACKGROUND

The Northern River Basins Study (NRBS) was initiated, in large measure, as a result of the concerns expressed by First Nations/Metis leaders in northern Alberta. The findings of this Study are currently being compiled for submission to both the Government of Alberta and the Federal government. It is anticipated that the results of the Northern River Basins Study will identify a number of subject areas requiring the follow-up of all levels of government.

Within the area encompassed by the Northern River Basins Study, a wide range of issues and opportunities exist in the area of natural resource management, environmental protection, and community health. In order to address these important matters at a policy level, the creation of an on-going process of discussion is required between the First Nations/Metis peoples involved, other stakeholders, and the Ministers responsible for water management and environmental protection in both the Government of Canada and the Province of Alberta.

The First Nations/Metis Leaders from the region encompassed by the Northern River Basins Study have prepared the following proposal as a means of maintaining a long-term, positive and constructive dialogue directly with the Ministers on matters of mutual interest.

Although this proposal focuses on the use of Part 1 of The Canada Water Act as the legal framework for the creation of the proposed committee, the First Nations/Metis Leaders are prepared to consider alternative legal mechanisms to establish the committee provided they are acceptable to everyone involved.

2.0 PROPOSAL FOR A REGIONAL RIVER BASIN COMMITTEE

2.1 Purpose

To establish a Regional River Basin Committee under Part 1 of The Canada Water Act in order to consult, advise, and implement the programs and projects resulting from the Northern River Basins Study, and to ensure that an ecosystem management approach is used in the management of watersheds within the region.

2.2 Proposed Terms of Reference

It is proposed that the Regional River Basin Committee would operate under the following terms of reference:

2.2.1 The jurisdictional responsibilities of the Province of Alberta and, specifically, the Minister of Environmental Protection shall be respected.

2.2.2 The jurisdictional responsibilities of the Government of Canada and, specifically, the Minister of the Environment shall be respected.

2.2.3 The Constitutional rights of First Nations and Metis peoples, and the Treaty Rights of First Nations shall be respected.

2.2.4 The rights and interests of each First Nations/Metis government and other Aboriginal self-government initiatives shall be respected.

2.2.5 The Regional River Basin Committee shall deal with the following subject areas on a policy and program level:

(a) forest management including, but not limited to, timber harvesting practices, timber allocation, reforestation, forest management practices, environmental protection, and future research needs;

(b) water management including, but not limited to, the effects of land use practices (forest management, agricultural practices, etc.) on surface and ground water hydrology, the state of the water resource in the region, water allocation and use, future research needs;

(c) water quality including, but not limited to, water quality standards, industrial and municipal effects, monitoring, the effects of environmental contaminants on community and individual health, and future research needs;

(d) fisheries management including, but not limited to, the overall state of the fisheries resources in the region, fish allocation and use, environmental factors needed to support the fisheries resource today and into the future, the effects of environmental contaminants on fish and fish habitat, the effects of contaminated fish on human health, and fisheries inventory and research needs in support of management decision making requirements;

(e) wildlife management including, but not limited to, the overall state of the wildlife resources in the region, wildlife allocation and use, environmental factors and habitat requirements needed to support the wildlife resources today and into the future at desirable population levels, the effects of environmental contaminants on wildlife and wildlife habitat, the effects of contaminated wildlife on human health, and wildlife inventory and research needs in support of management decision making requirements;

(f) air quality including, but not limited to, air quality standards, the effects of airborne contaminants on community and individual health, and air quality monitoring and research;

(g) economic development based on the natural resources in the region including, but not limited to, tourism and recreation, timber extraction, reclamation, manufacturing of timber resources including added value products, guiding and outfitting (fish and wildlife), eco-tourism, aquaculture, commercial fishing, fish processing and fish marketing, fur harvest and marketing, and game farming and ranching;

(h) renewable resource management including, but not limited to, increased training and employment opportunities for local First Nations/Metis people in Provincial, Territorial and Federal resource management program planning and delivery; increased integration of Traditional Ecological Knowledge with conventional science in natural resource policy development, research, management, and program delivery; and the development of a partnership relationship between First Nations/Metis peoples and the governments of Alberta and Canada with respect to natural resource management;

(i) more effective design, coordination and integration of government programming;

(j) more effective coordination and integration of First Nations/Metis interests and the interests of all communities in addressing matters of mutual interest;

(k) any other matter considered by the participants to fall within the general intent of the Regional River Basin Committee's purpose.

2.3 Proposed Composition of the Interface Committee

Government of Alberta

- The Minister of Environmental Protection or his/her designate(s) with representation not lower than the level of Assistant Deputy Minister.
- the Minister can invite other Provincial staff as and when required.

Government of Canada

- The Minister of the Environment or his/her designate(s) with representation not lower than the level of Regional Director General.
- the Minister can invite other Federal staff as and when required.

First Nations/Metis Representatives

- Each of the First Nations and Metis Leaders from the region encompassed by the Northern River Basins Study.

Other Stakeholders

- It is suggested that, among others, the Committee include representatives of other Provincial or Territorial governments, industry and municipal governments.

2.4 Operation of the Regional River Basin Committee

2.4.1 Funding

Funding in support of the Committee would be provided equally by the Government of Canada, the Government of Alberta, and industry.

Funding from other participating governments may be requested as and when required.

2.4.2 Meeting Schedule

The Committee would meet a minimum of every two months with the option of meeting more frequently, if necessary, at the call of the Chairpersons.

2.4.3 Chairpersons

The Committee would be co-chaired by the Federal Minister, the Provincial Minister and by an Aboriginal leader nominated by the First Nations/Metis representatives on the Committee.

2.4.4 Administrative Support to the Committee

The Committee would be supported through an independent consultant that would provide the following services:

- agenda preparation
- liaison with participants as required in order to ensure the Committee functioned effectively and the interests of each participant were considered
- follow-up on Committee decisions to ensure appropriate action was being taken
- facilitate the process of decision making of the Committee
- assist Committee members in the development of agenda items or with the implementation of Committee decisions

- facilitate the resolution of issues among or between Committee members
- provide a secretariat and research role on behalf of the Committee
- duties assigned by the Committee as required

2.4.5 Committee Decision Making

The Committee would attempt to achieve consensus on all matters while recognizing and respecting the legal responsibilities of each Committee member.

6.0 WORKSHOP COMMENTS

6.1 INTRODUCTION

The following represents a summary of opinions, suggestions and recommendations expressed at 17 Community Workshops held throughout the northern river basins from mid-February to late April 1996. Approximately 500 basins residents and other interested parties attended.

These workshops provided an opportunity for the Study to share its scientific results, to answer questions and to invite and record public comments. These meetings provided the Study Board with important local input as it developed its final recommendations to the Ministers.

Comments selected to this list were either voiced at two or more of the 17 meetings, or elicited strong audience support at a single meeting.

These comments are not intended to statistically reflect overall attitudes and opinions of basins residents, but rather to provide an overview of comments and suggestions expressed at these public meetings.

6.2 Post NRBS / Interjurisdictional

- ❑ There should be life after NRBS. An interjurisdictional body should be established to monitor and manage the river system. Streamlining is needed.
- ❑ Costs for an interjurisdictional body should not be borne by municipalities or other local governments. Funds from royalties or licences should help pay for such a body.
- ❑ Governments need to follow up on NRBS results. Time lines for meeting some of the NRBS recommendations should be established.
- ❑ A transboundary agreement is needed with British Columbia.
- ❑ A basin management plan should be established with public and First Nations participation.
- ❑ The government of Canada, in cooperation with provincial and territorial ministries, should work internationally to establish world-wide agreements and understandings to limit placing toxic substances into the environment.

6.3 Discharge / River Health

- ❑ A goal of zero discharge should be pursued.
- ❑ If zero discharge is not immediately attainable, then time lines should be established.
- ❑ A moratorium or reduction on input should be put into place until we better understand causes of river problems.
- ❑ There should be a cap on all expansion or additional loadings until we know more.
- ❑ We need to work towards a closed loop system.
- ❑ Pollution prevention should be a guiding principle.
- ❑ This is a good news study which shows industry's willingness to use the newest technology to reduce negative impacts on the river system.
- ❑ Municipalities should find ways to lower discharge. Governments should provide infrastructure support.

6.4 Regulations and Monitoring

- ❑ There needs to be standardized regulations between all governments with regard to nutrients, dissolved oxygen, drinking water and contaminants.
- ❑ The Alberta government should continue monitoring and should not download any of its responsibilities to industry.
- ❑ The Alberta government should strictly enforce current regulations.
- ❑ Governments should monitor, industry should pay.
- ❑ Water tables should be monitored over the long term.

6.5 Future Studies

- ❑ Studies should focus as well on forestry, oil and gas, coal mining, road building and agriculture, with particular attention to the effects of contaminants and nutrients.
- ❑ Studies should be conducted with participation from neighbouring provinces, in particular British Columbia.
- ❑ Studies should examine both micro and macro effects of nutrients, and agriculture.
- ❑ Studies should examine tributaries.
- ❑ Studies should look at hazardous waste in landfills.
- ❑ Studies should focus on resin acids and PCBs.
- ❑ Studies should be modelled after NRBS studies so that progress of the river system can be effectively modelled according to consistent standards.
- ❑ Studies should be ecologically based and not technologically based.

6.6 Traditional Knowledge

- ❑ Traditional Knowledge should be given equal status with conventional scientific research.
- ❑ Traditional Knowledge gatherings should be extended to other communities.
- ❑ Information gained from Traditional Knowledge should stand on its own. The information and concerns should be sufficient to follow up without the necessity of corroborating "western" science.

6.7 Citizen Involvement

- ❑ Citizens should be involved in future studies.
- ❑ Citizens should be involved in establishment of interjurisdictional bodies.
- ❑ Citizens should always have access to all verified scientific information.
- ❑ Citizens should be involved in the monitoring process.
- ❑ Citizens should be involved during consideration of future development.

6.8 First Nations

- ❑ First Nations should be involved in planning of future initiatives.
- ❑ First Nations should be consulted when considering future development.
- ❑ First Nations should be involved in any future interjurisdictional body.

6.9 Education / Communication

- ❑ NRBS results, maps, CD Rom etc. should be shared with schools and other institutions. Information should be added to respective curricula.
- ❑ NRBS results should be communicated to the media. Media should be encouraged to provide NRBS results and recommendations maximum coverage.
- ❑ Ways should be established to warn or advise residents when either contaminants are being placed in the river system, or river levels are about to significantly change. Industry, governments and municipalities have a responsibility to warn downstream communities.
- ❑ Environmental information is public property.

6.10 Human Health

- ❑ Fish advisories should be updated based on NRBS information.
- ❑ All NRBS information should be forwarded to health officials for consideration and action.
- ❑ Strong endorsement should be given to the Alberta Health funded Human Health Monitoring Program.
- ❑ Ozone and other alternatives should be pursued in the treatment and purification of drinking water.

6.11 Advice / Comments to the Board

- ❑ Board members should vote in an objective manner, based on fact and not affiliation.
- ❑ Do something to ensure that recommendations do not sit on the shelf.

- The final document should indicate whether Board motions are unanimous or not.
- It was the public who pushed for this Study and that should be reflected in the final report.

6.12 Other Recommendations

- Policies should be established to ensure that NRBS waters are never sold or routed to the south.
- Other processes for paper production should be considered (hemp, rice).
- There should be regulations and public consultation with regard to location of landfills.
- Fees for water usage should be based on consumer use.
- Contaminant and nutrient standards should not be the same for all basins locations. For example, nutrient standards in Jasper should be more stringent than in downstream communities.
- A more holistic approach to the river system is needed. "The river does not revolve solely on how humans can use it."

7.0

APPENDICES

7.1 LAYING THE GROUNDWORK: THE INTERGOVERNMENTAL STEERING COMMITTEE

In October 1989, a meeting was struck among federal, provincial and territorial agencies with interests in the basins (later to be known as the Intergovernmental Steering Committee). The meeting was struck to discuss the need for technical studies on the three river basins, a need emphasized by the AlPac EIA report released in March 1990.

The Steering Committee and its associated Task Force outlined the initial framework for the Northern River Basins Study and developed a draft federal-provincial-territorial agreement for carrying it out. The three and one-half year study would be funded under the *Canada Water Act*, Alberta's *Water Resources Act* and the Department of Indian Affairs' Northern Development Program.

In June 1990, the Task Force released a report that reviewed the scope of previous environmental investigations in the three basins. Although these studies were extensive, they presented a piecemeal picture of the basins, pockmarked by major data deficiencies. For instance, while licensed use of water (e.g., industrial use) was well documented, unlicensed withdrawals by farms and temporary camps was unknown. A complete picture of who was using the water and how they were using it was required. More information was needed regarding the fate and effects of organochlorines and other contaminants on the aquatic ecosystem. Water quality models were required to assess present and future contaminant levels. Knowledge of the habitat and water quality requirements affecting fish populations and movements was necessary. This included the importance of documenting current levels of contaminants in fish and understanding their cumulative effects.

Under the guidance of the Intergovernmental Steering Committee, the Task Force proposed a research program to fill these and other information gaps. The program was budgeted $12.3 million and covered five areas: hydrology / hydraulics, water use, water quality, fisheries and wildlife. Ninety per cent of the proposed program funds would be directed towards water quality and fisheries studies, reflecting the large knowledge gaps in these areas as well as widespread public concerns.

Original Agreement (September 27, 1991)

CANADA-ALBERTA-NORTHWEST TERRITORIES
PEACE-ATHABASCA-SLAVE RIVER BASINS STUDY
PHASE II - TECHNICAL STUDIES

THIS AGREEMENT made this 27th day of September, 1991

BETWEEN:

THE GOVERNMENT OF CANADA, represented herein by the Minister of the Environment and the Minister of Indian Affairs and Northern Development (hereinafter referred to as "Canada"),

AND

THE GOVERNMENT OF THE PROVINCE OF ALBERTA, represented herein by the Minister of Environment and the Minister of Forestry, Lands and Wildlife (hereinafter referred to as "Alberta"),

AND

THE GOVERNMENT OF THE NORTHWEST TERRITORIES, represented herein by the Minister of Renewable Resources and the Commissioner of the Northwest Territories (hereinafter referred to as "Northwest Territories").

WHEREAS the Canada Water Act encourages federal-provincial cooperation in the examination and resolution of water resource issues; and

WHEREAS the Minister of the Environment for Alberta is empowered under the Department of Environment Act to enter into agreements with the Government of Canada relating to any matter pertaining to the environment; and

WHEREAS the Minister of Indian Affairs and Northern Development is empowered under the Northern Inland Waters Act to enter into the agreements with a province respecting the management of transboundary waters; and

WHEREAS the Minister of Renewable Resources and the Commissioner of the Northwest Territories are empowered under the Water Resources Agreements Act to enter into agreements with the Government of Canada or a province respecting transboundary water resources; and

WHEREAS the Peace and Athabasca river basins are tributary to the Slave River Basin and part of the Mackenzie River Basin, and are a primary source of water for northern Alberta and the Peace, Athabasca and Slave river deltas and the Mackenzie River Basin in the Northwest Territories; and

WHEREAS Canada and Alberta and the Northwest Territories are negotiating a bilateral agreement on transboundary water management at the Alberta-Northwest Territories boundary which is intended to be consistent with the Mackenzie River Basin Master Agreement; and

WHEREAS Canada and Alberta and the Northwest Territories wish to ensure that existing and future developments make use of the water resources of the Peace, Athabasca and Slave river basins in a manner which does not diminish the potential for the use of these water resources; and

WHEREAS the water and aquatic environment of the Peace, Athabasca and Slave river basins may be altered by development projects such as forestry operations, pulp and papermills, hydroelectric facilities, oil sands plants, and associated municipal growth; and by the cumulative effects of these developments; and

WHEREAS there is a need to improve the existing information base in order to facilitate the effective monitoring and evaluation of the water and aquatic environment of the Peace, Athabasca and Slave river basins; and

WHEREAS there is a desire to coordinate environmental studies conducted under this program with other related activities to be carried out by other agencies and industry within the Peace, Athabasca, and Slave river basins, including the Slave River Environmental Quality Monitoring Program and the proposed human health study; and

WHEREAS the Governments of Canada, Alberta and the Northwest Territories agree that an open and cooperative approach to collecting and analysing data regarding the water and aquatic environment of the Peace, Athabasca and Slave river basins is essential; and

WHEREAS Phase I - Initial Inventory and Data Gap Evaluation of the Peace-Athabasca-Slave River Basin Study has been carried out by an intergovernmental task force; and

WHEREAS the Governor in Council, by Order in Council PC1991-7/1859 dated September 26, 1991, has authorized the Minister of the Environment and the Minister of Indian Affairs and Northern Development to enter into this Agreement on behalf of Canada; and

WHEREAS the Lieutenant Governor in Council, by Order in Council 376/91 dated June 6, 1991, has authorized the Minister of the Environment to enter into this Agreement on behalf of Alberta; and

WHEREAS the Northwest Territories Legislative Assembly through the Water Resources Agreements Act assented to September 10, 1983 has authorized the Minister of Renewable Resources and the Commissioner of the Northwest Territories to enter into this Agreement on behalf of the Northwest Territories.

IT IS THEREFORE AGREED BETWEEN THE PARTIES HERETO AS FOLLOWS:

Section 1 - Definitions

1. In this Agreement, unless the context otherwise requires:

(a) "aquatic environment" means the environment containing all growing or living things upon or in water including all bottom substrate, sediments and physical and biological constituents;

(b) "eligible costs" means directly related costs that have been approved and recorded by the Operations Committee as having been reasonably and properly incurred for the Study;

(c) "fiscal year" means the period commencing on April 1 of any year and terminating March 31 of the immediately following year.

(d) "Ministers" means the Ministers of the Environment, and Indian Affairs and Northern Development for Canada; and the Ministers of the Environment and Forestry, Lands and Wildlife for Alberta; and the Minister of Renewable Resources for the Northwest Territories;

(e) "Operations Committee" means the Canada-Alberta-Northwest Territories Peace-Athabasca-Slave River Basin Study Operations Committee of the Study Board established pursuant to Section 3.4;

(f) "Science Advisory Committee" means a group of objective and professional experts appointed by the Study Board appointed by the Study Board to advise on the design and implementation of the Study;

(g) "Study" means the Peace-Athabasca-Slave River Basin Study. Phase II - Technical Studies as outlined in Schedule "A";

(h) "study area" means the Alberta and Northwest Territories portions of the Peace, Athabasca and Slave river mainstems, their important tributaries, and their deltas;

(i) " Study Board" means the Canada-Alberta-Northwest Territories Peace-Athabasca-Slave River Basin Study Board established pursuant to Section 3.1;

(j) " Study Director" means the individual appointed pursuant to Section 3.5; and

(k) " Technical Advisory Group" means a group of scientists and interested people appointed by the Study Board to assist the Study Director with delivery of the Study.

Section 2 - Purpose

2.1 The purpose of this Agreement is to provide a cooperative interjurisdictional mechanism to undertake the Study.

2.2 The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the study area by coordinating with existing programs and undertaking appropriate new technical studies.

2.3 The study has the following objectives:

- (a) to provide a scientifically sound information base for planning and management of the water and aquatic environment of the study area so as to enable its long term protection, improvement and wise use;
- (b) to collect and interpret data and develop appropriate models related to hydrology/ hydraulics, water quality, fish and fish habitat, riparian vegetation/wildlife and use of aquatic resources for use in predicting and assessing cumulative effects of development; and
- (c) to ensure that technical studies undertaken in the basin are conducted in an open and cooperative manner and that their purpose, progress, and results are reported regularly to the public.

2.4 The Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies shall be carried out in accordance with the terms of reference as set out in Schedule "A" which is attached to, and forms part of this Agreement.

Section 3 - Management and Coordination

3.1 Canada, Alberta and the Northwest Territories agree to establish a Study Board to implement the terms of this Agreement, as follows:

- (a) the Study Board will consist of up to twenty-five members;
- (b) government members of the Study Board shall be appointed by their respective Ministers from the following departments:
  - (i) Alberta Environment (two members)
  - (ii) Alberta Forestry, Lands and Wildlife (one member)
  - (iii) Alberta Health (one member)
  - (iv) Environment Canada (one member)
  - (v) Fisheries and Oceans Canada (one member)
  - (vi) Indian Affairs and Northern Development Canada (one member)
  - (vii) Health and Welfare Canada (one member) and
  - (viiii) Government of Northwest Territories, Department of Renewable Resources (one member);
- (c) Subject to Section 3.1. (a), additional members of the Study Board may be appointed by joint agreement of the Ministers of the Environment for Canada and Alberta and with the Minster of Renewable Resources for the Government of the Northwest Territories.

3.2 The appointment of members as co-chairpersons of the Study Board shall be made by the Ministers of the Environment for Canada and Alberta.

3.3 The duties of the Study Board shall include:

(a) responsibility for the overall direction of the Study to ensure that the objectives and intent of the Agreement are carried out;

(b) meeting regularly, keeping minutes of its meetings and recording its decisions taken at its meetings, with such records to be made public;

(c) establishment of standards and procedures required for maintenance of order in its meetings, using such parliamentary rules of order as Bourinots Rules of Order;

(d) review of the Study program and making recommendations to the Operations Committee regarding the management of the Study;.

(e) approval of an annual program of work and an annual budget for proposed programs and projects to be done under this Agreement for the subsequent fiscal year, as prepared by the Operations Committee pursuant to Section 3.5 (d) (v);

(f) provision of recommendations to the Operations Committee on reallocation of funds as appropriate between the Study projects identified in Schedule "A";

(g) provision of an annual report to the Ministers within three months after the termination of each fiscal year and at any other time or times as the Ministers may require containing such information as is specified in the Agreement;

(h) appointment of a Science Advisory Committee and Technical Advisory Groups, as required;

(i) provision of a program of public information including, but not limited to, reports on the purpose, progress and results of the Study;

(j) provision of a final report of the Study with recommendations to the Ministers by March 31, 1995; and

(k) carrying out such other related duties as the Ministers may direct.

3.4 Canada, Alberta and the Northwest Territories agree to establish an Operations Committee of the Study Board to manage the affairs of the Study between meetings of the Study Board. The Operations Committee will be comprised of the following members of the Study Board:

(a) one Alberta Environment representative,

(b) the Alberta Forestry, Lands and Wildlife representative,

(c) the Environment Canada representative,

(d) the Fisheries and Oceans Canada representative,

(e) one member who was appointed pursuant to Section 3.1 (c), as selected by the Study Board, and

(f) the Study Director as an ex-officio member and secretary.

Members of the Operations Committee may designate an alternate to assume responsibilities during periods of absence.

3.5 The duties of the Operations Committee shall include:

(a) day-to-day management of the Study on behalf of the Study Board;

(b) appointment of and day-to-day direction of the Study Director on behalf of the Study Board;

(c) ensuring that studies done outside of this Agreement but within the study area are coordinated with this Study;

(d) responsibility for the discharge of the financial and accounting provisions of the Agreement and, in particular:

(i) ensuring that the manner in which funds are spent in the Study complies with the intent of the Agreement;
(ii) ensuring that funds are controlled and expended in accordance with the provisions of the legislative requirements of the funding parties;
(iii) reallocation of funds, as appropriate, between the Study projects identified in Schedule "A";
(iv) determination of eligible costs pursuant to this Agreement; and
(v) preparation, with the assistance of the Study Director, of annual budgets and work programs for review and approval of the Study Board.

(e) responsibility for provisions of guidance and assistance to the Study Board in all matters of financial accountability normally required by the parties in the discharge of this Agreement and the undertaking of the Study. The Operations Committee will report to the Study Board on these and all other matters at each meeting of the Study Board.

3.6 The Study Director may, subject to approval of the Operations Committee, enter into contracts with individuals, government departments or agencies, universities, consultants, or private firms to carry out various aspects of the work associated with the Study.

3.7 The ultimate responsibility for all decisions with regard to the operation of the Study will rest with the Ministers.

Section 4 - Financial Provisions

4.1 Subject to the terms and conditions of this Agreement, the total eligible costs of the Study shall not exceed $12,300,000, to be shared equally by Canada and Alberta.

4.2 The expenses of the members of the Study Board shall not be included within the eligible costs of the Study and Canada, Alberta and the Northwest Territories shall bear the entire costs of travel, salary and other expenses of each member of the Study Board appointed by that party and any other employee of that party, unless specifically authorized by the Operations Committee as an eligible cost.

4.3 Where Canada, Alberta and the Northwest Territories are supplying goods and services as part of their share of eligible costs, such goods or services shall be supplied at no more than cost.

4.4 Alberta shall, with respect to the costs to which Section 4.1 is applicable:

(a) pay such costs as they come due; and

(b) where the cost is incurred by other parties, Alberta shall reimburse the other party upon submissions of the claim in accordance with procedures to be established by the Study Board for such purposes.

4.5 Alberta shall submit, at least quarterly on a fiscal year basis, progress claims to Canada for its share of the eligible costs incurred and paid for in the performance of work, as certified by a senior financial officer of that party and in a mutually agreed manner.

4.6 The parties shall pay the progress claims submitted by the other party, at least upon a quarterly basis, after the claims are certified by a senior officer by that latter party.

4.7 Canada, Alberta and the Northwest Territories shall maintain adequate documentation and records of the costs that are to be shared by them and which are incurred pursuant to this Agreement and shall, upon requests, make such records and documents available for examination by auditors of the other.

4.8 Any discrepancy in the documents and records of costs incurred under this Agreement disclosed by an audit under Section 4.7 shall be promptly adjusted between Canada, Alberta and the Northwest Territories.

4.9 The provisions of funds by Canada and Alberta for the implementation of this Agreement are subject to the Parliament of Canada and the Legislative Assembly of Alberta having approved and appropriated such funds for the fiscal year in which they are required.

Section 5 - Amendments

5.1 This Agreement may be amended by the Ministers with the exception of Section 4.1. and 6.1 which can only be amended with the approval of the Governor in Council for Canada, the Lieutenant Governor in Council for Alberta and the Commissioner for the Northwest Territories.

Section 6 - General

6.1 This Agreement shall take effect from the date when last executed by a party hereto and, except as noted in Section 6.2. and 6.3, shall terminate on March 31, 1995.

6.2 The Parties agree that eligible costs shall include eligible costs incurred between April 1, 1991 and the signing of this Agreement, up to a maximum of $542,000.

6.3 The provisions of this Agreement respecting the payment, reimbursement and audit of eligible costs that are to be shared by Canada and Alberta shall remain in effect for six months after the termination date.

6.4 Any party may terminate involvement in this Agreement upon providing six months notice in writing to the other parties.

6.5 Canada, Alberta and the Northwest Territories shall, upon request, make available to each other and to the Study Board all available documents, including past and current reports, studies and analyses concerning water and the aquatic environment of the Peace, Athabasca and Slave river basins for use in the Study.

6.6 Where Canada, Alberta or the Northwest Territories undertakes or is responsible for any portion of the Study, it shall indemnify and save harmless each of the others, their officers, servants and agents, against all claims and demands of third parties in any way arising out of any work undertaken pursuant to this Agreement, except as such claims or demands relate to the act or negligence of any officer, employee or agent of the others.

6.7 No member of the Parliament of Canada or member of the Legislative Assemblies of Alberta or the Northwest Territories shall hold, enjoy or be admitted to any share or part of any contract, agreement, commission or benefit arising out of this Agreement.

IN WITNESS WHEREOF, the Minister of Environment for Canada and the Minister of Indian Affairs and Northern Development for Canada have hereto set their hands on behalf of Canada; the Minister of the Environment for Alberta and the Minister of Forestry, Lands and Wildlife for Alberta have hereto set their hands on behalf of Alberta; and the Minister of Renewable Resources for the Northwest Territories and the Commissioner of the Northwest Territories have hereto set their hands on behalf of the Northwest Territories.

IN THE PRESENCE OF

GOVERNMENT OF CANADA

Witness	**Minister of the Environment**
Witness	**Minister of Indian Affairs and Northern Development**

GOVERNMENT OF ALBERTA

Witness	**Minister of the Environment**
Witness	**Minister of Forestry, Lands and Wildlife**

Approved Pursuant to the Alberta Department of Federal and Intergovernmental Affairs Act.

Minister of Federal and Intergovernmental Affairs

GOVERNMENT OF NORTHWEST TERRITORIES

Witness	**Minister of Renewable Resources**
Witness	**Commissioner of the Northwest Territories**

PEACE-ATHABASCA-SLAVE BASIN STUDY
PHASE II - TECHNICAL STUDIES

SCHEDULE "A"
TERMS OF REFERENCE

INTRODUCTION

The Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies is comprised of four technical components as well as a study management component. The technical components include hydrology/ hydraulics, water quality, fish and fish habitat and use of aquatic resources. The objectives and programs for each component are described below. Annual programs of work prepared pursuant to Section 3.5 of the Agreement will present detailed descriptions of the technical studies program.

The study area is described as the Alberta and Northwest Territories portions of the Peace, Athabasca and Slave River mainstems, their important tributaries, and their deltas.

1. HYDROLOGY/HYDRAULICS COMPONENT

The objective of the hydrology/hydraulics component is to acquire hydrologic, hydraulic and sediment transport information to support the other Study components in their analyses needs.

The programs will include:

1.1 Hydrologic database program - to develop a complete hydrologic database, at the highest level of accuracy necessary.

1.2 Hydraulics program - to determine the hydraulic and mixing characteristics of the rivers during winter low flow, under-ice conditions.

1.3 Sediment transport program - to identify the amount and timing of the transport of sediment through the system.

Hydrology/Hydraulics Component Budget $1,000,000

2. WATER QUALITY COMPONENT

The objectives of the water quality component are:

(a) to characterize existing industrial and municipal effluents;
(b) to document the existing baseline quality of water, bed and suspended sediments and aquatic biota;
(c) to describe the fate and effects of the key contaminants within the aquatic environment and its food chain, including benthos, fish and riparian wildlife;
(d) to develop predictive tools that define cumulative effects of point discharges on the quality of the rivers; and
(e) to provide an information base for the design of long-term monitoring programs.

The programs will include:

2.1 Effluent characterization program - to characterize the existing industrial and municipal effluents and describe their ecotoxicity.

2.2 Dissolved oxygen program - to characterize the dissolved oxygen, biological oxygen demand, sediment oxygen demand and other relevant components of aquatic oxygen.

2.3 Toxic organics program - to assess the contamination and biological effects of key toxic organics and to study their transport and partitioning.

2.4 Metals in water program - to assess the contamination and effects of key metals on the aquatic environment.

2.5 Eutrophication and non-toxic variables program - to assess the levels and impacts of nutrients on the aquatic biota.

2.6 Common services program - to provide quality assurance and coordination services for cost effective water quality component programs.

Water Quality Component Budget $4,630,000

3. FISH AND FISH HABITAT COMPONENT

The objectives of the fish and fish habitat component are:

(a) to improve the level of knowledge on the species composition, relative abundance, temporal and spatial distribution, life history, predatory/prey relationships and habitat relationships of the fish resources so as to conserve, protect and manage the fish and fish habitat;
(b) to conduct pathological examinations of fish collected to evaluate fish health;
(c) to determine the water quality requirements for the protection of the fish populations, with a particular emphasis on dissolved oxygen; and
(d) to integrate fish population, habitat and health studies to better understand the direct and cumulative effects of development in the basin.

The programs will include:

3.1 Fish inventory program - to collect data on fish populations, their population dynamics and migrations, and on habitat utilization and food webs via fish and fish habitat surveys, radio telemetry tracking of fish and stable isotope analyses; and to supply fish for other components of the Study.

3.2 Dissolved oxygen requirements for fish program - to determine the effects of reduced dissolved oxygen levels on fish and to recommend dissolved oxygen levels for the protection of fish.

Fish and Fish Habitat Component Budget $5,014,000

4. USE OF AQUATIC RESOURCES COMPONENT

The objectives of the use of aquatic resources component are:

(a) to document the location, type and extent of consumptive and non-consumptive human use of the water resources;
(b) to identify the water quantity and quality requirements of these uses of water;
(c) to document native and sport/commercial consumption of fish and riparian wildlife;
(d) to assess the incidence and extent of tainting of water and fish; and
(e) to assess the impact of industrial development on municipal water treatment.

The programs will include:

4.1 Consumptive and non-consumptive water use program - to locate and quantify consumptive and non-consumptive uses of water and to identify their water quantity and quality requirements.

4.2 Native/traditional use of fish and riparian wildlife program - to document the use and importance of fishing, hunting and trapping of fish and riparian wildlife to the native lifestyle.

4.3 Taste and odour program - to document the incidence of taste and odour problems in river water and fish and to identify their causative agents.

4.4 Drinking water impacts program - to review effects of pulp mill effluents on drinking water quality and municipal treatment requirements.

Use of Aquatic Resources Component Budget $701,000

5. STUDY MANAGEMENT COMPONENT

The technical studies will be done under the direction and management of the Study Board and Operations Committee. Day-to-day delivery of the studies will be the responsibility of a study office that includes a Study Director and staff.

The duties of the Study Director shall include, but not be limited to, the following:

(a) efficient day-to-day delivery of a coordinated and complete Study to the Study Board and the Operations Committee;
(b) preparation of annual reports on Study progress;
(c) preparation of annual program and budget proposals;
(d) production of individual technical studies;
(e) production of a final report of the Study;
(f) provision of a public information program;
(g) operation of the Science Advisory Committee and Technical Advisory Groups; and
(h) provision of any other information requested by the Study Board or Operations Committee;

The Science Advisory Committee will be responsible for providing objective and professional scientific advice to the Study Board and Operations Committee with respect to the design and implementation of the Study. Specifically, it will confirm that the study program is scientifically sound, will monitor progress of the Study, will review the results of individual studies to ensure that the program is delivered as designed, and will report to the public on scientific matters related to the Study.

The Technical Advisory Groups will be responsible for assisting the study office staff in planning the program of studies, reviewing draft Terms of Reference, and reviewing reports. The participation of the Technical Advisory Groups will assist in coordinating the Study with other activities in the study area and in providing a wide scope of technical expertise from which the Study Director can draw advice.

Study Management Component Budget $955,000

Canada Alberta Northwest Territories

Northern River Basins Study

March 1, 1993

Since the beginning of the Study, up to and including the above date, the Ministers have endorsed the following amendments to the Study Agreement:

1) Amending Subsection 3.3(d) to reflect the fact that the Operations Committee reports to and receives its direction from the Study Board. The Study Agreement was amended by removing the term "making recommendations" and replacing it with "giving recommendations".

2) Amending Subsection 3.4 to increase the size of the Operations Committee from six to seven members. The Study Agreement was amended to include a seventh member on the Operations Committee by adding the following clause:

   g) one Northwest Territories representative

3) Amending Schedule A, Terms of Reference, Subsection 5, Paragraph 3 with the addition of the phrase "through the Study Board" on the final line. The final sentence in the paragraph was amended to read as follows:

   Specifically, it will confirm that the Study Program is scientifically sound, will monitor the progress of the Study, will review the results of individual studies to ensure that the program is delivered as designed, and will report to the public through the Study Board on scientific matters related to the Study.

Bev M. Burns
Regional Director General
Conservation and Protection
Environment Canada
Co-Chairman, Study Board

Peter G. Melnychuk
Deputy Minister
Alberta Environmental Protection
Co-Chairman, Study Board

CANADA-ALBERTA-NORTHWEST TERRITORIES
NORTHERN RIVER BASINS STUDY
AMENDING AGREEMENT (#1)

THIS AMENDING AGREEMENT made this 15 **day of** Sept, **19~~94~~ 95.**

BETWEEN:

THE GOVERNMENT OF CANADA, represented herein by the Deputy Prime Minister and Minister of the Environment, and the Minister of Indian Affairs and Northern Development (hereinafter referred to as "Canada"),

AND

THE GOVERNMENT OF THE PROVINCE OF ALBERTA, represented herein by the Minister of Environmental Protection (hereinafter referred to as "Alberta"),

AND

THE GOVERNMENT OF THE NORTHWEST TERRITORIES, represented herein by the Minister of Renewable Resources and the Commissioner for the Northwest Territories (hereinafter referred to as "Northwest Territories").

Hereinafter referred to collectively as the "Parties".

WHEREAS Canada, Alberta and the Northwest Territories entered into an Agreement dated the 27th day of September, 1991 entitled the "Canada-Alberta-Northwest Territories Peace-Athabasca-Slave River Basin Study Phrase II - Technical Studies" Agreement ("the Agreement");

WHEREAS Canada, Alberta and the Northwest Territories wish to make certain amendments to clarify and amend the terms of the Agreement;

WHEREAS the Governor in Council, by Order in Council ________ dated ________ has authorized the Deputy Prime Minister and Minister of the Environment, and the Minister of Indian Affairs and Northern Development to enter into this Amending Agreement on behalf of Canada; and

WHEREAS the Lieutenant Governor in Council, by Order in Council dated has authorized the Minister of Environmental Protection to enter into this Amending Agreement on behalf of Alberta; and

WHEREAS the Northwest Territories Legislative Assembly through the authority of the Water Resources Agreements Act SNWT 1983, c. 9, has authorized the Minister of Renewable Resources and the Commissioner of the Northwest Territories to enter into this Amending Agreement on behalf of the Northwest Territories.

IT IS THEREFORE AGREED BETWEEN THE PARTIES THAT THE AGREEMENT SHALL BE AMENDED AS FOLLOWS:

1. The title of the Agreement is amended by replacing "Peace-Athabasca-Slave River Basin Study" with "Northern River Basins Study".

2. The parties provision of the Agreement is amended by replacing "THE GOVERNMENT OF THE PROVINCE OF ALBERTA, represented herein by the Minister of the Environment and the Minister of Forestry, Lands and Wildlife" with "THE GOVERNMENT OF THE PROVINCE OF ALBERTA, represented herein by the Minister of Environmental Protection".

3. The WHEREAS provision of the Agreement which refers to "the Department of the Environment Act" is amended by adding "(now the Minister of Environmental Protection)" after "the Minister of the Environment for Alberta".

4. The WHEREAS provision of the Agreement which refers to "Phase I - Initial Inventory" is amended by adding "(now called the Northern River Basins Study)" after "Peace-Athabasca-Slave River Basin Study".

5. The WHEREAS provision of the Agreement which refers to "Order in Council 376/91" is amended by adding "(now the Minister of Environmental Protection)" after "the Minister of the Environment".

6. S. 1(d) is amended by replacing "the Ministers of the Environment and Forestry, Lands and Wildlife for Alberta;" with "the Minister of Environmental Protection for Alberta;".

7. S. 1(e) is amended by replacing "the Canada-Alberta-Northwest Territories Peace-Athabasca-Slave River Basin Study" with "the Canada-Alberta-Northwest Territories Northern River Basins Study".

8. S. 1(g) is amended by replacing "the Peace-Athabasca-Slave River Basin Study" with "the Northern River Basins Study".

9. S. 1(i) is amended by replacing "the Canada-Alberta-Northwest Territories Peace-Athabasca-Slave River Basin Study" with "the Canada-Alberta-Northwest Territories Northern River Basins Study".

10. S. 1(j) is amended by deleting "and".

11. S. 1 is amended by adding the following:

    (j.1) "Science Director" means the individual appointed pursuant to Section 3.5; and

12. S. 1(k) is amended to read:

    "Technical Working Group" means a group of individuals appointed to assist the Science Director with the delivery of the Study.

13. S. 2.3(b) is amended by replacing "data and" with "information and data and to".

14. S. 2.3(c) is amended by replacing "their" with "the public is provided with opportunities to provide input to the studies and that the".

15. S. 2.4 is amended to read:

    The Northern River Basin Study, Phase II - Technical Studies will, in general, be composed of the components outlined in Schedule A and will focus on answering the questions listed in Schedule B, both of which are attached to and form part of this Agreement.

16. S. 3.1(b)(i) is amended to read;

    Alberta Environmental Protection (three members)

17. S. 3.1(b)(ii) is deleted.

18. S. 3.1(c) is amended by replacing "Ministers of the Environment for Canada and Alberta" with "the Minister of the Environment for Canada, the Minister of Environmental Protection for Alberta,".

19. S. 3.1 is amended by adding the following:

    (d) Each member of the Study Board may designate an alternate to assume their responsibilities during periods of absence.

    (e) Quorum for any Study Board meeting is two-thirds of the total appointed members or their alternates where members are absent.

20. S. 3.2 is amended by replacing "Ministers of the Environment for Canada and Alberta" with "Minister of the Environment for Canada and the Minister of Environmental Protection for Alberta".

21. S. 3.3(b) is amended by adding "once approved by the Board" after the words "such records".

22. S. 3.3(d) is amended by replacing "making recommendations" with "providing direction".

23. S. 3.3(f) is amended by replacing "provision of recommendations" with "providing direction".

24. S. 3.3(h) is amended by replacing "Technical Advisory Groups" with "Technical Working Groups".

25. S. 3.3(j) is amended by replacing "1995" with "1996".

26. S. 3.4(a) is amended to read:

    two Alberta Environmental Protection representatives,

27 S. 3.4(b) is deleted.

28 S. 3.4(e) is amended by deleting the word "and".

29. S. 3.4(f) is amended replacing "secretary." with "secretary,".

30. S. 3.4 is amended by adding:

    (g) the Science Director as an ex-officio member, and

    (h) one representative of the Government of the Northwest Territories.

31. S. 3.5 is amended replacing "The duties" with "Subject to the direction of the Board, the duties".

32. S. 3.5 is amended by adding:

    (f) "appointment of and, with the assistance of the Science Advisory Committee, provision of day to day direction of the Science Director on behalf of the Study Board."

33. S. 3.5(d)(iii) is amended by adding "including associated administrative costs," after "reallocation of funds,".

34. S. 3.5(d)(iii) is amended by replacing "projects" with "components".

35. S. 4.1 is amended by replacing "$12,300,000" with "$11,380,000".

36. S. 6.1 is amended by replacing "1995" with "1996".

37. Schedule A to the Agreement is deleted and Schedules A and B attached hereto are incorporated into and form part of the Agreement.

IN WITNESS WHEREOF, the Deputy Prime Minister and Minister of the Environment for Canada, and the Minister of Indian Affairs and Northern Development for Canada have hereto set their hands on behalf of Canada; the Minister of Environmental Protection for Alberta has hereto set his hand on behalf of Alberta; and the Minister of Renewable Resources for the Northwest Territories and the Commissioner of the Northwest Territories have hereto set their hands on behalf of the Northwest Territories.

IN THE PRESENCE OF:

CANADA

Witness

Deputy Prime Minister and Minister of the Environment

Witness

Minister of Indian Affairs and Northern Development

THE PROVINCE OF ALBERTA

Witness

Minister of Environmental Protection

Approved pursuant to the Alberta Department of Federal and Intergovernmental Affairs Act

Minister of Federal and Intergovernmental Affairs

THE NORTHWEST TERRITORIES

Witness

Minister of Renewable Resources

Witness

Commissioner of the Northwest Territories

SCHEDULE A
COMPONENTS OF THE NORTHERN RIVER BASINS STUDY

TRADITIONAL KNOWLEDGE $740,000

Information from local residents, elders and other traditional river users will play an important role in the overall examination of the northern river basins. This component involves the gathering of historical accounts, observations, information and views from these people regarding changes in the river system and how the rivers have been used.

The focus of this component is on obtaining local historical knowledge and views. Protocols to acquire traditional knowledge, including aboriginal and local knowledge, will be developed and used. Traditional values, specific descriptions of traditional uses (both historical and current), and traditional indicators of ecosystem integrity will be included. Local communities as well as individuals will be actively involved in the design and delivery of the program.

HYDRAULICS/HYDROLOGY $760,000

This component acquires and analyzes hydrologic, hydraulic and sediment transport information. The influence of these processes on the aquatic environment will be characterized. Models will be developed to simulate the hydraulics of the rivers to different flow regimes. As well, this component will examine the effects of ice and ice jams on water and sediment movement.

The focus of this component is on the hydrologic/hydraulic processes associated with flow regime, sediment transport and deposition. Flow under ice and the influence of ice jams on flow will be considered. Time of travel and effluent mixing will be examined. The analysis will allow the inter-relationships of hydrology, water quality and biota to be investigated. Descriptive and predictive, flow and sediment transport models will be developed.

NUTRIENTS $1,120,000

This component involves the assessment of the effects of nutrients such as phosphorus and nitrogen on the aquatic environment. Nutrients are being introduced into the river system through natural, industrial, agricultural and municipal processes.

The focus of this component is the assessment of the effect of nutrient and oxygen-consuming effluent on the related chemical, physical and biological processes of the rivers. Analysis will be carried out on the role of nutrients in influencing aquatic ecosystem productivity and its possible effects on other aspects of the system, e.g., dissolved oxygen concentrations. Impacts of effluent on under-ice dissolved oxygen levels will be investigated. The utility of quantitative models for predicting key water quality parameters will be assessed.

CONTAMINANTS $2,660,000

This component will examine the occurrence, distribution, abundance and effects of contaminants contributed by natural and man-made sources. The component will address historic impacts and likely changes relating to contaminants in the aquatic environment.

The focus of this component is the type, sources, toxicity and fate of contaminants particularly those that may have human health implications. The study will include the development of water quality models to predict cumulative impacts. The ultimate fate of these contaminants in the aquatic environment and impacts on the food chain will be evaluated. A long-term monitoring plan will be proposed.

FOOD CHAIN $1,250,000

This component will focus attention on describing the interrelationships between the living and non-living elements of the aquatic ecosystem. The component addresses fish health, behaviour, movement, distribution and food sources, critical habitat requirements, and their interaction with dissolved oxygen content and contaminants.

The component is characterized by a combination of field and laboratory studies directed at determining food chain relations and the occurrence, seasonal distribution, abundance and movement of fish species with various habitat types. Work also includes the determination of the influence of dissolved oxygen levels on embryo development and fry survival.

DRINKING WATER $510,000

This component will characterize human drinking water sources and the quality of water available for consumption. Work will include the examination of drinking water treatment processes and their effectiveness in meeting human consumption needs. The component will also study the potential impact of pollutant loading on drinking water.

The focus of this component is drinking water quality (chemistry, taste, odour and microbiology), and current drinking water control priorities and treatment processes. The sources and impacts of contaminant inputs on the quality of drinking water will be examined. Tainting of fish within the Northern River Basins will be characterized.

OTHER USES $460,000

Characterization of the historical and current uses made of the basins aquatic ecosystem is a primary task for this component. In addition to providing a historical perspective of use, the component will document the changes that residents have made towards their use and values of the aquatic ecosystem. This work will include projections of likely uses and values. Efforts will also be directed towards determining basin user expectations for maintaining a sustainable aquatic ecosystem.

The component will identify probable resource management needs and assess various institutional alternatives for ecosystem (basin) management, with a strong emphasis on community participation.

SYNTHESIS AND MODELLING $510,000

This component is responsible for integrating the findings of the other components into the development of synthesis documents on the state of the basins aquatic ecosystem. In addition to providing an assessment of the cumulative effects of basin development on the aquatic ecosystem, the component will lead the development of predictive tools for assessing the probable effects of development/growth.

The component will propose long-term monitoring plans and strategies for assessing the state of the aquatic ecosystem on an on-going basis. Indicators of ecosystem integrity and cumulative effects will also be investigated.

ADMINISTRATION $3,370,000

This component covers all of the support necessary for implementing a multidisciplinary study. This includes expenses associated with the Board and its sub-committees, the Study Office, Science Advisory Committee and the Science Office. Expenses associated with the provision of public gatherings, science forums, project reports and the study report are included.

TOTAL BUDGET = $11,380,000

SCHEDULE B
QUESTIONS TO BE ADDRESSED BY
THE NORTHERN RIVER BASINS STUDY

SCIENTIFIC QUESTIONS

1. a) How has the aquatic ecosystem, including fish and/or other aquatic organisms, been affected by exposure to organochlorines or other toxic compounds?

   b) How can the ecosystem be protected from the effects of these compounds?

2. What is the current state of water quality in the Peace, Athabasca and Slave river basins, including the Peace-Athabasca Delta?

3. Who are the stakeholders and what are the consumptive and non-consumptive uses of the water resources in the river basins?

4. a) What are the contents and nature of the contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?

   b) Are toxins such as dioxins, furans, mercury, etc. increasing or decreasing and what is their rate of change?

5. Are the substances added to the rivers by natural and man made discharge likely to cause deterioration of the water quality?

6. What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave river? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats?

7. What concentrations of dissolved oxygen are required seasonally to protect the various life stages of fish, and what factors control dissolved oxygen in the rivers?

8. Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish tissue and how are these levels changing through time and by location?

9. Are fish tainted in these waters and, if so, what is the source of the tainting compounds (i.e., compounds affecting how fish taste and smell to humans)?

10. How does and how could river flow regulation impact the aquatic ecosystem?

11. Have the riparian vegetation, riparian wildlife and domestic livestock in the river basins been affected by exposure to organochlorines or other toxic compounds?

12. What local traditional knowledge exists to enhance the physical science studies in all areas of enquiry?

13. a) What predictive tools are required to determine the cumulative effects of man made discharges on the water and aquatic environment?

    b) What are the cumulative effects of man made discharges on the water and aquatic environment?

14. What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems. These programs must ensure that all stakeholders have the opportunity for input.

NON-SCIENTIFIC QUESTIONS

15. How can the Study results be communicated most effectively?

16. What form of interjurisdictional body can be established, ensuring stakeholder participation for the ongoing protection and use of the river basins?

7.3 NRBS Organization

A NRBS Study Board reported annually to the ministers of Environment Canada, Indian and Northern Affairs Canada, Alberta Environmental Protection and Northwest Territories Renewable Resources. The Board met every second month at different communities within the basins. This allowed Board members to gain a personal sense of the geography and culture of the river basins communities. The meetings were complemented by community gatherings where Board members could respond to public concerns and garner input on public expectations of the science program.

The day-to-day administration of the Study was performed by the Study Office. Led by the Study and Science directors, the Study Office handled administrative issues and guided the science program (Figure 6.3.1).

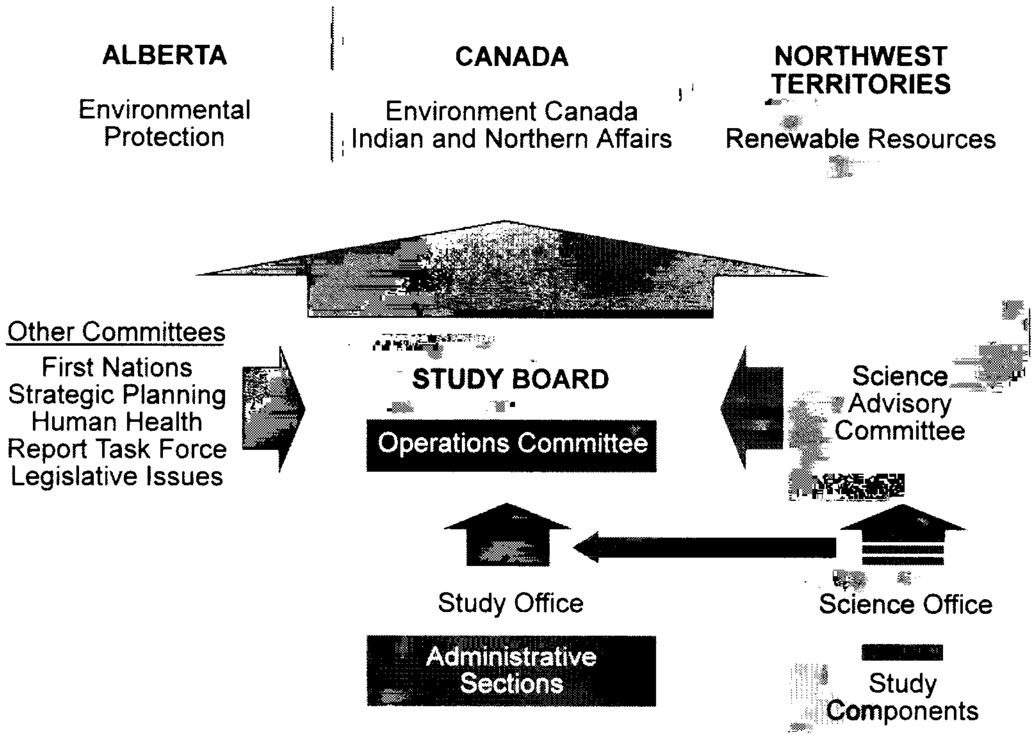


Figure 6.3.1 NRBS: Organizational Structure

The Study Board was also assisted by a number of committees providing specific services:

- ❒ The **Operations Committee**, a sub-group of the Study Board, oversaw the day-to-day management of the Study on behalf of the Board. It provided direction to the Study and Science directors, and tended to the daily accounting and financial matters.
- ❒ The **Science Advisory Committee** provided the Board with professional, impartial scientific guidance on the design and results of the science program. It also monitored the progress of research projects, reviewed scientific reports and responded to technical questions from the Board. Each year, the committee hosted a Science Forum to inform the public of the current status and key findings of the research program.
- ❒ The **Strategic Planning Committee** ensured that Study activities remained congruent with the objectives of the Study Agreement and the NRBS Vision Statement. It also ensured that the research program provided answers to the Study's 16 guiding questions.
- ❒ The **Legislative Issues Committee** ensured that the final recommendations to the Ministers provided answers to the 16 questions that guided the Study. It was later amalgamated with the Report Task Force committee.

- The **Human Health Committee** served as a health-oriented resource to the Study Board and established linkages with the human health studies within the Study area.
- The **First Nations Committee** facilitated harmonious interaction with peoples and organizations within the boundaries of the Grand Council of Treaty 8 First Nations.
- The **Report Task Force** organized the preparation and release of the Study's final scientific findings, conclusions and recommendations.
- The **Joint Steering Committee** was an external committee that ensured that all consultative processes complied with the provisions of the Grand Council of Treaty 8 First Nations consultation protocol. It also facilitated and coordinated activities between the Traditional Knowledge component and the Great Bear Environmental Health Study.

NORTHERN RIVER BASINS STUDY VISION STATEMENT

Given the available resources, within the scope of the Agreement, and recognizing the diversity of stakeholder interests, the Northern River Basins Study will have successfully:

1) promoted a shared, holistic understanding of a broad spectrum of baseline ecosystem conditions and processes in the basins;
2) presented recommendations for action on alleviating the cumulative effects of development in the basins;
3) promoted actions that are alleviating pollution problems; and
4) recommended mechanisms and ongoing consultative management processes for ensuring long-term protection and stewardship of the vitality and integrity of the basins' ecosystem.

These accomplishments will have been achieved through:

a) establishing an appropriate information base coupled with competent information evaluation and management systems;
b) applying up-to-date knowledge of the state of the aquatic and related ecosystems;
c) a process of gaining the necessary understanding to develop an effective framework for assessing and monitoring the cumulative effects of development;
d) adhering to accepted principles of sustainable development;
e) cooperation and consultation; and by
f) involving the public.

7.4 NRBS Membership

Study Board Membership

Current

Dr. G. Burton Ayles
Director General, Central and Arctic Region
Department of Fisheries and Oceans
Winnipeg, Manitoba

His Worship Dennis Bevington
Mayor
Fort Smith, Northwest Territories

Dr. Stephan Gabos
Director, Population Health
Alberta Health
Edmonton, Alberta

Dr. Bob James
Professor of Electrical Engineering
University of Alberta
Edmonton, Alberta

Mr. Donald J. Klym
Alberta Chamber of Resources
Fort McMurray, Alberta

Mr. David Livingstone
Director, Natural Resources and Environment
Indian Affairs and Northern Development
Yellowknife, Northwest Territories

Mr. Danny MacDonald
Dene and Métis Nation
Fort Smith, Northwest Territories

Mr. David MacDonald
Alberta Forest Products Association
Hinton, Alberta

Mr. Gerald McKeating
Regional Director,
Environment Conservation Branch
Environment Canada
Edmonton, Alberta

Mr. Robert McLeod (Co-chair)
Assistant Deputy Minister, Management
Department of Renewable Resources
Government of the Northwest Territories
Yellowknife, Northwest Territories

Chief Bernie Meneen
Tall Cree Tribal Government
Fort Vermilion, Alberta

Mr. Vern Moore
Unifarm
Debolt, Alberta

Mr. James R. Nichols
Assistant Deputy Minister
Natural Resources Service
Alberta Environmental Protection
Edmonton, Alberta

Mrs. Lucille Partington (Co-chair)
Member-at-Large
Sexsmith, Alberta

Mrs. Lucille Polukoshko
Health of the Public-at-Large
Hines Creek, Alberta

His Worship Michael Procter
Mayor
Peace River, Alberta

Mr. Fred Schulte
Director, Pollution Control Division
Alberta Environmental Protection
Edmonton, Alberta

Chief Johnsen Sewepagaham
Little Red River Cree Nation
High Level, Alberta

Councillor Diane Slater
Municipality of Wood Buffalo
Fort McMurray, Alberta

Mrs. Elizabeth Swanson
Environmental Law Centre
Edmonton, Alberta

Mr. Doug Tupper
Director, Water Resources Administration Division
Alberta Environmental Protection
Edmonton, Alberta

Mr. Lawrence Villeneuve
Métis Settlements
Paddle Prairie, Alberta

Dr. Ron Wallace
Environmental Consultant
Calgary, Alberta

Chief Archie Waquan
Mikisew Cree First Nation
Fort Chipewyan, Alberta

Dr. Brian Wheatley
Director, Research and Development,
Environmental Contaminants
Health Canada
Ottawa, Ontario

Past:

Mr. Dennis Barton
Public Health Association
Slave Lake, Alberta

Dr. Ron Dyck
Alberta Health
Edmonton, Alberta

*Mr. Bev Burns (Co-chair)
Regional Director General,
Conservation and Protection
Environment Canada
Edmonton, Alberta

Mrs. Betty Collicott
Mayor / Member-at-Large
Fort McMurray, Alberta

Mr. George Flynn
Director, Environmental Health Services
Alberta Health
Edmonton, Alberta

Mr. Peter Melnychuk (Co-chair)
Deputy Minister,
Alberta Environmental Protection
Edmonton, Alberta

Chief Tony Mercredi
Athabasca Chipewyan First Nation
Fort Chipewyan, Alberta

Mr. Angus Robertson
Director, Renewable Resources and Environment
Indian and Northern Affairs Canada
Yellowknife, Northwest Territories

Mr. Ken Smith
Assistant Deputy Minister,
Environmental Protection Services
Alberta Environment
Edmonton, Alberta

Mr. Ron Staple
Alberta Forest Products Association
Hinton, Alberta

Mr. Paul Sutherland
Director General,
Central and Arctic Region
Fisheries and Oceans Canada
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7.5 The Evolution of the Science Program

The NRBS science program was launched in December 1991 with the winter Quick Start Program. Conforming to the Phase II Study Agreement, the Quick Start Program initiated a series of projects to address knowledge gaps in four areas: hydrology / hydraulics, water quality, fish and fish habitat, and use of aquatic resources.

It soon became apparent that this organizational framework did not conform to the Board's or the Science Advisory Committee's expectations for meeting the objectives of the Study. The Science Advisory Committee expressed concerns that the current format focussed on data compilation, but lacked the expertise to interpret these data and make meaningful recommendations. There was also concern that the design and administration of research was very government-based, and should be expanded to capitalize on the wealth of scientific expertise available in other sectors.

In June 1992, the Science Advisory Committee proposed a new structure for the research program that was later approved by the Study Board. The new program consisted of eight components: contaminants, drinking water, food chain, hydraulics / hydrology, nutrients, other river uses, and synthesis and modelling. The eighth component (human health) was later set aside. By April 1993, the content for the improved science program had been fleshed out. It represented a shift in emphasis from data collection to research directed to finding answers to the 16 questions.

In December 1992, Traditional Knowledge was added as a component group. The research program for the Traditional Knowledge Component worked closely with the First Nations Committee. The Committee was empowered with the task of ensuring that all NRBS activities pertaining to First Nations peoples were in accordance with provisions of the *Protocol for the Northern River Basins Study*. The Protocol, developed in coordination with the Grand Council of Treaty 8 First Nations, set forth a series of guidelines for gathering scientific and traditional knowledge that respected the community structure, culture and knowledge of First Nations peoples. The end result was a positive working relationship based on cooperation, collaboration, trust and mutual respect.

7.6 Concurrent Investigations and Companion Studies

The Intergovernmental Steering Committee realized that the Northern River Basins Study did not exist in isolation. Quite the opposite, the NRBS was one project among many in a large and progressive scientific community. Ongoing advances in science and technology are making it easier to detect, understand and predict changes in the environment.

Industry is moving ahead at an equal pace with technical advances and management programs to reduce environmental impacts. Advances such as these continually modified the direction of the NRBS science program and guided many of the Board's recommendations.

The NRBS liaised closely with studies ongoing in, or pertaining to, the three river basins. These included studies from universities (e.g., the Terrestrial-Riparian-Organisms-Lakes-Stream, or "TROLS" experiment), government (e.g., Slave River Environmental Quality Program), industry (e.g., the Wapiti / Smoky River Ecosystem Study) and native governments (e.g., The Great Bear Environmental Health Study). Coordination among these studies provided the context for NRBS work by decreasing overlapping research, providing guidance on key recommendations and maximizing the reach of the Study.

7.7 Recommendations by the Science Components

Impacts of Flow Regulation on the Aquatic Ecosystem of the Peace and Slave Rivers

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Primary Recommendations

[1] ***"Naturalized" Flow Modelling***
Evaluating the effects of regulation on the overall flow regime is hampered by the brevity of the pre-regulation period data set. One method to extend the "un-regulated" period is to model flow conditions since regulation without the effect of the dam. Such a model has been under development by Alberta Environment in conjunction with British Columbia Hydro. It was originally hoped to incorporate the results of this model into some of the NRBS studies but the model is still being calibrated and results remain in draft form. It is recommended, therefore, that a priority be placed by Alberta Environment and B.C. Hydro on finalizing this work, and a re-evaluation made of the type of flow statistics presented in this report. Integral to this study should be an assessment of the significance of hydro-climatic variations in affecting the post-regulation flow characteristics.

[2] ***Hydro-climatic Studies of Tributary Flow***
Given the importance of tributary flow in producing downstream peaks on the Peace and Slave River systems, a hydro-climatic study needs to be conducted of inter-annual variations in tributary flow. Special attention should be placed on spring snowmelt events that are known to enhance sediment contributions and be a driving force in producing break-up floods. A companion study should also be undertaken of the apparent climatic signal in the snowpack record. Temporal anomalies need to be evaluated relative to atmospheric circulation and synoptic climatic variations. The network of snow survey stations must also be improved/expanded to permit more accurate snowmelt modelling of critical tributary basins. No data, for example, is currently collected within the Wabasca catchment, a tributary known to be important to break-up conditions near the Peace-Athabasca Delta.

[3] ***Linking of Hydraulic Models***
The current one-dimension hydraulic model of the Peace-Athabasca Delta needs to be coupled with the new hydraulic flood-routing model of the Peace and Slave Rivers. The focus of the Peace-Athabasca Delta model should be expanded beyond water levels within the Peace-Athabasca Delta to include explicitly full-season modelling of discharge to the Slave River, including the dynamic freshet period. Obtaining reliable modelled discharge from the Peace-Athabasca Delta is the only way by which flow can be modelled accurately through to Great Slave Lake and by which pre-regulation and "naturalized" flows can be calculated for the Slave River. The one-dimensional flow model of the Peace-Athabasca Delta should also be integrated with ice-jam models currently being developed in the PADTS for the reach of the Peace River that controls spring flooding of the Peace-Athabasca Delta.

[4] ***Ice Break-up Modelling***
The importance of ice-jam floods on the Peace River (negative impacts to settlements and positive to riparian ecosystems) presents an excellent reason for developing and testing a river-ice break-up model. The Peace River hydraulic flood routing program, developed for the NRBS, offers the ideal building block for the development of such a break-up model. Testing and validation of the model will require more extensive monitoring of break-up conditions in the lower portions of the Peace River. This could be accomplished by extending downstream the current ice observation program conducted near the town of Peace River.

[5] ***Ice Jam Enhancement***
Although break-up modelling and forecasting is still in a state of early development, it is recommended that the current regulation scheme be modified to

increase the chances of creating a break-up jam near the Peace-Athabasca Delta. Relying solely on the reservoir to produce a major break-up near the Peace-Athabasca Delta would require an enormous release of water from the Williston reservoir. Notably, this could also lead to unpredictable ice-related backwater flooding at other upstream and downstream locations. Some success could be achieved, however, if minor adjustments are made to the regulation strategy in years where tributary inflow is forecast to be large. In some years, the only modification might be a delay in the retarding of spring flows. Current ice jam modelling by the PADTS should provide an idea of the size of combined flow needed to initiate flooding of the Peace-Athabasca Delta. Furthermore, PADTS water-balance modelling will provide guidance on how frequently such intervention might be required. A single agency is needed to co-ordinate these scientific activities.

[6] *Changes to Morphology and Riparian Habitat*

Evaluation of morphologic/vegetative changes to the Peace River involved comparison of two sets of aerial photography: just prior to regulation in the mid-1960's and a recent set obtained by the NRBS in 1993. Additional sets of photography covering other decades before and after regulation were also assembled but insufficient time precluded their analysis. It is recommended that this additional photography be analyzed to provide a better long-term record of morphological and vegetative change, one that permits validation of predicted rates of change likely to result from flow regulation.

Although morphologic studies of the Peace River included four representative reaches, the lack of aerial photography precluded an analysis of the lowest reaches, characterized by broad floodplains and numerous large islands. This zone represents a significant and productive riparian habitat consisting of a multitude of wetlands interspersed among old-growth boreal forest. Furthermore, it has been observed that the large number of split and side-channels located in this area (downstream of Peace Point) may contain backwater areas bedded with silt and clay sediment — the fine fractions known to be associated with industrial pollutants. It is therefore recommended that this reach be selected for long-term monitoring and that monumented cross-sections specifically include backwater areas that can be assessed for changes in bed sediment quality. Monumenting of sites should be conducted in collaboration with Parks Canada who have already established some permanent study plots to monitor vegetation succession within the floodplain.

[7] *Riparian Habitat Assessment*

Some of the most significant ecological impacts produced by altered flow and water level regimes are experienced along the flow margins. To evaluate the nature and spatial extent of habitat impacts within this zone, it is recommended that further quantification (following from experience gained from the test trials of multi-spectral imaging) be made of habitat availability, over the full range of flow conditions. This will provide the basis for establishing requisite seasonal sets of regulated flow conditions, specifically in terms of timing, duration and magnitude.

There is also a need to more fully understand how vegetation changes on the river mainstem and particularly in the two deltas affect wildlife habitat and related species populations and diversity. It is recommended that wildlife habitat changes be assessed through such methods as Habitat Evaluation Procedures (HEP) and associated wildlife surveys. Because it is not practical to assess the habitat suitability for all affected wildlife species, representative species such as muskrat, moose and buffalo should be used. A recommendation should be made to the upcoming "Bison Research and Containment Program" for the Peace-Athabasca Delta to include a science component that focuses on developing linked hydrologic, vegetation-succession and wildlife-habitat models.

[8] *Peace-Athabasca Delta Lake Stabilization Effects*

Further investigations of the aquatic impact of stabilized water levels should be conducted for some of the large delta lakes, especially regarding changes in the nature and availability of waterfowl habitat. A special focus should be placed on fall and winter water levels that do not experience the natural seasonal drawdown as a result of both forms of regulation (weirs and upstream reservoir).

[9] *Slave River Delta*

To obtain a better understanding of the temporal and spatial effects of flow regulation in the Slave River Delta, further studies related to the changing dynamics of the Delta are recommended possibly similar to those of the PADTS. Integral elements of this ecological monitoring program should include assessments of: a) flood frequency, including open-water and ice-jam flooding, and the role of Great Slave Lake fluctuations; b) water-balance studies to determine the relative importance of flooding recharge; c) sediment regime changes including under-ice investigations; and d) vegetation succession, aided by remote-sensing assessments and the establishment of permanent transects through representative cover.

2 Secondary Recommendations

The following recommendations stem from the results of studies conducted in response to NRBS Question #10 but are considered secondary to completing a first-order assessment of flow-regulation impacts. Aspects of some, however, relate directly to the primary recommendations.

[i] A water temperature model should be applied to the Peace River so that the relative effects of variations in climatic conditions and regulated flow can be discerned. Ideally, the model should be integrated with the new hydraulic flood-routing model developed for the NRBS.

[ii] A detailed ice-hydraulic study should be conducted of flow conditions leading to reductions in open-water zones associated with rapids such as the Vermilion Chutes. Such an evaluation should include other turbulent reaches that historically remained open under lower pre-regulation flow conditions and be coupled with hydro-ecological studies of the importance of open-water zones to aquatic life, especially fisheries.

[iii] Studies should be conducted of the long-term effect of freeze-up staging on regional groundwater levels and of its more local effect on riparian zone habitats, such as in the recharging of backwater snyes or in the succession of seral vegetation.

[iv] Studies should be conducted on the role of frazil deposition in modifying/eliminating winter aquatic habitat.

[v] The ultimate adjustment time of a large river is extremely long but no system has been studied systematically for more than a few decades. The Peace River data set provides an excellent opportunity to evaluate fully the long-term effects of flow regulation. As part of a long-term study, it is recommended that monumented cross-sections for monitoring changes in channel morphology and riparian vegetation be established within the representative reaches used in the current NRBS studies.

[vi] More detailed studies of sedimentation processes in the outer delta are required. These are essential to separate the effects of flow regulation from natural processes, such as isostatic rebound and the role of wave action from Great Slave Lake. Such work first requires completion of the hydraulic flood-routing model of the Peace-Slave Rivers, preferably with a delta-channel network component similar to that developed for the Peace-Athabasca and Mackenzie deltas.

[vii] An attempt is being made by the PADTS to improve the understanding of how changes in the hydrologic regime of the perched basin environments control changes in the vegetation regime. It is recommended that further efforts be expended on such model development and that the model be applied and validated for conditions on the Slave River Delta.

PEACE-ATHABASCA DELTA ACTION PLAN

The following was produced in response to a request from the NRBS for an experimental action plan for the Peace-Athabasca Delta. It presupposes, based on groundwork conducted by the PADTS, that flooding of the PAD is the key to restoring the ecosystem health of the perched-basin environments. Many of the proposed actions also stem from the results of PADTS discussions about potential methods and, in some cases, actions that have already been field tested in the PAD. Prior to describing these, it is useful to review the PAD hydrology so that the recommendations can be placed in context.

1 Background Review

As earlier described in Sections 2.6.2; 3.2; and 3.8.2, the PAD is composed of two different hydrologic regimes. The first includes the large shallow lakes and the major deep channels which link them to Lake Athabasca and the Peace, Athabasca and Slave rivers. It is this flow system that has been affected by the construction of rockfill weirs. In general, the weirs have restored the summer mean-maximum water levels to near pre-regulation values but they have also reduced the seasonal amplitude in water levels. Although the decrease in amplitude should create an ecological impact on lake margins, research in this area has been meagre (see Section 4.8.1: Recommendation [8]).

The second major regime is that of the "perched basins" which are to varying degrees disconnected from the main flow system. It is these basins that have experienced the most extensive drying and are not affected directly by water levels produced by the rockfill weirs. Notably, however, this perched-basin regime can be further subdivided according to source and frequency of flooding. For example, since the time of the last major flood of 1974, the Athabasca River has inundated some of the perched basins in the southern portions of the PAD. Similarly, some of the low-lying southern basins have been flooded by high lake levels. Perched basins that have experienced the most extensive drying exist in the northern portions of the PAD and are dependent on macro-scale flooding of the Peace River for filling.

2 Proposed Experimental Actions

Given the above differences in hydrologic regime, it is useful to consider experimental actions that differ by scale and location.

2.1 *Small-Scale Basin Specific*

The basic experimental approach here is to capture water in single basins during high flow events with the use of simple control structures. The structure is constructed within the levee of the basins and operated to permit the entry of water during periods of high stage and prohibit its exit when flow in the main channels and lakes decline. Since this method relies on the main flow network, it can only be conducted in basins with suitable levee/elevation characteristics. The results of such an approach (e.g., on vegetation succession or small mammal populations) are limited to the experimental basin. Results could provide, however, invaluable data for developing the requisite models for predicting vegetative response to large-scale wetting of the PAD.

An alternative to the expensive construction of variable-height weirs is the use of pumps to recharge specific basins. Pumps offer the additional opportunity of flooding basins perched above the main flow network.

2.2 *Meso-Scale Basins Adjacent to Large Lakes and Channels*

Meso-scale flooding of the PAD requires the redirection of water flowing through the Delta onto the adjacent landscape. The best method to achieve this is to present an obstruction to the flow at a critical hydraulic node in the delta channel-lake system, thereby creating backwater which would inundate the surrounding perched-basin environment. The natural levels around such basins would retain the water after the backwater recedes.

The best hydraulic node for the construction of a flow obstruction within the PAD is near the Quatre Fourches Dog Camp. Notably, this was the site of one of the early rockfill weirs; a structure that was successful in significantly raising lake water levels during a large spring-runoff event in 1971, but also one that proved to be ecologically unsuitable because it impaired the migration of fish. As part of the PADTS (see section 3.8.2), an artificial ice dam was constructed overtop of the old weir. The objective was to use the temporary ice structure the passage of spring snowmelt runoff through the Delta, thereby creating backwater that would flood basins adjacent to the large delta lakes. Since construction of the early weirs, a significant percentage of the Athabasca flow has been diverted naturally into the Delta lakes through development of the Embarras River breakthrough to Mamawi Creek. This has increased the possibility of obstructing spring flow in the delta lakes. Success of using an artificial ice dam at this site is dependent on the vagaries of winter climate (specifically the magnitude, rate and timing of spring snowmelt) and the winter flow strategies of B.C. Hydro. For example, it appears that sudden winter decreases in upstream flow over the winter of 1994/95 hampered the ability of the artificial ice dam to elevate water levels to flood stage. If such an attempt is undertaken again, agreements should be made regarding winter flow operations.

An alternative to using an artificial ice dam would be to employ a gated structure. This, like the ice dam, would minimize problems associated with fish migration among the lakes and channels but problems may exist about the construction of such a permanent feature within a National Park.
It should be stressed again, however, that the above medium-scale approaches still only have the possibility of affecting perched basins close to the backwater effect that could be established near the Dog Camp hydraulic node. Such flooding will not affect the northern perched basins close to the Peace River — ones that are believed to have experienced the most drying since 1974.

2.3 *Macro-Scale Flooding from the Peace River*

Introducing macro-scale flooding of the PAD is possible only through disruption of flow on the large Peace or Slave rivers. Again, a permanent gated structure could be used but construction/ engineering costs would be enormous. The possibility of constructing an artificial ice dam has also been considered by the PADTS. Recognizing the need for an environmental impact assessment of related effects, early community information meeting were also held by the PADTS.

Similar to the meso-scale approach, the success of an artificial ice dam depends very much on the vagaries of climate, especially as they affect the magnitude of spring runoff produced by tributaries downstream of the Bennett dam, such as the Smoky and Wabasca rivers. Given this, the most practical recommendation is "[5] Ice Jam Enhancement" outlined in Section 4.8.1. The success of an artificial ice jam could be enhanced further if there was a concurrent attempt near the PAD to increase the resistance of the Peace River ice cover to breakup. This could include increasing thickness using spray-ice techniques and/or the retardation of melt through the application of insulating materials.

EFFECTS OF CONTAMINANTS ON AQUATIC ORGANISMS IN THE PEACE, ATHABASCA AND SLAVE RIVER BASINS

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CONCLUSIONS AND RECOMMENDATIONS

In summary, there was little evidence from the basin-wide survey of physiological parameters in wild fish or from either of the more new approaches to specific monitoring of regional effects on biota in the basins. The Sediment toxicity studies supported this statement. There was some limited evidence that pulp mills may be causing depressed sexual hormones in fish, but in light of the physiological responses observed in the lower Athabasca River area and in tributaries in this region, more attention needs to be devoted to understanding the long term effects of the tar sands and related petroleum pollution.

To further improve our understanding of the responses there are several scientific studies that could be conducted both in the field and laboratory:

- The long-term response of fish in the lower Athabasca River to contaminants from the petroleum seeps, tar sands and other hydrocarbon related pollution needs to be investigated. In particular, the connection, if any, between the distribution of immature burbot in the downstream areas needs to be addressed.
- More information needs to be obtained concerning the ecology of burbot to determine if the anomalous distributions observed in this study were caused by contaminants or are the result of some previously unknown aspect of burbot lifestyle
- The apparent anomalous high concentrations of free retinols and depressed tocopherol in the lower Peace River needs to be further investigated. If the observation is replicated, it needs to be explained.
- Not enough information is available on the growth rates, reproductive strategies, or life history of these species to help plan monitoring programs based on forage fish to monitor impacts of industrial discharges in large rivers. Baseline data on life history characteristics of these species needs to be collected. Greater knowledge of the general biology would also improve the capture efficiency of small species. Due to higher levels of abundance associated with many forage species, the collection of adequate sample sizes would become very cost-effective.
- The NRBS studies demonstrated substantial variability in whole organism responses among reference populations of the small fish species studied, spoonhead sculpin and lake chub. More effort needs to be directed towards

establishing the full range of variability associated with reference fish; both within a monitoring system and among a variety of similar aquatic systems. Interpretation of results of a small fish-based monitoring program will depend on a good understanding on the extent and causes of natural variability.

- More information is needed to further evaluate the mobility of smaller fish species. Although small species in this study were not as mobile as many of the large fish species, it is still necessary to increase our understanding of the degree and pattern of mobility, size of home range and habitat requirements associated with specific small species of interest.
- To further evaluate the suitability of small fish species, it would be of interest to compare responses between small and large fish species of the same monitoring system. If possible, it would be advantageous to monitor a system possessing habitat or man-made barriers that would restrict the movement of the larger fish species. The comparison would examine the consistency of responses between species and investigate the relative sensitivity of each species.
- Laboratory evaluations of the potential of Athabasca effluents to disrupt steroids and induce MFO activity need to be repeated. Preliminary work was during the current project, but the steroid exposure protocol was still under development and has just been recently finalized. The exposures should be repeated using the final protocol. This information would be valuable to evaluate whether the effluents show the potential to induce the physiological changes.
- work on developing the SPMD concept further should be encouraged so that a standardized protocol for their use in a monitoring program can be achieved

NUTRIENT ENRICHMENT IN THE PEACE, ATHABASCA AND SLAVE RIVERS: ASSESSMENT OF PRESENT CONDITIONS AND FUTURE TRENDS

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SCIENTIFIC AND MANAGEMENT RECOMMENDATIONS

1 MONITORING, DATA HANDLING AND REPORTING

- Regular monitoring and reporting of nutrients from sewage treatment plants should be license requirements, particularly the larger sewage treatment plants such as Grande Prairie and Fort McMurray. These larger sewage treatment plants have nutrient loads similar to that of pulp mills in the basins. Yet under the 1993 *Alberta Environmental Protection and Enhancement Act*, operators of continuously-discharging sewage treatment plants need only report exceedances (within 24 h) to Alberta Environmental Protection.
- Compliance with sampling and analytical procedures should be mandatory for all licensed dischargers. Demonstration of QA/QC for sampling and analytical procedures and adequate detection limits should be a license requirement and conducted at regular intervals. While all licenses stipulate that sample analysis must be done following the latest edition of *Standard Methods for the Examination of Water and Waste Water* (APHA 1995), some samples have been analyzed incorrectly. In addition, some laboratories are not analyzing to current detection limits (i.e., TP detection limits are reported as 0.05 mg/L).

Standard reporting requirements for water quality parameters should be established. For example, the units of reporting are not consistent (e.g., reporting of nitrite as nitrogen rather than nitrite) or misleading (e.g., nitrite reported as nitrogen but "as N" left off data sheet). Phosphate is reported when the analysis (digestion) would appear to be TP. TDP concentrations are greater than TP concentrations. Provision is needed for ensuring trained personnel to collate laboratory results and prepare data reports. Reporting proper water quality data should be a license requirement

- Provisions are needed to ensure training of certified operators to measure (and record) flows and discharge volumes and for enforcement of reporting requirements. At present, sewage treatment plant operators often supply missing, unreliable and/or ambiguous discharge data that then become incorporated in effluent databases (e.g., the Towns of Peace River, Barrhead and Wabasca have not reported reliable flow data). Reporting accurate discharge data should be a license requirement
- A properly-maintained central database should be established for: (a) effluent monitoring data (discharge and water quality parameters for all industries and municipalities with licensed monitoring requirements), and (b) environmental data collected by industries. These databases should be linked with the provincial surface-water quality database.
- The bioavailability of nutrients in industrial and municipal effluents should be characterized. At present, pulp mill licensing requirements include monitoring of NH_4, NO_3, NO_2, total Kjeldahl N, TDP and TP in weekly grab samples; there is not a monitoring requirement for nutrients by municipal dischargers. Analysis of SRP concentrations and/or algal bioassays for N and P availability in effluents would allow better assessment of instream impacts.
- Artificial streams and nutrient diffusing substrata developed for NRBS should be considered as a promising tool for environmental effects monitoring by the pulp and paper industry. Artificial streams allow investigation of cause and effect scenarios and development of ecological indicators for riverine biota under experimentally controlled dose-response regimes. They also facilitate the development, parameterization and testing of water quality models for predicting ecosystem-level responses to nutrient and contaminant addition. Nutrient diffusing substrata permit *in situ* assessment of the effect of effluents on river nutrient status. These approaches would assist in defining the effects of pulp mill effluent on benthic biota.
- Limited data are collected on nutrient concentrations during fall, which is the time of maximum biological productivity. Environmental monitoring by industries should be undertaken in fall and, in the case of the Athabasca River, should be coordinated such that a comprehensive longitudinal survey of the river is obtained each fall.

2 MODELLING

- The scope of nutrient and biotic data collected to date is too limited for simulation modelling. The season of concern is fall and nutrient concentrations are not usually monitored at this time of year. The limitations in the nutrient, periphyton and benthic invertebrate data could likely be addressed if industries coordinated their environmental monitoring. However, there is still no information on rates of nutrient uptake and cycling for the Northern Rivers.
- Given the limited database and the problems identified in attempting to model other less complex parameters in the Northern Rivers (Chambers and Mill 1996; McCauley 1996), simulation modelling of nutrient dynamics and associated biological responses is not recommended at this time. At present, predictions of changes in benthic communities can better be made from studies conducted in artificial streams or through empirical modelling.

3 RESEARCH

- *In situ* experiments have identified nitrogen limitation of periphyton growth in the 230 km reach of the Athabasca River from downstream of Alberta Newsprint Co. to the Lesser Slave River and in the Smoky River downstream of the Wapiti River confluence. Controlled experiments are required to evaluate the effects of nitrogen addition on biota in these river reaches.

- Data are almost entirely lacking on the contribution of non-point sources to nutrient loads in the Northern Rivers. While contributions can be estimated from the limited data for Alberta and other parts of the world, the large changes in land use patterns that have taken place and continue to occur (e.g., agricultural land clearing, timber harvesting, oil and gas activities) warrant closer examination of the impacts of changing land use on nutrient loading.

4 WATER QUALITY AND EFFLUENT GUIDELINES

- Effluent permit limits should be assessed and should be based on environmental effects rather than on technology design standards. The 1 mg/L TP level for most municipal permits is a technology-based limit since tertiary sewage treatment plants can usually achieve P removal to less than 1 mg/L. Similarly, the 3 kg BOD_5/air-dried tonne for most pulp mill permits is a technology-based limit. All industries and municipalities should be licensed on the basis of environmental effects. In the case of no perceptible environmental effects, industries and municipalities should be regulated to a designated technology standard. It should be noted, however, that while phosphorus (and, in some locations, nitrogen) are important factors controlling periphyton abundance in the Athabasca and Wapiti-Smoky rivers, we still lack quantitative relationships between phosphorus concentrations and periphyton biomass for any given site. Thus, it is not possible to set effluent permit limits for phosphorus so as to control periphyton abundance at a specific level.
- *Alberta Water Surface Quality Objectives* (Alberta Environment 1977) are frequently exceeded for TP and occasionally exceeded for TN in the Athabasca, Wapiti, Smoky and Peace rivers. With the exception of the Wapiti River, many of these exceedances are attributable to high particulate loads associated with high flows. In the Wapiti River, many of the exceedances appear attributable to effluent discharge from Weyerhaeuser Canada Ltd. and, in the case of TP, to the Grande Prairie sewage treatment plant. Many regulatory agencies are moving away from numeric guidelines for nutrients but, instead, are evaluating or implementing qualitative or numeric guidelines based on aquatic plant abundance in the receiving water. At present, increased periphyton biomass is observed downstream of all mill and large sewage treatment plant (Fort McMurray and Grande Prairie) discharges. There is no evidence that this increased periphyton biomass has impaired spawning habitats, contributed to DO declines during winter or caused consistent long-term changes in benthic invertebrate taxonomic composition. However, if these reaches are deemed to be of recreational or aesthetic value, then a site-specific guideline for plant biomass may be desired. The British Columbia Ministry of Environment has recommended a criterion based on periphyton biomass of < 50 mg/m^2 chlorophyll *a* to protect uses related to recreation and aesthetics in streams and < 100 mg/m^2 chlorophyll *a* to protect against undesirable changes in aquatic life. However, before adopting a guideline based on a quantitative nutrient response (i.e., a specific level of aquatic plant abundance), a quantitative relationship between periphyton biomass and its environmental controls must be established.

Dissolved Oxygen Conditions and Fish Requirements in the Athabasca, Peace and Slave Rivers: Assessment of Present Conditions and Future Trends

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SCIENTIFIC AND MANAGEMENT RECOMMENDATIONS

1 MONITORING, DATA HANDLING AND REPORTING

- Regular monitoring and reporting of BOD_5 from sewage treatment plants should be license requirements. Some of these larger sewage treatment plants, such as Fort McMurray, have BOD_5 loads approaching that of pulp mills in the basins. Yet under the 1993 *Alberta Environmental Protection and Enhancement Act*, operators of continuously-discharging sewage treatments plants need only report exceedances (within 24 h) to Alberta Environmental Protection.
- Compliance with sampling and analytical procedures should be mandatory for all licensed dischargers. Demonstration of QA/QC for sampling and analytical procedures should be a license requirement and conducted at regular intervals. While all licenses stipulate that sample analysis must be conducted following the latest edition of *Standard Methods for the Examination of Water and Waste Water* (APHA 1995), some samples have been analyzed incorrectly (e.g., some BOD_5 samples) and other methodologies (e.g., for BOD_u analysis) vary between laboratories.
- Provisions are needed to ensure training of certified operators to measure (and record) flows and discharge volumes and for enforcement of reporting requirements. At present, sewage treatment plant operators often supply missing, unreliable and/or ambiguous discharge data that then become incorporated in effluent databases (e.g., the Towns of Peace River, Barrhead and Wabasca have not reported reliable flow data). Reporting proper discharge data should be a license requirement.
- A properly-maintained central database should be established for: (a) effluent monitoring data (discharge and water quality parameters for all industries and municipalities with licensed monitoring requirements), and (b) environmental data collected by industries. These databases should be linked with the provincial surface-water quality database.
- Concern has been raised about DO concentrations in mixing zones. DO concentrations in mixing zones have never been explicitly studied although the Alberta Environmental Protection winter water quality surveys usually sample from both banks in reaches of effluent mixing. At low flow conditions, effluents to the Athabasca and Wapiti River are usually fully mixed by approximately 10 km downstream of the outfall. Since there have been no reports of impairment to fish in the mixing zones, further field work on mixing zones with respect of DO conditions is not recommended at this time.
- DO monitoring and modelling must be more closely tied to the distribution of fish and fish habitat and fish DO requirements.

2 DO MODELLING

2.1 <u>Modelling Deficiencies</u>

- Modelling goals need to be clearly defined. There appear to be two goals with respect to DO modelling in the Northern River basins: (1) short-term compliance assessments (i.e., predicting DO levels during the upcoming winter), and (2) long-term basin management (i.e., establishing license requirements with respect to changing industrial operations). Dynamic models (i.e., allowing for temporal and downstream variability in DO) may be better suited for addressing the short-term goal because early DO winter data could be used in predicting DO concentrations during late winter. Modelling for long-term basin management focuses on average or low-flow conditions and, hence, could be accomplished using a deterministic approach. For both approaches, a probabilistic model should be employed so as to allow assessment of the effect of variances in model input parameters on the confidence of the model predictions.

- Implementation of a dynamic model such as WASP (Water Quality Analysis Simulation Program) will address questions regarding temporal variability in the decrease in DO in the Athabasca River with distance (i.e., the changing relationship between upstream and downstream DO concentrations as the winter progresses). However, basic issues such as validating the ice-cover Leopold-Maddock coefficients used in calculating reach velocities (see Section 8.2.2) need to be resolved before more complex modelling is attempted. If WASP or any other DO simulation model is implemented, the model rates established and validated by Chambers *et al.* (1996) should be employed rather than calibration values.
- Concerns about DO concentrations in mixing zones could be addressed by moving to a model capable of 2-dimensional simulation (i.e., changes across the channel as well as longitudinally down the channel). However, there are currently only limited data on DO concentrations within mixing zones.
- Modelling of temporal DO patterns in the Athabasca River and the cumulative impacts on populations of mountain whitefish, bull trout and burbot should be attempted.
- Modelling of effluent discharge timing and seasonal DO sagging in the Athabasca River should be conducted whenever industrial operations change or unusually low winter flows are forecast, and a schedule developed to minimize increases in chemical and biological oxygen demand during late winter.
- Modelling needs to be undertaken by one group and independently reviewed by another group with modelling expertise to validate the assumptions and subjectivity that comes into play when modelling complex systems with parameter-rich (sometimes data-poor) models.

2.2 <u>Data Deficiencies</u>

- Additional measures of STP BOD_5 decay rates and BOD_u:BOD_5 ratios are required to verify the values currently used in the modelling. Currently this information is limited to data from Grande Prairie STP on one date.
- Cross-channel variability in SOD should be examined and the relationship between sedimentation and SOD should be assessed, particularly below mill outfalls and tributary inflows.
- Ice-cover Leopold-Maddock coefficients, which are used to establish reach velocities and to convert areal SOD to volumetric SOD rates, should be re-evaluated for discharges similar to the long-term average discharge at Hinton. Comparisons of time-of-travel by Thompson and Fitch (1989) and Andres *et al.* (1989) showed discrepancies particularly in the reach downstream of Hinton (Chambers *et al.* 1996). An additional under-ice time of travel study should be conducted to verify the results of Andres *et al.* (1989) and provide further data for re-assessing the ice-cover Leopold Maddock coefficients.
- Temperature correction coefficients for correcting laboratory measurements of BOD decay made at 20°C to the river temperature of 0°C in winter must be validated.
- Photosynthetic rates below ice and snow cover of differing thicknesses should be measured during years when this is deemed significant and the influence of this parameter on DO modelling should be evaluated.
- With respect to two-dimensional modelling (i.e., changes in DO over time and with distance downstream), little or no temporal data exist on parameters such as SOD, the size of open-water leads, photosynthetic rates (both temporally and diel), and BOD_5 sedimentation.
- The use of "balanced", "estimated" or "measured" river and tributary flows should be standardized. What discharge should be used for tributaries that are not gauged? How is discharge calculated on the mainstem between gauged stations?
- Data are not available on groundwater inputs, diffuse loading, the size of open-water leads, nitrification (i.e., nitrogenous oxygen demand), and the applicability of SOD rates measured near shore to the entire channel.
- The concentration of DO upstream of Hinton is an important factor determining

downstream concentrations in the Athabasca River. Between 1990 and 1993, DO concentrations in the Athabasca River upstream of Hinton ranged from 11.5 to 12.5 mg/L approximately 3-4 weeks after freeze-up. Concern about forecasting DO concentrations upstream of Hinton could be resolved by recognizing that modelling for: (1) long-term basin management must focus on average or worst-case scenarios (thereby eliminating the need to predict headwater DO concentrations for any particular year), and (2) short-term compliance assessments could be initiated in early winter using headwater DO concentrations measured in early winter (December or January) and average winter variance of headwater DO, or could incorporate a model relating headwater DO concentration to ice development.

3 RESEARCH

- *In situ* measurements of DO levels in the substratum during winter and their relationship to water-column DO concentrations are necessary to assess the DO status of fish and benthic invertebrate habitat and to predict substratum DO concentrations from the more routine measurements of water-column values.
- Studies of the combined effects of effluent and low DO levels should be expanded to include other fish species and important benthic invertebrates and to assess how impacts may be modified by differences in developmental stage or in acclimation time to low DO levels. In fish, contaminant-DO interactions should be examined, specifically the relationship between various hormonal and enzyme induction indicators of stress and seasonally low DO.
- Sedimentation rates should be measured below all mills to determine if settling rates are the same for different effluent types. Also, a determination of whether the sedimentation rates measured for all material (organic and inorganic) applies to only oxygen-consuming material is needed.
- The cause of elevated SOD rates below pulp mill discharges needs to be established. These higher SOD rates may be due to organic carbon loading or enhanced periphyton growth due to nutrient loading from pulp mills.
- *In situ* bioassays with eggs of mountain whitefish, bull trout and burbot should be conducted at key sites in the Athabasca River in conjunction with measurements of DO, BOD_5, contaminant occurrence and effects, and ice cover effects. In addition, laboratory studies are required to determine a dose-dependent relationship between individual embryonic development stages and DO concentration for each of the major fish species. This work should include incubation trials at 0 to 1°C to more closely simulate natural winter temperature regimes.

4 WATER QUALITY AND EFFLUENT GUIDELINES

- Effluent permit limits should be assessed and based on environmental effects rather than technology design standards. The 3 kg BOD_5/air-dried-tonne limit for most pulp mills and the 25 mg/L BOD_5 limit for most municipal discharge permits is a technology-based limit.
- The Towns of Peace River, Fort Smith and Fort Chipewyan have continuous sewage discharges that often exceed the permit limit of 25 mg/L BOD_5. In the case of Peace River and Fort Smith, these high discharges may not have biological consequences due to the large volumes of water in the Peace and Slave rivers. In addition, 26 periodic municipal dischargers (i.e., discharge from wastewater stabilization lagoons) exceeded the 25 mg/L BOD_5 limit (based on 1990-1993 data). An assessment of the environmental impacts of these exceedances is recommended.
- Regulatory standards for DO need to be reviewed to ensure that they are consistent with the minimal requirements known to be important for the native fishes of the Northern River basins. Laboratory studies on effects of lowered DO levels (3 mg/L) at low temperature (2-3 °C) showed that mountain whitefish eggs took longer to hatch and bull trout alevins were less well developed than at higher DO concentrations. DO concentrations of 6 mg/L may also extend the time required to hatch by some burbot. The commonly-occurring mayfly in the Northern Rivers (*Baetis tricaudatus*) was also found to have decreased survival and reduced feeding rates at a DO concentration of 5 mg/L. Given the fact that mayflies and the early life stages of fish live at or in the surface layers of the riverbed and that DO concentrations can

differ by 3 mg/L DO between the water column and the sediment-water interface (Chapman 1986), DO concentrations in the Athabasca River could already be at levels that could have chronic effects on these animals at localized sites. Based on the fact that many fall-spawning fish species in the Northern River basins are in the salmonid family, the more conservative *Canadian Water Quality Guideline* (CCREM 1987) of 6.5 mg/L DO for salmonids is recommended as a policy-based guideline to be used in setting effluent license conditions for periods of ice-cover.

A REVIEW OF POPULATION HEALTH STATUS IN NORTHERN ALBERTA

By: Dr. S. Gabos

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RECOMMENDATIONS

❒ ***Develop better health information related to environmental contaminants.***

People living in the Northern River Basins are concerned about the subtle impact of environmental changes and contaminants on their health.

At present, our knowledge about the potential human health risks and the environmental contaminants is extremely limited. Developing better heath information related to contaminants should be a major direction for future research and monitoring. Particularly, the long term effects of low levels of exposure to contaminants should be investigated. Since one time health studies are not likely to yield results (in spite of the associated costs), this should strategically be accomplished through the ongoing monitoring and surveillance of both environmental and human health indicators including exposure, biological markers of exposure and effect, and health outcomes.

❒ ***Undertake periodic and systematic health risk assessments of contaminants in fish (and other traditional foods).***

The presence of contaminants in the food chain is a concern for many local people who rely extensively on traditional foods for subsistence.

A thorough health review of the data on contaminants gathered by the Northern River Basins Study should be a priority issue. Existing fish consumption advisories should be re-evaluated based on the new information. New health based standards should be developed as opposed to the current mechanistic approach. The approach should include periodic and systematic health risk assessments to detect trends and emerging issues. The provincial, territorial, federal and first nations governments should work together toward developing a common integrated process to share resources and provide accurate and timely information for the communities.

❒ ***Human health assessment be included in the future development projects.***

Local people are concerned about the health impacts of major development projects.
In making sustainable development a fundamental value in our society, the governments and corporations should ensure that health is being given appropriate consideration in all major development projects.

USE OF AQUATIC RESOURCES IN THE NORTHERN RIVER BASINS: SYNTHESIS REPORT

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Recommendations

The socio-economic component of the NRBS represents a departure from the conventional, technical approach to water management studies. In mapping out public perceptions on water issues, the study has yielded information that allows water and environmental managers to better differentiate between technical and perceived management issues. Perceived problems are real problems, regardless of whether or not there is a technical cause, and still need to be dealt with by resource managers. However, the management approaches used to address perceived problems are substantially different from the technical solutions often considered.

The socio-economic studies also provide a rare, quantified summary of public views and understanding of current issues that can only be attained through surveys. This study shows that there are often very large differences between public and stakeholder values and opinions. It demonstrates that what industry wants or what local government wants, is not always what the general public wants.

This study is also a landmark in that no comparable research on water use and management issues has been attempted to date in the NRBS area. The social, economic, environmental, legal, jurisdictional and institutional views of northerners from both sides of the NWT-Alberta border will be of considerable value to the legislators and regulators of the three jurisdictions involved. Some basin residents who responded to the survey also mentioned that this type of survey provides a valuable means of monitoring river health and public perceptions of river management, and recommended that it be repeated on a regular basis.

In response to these suggestions it is recommended that assessments of public perceptions of river health should be undertaken at regular intervals as a way of monitoring change. These assessments should follow the survey approach used by the NRBS in order to allow direct comparison of results. This approach, which was based on a combination of telephone and mail surveys from a stratified random sample of basin residents, proved to be quite satisfactory and cost effective. The surveys and related analysis conducted for the Northern River Basins Study were undertaken at a modest expenditure (approximately $150,000).

It is also recommended that the same regional boundaries (based on telephone prefix regions or nearest equivalent) be used in future surveys. The NRBS surveys showed few regional differences in public opinion at the present time. However, some regional differences in perceptions and issues may evolve in the future, and these should be monitored so that water management can be responsive to regional needs.

Finally, it is recommended that future river or resource management studies be undertaken using an ecosystem approach. This approach involves:

- ❐ defining the area to be studied in terms of river basin or other ecoregion boundaries;
- ❐ using an integrated approach to examine the interactions among land, water and other resources;
- ❐ supplementing technical, biophysical information with socio-economic information that include perceptions and values; and,
- ❐ considering transboundary effects.

Within this process, surveys of the general public and stakeholder groups can be used to provide decision-makers with quantitative, representative data on public perceptions and values. In addition, surveys offer a structured opportunity for public involvement. They can be used to solicit input from a broad range of interests, and present a less intimidating and more user-friendly method for personal involvement in resource management decisions.

Assessment of Drinking Water Quality in the Northern River Basins Study Area: Synthesis Report

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SCIENTIFIC AND MANAGEMENT RECOMMENDATIONS

Public Health

As has been stated, drinking water quality and public health are closely related. The assessment of public health should continue with special attention given to the correlation of public health with drinking water quality and drinking water supplies in the study area. This would require additional monitoring of health records in conjunction with water quality data if possible. Also, in terms of public health, the Drinking Water Component perceives that there is a need for some public health educational programs in the NRBS area, particularly in communities where there is a large objection to chlorination. This would be beneficial to those that turn to other supplies of drinking water as a result of their distaste for chlorine, to know why chlorine is used, and the risks and benefits associated with chlorinated versus unchlorinated water. Educational programs would also be beneficial for individuals who are involved in living off the land expeditions or other wilderness activities, so that they are provided with information with which they can make the best decisions regarding drinking water, sanitation and hygiene during activities such as these. Since all of these have an effect on health, good decisions in these regards would have a positive impact on public health protection.

Aesthetics

Since the aesthetic quality of water is generally the basis of evaluation by which consumers judge the safety of their drinking water, it is important that the aesthetic quality of the water in the northern river basins continues to be monitored and assessed. In this manner, an historical database with baseline information would be compiled. Furthermore, additional scientific studies are required to characterize influences that affect the aesthetic quality of water.

Drinking Water Supplies

The main recommendation in terms of the conventional drinking water facilities in the study area is that the existing facilities in the study area are optimized so that the best quality drinking water is supplied to consumers. This involves action at several levels. First, the existing monitoring practices should be improved so that they are more representative of the plants performance. Samples of raw, treated and distributed water should be analyzed in order to assess the overall quality of treatment and distribution. Second, based on this monitoring, proper remedial actions should be practised for parameters that do not meet recommended guidelines. Third, the operation and maintenance of the existing facilities is critically important for the assurance of good quality drinking water. Therefore, continuing educational programs and monitoring are necessary for plant operators. A fourth recommendation regarding conventional drinking water supplies in the study area has to do with some of the distribution systems that are currently in place. Although piped distribution systems are ideal, they are not financially or technically feasible for many of the remote areas typical in the NRBS area. Where trucked delivery of water is supplied, the water should be delivered to water cisterns rather than water barrels which are still in use by some NRBS residents. Furthermore, the state of the distribution system, piped and trucked, should be monitored.

An effective water supply system will involve the community in all aspects of decision making. Although this is especially important during the design stages, it is also important for the maintenance of an existing water supply system. Figure 24 (provided in the synthesis report) illustrates a simple approach that can be used in communities in the NRBS area in the maintenance of a successful drinking water system.

According to this figure, there are three main components involved in the maintenance of a community water supply system. Community involvement is of paramount importance to the success of any project in the community. If an outside *expert* is to be involved in the project, then that person should spend time in the community getting to know the residents. During this time in the community, public forums can be held where questions, concerns and ideas can be discussed. The forums would also be a good time to educate residents regarding drinking water quality and general public health. Educational programs such as these comprise the second important component in this model. The third main component in the maintenance of an effective water supply program is the proper operation and maintenance of the system implemented. This is done through appropriate selection of community members to operate the designed system and through continued community involvement in future decisions. If a mode such as this is followed in the design of a water supply system in the study area, a safe and sustainable supply of potable water is possible.

Further scientific studies on non-conventional drinking water supplies in the study area and elsewhere are necessary. More drinking water quality data is needed, as well as the extent of consumption of non-conventional supplies. As part of the scientific investigation into non-conventional drinking water, an epidemiological study could be carried out which would look at waterborne disease rates in selected areas and potential links with non-conventional drinking water consumption and/or quality. If a significant relationship was found, the results could then be used for educational programs and determining possible solutions.

Remote access to good quality drinking water is a challenge. When possible, the best source of drinking water for people living in remote areas away from conventional facilities is from a protected groundwater well. If groundwater is unavailable, then other supplies should be tapped and treated appropriately. If the safety of a given water supply is unknown or questionable, then the water should be boiled.

Finally, it is vitally important that all present and future drinking water sources are protected from physical, chemical and bacterial contaminants. In doing so, additional precautions are taken in the maintenance of safe drinking water supplies in the Northern River Basins.

ECOSYSTEM HEALTH AND INTEGRATED MONITORING IN THE NORTHERN RIVER BASINS

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Recommendations

1. ***We recommend a basins' Integrated Ecosystem Monitoring Committee (IEMC) be established to coordinate all ecosystem monitoring in the northern river basins.***

Governments, industries, some municipalities and to a lesser extent other organizations conduct various types of monitoring. This committee should play a key role in overseeing all aspects of monitoring within these basins (e.g., scientific implementation and assessment of societal goals/ objectives, evaluate protocols for design, data collection, analyses, quality assurance and data management).

2. *We recommend that the IEMC adopt the ecosystem approach to environmental monitoring and the Integrated Ecosystem Monitoring framework described in this report.*

This synthesis report has provided in some detail the basis for the design and implementation of a holistic and integrated ecosystem monitoring program and should be considered at the starting point for future monitoring in the basins.

3. *We recommend a panel of scientific experts (including representatives of Traditional Knowledge) be established to advise the IEMC.*

A scientifically rigorous IEM program requires expert advice on its design, implementation, data interpretation, and scientific recommendations. Similar to the Science Advisory Committee of the NRBS, this committee would serve as an independent and objective reviewer of the IEM program.

4. *We recommend current and future monitoring activities within the basins be integrated following the framework developed in this report. Particular attention must be given to standardization of monitoring activities and the adoption of appropriate quality assurance / quality control protocols.*

There is a need to ensure that monitoring within the basins is coordinated and avoids duplication. Appropriate priority needs and scientifically acceptable protocols must be identified and applied across agencies. Quality assurance and quality control practices as well as procedural standardization must incorporated into all aspects of monitoring activities.

5. *We recommend an IEM database for the basins be established and maintained.*

A critical component to an effective integration of monitoring data is the existence of a standardized database that will allow for interpretation of monitoring information at a variety of scales (spatial and temporal). A process is required by which this database can monitored, updated and made publicly available.

6. *We recommend a process be established whereby the integration of monitoring data collected in the basins be subject to scientific interpretation by an independent group.*

The individual agencies contributing to the IEM database are responsible for the interpretation of their own monitoring data. However, there is also a need for interpretation of the integrated data. Such an interpretation should be scientifically-based and consider a broader range of issues that would any single monitoring agency. It is also necessary that the scientific validity of monitoring activity be assessed by independent experts.

7. *We recommend that volunteer organizations and individuals be incorporated into the IEM implementation strategies.*

Community involvement in the implementation of basin-wide monitoring provides an unique opportunity. The involvement of volunteers (including schools) in monitoring results in a more holistic consideration of ecosystem health. A major challenge will be to adapt community-based monitoring to the scale of the northern river basins. Paramount in any decision to introduce community-based participation in monitoring will be the development of appropriate manuals, other educational material and the adoption of an ongoing training plan.

8. *We recommend that future management programs recognize that the aquatic ecosystem is directly related to the adjacent terrestrial ecosystem and that the evaluation of aquatic ecosystem health must include considerations of land use activities (forestry, agriculture, urban development, mining, etc.).*

The Study Board deliberated at length about the inclusion of terrestrial components within the research program of the NRBS. Due to its restricted mandate and limited budget, NRBS was unable to incorporate such issues as forestry management and other land uses, climate change and biodiversity. The science components responsible for the design and implementation of the NRBS science program also recognized the need to focus primarily on the aquatic ecosystem, but expressed concerned over the limited research pertaining to terrestrial issues. Future IEM in these basins should extend beyond the mainstems of the major rivers and tributaries to consider importance of terrestrial activities and processes.

9. ***We recommend a process of public consultation be undertaken every 3-5 years to assess and re-evaluate societal priorities and to identify emerging issues.***

An essential component of an effective IEM is the requirement to assess periodically and re-evaluate societal priorities, goals, and objectives for these basins and to incorporate this information in the refinement of monitoring activities. As discussed in this synthesis report, the identification of appropriate ecosystem indicators is dependent on the development of precise statements of ecosystem goals and objectives.

CUMULATIVE IMPACTS WITHIN THE NORTHERN RIVER BASINS

By: Fred J. Wrona[1], William D. Gummer[2], Kevin J. Cash[1] Kenneth T. Crutchfield[3]

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Recommendations
These recommendations are a result of an interpretative, integrated synthesis of results from the eight study components. The analysis also considered advice received from public gatherings and science fora held during the study. These recommendations are science-based and not reflective of societal values. It is the challenge of the Study Board with its multi-stakeholder representation to incorporate societal values in the final NRBS recommendations.

Each of the Component synthesis and project reports contain a number of issue- and discipline-specific scientific recommendations, too many to list here. We recommend that management authorities review and consider these recommendations as the issues and concerns warrant.

The recommendations which follow are divided into four primary issue areas:

I Environmental Contamination
II Aquatic Ecosystem Health
III Environmental Management and Monitoring
IV Cumulative Effects

Within each of these areas, recommendations are presented in order of priority.

I Environmental Contamination

Given the prevailing concerns about the presence, concentration and distribution of contaminants in the aquatic ecosystems of the Peace, Athabasca and Slave River systems, the following monitoring and research recommendations should be considered immediately by governments:

1. ***We recommend that a basin-wide monitoring program be undertaken at least once every three years to assess fish health and levels of contaminants in fish tissue.***

NRBS research has identified that although the health of fish is generally believed to be good across the basins there are indications that some fish may be showing early signs of stress and possibly exposure to contaminants. For instance, there is a high incidence of abnormalities reported in fish below Whitecourt, and higher than normal incidence of abnormalities in fish below other pulp mills. As well, our findings indicate depressions in sex steroids in fish from these same locations. Together, there is a body of evidence which suggests that there may be sub-lethal toxicological concerns. There is no active fish contaminant monitoring program in the basins. Given the concerns related to human consumption of fish containing mercury, dioxins, furans, PCBs and toxaphene (various fish consumption advisories exist now in the basins), and given that fish contamination is changing over time and space due to improvements in technologies and due to biological and ecological processes, periodic assessments would provide governments, public and other stakeholders with current information. It is our view that a three year monitoring cycle reflects a reasonable time frame over which one could expect fish and other organisms to respond to changing conditions within the basins.

2. ***We recommend that the federal and provincial governments and industry consider further optimization of the Environmental Effects Monitoring (EEM) protocols for pulp mills based upon the NRBS findings.***

NRBS undertook investigations to assess the state of aquatic ecosystems, and in particular, the health of fish and the benthic communities upstream and downstream of pulp mills. The most in-depth work was conducted on the Athabasca River.

Considerable effort went into the selection of appropriate fish species, sampling design and selection of assessment protocols. We anticipate that the fish information concerning contaminants, fish movement and distribution, fish health (biomarkers) and indicator development, and sampling design could be used to optimize the Environmental Effects Monitoring (EEM) protocols. Consideration should be given to coordinating the industry collections (timing, species, number of samples, etc.) of all the mills so that data can be comparable and integrated on a larger basin scale.

3. ***We recommend that all levels of government actively support and encourage ongoing research investigating ecosystem structure and function within these basins.***

An explicit objective of the NRBS was to acquire a baseline data set pertaining to the basic ecology of the Peace, Athabasca, and Slave river basins. The importance of understanding the structure and function of the ecosystem cannot be over emphasised. It is this understanding which determines our view of the system and provides a context within which all management priorities and objectives are developed. Gaps in this understanding could result in a failure to identify key issues or in the misdirection of time and effort. Unfortunately, there are considerable gaps in our current knowledge of the ecology of the Peace, Athabasca, and Slave river basins. These knowledge gaps are reflective of the difficulties associated with working in these systems and of a more general lack of information on the ecology of large rivers, particularly large northern rivers.

Additional research on ecological structure and function is required to determine more precisely the distribution and fate of contaminants in the environment and to further parameterize analytical models developed to predict the consequences of discharging contaminants to the environment. Governments should participate directly in such research, particularly when the research question falls within their mandate. In addition, governments should actively encourage, and perhaps subsidize, ecological research conducted in these basins by other groups such as universities, colleges, community groups and international agencies.

4. ***We recommend that the governments of Canada, Alberta, and Northwest Territories and the key Industries investigate the feasibility and implementation of an integrated environmental information system.***

There is a continuing problem, not unique to these basins, of access to environmental data and information. Virtually every industry, certainly the senior governments, all have computerized systems for handling their own data. For purposes of facilitating the sharing of information, protocols could be developed which would outline the basic standards for handling, storing and reporting of environmental data. Furthermore, protocols could be developed which would link the many databases together so as to permit the transfer of data between them, or at the very least, could direct the user to where the data could be obtained. The five private laboratories and the several provincial and federal laboratories used by NRBS all had different analytical method codes, methods of reporting detection limits, quality assurance methods, and reporting protocols. Considerable human intervention was needed to ready the laboratory data for NRBS use. We believe that a concerted effort by the partners could be successful at reconciling these sorts of problems and the product ultimately developed could be marketable nationally and internationally. This multiplicity of approaches and techniques amongst agencies can be reduced but not eliminated because differing methods are often justifiable. Opportunities exist to make advances now through such organizations as the Canadian Association of Environmental Laboratories, using the INTERNET, and through existing informatics initiatives of governments. Bibliographic inventories of studies and reports undertaken in the basins, land and water use, monitoring data, etc. could be incorporated.

II Aquatic Ecosystem Health

5. ***We recommend further research be undertaken to address the observation of endocrine disruption and increased numbers of sexually immature fish in reaches immediately below pulp mills.***

Preliminary NRBS data concerning endocrine function and sexual maturity of at least two fish species (burbot and longnose suckers) suggest that pulp mill effluents may adversely affect the reproductive ecology of individual fish; however, there is as yet no evidence for an effect at a population level. Using a weight-of-evidence approach, we recommend using the precautionary principle as the basis to initiate more detailed studies examining the linkages between reproductive ecology and exposure to pulp-mill effluent before further developments, singularly or in combination, cause additional ecological stress on the fish populations.

6. ***We recommend investigations be undertaken to determine the linkages between exposure to environmental stresses and sub-lethal effects on fish and other aquatic biota, including physical abnormalities and biomarker responses.***

NRBS studies reveal basin-wide variation in the frequency of physical abnormalities and in the extent of biomarker response. In some cases the measured response appears to be associated with specific point-source discharges (e.g., increased incidence of fish abnormalities below pulp mills); however, in other cases the measured response is not as obviously associated with a particular environmental stress, this is particularly true in some of the tributaries not intensively studied by the NRBS (e.g., elevated levels of metallothionein response in fish collected from the Pembina River and MFO induction in fish from the Wabasca River). The consequences of long-term exposure to contaminants takes on added significance in light of NRBS data indicating the presence, usually at low levels, of environmentally persistent contaminants (e.g., dioxins, furans and PCBs) throughout the basins.

7. ***We recommend investigations be undertaken to identify the sources of PCBs to the upper portions of the Peace River Basin, including the Smoky and Wapiti river systems, in the upper Athabasca River between Jasper and Athabasca and the extent to which PCBs are concentrated in the food web.***

PCBs are known to bio-concentrate and in some cases higher measured levels of PCBs in fish tissue (e.g., burbot) may be a consequence of changes in the fish foraging behaviour (e.g., large burbot feeding on other fish will concentrate PCBs to a greater extent than those feeding on macroinvertebrates) rather than a consequence of exposure to a PCBs spill. The role of food web interactions in observed tissue concentrations of PCBs could be investigated using stable isotope analysis.

NRBS has identified that PCBs are one of the major contaminants in the tissue of biota from these basins. Importantly PCBs are not produced by pulp mill activities and are not uniformly distributed throughout the basins. In particular, PCBs concentrations have doubled in several locations in the Peace River Basin between 1992 and 1994, although the explanation for this increase is unknown.

8. ***We recommend the development of ecologically rather than technologically-based endpoints for the regulation of nutrient discharges from industries and municipalities.***

Current levels of nutrient discharge from both industry and municipalities have been demonstrated to change patterns of nutrient limitation and hence primary and secondary productivity. At present issues associated with these changes are largely aesthetic, but continued and or additional loadings have the potential to dramatically impact the trophic structure in these basins. Current guidelines focus exclusively on technology-based endpoints and do not incorporate ecological responses. Technologically-based effluents guidelines and regulation should be viewed as a means to preserve adequate ecological structure and function, and not as an end in themselves. Implicit in this approach is the recognition that regulatory levels may vary from reach to reach as a function of river size, cumulative effects and unique ecology of each reach.

9. ***We recommend further research into the dissolved oxygen requirements of the most sensitive life-history stages of fish species and their invertebrate prey. We further recommend the development of ecosystem / reach specific dissolved oxygen guidelines.***

Much of the available information on dissolved oxygen is not representative of the aquatic species and conditions existing in these northern rivers.

NRBS review of under-ice river dissolved oxygen levels reveal an enhanced diminishment of dissolved oxygen in the Wapiti-Smoky rivers, and the Athabasca River between Hinton and Grand Rapids. These river reaches receive major inputs of municipal and pulp mill effluent. In a river channel fish and other riverine biota focus much of their life processes, close to the river bed or bank. Current dissolved oxygen monitoring practices record dissolved oxygen levels away from the streambed. Consequently, the dissolved oxygen data does not accurately reflect conditions existing within habitats utilized by fish and other biota. Available scientific knowledge indicates that an average three mg/L differential exists between dissolved oxygen levels within the water column and those existing in the streambed. The availability of sufficient dissolved oxygen influences the aquatic community composition within a river reach. Fish and other biota exposed to diminished dissolved oxygen will respond by altering life processes. NRBS work into the embryonic development of three fall-winter spawning fish species: mountain whitefish, bull trout, burbot, and the feeding behaviour of an invertebrate species provided insightful information. The information indicated a need for further research and the establishment of reach specific dissolved oxygen guidelines. More specific information is needed to manage effluent for the protection of sensitive life stages in biota likely to be subjected to diminished dissolved oxygen levels. Research must be done to find out the acceptable limits of northern river aquatic biota to lowered dissolved oxygen levels, and the relationship between water column and substrate-water/ substrate interface dissolved oxygen levels.

10. ***We recommend that research be undertaken by Environment Canada and partners to develop an understanding of the inter-relationship between climate variability and hydrologic regimes of the mainstem rivers and major tributaries in the basins.***

The NRBS has determined that variability in precipitation and reduced winter snow pack have reduced the magnitude of recent (up to 1995) spring run-off in the Peace River drainage and the probability of ice-jam formation in the delta area. Reductions in the spring runoff volumes in recent years are therefore not just a result of the Bennett Dam. The implications of climate change on the regulated flow regime of the Peace River and on the ecology of the delta must be understood, especially if solutions for the long term are to be sought for alleviating the ecological problems in the Peace-Athabasca Delta. Eventually, scenarios of climate variability could be factored into water management strategies and the operational plans for Bennett Dam.

11. ***We recommend that current human health advisories for the consumption of fish, including the "recommendation" issued by the Government of the Northwest Territories, be reviewed, revised and/or developed, based upon human dietary and fish contaminant information reported by NRBS. Further, we recommend starting an ongoing contaminant monitoring effort for fish consumed as food by domestic and sport fisherman.***

Similar to previous investigations, NRBS has identified contaminants in the fish flesh and organs (liver) that are the subject of current provincial human health consumption advisory (e.g., mercury, dioxin-furan) or territorial recommendation (e.g., toxaphene). NRBS sampled fish from the mainstem rivers of Peace, Athabasca and Slave rivers and major tributaries (e.g., Wapiti-Smoky rivers). Many of these sampled fish species are eaten for domestic and sport purposes. Currently, aside from the monitoring associated with the export of commercial fish products (Freshwater Fish Marketing Corporation), a program does not exist for the regular collection and analysis of fish obtained for domestic and/or sport purposes. The current guideline utilized by Health Canada in preparing human health assessments has provision to incorporate the unique dietary information of the human population consuming the contaminated fish product. Often this dietary information on the human population consuming the contaminated fish product are scant. There are instances where an advisory or recommendation can be in force within one jurisdiction and not an adjoining jurisdiction when but for a line on a map the same fish population is being considered, e.g., dioxin-furan advisory on the upper Athabasca River downstream of Jasper National Park but not in the Park, toxaphene recommendation for burbot liver in the NWT portion of the Slave River but not in Alberta. The public perception of the risk is at best confusing. The current human health consumption advisory or recommendation should be reviewed in light of the NRBS findings. As well, the traditional users who rely or used to rely on fish for a significant portion of their dietary protein source, require special consideration in preparation of the advisories and/or recommendation that takes note of their consumption use patterns. A need also exists for a semi-regular monitoring program that acknowledges the likely variation in contaminant levels as effluent standards are modified.

12. ***We recommend the extent and causes of fish tainting be quantified and action taken as appropriate to remediate the problems.***

Although human health is not believed to be threatened by current levels of fish tainting, NRBS scientists learned that a widely held public perception is that fish are contaminated. This perception is based on fish odour and appearance; fish possessing oil and/or pulp mill odours are immediately perceived to be "contaminated" and unfit for human consumption. The occurrences of these observations is highest in the lower end of the basins but also occur in the Smoky and Wapiti systems, and some evidence exists (traditional knowledge) that suggests that the quality of fish livers has deteriorated. As long as these issues persist in the basin, the public will associate taste and odour with polluted fish and drinking water. In-depth assessment of tainting substances (synergistic effects of multiple effluent types) and alternatives for their control may be required to meet the public need to know. Insufficient data exist to address the issue of fish tainting and the particular substances responsible for tainting of drinking water supplies. The primary sources of tainting substances to the Athabasca River exist in the reaches between Hinton and Fort McMurray where dilution ratios are lowest and where there is a succession of industrial and municipal waste sources.

13. ***We recommend that provincial and federal authorities undertake, in accordance with their responsibilities, to ensure the ongoing training and certification of drinking water treatment plant operators, education of the public about their choices concerning drinking water sources and treatment, and timely reporting and corrective action for water quality problems.***

The vast majority of people within the basins receive excellent quality drinking water. The problems which have been most frequently observed are usually in communities of populations less than 500. Typical problems have included: high bacteria, turbidity, odours, and trihalomethane compounds. High levels of coliform bacteria indicate the potential risk associated with viruses and waterborne diseases. Although some of the facilities may be aging and therefore not capable of high performance, concern was expressed by some community members over the experience and dedication of treatment plant operators. Given the importance of quality water to the health of people, treatment plant operators should be recognized as critical assets to the community and afforded the best level of training and certification. Furthermore, monitoring protocols must be standardized and subject to quality assurance, and monitoring data regularly reported with timely corrective action taken, as needed.

NRBS public surveys have confirmed that tainting substances (derived from pulp mill discharges and municipal disinfection with chlorine) are still an issue with respect to drinking water. Basin communities should be provided with documentation about the quality of their drinking water, explanations of why odours exist (natural occurrence included), and advice as to alternatives and choices people can make about their drinking water.

III Environmental Management and Monitoring

14. ***We recommend the adoption of an integrated basin management and the assessment of cumulative effects of developments. Such an approach requires an integrated environmental monitoring framework to ensure the ongoing scientific validity of results, and rationalization and optimization of monitoring and research conducted within the basins. It is further recommended that an Integrated Environmental Monitoring Committee (IEMC) be immediately established to coordinate basins' monitoring and research within this framework.***

Governments, industries, some municipalities and to a lesser extent other organizations conduct various types of monitoring within the basins. Individual agencies collect monitoring data for their own purposes, however, the total benefit realized would be greater if monitoring within the basins was coordinated so as to avoid duplication and provide the maximum return in information for each dollar invested. Such an approach would also allow for the consideration of a broader range of issues (e.g., basin-wide effects, cumulative effects) than would be considered by any one agency or industry. Appropriate priority needs and scientifically acceptable protocols should be identified and applied across agencies. Quality assurance and quality control practices as well as procedural standardization should be incorporated into all aspects of monitoring activities. A process is required by which this database can be maintained, updated and made publicly available. A scientifically rigorous integrated environmental management program requires expert advice on its design, implementation, data interpretation, and scientific recommendations. Similar to the Science Advisory Committee of the NRBS, this committee would serve as an independent and objective reviewer of the integrated environmental management program.

The Synthesis and Modelling Component has presented a practical procedure for the development and application of ecosystem indicators and has recommended indicators for adoption by governments, industry and the public.

Conformance with this monitoring and research template should be a condition of all monitoring and research undertaken in the basin. Government authorities may wish to consider the requirement of monitoring and research permits in order for agencies to conduct their work in the basins similar to what is done in the Northwest Territories. This would be a means of optimizing the monitoring and research in the interests of the basins needs.

15. ***We recommend that existing information on northern river fish movement, behaviour, and habitat use, must be compiled and interpreted. On completion, this work should be assessed for its support of cumulative effects assessment, deficiencies in knowledge identified and corrective action implemented.***

The composition and extent of fish species within the basins is generally known. A wide gap in knowledge continues to exist on seasonal distribution / abundance, habitat utilization and general biology of fish species, particularly for the non-domestic/ sport/commercial varieties. NRBS, industry and government investigations since the start of the Study have further augmented the available knowledge but there remains a lack of interpretation on this existing body of knowledge. Consequently, the likelihood of redundant information being gathered at the expense of needed information remains high. NRBS investigations have identified significant freeze-up and morphological changes to the Peace River downstream of the Bennett Dam. The implications of these changes to the fish community reliant on the mainstem Peace River are unknown, particularly in the river reach downstream of Peace River and the lower portion of the Peace River within Wood Buffalo National Park. Without better understanding of fish movements and populations there is much difficultly in interpreting the significance of contaminant levels on the fish health effects documented by NRBS and others. It is also difficult to design effective monitoring programs to assess changes in fish health. This compromises the use of fish as reliable indicators of ecosystem health even though they remain the most obvious animal for the public to do their own evaluation of risks to human health.

IV. Cumulative Effects

16. We recommend additional research and/ or remediation in those areas of the basin identified as deserving of special attention by applying the weight of evidence approach to the assessment of cumulative effects.

Cumulative environmental effects manifest themselves at a variety of spatial, temporal, and organizational scales within the ecosystem. Although it is important not to lose sight of cumulative effects occurring at a basins-wide level and the inter-relatedness among river reaches, it is equally important to employ a weight of evidence approach to identify those portions of the ecosystem particularly deserving of attention. This approach provides the opportunity to focus on characteristics which are unique to reaches and identify related management considerations. What follows is a brief description of what we consider to be the five areas in the basins requiring priority consideration by managers at the federal, provincial and territorial levels.

16a. Protection of the Wapiti-Smoky river systems

Based on the weight of evidence approach, the Smoky-Wapiti River system is currently the most heavily stressed in the Northern River Basins. Issues of concern include high levels of nutrient addition from the city of Grande Prairie and the Weyerhaeuser pulp mill, sharp declines in under-ice dissolved oxygen, and high PCB loadings in fish. Dioxin and furan concentrations in biota have declined since 1992, but remain among the highest observed in the basins. Reduction in winter snow pack and subsequent declines in discharge levels will serve to further concentrate contaminants and nutrients in the system. Prevention of further deterioration should be a priority of both provincial and federal management authorities as should be the remediation of an already stressed aquatic ecosystem. These small and relatively shallow systems provide critical fish spawning habitat and are therefore particularly vulnerable to pulp mill and municipal wastes.

16b. Remedial action plan for the Peace-Athabasca Delta

The Peace-Athabasca Delta is internationally recognized as one of the most important and largest freshwater deltas in the world and has been designated as a Ramsar site under the international Ramsar Convention as well as a World Heritage Site. The NRBS has recognized that the Peace-Athabasca-Delta has been significantly impacted by flow regulation and climatic variability. Most significantly, a reduction in the frequency and extent of ice-jam flooding has resulted in the drying of perched basins and delta lakes. This in turn has had profound ecological consequences for the geomorphology of the delta and for the aquatic biota, terrestrial wildlife, and riparian vegetation in this region. Moreover, the ability of aboriginal peoples to pursue a traditional lifestyle has been significantly compromised.

We believe that sufficient information now exists based on the previous studies in the delta, studies by Wood Buffalo National Park, research by NRBS, and the forthcoming results of the Peace-Athabasca Delta Technical Studies to develop and implement a remedial action plan. We further believe that options for remediation could include modifying the operation of the Bennett Dam so as to be more ecologically sensitive to the needs of the downstream ecosystem. Adaptive management strategies, whereby the best option (based on collective knowledge) can be implemented, and then modified based on the results, should be considered. To begin with, it will be necessary to have the stakeholders agree upon the ecosystem attributes (goals and indicators) which should guide the action plan.

16c. Intensify monitoring activity in the reach of the Athabasca River from Hinton to below Whitecourt

Recent improvements in process technology at the Hinton and Whitecourt pulp mills have reduced levels of persistent organochlorine contaminants entering the environment. This improvement is reflected by declines in measured levels of certain contaminants (e.g., dioxins and furans) in sediment and biota. However, NRBS has identified contaminant-related concerns in the Emerson Lakes area below Hinton and has recorded a high incidence of fish abnormalities below Whitecourt. In addition, nutrient discharges from the Weldwood mill have resulted in "nuisance" growth of algae for up to 30 km downstream of Hinton. Improvements in pulp mill technology may serve to reduce these impacts, but given current conditions in this reach, we recommend that monitoring be particularly vigilant.

16d. Research into the ecological consequences of exposure to hydrocarbon-related contaminants in the oil sands area

In the 1994 basin-wide fish survey, the only locations to produce significant MFO induction in burbot were located in the oil sands area (below Ft. McMurray and the Wabasca River). Moreover research using semi-permeable membrane devices supported this observation in the Athabasca mainstem as well as in the Steepbank and Clearwater rivers. These observations point to the importance of environmental stress caused by exposure to natural sources of hydrocarbons in the oil sands area and to the need to distinguish and characterize the consequences of exposure to these natural sources and to effluent from oil sands refineries.

16e. Protection of the Slave River Delta ecosystem

NRBS studies consistently found that fish in the Slave River Delta were the largest and in the best condition. However, these same populations also exhibited elevated biomarker responses (e.g., metallothionein). Although NRBS has obtained evidence that pulp mill contaminants are deposited in the delta and Great Slave Lake, observed levels are currently low and the actual exposure of these fish to contaminants, either from Great Slave Lake or from upstream sources remains unknown. Similarly, although there is little evidence to suggest that flow regulation on the Peace River is currently impacting the Delta there are suggestions that such impacts will become more apparent over time. The current state of the Slave River Delta thus provides an opportunity for conservation rather than remediation. An appropriate conservation strategy is particulary important in light of the fact that the Delta is downstream of all development in the basins.

17. We recommend that future management of these basins explicitly recognize and consider land use activities (forestry, agriculture, urban development, mining, etc.) occurring in the adjacent terrestrial ecosystem.

The Study Board deliberated at length about the inclusion of terrestrial components within the research program of the NRBS. Due to its restricted mandate and limited budget, NRBS was unable to incorporate such issues as forestry management and other land uses, climate change and biodiversity. The science components responsible for the design and implementation of the NRBS science program also recognized the need to focus primarily on the aquatic ecosystem, but expressed concerned over the limited research pertaining to terrestrial issues. Future IEM in these basins should extend beyond the mainstems of the major rivers and tributaries to consider importance of terrestrial activities and processes.

A Report of Wisdom Synthesized from the Traditional Knowledge Component Studies

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7.0 RECOMMENDATIONS

The Traditional Knowledge Component of the Northern River Basins Study recommends that:

1. ***Traditional knowledge research of the Northern River Basin Study be extended to include all Aboriginal communities within the NRBS study area, especially those in the southern portions of the area; these locations were not included in the present study due to fiscal constraints.***

2. ***A comprehensive study be conducted to assess the economics of a traditional hunting/ trapping economy within the Northern River Basin Study area.***

<u>Comment</u>:

There currently prevails a "doctrine of inevitability" which is a powerful idea held by prominent and influential people that supporting and sustaining the hunting/trapping economy is a futile exercise.

This doctrine is based on the myth that the human race has progressed by stages from hunting/ gathering, to nomadic pastoralism, then to horticulture and agriculture, and finally to industrial society. This perspective is one with which we are so familiar that we take it as common sense. It is a basic cultural theme which biases the way in which, those who subscribe to this myth view the world. If one accepts this myth, it is clear that hunting and trapping cannot be taken seriously, because these activities are seen as an economic form that have historically been superceded. As such, those who partake in hunting and trapping are viewed as existing in an evolutionary backwater and they are thought, by those who subscribe to the myth, to have a need to move into a "more progressive," modern way of life.

There is a dearth of comprehensive research on the true economics of a hunting and trapping economy. The only fact that can be stated with confidence is that the people who devote labour at hunting and trapping do so to secure sustenance for economic reasons. It is, therefore, imperative that the fiscal realities of such an economy be carefully assessed and understood, and that sound methodology be developed in order that the true value (ie. economic, social, cultural, spiritual, health, ecological, etc.) can be identified. This research will enable the hunting and trapping economy to be weighed more realistically, and to be reviewed in context with other development initiatives that may negatively impact on this life-style.

3. ***A "Handbook on Methodology for Traditional Knowledge Research" be developed for application on a local, national and international basis, and that the handbook be based on the experience gained by the Northern River Basin Study.***

4. ***A comprehensive research and monitoring program be established, incorporating both traditional knowledge and conventional science, to assess the effects of land-use practices (eg. agricultural land clearing, logging, industrial development, municipal development, etc.) on the capacity of river basins to sustain ecologically desirable hydrologic regimes (surface and ground water) for future needs, and to recommend land-use management requirements to achieve this goal.***

5. *A water quality monitoring program be initiated throughout the Northern River Basin Study area, integrating traditional knowledge and conventional scientific methodologies.*

6. *Natural Resource Co-management Agreements (or cooperative management agreements) reflecting a partnership relationship between the Province of Alberta and the Aboriginal people inhabiting the Northern River Basin Study area be developed and implemented. Such agreements will integrate traditional knowledge and conventional science throughout the information-gathering processes, information interpretation, management, and decision-making processes on all matters relating to renewable natural resources within the region.*

7. *A comprehensive economic development strategy and implementation plan for the region encompassed by the Northern River Basin Study be developed, focusing on opportunities for local people using traditional knowledge as the key factor in pursuing economic development within the region.*

8. *A traditional knowledge transfer and extension program be developed and implemented to encourage the perpetuation of traditional knowledge from Aboriginal elders to the youth, as well as to other sectors of society.*

9. *An extensive literature search and information analysis be conducted to obtain the information that others have prepared, following analysis of specific aspects of archival and non-archival records relevant to this study.*

10. *Additional archival studies be undertaken to expand the present database, to ensure comprehensive coverage of relevant environmental information within the study area.*

11. *The Hudson Bay Company records of weather be studied and analyzed, then correlated with the data now included in the database(s) of Environment Canada; determine the extent to which decreased precipitation has been caused by developmental change factors.*

12. *Health-related issues that have been alluded to throughout the community research component, but for which no detailed documentation exists, be the subject of extensive studies.*

13. *Industrial sites such as the now-closed mine at Pine Point be forced to adhere to environmental regulations, and to not contravene the ecological wisdom of those who live in close liaison with the land.*

14. *The climatological effect of land stripped of trees and used for agricultural purposes, compared with farm land left with 30 to 50 foot strips of trees along road allowances or in rows throughout the land mass of the larger farms, be specifically studied and analyzed.*

15. *A protocol be developed jointly and immediately by the Province of Alberta and the First Nations/Metis, to ensure that the knowledge and the respectfulness of the First Nations/Metis peoples toward the land is incorporated into each industrial process now in existence or contemplated for future development.*

16. *An elder of the First Nations/Metis community be appointed to a senior consultancy position with each major industry now operating or being planned, to ensure that the wisdom of the ages is incorporated into the day-to-day operational practices of the industries. Support by the First Nations/Metis community, of the elder and his/her appointment, is implicit and essential.*

Synthesis of Fish Distribution, Movements, Critical Habitat and Food Web for the Lower Slave River North of the 60th Parallel: A Food Chain Perspective

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SUMMARY CONCLUSIONS AND RECOMMENDATIONS

The lower Slave River is a distinct habitat in the Northern River Basins in that it is connected hydrologically and chemically to the upper part of the watershed but isolated at the level of the fish community. There is virtually no interaction between the fish communities upstream of Rapids of the Drowned and those in the lower Slave River. Habitat requirements for fishes are unique in the lower Slave River because of the life cycles of the species and the surrounding abiotic and biotic environment.

Three guiding questions were posed by NRBS that are relevant to fish ecology: # 1a " How has the aquatic ecosystem including fish and / or other aquatic organisms been affected by exposure to organochlorines or other compounds?"; #6 "What are the distribution and movements of fish species in the Peace, Athabasca and Slave Rivers? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats?"; #8 "Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish and how are these levels changing by time and location?"

To respond and/or provide supporting information to answer these questions I provided the following: 1) a review of the existing models for large rivers that could make predictions regarding the pathways contaminants and other anthropogenic effects might take to reach the fish food chain through hydrological regime and movements of the biota; 2) a general description of the major abiotic and biotic features of the environment surrounding the fish community in the lower Slave River; 3) a summary of the available knowledge (including NRBS studies) on the community composition, distribution and abundance of the fishes in time and space in the lower Slave River; 4) a synthesis of the available knowledge of geographic migratory patterns of fishes of the lower Slave River; 5) a summary of vital rates of major species; 6) a description of the pathways in the fish food web.

7.0.1 Theoretical Models and the lower Slave River

Further research on the lower Slave River should be undertaken with a unifying theoretical model in mind. Such an approach will do more to preserve all ecosystem components than studies specializing in one or two species or aspects of fish biology in the river. On the other hand the present theoretical models which have been developed based on river systems in the southern temperate and tropical regions may not be sufficient to describe the sub-Arctic Slave River. As stated before, the river continuum concept is most appropriate for headwater streams and small rivers, whereas the flood pulse concept is limited to large floodplain rivers and the RPM is relevant to large rivers with constricted channels and firm substrates in the photic zone. Where does the lower Slave River fit in? The original concern from NRBS was probably partly based on a river continuum model; that what happens upstream profoundly affects function downstream. This is undoubtably true. However, the lower Slave River seems to fit better between the flood pulse and riverine productivity models because there is certainly a flood pulse and yet much of the river is a restricted channel with productive tributaries. The recommendations that follow, therefore, keep in mind that much of the focus in the NRBS has been dealing with the linear nature of riverine systems and that research into lateral inputs and local productivity must be undertaken.

7.1 Effects on the fish community

Flow regulation from the Bennett Dam has produced a change to the seasonal hydrograph of the Slave River (Prowse and Conly 1996). By the lower Slave River the effects are diminished due to tributary flow becoming an increasing part of the total discharge. Contaminants have been found in some indicator fish (burbot) in the lower Slave River although at generally low levels (Brown 1996). The fish community could be affected by these changes in the environment in terms of vital rates, species composition and diversity.

7.1.1 Vital Rates

Vital rates respond to changes in the environment by re-partitioning energy between maintenance, growth and reproduction (Roff 1992). Growth and reproduction are the basis for productivity in fish populations. Unfortunately, there is no general model predicting precisely how vital rates will respond to changes in the abiotic environment. Presumably, the first level that the above changes might affect fish is to increase their maintenance costs with a trade-off in reduced growth, delayed age at maturity and/or reduced fecundity.

7.1.1.1 Growth

Ideally, one would like pre- and post-impact information with which to judge, but this is not the case, in general. Inconnu, burbot and lake whitefish have data of this type for growth but the other species do not. Therefore, the information presented in the report on the other species serves only as a bench mark of productivity indices to judge further changes.

Inconnu in the lower Slave River has one of the highest growth rates in North America. The high growth rate is likely attributable to the normal response of the life history to fishing pressure and the fact that inconnu are at the southern end of their range. There appears to have been little change in growth patterns from 1983 to 1994. Burbot in the lower Slave grow more slowly than other populations but not substantially so. From the late 1970's to 1994 there may have been an increase in growth of the younger ages and a decrease in the growth rate of older ages. Based on data from the late 1970's and the early 1980's Slave River lake whitefish grow more slowly than surrounding populations. Between 1978 and 1984 there was little change in growth rate. Slave River goldeye also grow more slowly than other populations in the area whereas northern pike growth seems to be about average. Other than the changes observed in burbot there appears to be no unusual patterns in the growth of Slave River fishes that would suggest an impact. However, the conclusion is based on limited data.

7.1.1.2 Age at maturity

There is no information to check for changes in age at maturity among Slave River fishes. Therefore, the limited age at maturity data will be considered as a bench mark for future assessment of impacts. Some populations were distinct compared to conspecifics.

Inconnu had a low age at maturity compared to other North American populations. This is probably due to the rapid growth rate. Burbot in the lower Slave River matured about one year later than other burbot populations but this is not noticeably outside the inter-population variation one might expect. Lake whitefish and pike, age at maturities are similar to most other conspecific populations. Walleye, goldeye, and longnose sucker matured later than conspecific populations. Age at maturity does not appear to be outside the expected range for any of the major species in the Slave River.

7.1.1.3 Fecundity

There was no information available to determine if fecundity has changed in fishes in the Slave River.

Fecundity of inconnu, burbot and pike were comparable to other conspecific populations. Lake whitefish had a lower fecundity than most other lake whitefish populations. Fecundity levels were in the normal range and showed no evidence of impact.

7.1.1.4 Age Structure

Inconnu had a narrow age structure compared to other populations. Burbot, goldeye longnose sucker, lake whitefish, walleye, and pike had broad age structures suggesting little impact from anthropogenic activities. The narrow age structure of the inconnu would make it less able to adjust to environmental changes than the other species.

The major species are mainly in the two categories of large and medium sized fishes which Zaret (1980) described as being most vulnerable to anthropogenic activities and therefore the first to show any effects. The vital rates of these species given no indication that contaminants or flow changes have affected the Slave River fish community to any appreciable degree. However, the data is not sufficient to make conclusive judgements.

RECOMMENDATION 1): Evaluating changes to the vital rates is limited by the lack of data prior to the construction of the Bennett Dam and other developments. Except for inconnu and burbot, most of the vital rates available are from 1978-79 collections by Tripp et al. (1981). Analysis of the current vital rates of other species should be undertaken — especially goldeye, northern pike, walleye and lake whitefish.

RECOMMENDATION 2): Future evaluations of the impact on fish productivity will require good data on vital rates. Key species, such as inconnu, northern pike, burbot, walleye and goldeye should be assessed on a regular basis. The Department of Fisheries and Oceans should continue collection and analysis of inconnu from the lower Slave River. Collections and analysis of the other key species should be made at least once every five years to assess changes in productivity.

RECOMMENDATION 3): There is little information on the growth patterns of juveniles of the major species in the lower Slave River. Impacts from environmental degradation will probably affect juvenile stages first. Projects that focus on factors important to juvenile life history should be encouraged.

RECOMMENDATION 4): There is almost no information on the vital rates of forage species such as emerald shiner, flathead chub, trout-perch . These species may be good indicators of changes that will ultimately affect the production of their predators, the harvested fish species. Studies that quantify the life history trajectory (growth, age at maturity, fecundity, longevity, mortality) of forage species in the lower Slave River should be undertaken.

RECOMMENDATION 5): There are no models that can be used to predict the response of the life history trajectory (hence how fishes are affected) to environmental degradation in the lower Slave River. Existing life history trajectory models relate to mortality factors such as fishing. Quantitative models of the potential consequences to vital rates of flow changes and/or contamination should be developed for the lower Slave River. Such models would allow more precise hypothesis testing and prediction of the effects of habitat change. This recommendation is key because it may help to priorize Recommendations 1-4 and others.

7.1.2 Fish Species Diversity

A major problem with environmental degradation is the permanent loss of species. Lowering the diversity of ecosystems makes them less stable and able to withstand further environmental impacts. A total of 30 species have been reported in the Slave River and its delta. Twenty-seven of these species are confirmed from collection records. The other three are only reported in McCart (1986) but the references he provided do not confirm actual collections of these species. Within the confirmed group the most important family is the Salmonidae with 10 members. The Cyprinidae (5 species) is next followed by Percidae (2), Catostomidae (2), Cottidae (2), Percopsidae (1), Petromyzontidae (1), Esocidae (1), Hiodontidae (1), Gadidae (1), and Gasterosteidae (1). In the late 1970's 23 species were captured in the system compared to 18 in the mid-1980's and 19 in 1994/95. Different fish species are more or less vulnerable to capture depending on the gear used. When considering only one gear type common to all studies (gillnet) then there was no change in the number of species recorded (14) from the 1978-80 period to 1994-95.

The NRBS funded study added two species not collected before to the lower Slave River list - Oncorhynchus nerka and O. tshawytsha. Overall, community composition differences were minor and are likely a result of chance in sampling. Therefore, there does not appear to be any affect of flow changes or contaminants on the fish species diversity in the lower Slave River.

*RECOMMENDATION 6): **Fish species diversity is a fundamental indicator of ecosystem health. Collections by gillnet and other means should be made at least once every 5 years over the entire season to determine if fish species diversity has changed.***

*RECOMMENDATION 7): **A more formal analysis of the existing data using indexes of diversity should be undertaken.***

7.1.3 Fish Species Abundance

While some species have been a relatively stable percentage of the community others have shown fluctuations in their relative abundance between 1978 and 1995. Lake whitefish, white sucker, northern pike, flathead chub and walleye have remained relatively constant. Inconnu appears to have increased, probably due to reductions in fishing pressure. Burbot and longnose sucker appear to have decreased somewhat. Some of the differences may be due to sampling location — the late 1970's samples were taken more heavily from the Slave River Delta than the recent samples.

*RECOMMENDATION 8): **To validate the catch per unit effort method of estimating abundance and to get a benchmark estimate of the numerical abundance of each species it is recommended that mark-recapture studies be undertaken for each species.***

7.1.4 Invertebrate Diversity

In the flood-pulse and river continuum models all fish species in the Slave River would be considered predators. The basic medium of energy transfer is invertebrates. It is clear that maintenance of invertebrate populations is critical to the productivity of the fish populations. Effects of contaminants or flow changes may first affect the productivity of invertebrate populations.

*RECOMMENDATION 9): **Studies to determine the species diversity, habitat requirements and productivity of invertebrates in the lower Slave River should be undertaken.***

7.2 Fish Distribution and Movement

The lower Slave River fish community is seasonally dynamic, constantly changing throughout the year. Fish movements vary according to species from extensive to limited. The lower Slave River is an important habitat used for spawning, feeding, rearing of juveniles and for over-wintering of fishes and serves as a migratory corridor for all of these activities. All major species appeared to show seasonal aggregations and all seasons were important for spawning or feeding of at least one of the major species.

7.2.1 Distribution

7.2.1.1 Large Scale Patterns

Goldeye were abundant in the Slave River, Slave River Delta and Salt River. Inconnu could be found near the outer Slave River Delta in the spring but generally used the Slave River, only, as a migration corridor and spawning area in the fall. Lake whitefish utilized the Slave River for feeding and spawning. The Salt River was an important nursery area for lake whitefish and juvenile pike. Northern pike adults were distributed throughout the system but were most abundant in the Slave River delta. Burbot were also widely distributed but had apparently much lower abundance. Longnose sucker inhabited the Delta and Slave River channel, while white sucker inhabited mainly the Salt River. Walleye had resident populations in the Salt and Slave rivers but also had spawning and overwintering runs from and to Great Slave Lake in the spring and fall, respectively. Some species like flathead chub, preferred the Slave River channel. A large number of others (Arctic lamprey, pearl dace, lake chub, trout-perch, round whitefish, ciscos, Arctic grayling, emerald shiner, yellow perch, spoonhead sculpin and slimy sculpin) inhabit the Delta and the extreme lower reaches of the Slave River channel.

7.2.1.2 Micro-habitat

Shallow, well vegetated areas were preferred by a greater diversity of species in greater numbers than other habitat types. However, the number of habitat types were limited to four defined by Tripp et al. (1981).

*RECOMMENDATION 10): **Field and simulation studies to characterize the differences in fish habitat among the major areas of the lower Slave River drainage should be undertaken to determine what are the habitat characteristics that separate species in these areas. Particular attention should*** *be made to develop a detailed scale of micro-habitat types and the preferences of fish to each.*

7.2.1.3 Seasonal Variation in Community Structure

The Slave River community changed greatly over the season. In the spring goldeye, flathead chub, walleye were numerically dominant. The high abundance was probably due to spawning aggregations. Longnose sucker, pike and lake whitefish were also present. Burbot and inconnu were absent. During the summer the community composition included most major species except inconnu. Goldeye was the most abundant but less so than in the spring. In the latter part of the summer the fall spawning species, inconnu and lake whitefish begin to dominate the biota. During the fall inconnu, lake whitefish and goldeye dominate but all species are present. Late in the fall ciscos enter the Delta in great numbers. In the winter there is a run of burbot downstream to spawn in the Delta.

RECOMMENDATION 11): Little is known regarding the seasonal distribution under ice. Field studies over the entire ice on period should be undertaken to determine the fish community composition in different parts of the lower Slave River drainage and over-wintering habitat of each species. Sampling would necessarily be limited to the gillnetting techniques used by local fishermen unless new methodologies could be developed.

RECOMMENDATION 12): Recognizing the seasonally dynamic nature of the Slave River fish community, geographic information system (GIS) analysis of relationship between probable point sources, fish distribution and contaminant concentrations in the fish over the seasonal cycle should be undertaken.

7.2.1.4 Distribution in side channels, tributaries and on floodplain

Studies to date (including the NRBS) have focussed on the main channel or the Delta of the Slave River. Much of the productivity, including fish production, must take place in still side channels, tributaries such as the Salt River, quiet backwaters and seasonally on the floodplain of the river. There is no information available on the fish distribution in these areas. Therefore, the importance of these areas to fish as habitat and the probability that fish might be exposed to contaminants while in these areas cannot be determined. The effects of hydrological changes on these areas must be considered, especially in the Delta, where the Bennett Dam effects may be or are ongoing.

RECOMMENDATION 13): A study to determine the fish species composition in tributaries , backwaters and side channels throughout the season should be undertaken in the lower Slave River.

RECOMMENDATION 14): A study of the distribution and activities of both juvenile and adult fish during the flood-pulse on the lower Slave River should be undertaken.

7.2.2 Movements

The seasonally dynamic community composition in the Slave River is a result of fish migrations to feeding, spawning, rearing or over-wintering habitat. Movements can be extensive or limited depending on the season and species.

The annual movement patterns of the adults of one of the most important harvested fishes, inconnu can now be described in detail. Inconnu spawn in the Slave River at sites near Fort Smith and near Cunningham Landing. The offspring apparently migrate directly to Great Slave Lake where they spend five or more years in the case of the males and seen or more years in the case of the females until they are mature. Once mature inconnu return to the Slave River to spawn, entering the river in the late summer and proceeding up-river to their spawning site. They aggregate at the spawning grounds for several days to weeks until spawning occurs, usually around the third week of October. After spawning the return to Great Slave Lake is rapid occurring over less than a week. Within the lake migrations are geographically extensive. The inconnu migrate in a large counter-clockwise gyre in the western basin of the lake bounded by the south and north shores, the Simpson Islands and the Mackenzie River outlet. In the spring the inconnu are located in the open water near the outlets and deltas of rivers on the south shore. After this they proceed along the shore to the Slave River. Therefore, inconnu have great potential to transport contaminants from the northern river basins area into Great Slave Lake. Similarly, they could also import contaminants into the lower Slave River from sources around Great Slave Lake. On the other hand, as adults they are the top predator among fishes and thus contaminant transfer would not be to the fish food chain but mainly to the next level of dogs and humans.

In contrast, burbot migrate little, apparently holding small feeding territories in the river or delta. In the winter they migrate downstream in the Slave to spawn in the Delta probably in January or February and return back up river prior to the spring.

Lake whitefish appear to follow a similar migratory pattern both seasonally and geographically to inconnu except that at least some of their juveniles may rear in the river and not migrate to the lake until they mature. As well, some lake whitefish may over-winter in the lower river.

Goldeye, flathead chub and walleye migrate to the river near the Fort Smith area during the spring to spawn then disperse into the river for the rest of the year. Adult walleye may leave the river after spawning. Juveniles and some adult walleye remain in the river during the open water season. Lake ciscos migrate into the Slave River delta in late fall to spawn and spend the rest of the year in Great Slave Lake. Given the reliance of ciscos on the Delta for reproduction changes there may effect them the most. Northern pike, probably move into the Slave and Salt rivers from the Slave River delta to spawn in the early spring prior to the completion of ice-out. Pike then re-distribute themselves along the Slave River and the delta for the rest of the year. The seasonal movement patterns of longnose and white sucker are uncertain as there has only been limited data collected.

Most importantly, no fish have been observed to migrate above the Rapids of the Drowned. Thus, the lower Slave River populations are isolated from the conspecific populations upstream except when a fish slips downriver through the rapids.

7.2.3 Probability of exposure to water quality changes due to distribution and movements

If the flow and water quality changes are transported from upstream then fishes undergoing critical phases of their life cycle near Rapids of the Drowned would be at greatest risk. Thus, lake whitefish and inconnu during spawning in the fall; pike, goldeye, flathead chub and walleye spawning in the spring near Fort Smith would most likely be exposed. However, if the change in water quality is strong enough to be transmitted from a great distance it is unlikely to attenuate at Rapids of the Drowned. Thus, species that rear or are resident in the Slave River Delta, or even Great Slave Lake since 85% of the water entering it comes from the Slave River, such as northern pike, lake whitefish, walleye, flathead chub, goldeye, burbot and longnose sucker would be most vulnerable.

RECOMMENDATION 15): There is nearly no data on winter movements of fishes (inconnu movements in Great Slave Lake during winter are known) in the Slave River and delta. While it is assumed that most species are relatively inactive at this time it is not confirmed and remains a gap in the knowledge base. A study of winter ecology, including floy tagging and radio-tracking experiments on the major species excepting inconnu and ciscos should be undertaken.

RECOMMENDATION 16): Other than inconnu and burbot there is only limited knowledge of the details of movement patterns of major species, such as northern pike, goldeye, lake whitefish, and walleye, in the lower Slave River. Radio-telemetry studies of these species' movement patterns throughout the year should be undertaken in order to determine their probability of exposure to contaminants and other effects of environmental degradation.

RECOMMENDATION 17): There is almost no knowledge of the movements of forage species such as trout-perch, emerald shiner, lake chub, and flathead chub. The movement patterns of these species may determine whether or not contaminants enter the fish food chain. Studies of movement patterns using floy tags and dye markers should be encouraged.

RECOMMENDATION 18): Juvenile movements in the river have not been investigated to date. Studies of the movements of juvenile fish should be undertaken.

RECOMMENDATION 19): If, when and how fishes migrate onto the floodplain of the lower Slave River has not been studied. Studies to determine the degree of flooding during the spring pulse and the movement patterns of fishes should be undertaken. This is a key recommendation given the present Bennett Dam and future hydrological impacts.

RECOMMENDATION 20): A simulation model of the probable movement patterns of all species of fishes to feed, spawn, rear and over-winter should be constructed as a reference for habitat managers. The model could be checked against available data and modified as new data becomes available in the future. This is also key relative to assessing impacts from obstructions, such as dams.

7.3 Food Web

All fishes in the lower Slave River are carnivorous and would be classified as predators by general models of large rivers. Those lower in the food web, such as suckers, goldeye, lake whitefish, flathead chub and shiners concentrated on invertebrate prey. The top predators, such as inconnu, northern pike, walleye and burbot ate exclusively fish. Three species played key roles in the food web. Pike consumed all other major species of fish present except inconnu. Of the fish species occupying the lower part of the food web, goldeye and lake whitefish consumed the widest variety of invertebrates. Of the invertebrate fauna the most important by far were the chironomids, followed by the corixids.

In the Slave River delta the food web again revolved around pike, goldeye and lake whitefish. Corixids and chironomids were about equal in importance to invertebrate feeders and often composed 60 to 80% of the diet.

Because all fish in the lower Slave River and Slave River delta are predatory they are all at risk of bio-accumulation of toxicants through the food chain. Clearly, the fish predator group, including inconnu, northern pike, walleye, and burbot are the most likely to concentrate contaminants to a high level.

RECOMMENDATION 21): The importance of invertebrates to the productivity of the fish community and as potential conduits of contaminants is obvious. Detailed studies of the ecology and habitat requirements of the invertebrate community, especially the chironomids and corixids, should be undertaken in the lower Slave River.

RECOMMENDATION 22): To determine the organisms most at risk a bio-energetic model of the food web should be constructed.

7.4 Priorization of Recommendations

While all recommendations, above, should be carried out I believe it reasonable to emphasize some of the key ones in order to help researchers and habitat managers on the question of 'Where to proceed next?'. The key recommendations fall into three categories: critical gaps in the database, quantitative model development and long-term monitoring. There are serious knowledge gaps in the understanding of invertebrate ecology, winter ecology of the aquatic biota and the biological importance of side channels and the annual flood-pulse which are addressed in recommendations 13, 15, 19 and 21. Models to make predictions and quantitatively understand processes are completely lacking and therefore additional key recommendations are 5, 20 and 22. Finally, for the fish community there should be a monitoring effort that is ongoing, consistent and long-term in order to detect future changes, such as suggested in recommendation 6.

7.8 Possible Successor Structures Considered

The Study Board considered a variety of possible ways that a successor organization could be structured to build on the foundation established by the NRBS. Seven different structures evolved from this consideration, representing a spectrum of choice. Other variations could be developed from these primary structures. The seven structures are:

1. Northern River Basins Management Board
2. Northern River Basins Environmental Board
3. Northern River Basins Advisory Board
4. *Mackenzie River Basin Master Agreement* and Board
5. Two-Tier Board Structure
6. Northern River Basins Stakeholder Council
7. Alberta Northern River Basins Branch

A commentary on each follows, including description, advantages and concerns identified by the Study Board.

Northern River Basins Management Board

Description

- ❒ An interjurisdictional Board appointed jointly by the Alberta, Northwest Territories and federal governments with mandate and power to research, monitor and regulate the environmental health of the aquatic ecosystems of the northern river basins
- ❒ Board members would be selected to represent a cross-section of the community, similar to the NRBS Board, but somewhat smaller in size, say, 10 or 12 members
- ❒ First Nations would participate on the Board
- ❒ Existing resources (funding, manpower, etc.) dedicated to these duties by the participating governments are to be seconded to the Board
- ❒ Board reports periodically to the sponsoring governments via a master agreement
- ❒ Enforcement responsibilities remain with the sponsoring governments
- ❒ Board periodically holds public information meetings and seeks public input to promote understanding, awareness and education on river basin environmental issues

(This Management Board is similar to the Prairie Provinces Water Board, and it is also like the 'management board' of the Two-Tiered Model, Alternative five, but with power assigned to it by participating governments)

Advantages

- ❒ Management of the environmental health of the aquatic ecosystems of the northern river basins is transferred from the individual governments to the Board
- ❒ Board concentrates its attention exclusively on the northern river basins as defined for NRBS
- ❒ Could incorporate the work of an Integrated Ecosystem Monitoring Committee (as recommended elsewhere by the NRBS Board)
- ❒ Scope could be expanded to include land use issues if governments so chose
- ❒ Is explicit in proposing whole ecosystem approach to managing the northern river basins
- ❒ Governments can define their own terms and extent of participation
- ❒ Some cost saving may result from elimination of any duplication that exists between the governments now, and could offset research and public communication costs not currently incurred

Concerns

- ❒ A risk of devolving into cross border flow problems only
- ❒ Assignment of powers from the governments to this Board may be politically unacceptable
- ❒ British Columbia and Saskatchewan have not participated in the NRBS; they may decline to participate in this agreement and agency.

NORTHERN RIVER BASINS ENVIRONMENTAL BOARD

Description

- An interjurisdictional Board appointed jointly by the Alberta, Northwest Territories and federal governments with mandate and power to direct the research and monitoring of the environmental health of the aquatic ecosystems of the northern river basins
- Empowered to advise the respective governments on regulation needed for ecological health of the northern river basins
- Board members would be selected to represent a cross-section of the community, similar to the NRBS Board, but somewhat smaller in size, say, 10 or 12 members
- First Nations would participate on the Board
- Existing resources (funding, manpower, etc.) dedicated to these duties by the participating governments remain with the respective governments, but are directed by the Board
- Board reports periodically to the sponsoring governments via a master agreement
- Enforcement responsibility remains with the sponsoring governments
- Board periodically holds public information meetings and seeks public input to promote understanding, awareness and education on river basin environmental issues

Advantages

- A cooperative means, among governments and stakeholders, to address and preserve the best monitoring of the river ecosystems
- Board is independent in its power to conduct research and to monitor conditions
- Board's ability to influence governments in regulatory matters would be a function of research and monitoring credibility
- Board concentrates its attention exclusively on the northern river basins as defined for NRBS
- Could incorporate the work of an Integrated Ecosystem Monitoring Committee (as recommended elsewhere by the NRBS Board)
- Potential for monitoring to go beyond the technical to include social values
- Scope could be expanded to include land use issues if governments so chose
- Some cost saving may result from elimination of any duplication that exists between the governments now, and could offset research and public communication costs not currently incurred
- Board may use its own staff to do or direct research and monitoring, or may contract the work out to government departments, universities and others qualified to do it

Concerns

- Board has no regulating power
- The government agendas are central and may dominate
- Risk that attention may focus on one jurisdiction to the exclusion or neglect of others
- British Columbia and Saskatchewan have not participated in the NRBS; they may decline to participate in this agreement and agency

NORTHERN RIVER BASINS ADVISORY BOARD

Description

- An interjurisdictional Board appointed jointly by the Alberta, Northwest Territories, British Columbia and federal governments to hold a watching brief on the environmental health of the aquatic ecosystems of the northern river basins, and advise the governments on policy and regulation affecting the river basins
- Board members would be selected to represent a cross-section of the community, including respected members of the public and scientific communities
- First Nations would participate on the Board
- Board conducts periodic public forums and workshops throughout the river basins to obtain public input and share information with the public
- Board has no power to act independently with regard to regulation or enforcement
- Existing government departments retain present responsibilities
- Funding for the Board is provided by the participating governments

Advantages

- Board's credibility with governments and in particular with the public, will depend on its perceived independence and the scientific and public authority with which it speaks
- Board concentrates its attention exclusively on the northern river basins as defined for NRBS
- Scope could be expanded to include land use issues if governments so chose
- An open forum for public vetting of environmental standards and practices has potential through influence to bring non government thinking to government policy and action
- The public venue could enhance pressure for government decisions to be more ecologically based and basin wide in consequence

Concerns

- Board is empowered only to generally monitor conditions and advise governments
- The Board will need public support and members of sufficiently known reputation and respect for its advice to be effective and receive insufficient attention
- Budget limitations would restrict the useful work of the Board
- British Columbia and Saskatchewan have not participated in the NRBS; they may decline to participate in this agreement and agency

MACKENZIE RIVER BASIN MASTER AGREEMENT AND BOARD

Description

- Assuming the agreement is signed, utilizes the structure and approach already developed by the Mackenzie River Basin Committee to manage the northern rivers within the overall Mackenzie River drainage system
- A bilateral Alberta - Northwest Territories transboundary agreement could follow from provisions in the Master Agreement
- Fully interjurisdictional
- Provides for maximum coordination and cooperation in addressing environmental and related issues of the entire river system

Advantages

- A whole drainage basin perspective is provided
- All jurisdictions have to be sensitive to the downstream users
- First Nations are participants
- Governments affected already have a positive attitude to this format

Concerns

- Issues of local importance may receive low priority when ranked against the entire river basin system
- Upstream users may feel little in common with users far downstream
- Would probably still require some degree of regional sub-organization to adequately address issues throughout the system
- Primarily a governmental organization designed to meet basin management needs, focusing on aquatic issues, without prescribed public participation
- Cost savings, if any, compared with current would likely be negligible
- The agreement process begun over a decade ago is still not final
- It is likely that the best results will have to wait for bilateral agreements between neighbouring jurisdictions

TWO-TIER BOARD STRUCTURE

Description

- An intergovernmental agreement establishing a Board to manage the river basin as a unit
- A second "Overseeing" Board, independent from the first but established within the same agreement, to monitor management of the river basin, track conditions and development in the river basins, and provide for public input

- ❐ Members of the management Board would represent government, scientists, First Nations and other residents
- ❐ Members of the independent Board would be selected to represent a cross-section of the community, including government, but with non-government elements dominant
- ❐ Both boards fully interjurisdictional
- ❐ Both boards could be nested within a signed Mackenzie River Committee Master Agreement
- ❐ Details described in Report No. 84

Advantages

- ❐ Separates administrative functions from overseeing functions
- ❐ Independent overseeing or "watchdog" board may build public confidence in how the basin management functions are carried out
- ❐ Overseeing Board can provide for wide range of public and First Nations participation
- ❐ Basin management Board can work with existing government resources / departments, act independently, or assume direct operation of those resources, as sponsoring governments prefer
- ❐ First Nations peoples could be involved in co-management agreements with the management Board
- ❐ Could encompass either the aquatic ecosystem only or the land and aquatic ecosystems, depending on government preference
- ❐ Fits well within existing Mackenzie Valley initiatives and thinking
- ❐ Follows directly in the spirit of NRBS and how it approached its mandate

Concerns

- ❐ Would probably require some time (a year or more?) to establish and place into operation
- ❐ The public participation may seem a bit too structured, and for some interest groups, weak in representation
- ❐ The two tiers may appear to be less efficient or more costly than a single board
- ❐ The boards have no authority except that which might be delegated; inter- and intrajurisdictional disputes would rely heavily on good will for resolution

NORTHERN RIVER BASINS STAKEHOLDER COUNCIL

Description

- ❐ An interjurisdictional stakeholder steering committee to organize a representative basin-wide council of delegates
- ❐ Periodic meetings of the council to receive status reports from government and industry, address environmental issues of the basins, and recommend policy and action to government and industry
- ❐ Periodic forums, workshops and other communication to promote public education and understanding regarding river basin environmental issues
- ❐ Community driven and funded, with delegates paying their own way, similar to a regional Chamber of Commerce in concept
- ❐ Details described in the Swanson proposal presented to the December 12 - 14 NRBS Board session (Hay River)

Advantages

- ❐ A fully independent vehicle for public input and participation, open to all interests and interest groups, able to define its own mission and strategies
- ❐ A fully "democratic" process
- ❐ Unencumbered by government thinking or processes able to offer recommendations, and would have the potential to mobilize public
- ❐ Opinion for political influence
- ❐ Could readily include First Nations involvement
- ❐ Intensity of issues would determine level of active support
- ❐ Operational funding could be through an innovative approach such as a regional water use levy, or through membership dues

Concerns

- No power to act
- Delegate self-funding may be a barrier to participation by some community sectors
- Ability to generate initiatives would depend on level of community or government funding that could be won
- Would government be prepared to pay costs of a secretariat / office? — perhaps $250,000 per year or about $1 per resident annually (excluding all delegate costs)
- Would enough residents and businesses agree to pay membership dues?
- The 'alliance' of participants is not stable, and subject to change according to rising or falling interests, successes or failures
- The agenda and control could gravitate towards narrowing foci of persevering special interests

ALBERTA NORTHERN RIVER BASINS BRANCH

Description

- Established by the Alberta government, a branch (probably within Alberta Environment) which would bring together in itself, all research, monitoring, regulatory and enforcement responsibilities of the Alberta government in all matters related to the northern river basins
- Designed to maximize coordination of Alberta's activities concerning the environmental health of the northern river basins aquatic ecosystems
- Could become the agency to effect cooperation with the governments of British Columbia, Saskatchewan, Northwest Territories and Canada for interjurisdictional northern river basins matters

Advantages

- Assumes that an interjurisdictional agency is not feasible, at least in the short-term, and that Alberta, as the "owner" of the largest portion of the northern river basins area wishes to coordinate its management of the basins in line with the NRBS recommendations
- Only the action of the government of Alberta is needed to begin this initiative; other government cooperation can be built later
- Could introduce some efficiencies or cost savings within the Alberta government service on northern water matters
- A large part of the 'problem areas' for the Northern Rivers lies within Alberta; this branch would address many if not most of the problems
- Would offer some fresh assurance to the public that the government is acting to coordinate the basins' aquatic environment management

Concerns

- Provides no obvious mechanism for First Nations involvement
- Any public involvement or consultation would be on the same basis as could be done by any government department
- Could be an administrative improvement, but represents little new initiative as an Alberta initiative, the costs would be entirely Alberta's, unless downstream benefits could be negotiated at a price
- The security of downstream locations with respect to changes coming to the northern rivers within Alberta would not be high
- The Alberta leadership of this initiative will have to be strong to persuade neighbouring governments to join a cooperative venture

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Glossary

acutely toxic: a substance that is toxic enough to cause severe biological harm or death within a short time, usually 96 hours or less

aesthetic: dealing with those aspects that are perceivable by the senses

aesthetic objective (AO): defined under the *Guidelines for Canadian Drinking Water Quality* as the highest recommended level of a particular substance in water that does not cause an objectional taste, smell, etc. to consumers

algae: a large group of mainly aquatic one-celled or multi-celled plants, lacking true stems, roots and leaves

alkyl benzenes: aromatic compounds associated with gasoline and runoff from roads

annual allowable cut: the volume of forest produce that may be harvested on an annual basis from a specified area in accordance with management regulations

anoxic: depleted of oxygen; anaerobic

aquifer: permeable rock capable of yielding groundwater to wells and springs

aromatic compounds: organic compounds incorporating a closed chain or ring nucleus in its structure

baseline data: information describing select characteristics of the existing environment, serving as a base against which future changes in the environment can be compared

basin plan: a systematic, orderly approach for managing the natural resources of a river basin

benthic invertebrates: spineless, insect-like organisms that live in the bottom sediments of lakes and rivers

benthos: the plant or animal life whose habitat is the bottom of a sea, lake or river

benzothiazoles: highly toxic compounds used chiefly as rubber softeners or as a dyestuff intermediates

bioaccumulation: a process by which substances are ingested and retained by organisms, either from the environment directly or through the consumption of food containing the chemicals

biochemical oxygen demand (BOD): the quantity of dissolved oxygen used in the breakdown of organic matter by bacteria and in the oxidation of minerals such as ferrous iron

biofilm: a thin layer of slime-like material made up of algae, fungi and bacteria

bioindicators: living organisms used to monitor changes in an ecosystem

biology: the study of life

biomagnification: a cumulative increase in the concentration of a persistent substance in successively higher levels of the food chain

biomarker: a physiological measure used to indicate a toxic event in an animal

bitumen: a general term for various tar-like solid and semi-solid hydrocarbons

bleached kraft pulp mill: an industrial plant that manufactures pulp from wood, using a process that relies on strong and highly alkaline chemicals to break down wood chips and whiten pulp; chlorine is often employed as a bleaching agent in this process

bloom: an unusually large number of organisms per unit of water, usually algae, made up of one or a few species

calibration: the adjustment or correction of a measuring device or mathematical model, so that the measurement of model output contains the least possible error when compared against a standard or known result

carcinogen: a cancer-causing substance

carnivore: any strictly flesh-eating organism; a secondary consumer in the food chain

cerebral palsy: a group of health-related syndromes that affect the motor control centres of the brain and are characterized by a form of paralysis manifested by spastic movements

chemithermomechanical pulp (CTMP) mill: an industrial plant that manufactures pulp from wood, using a process that combines heat, mild chemicals and mechanical action to break down wood chips into a soft pulp

chironomid: midge; an animal in the family chironomidae

chloracne: a disfiguring skin disease caused by exposure to certain chlorinated compounds

chlordane: a colourless, viscous and toxic liquid that is used as an insecticide

chlorinated resin acids: substances derived from wood to which chlorine is attached

chlorine dioxide: a chlorine-containing chemical increasingly used by pulp mills as a substitute for molecular chlorine to bleach pulp

chlorine substitution: in relation to pulp mill technology, the substitution of molecular chlorine with more environmentally sound equivalents to bleach wood pulp (e.g., chlorine dioxide)

chloroform: a simple organochlorine compound that may cause cancer and organ damage in high doses

chlorophenols: chlorinated organic compounds used predominantly in the production of dyes, and as herbicides or pesticides

cholera: a potentially fatal disease characterized by violent vomiting and diarrhea

chronic toxicity: toxicity marked by a long duration that produces an adverse effect on organisms; the end result can be death, although the usual effects are sublethal (e.g., inhibition of reproduction or growth)

co-management: management shared by more than one individual or party

commercial fishery: the catching of fish for sale and profit

congener: a compound having the same chemical formula as another compound, but a different molecular structure

congenital: a physical malformation or abnormality existing at or prior to birth, especially non-inherited defects and diseases that are environmental in origin

contaminant: any foreign or unwanted substance

conventional drinking water: water that has been purified by a drinking water treatment facility

conventional oil: also called petroleum or crude oil, a thick, greenish-brown mineral oil found in permeable rock formations of some areas

cumulative effects: the sum total of environmental impacts resulting from a number of individual developments

cyst: a bladder or bag-like structure that may contain the resting stage of an organism; a number of organisms (e.g., Giardia, tapeworms, etc.) form cysts as part of their lifecycle

database: a collection of information on a particular topic

delta: the body of sediment deposited at the mouth of a river

detection limit: the lowest concentration of a substance that can be measured with certainty by an analytical process

1,2 dichlorobenzene: a toxic and combustible liquid that can be produced as a by-product of water chlorination, but is also used for a variety of industrial purposes

DDE (dichlorodiphenyldichloroethylene): a breakdown product of DDT that is often found in eggs or the fat of animals that have been exposed to DDT (see also: DDT)

DDT (dichlorodiphenyltrichloroethane): a toxic insecticide that is now banned in many countries because it persists and accumulates in the living tissues of organisms, especially fish and birds

detrivores: organisms that consume refuse (or "detritus") such as dead plant material, feces and animal remains

dimethylsulphones: a group of compounds produced by the process of pulp digestion in bleached kraft mills

dioxins and furans: Popular names for two classes of chlorinated organic compounds, known as polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs); both dioxins and furans are formed either as by-products during some types of chemical production that involve chlorine and high temperatures or during combustion where a source of chlorine is present.

discharge: (1) the rate of flow in a stream or river, or (2) flow of effluent from a point source

disinfection: the destruction of disease-causing organisms through the application of specific agents (i.e., disinfectants) such as chlorine

dissolved oxygen: molecular oxygen that is in solution in a liquid

domestic fishery: the catching of fish for individual needs

downstream: away from the source of a stream (i.e., downriver)

drainage basin: the land surrounding a water body that contributes surface water to that body

drinking water treatment plant: a central facility for purifying drinking water

ecology: the study of the interaction among plants, animals and their environment

ecoregion: one part of an ecoprovince characterized by regional ecological interactions between the four major environmental components of the ecosystem: air, water, land and biota

ecosystem: the interaction between organisms, including humans, and their physical environment

ecosystem approach: an approach to ecosystem management that 1) emphasizes the need to collect and synthesize information on ecosystem structure and function; 2) recognizes that different levels within the ecosystem are interrelated and interdependent; and 3) necessitates management strategies that are ecological, anticipatory and ethical

ecosystem health / integrity: the adequate structure and functioning of an ecosystem, as described by scientific information and societal priorities

ecosystem indicators: a measure (e.g., physical, chemical, biological, sociological, etc.) that provides evidence as to the state of the ecosystem

effluent: a waste material (e.g., sewage or industrial discharges) discharged to the environment

environmental contamination: the introduction of any foreign or unwanted substance into the environment

Environmental Impact Assessment (EIA): appraisal of the likely effects of a proposed project, activity or policy on the environment, both positive and negative

epidemiology: a branch of medicine studying the incidence, distribution and control of diseases

erosion: the breakdown of rock into smaller particles and its removal by wind, water or ice

eutrophic waters: waters with a good supply of nutrients capable of supporting rich organic productions, such as algal blooms

eutrophication: the process whereby water bodies become biologically more productive due to an increased nutrient supply

***ex-situ*:** out of its original place, used to describe experiments that are not conducted in the field

far-field: further than 100 km from a point-source

fecal coliform bacteria: organisms associated with the intestines of warm-blooded animals that are used to indicate the presence of feces in water and the potential presence of disease-causing organisms

flood plain: lowland and relatively flat areas adjacent to a river channel, formed from sediments deposited by the river during floods

flow regulation: the control of natural water flow by means of water diversions, impoundments or withdrawals

flyway: a geographic migration pathway for birds, including breeding and wintering areas

food chain: a specific nutrient and energy pathway in ecosystems proceeding from producer to consumers; along the pathway, organisms in higher trophic levels gain energy and nutrients by consuming organisms at lower trophic levels

food web: the complex intermeshing of individual food chains in an ecosystem

Forest Management Agreement (FMA): in Alberta, an agreement between the government and a company regarding timber harvesting access, rights and obligations in a given area

frazil ice: a slushy mush of ice spikelets formed by freezing in turbulent waters

geomorphology: the physical shape and configuration of landforms

giardiasis ("beaver fever"): a waterborne intestinal disease caused by giardia, a flagellated protozoan; giardia is commonly found in feces-contaminated water

glacial till: unstratified, poorly sorted material deposited directly by ice; consisting of clay, silt, sand, gravel and boulders

gross pathology: pathology dealing with the "naked eye appearance" of diseased tissues and organs *(see also pathology)*

groundwater: water that occupies pores and crevices in rock and soil, below the surface and above a layer of impermeable material

Guidelines for Canadian Drinking Water Quality (GCDWQ): recommended limits on the levels of various physical, chemical, microbial and radiological parameters in drinking water, as established by the federal government for the protection of human health or other reasons

habitat: the environment in which a population or individual occurs, including the particular characteristics of that place (e.g., climate, food availability, etc.) that make it especially well-suited to that species

halogen: one of the family of chemical elements including fluorine, chlorine, bromine and iodine

halogenated hydrocarbon: one of a group of halogen derivatives of organic hydrogen and carbon-containing compounds

headwaters: the upper reaches of a drainage system

heavy metal: a metallic element of high atomic weight (e.g., gold, platinum and lead)

herbicide: a chemical used to destroy or deter plant growth

herbivores: strictly plant-eating animals; primary consumers in the food chain

home range: the general area of an organisms' normal activity

hydraulic: pertaining to fluids in motion, or to the power exerted by water conveyed through pipes or channels

hydrocarbons: chemical compounds composed only of hydrogen and carbon (e.g., fossil fuels are often referred to as hydrocarbon fuels)

hydrogen peroxide: a chemical compound with the formula H_2O_2, commonly used as an oxidizing or bleaching agent

hydrograph: a graph indicating the flow (discharge), stage (level), velocity, or other characteristics of flowing water at a given location over time

hydrology: the science of water, its properties, phenomena, laws and distribution

hypoxia: the failure of oxygen to gain access to, or to be utilized by the body

ice jam: an accumulation of broken river or sea ice caught in a narrow channel

inconnu: a game fish belonging to the family Salmonidae found in Alaska and northwest Canada

indicator species: an animal species used to indicate the presence or absence of any particular factor, such as heavy metals

inorganic: referring to a substance that is neither plant nor animal in origin

in-situ: in its original site or position, commonly used to describe "in the field"

instream flow needs: the quantity of water that must remain in a river or stream to either protect aquatic or riparian ecosystems or satisfy human activities

interim maximum acceptable concentration (IMAC): a temporary guideline prescribed under the *Guidelines for Canadian Drinking Water Quality* for those substances for which there is insufficient information to form a reliable maximum acceptable concentration (see also maximum acceptable concentration)

land drainage: the removal of water from wet or waterlogged land to render it suitable for cultivation, building development, etc.

leachate: a liquid that has filtered slowly through a solid and dissolved parts of the solid; also, leakage from a landfill site

lindane: a toxic pesticide that is now under restricted use in many countries

loading: a quantity of a particular chemical entering the environment, calculated over time (e.g., tonnes per month)

luvisolic soils: soil developed on a wide range of parent materials under mixed deciduous-coniferous forests in moderately well-drained to imperfectly drained sites

macroinvertebrate: invertebrate that can be seen with the naked eye

mainstem: the primary path of a river

maximum acceptable concentration (MAC): defined under the *Guidelines for Canadian Drinking Water Quality* as the highest concentration of a chemical that will not result in a significant risk to consumer health over a lifetime of consumption

mean: average of a series of values

median: value dividing a series into two equal parts: those of greater and those of lesser value

mercury: a liquid metallic element that may damage the nervous system if ingested or inhaled, and whose organic compounds are poisonous

metallothionein: a group of proteins that are produced when animals are exposed to heavy metals such as cadmium and mercury.

methylmercury: a toxic form of organic mercury often found in recently submerged areas

microorganism: a living organism that is too small to be seen with the naked eye

Ministers: in the context of this report and unless otherwise specified, "Ministers" refers specifically to the Ministers representing Environment Canada, Indian and Northern Affairs Canada, Alberta Environmental Protection and the Northwest Territories Department of Renewable Resources

mitigation measure: an activity that lessens or offsets an effect or impact

mixed function oxygenases (MFOs): a group of hormones found in the liver that serve as a natural defence against toxic compounds

monitoring: the process of checking, observing, or keeping track of something for a specified period of time or at specified intervals

municipality: a town, city or district having a charter of incorporation or possessing self-government

muskeg: wetland in boreal forests, typified by sphagnum moss which accumulates to form peat, and black spruce

mutagenic: causing heritable alteration of the genetic material within living cells

near-field: within 100 km of a point source discharge

nephelometric turbidity unit (NTU): a measure of the cloudiness of a solution

non-conventional drinking water: water that has not been processed by a drinking water treatment facility, but may be treated by alternative methods (e.g., boiling, filtering, etc.)

non-point source: a pollution source by which contaminants are discharged over a widespread area or from a number of small inputs rather than from distinct, identifiable sources

northern river basins: within the context of the Northern River Basins Study, the watershed, including all land and freshwater, within the confines of the combined drainage areas of the Peace, Athabasca and Slave Rivers

nutrients: chemicals necessary for the growth and reproduction of plants; the major plant nutrients include carbon, nitrogen and phosphorus

oil sands: a surface or near-surface sand or sandstone containing a high percentage of very viscous hydrocarbons

organic: describing material originating from living organisms, or chemicals based on carbon and hydrogen

organism: any living animal or plant

organochlorines: organic compounds containing chlorine

part per "X":
part per million (ppm):
one part in 1 000 000 parts
part per billion (ppb):
one part in 1 000 000 000 parts
part per trillion (ppt):
one part in 1 000 000 000 000 parts
part per quadrillion (ppq):
one part in 1 000 000 000 000 000 parts

pathogen: any disease-producing substance or microorganism

pathology: branch of medical science dealing with the essential nature of disease, especially the changes to the structure and function of tissues and organs

periphyton: algae living on rocks or sediments at the bottom of a river or lake

persistent toxic substances: substances that kill, injure or impair organisms, and endure a long time in the environment

pesticide: a chemical used to destroy, deter or mitigate unwanted plants or animals

pH: a measure of acidity; on a scale of 1 to 14, solutions with a pH less than 7 are acidic, those with a pH greater than 7 are basic, and those with a pH of 7 are neutral

photosynthesis: the synthesis of living cells of organic compounds from simple inorganic compounds using light energy

physiography: a general description of nature and natural phenomena

point-source: any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, landfill leachate collection system or vessel from which pollutants are discharged

pollution prevention: within the context of Board recommendations, the elimination or virtual elimination of the generation, use and discharge of persistent toxic substances that tend to accumulate in the environment

polychlorinated biphenyl (PCB): one of a group of chlorinated substances that are often linked to cancer, reproductive disorders and liver disfunction

polycyclic aromatic hydrocarbon (PAH): one of a class of hydrocarbon compounds containing more than one aromatic ring structure; e.g., naphthalene

predator: an animal that preys on others as a food source

productivity: the rate of organic matter production by organisms for maintenance; usually measured as the increase in growth or carbon content over a time interval

progradation: the outward advance of a shoreline resulting from the nearshore deposition of sediments by a river

radionuclide: a radioactive element contained in a radioactive compound

raw water: surface or groundwater that is available as a source of drinking water but has not received any treatment

reaeration: recharging of dissolved gases in water

reference site: an area used as a control in a scientific experiment

reservoir: an artificial lake created behind a dam for storing water or producing hydroelectric power

respiration: breathing; the use of oxygen to provide energy

riparian: related to, living in, or located on the bank of a river or lake

river reach: a relatively uniform section of a river

river stage: the level of the water surface

runoff: the portion of the total precipitation on an area that flows away into surface streams

salmonellosis: any infection caused by salmonella bacteria; usually manifested as food poisoning and causing severe diarrhea and cramping

sediment oxygen demand (SOD): the rate that dissolved oxygen from the water column is consumed by chemical and biological processes at or near the riverbed, such as respiration by benthic organisms, degradation of organic matter and chemical oxidation

sediment: material such as sand, silt and clay that is suspended in moving water but will settle to the bottom in still water

seismic lines: strips where the land surface has been bulldozed for the purpose of seismic exploration of petroleum reserves; survey crews travel along these strips to map the underlying geological structure by measuring return vibrations

sensory: of sensation or the senses

sewage treatment plant (STP): municipal or domestic treatment facilities where sewage undergoes a process to remove or alter its original bacterial content

shigellosis: also known as bacillary dysentery, acute diarrhea acquired by person-to-person contact usually through eating contaminant food or drinking contaminated water

silt: fine sediments deposited by water

snowmelt: water resulting from melting snow

snye: a side channel in a river or creek

solenetzic soils: moderately well-drained to imperfectly drained soils developed on saline parent material in cool sub-humid to sub-arid climates under grassland vegetation

species: a group of individuals that share certain identical physical characteristics and are capable of producing fertile offspring

spring freshet: the annual spring rise in the water level of streams in cold climates as a result of the influx of water from melting snow

stakeholder: any individual or group that affects, or is affected by, management decisions in a specific area

summerfallow: land left unsown, usually for a season, to conserve moisture in the soil and allow accumulation of nitrogen

surface water: water that remains at, or close to the land surface (e.g., a river)

suspended solids: small particles of solids distributed through water

terpenes: a class of hydrocarbons found especially in plant oils, resins or balsams

terrestrial ecosystem: an interactive relationship among all land plants and animals (including humans) and the non-living environment

terrestrial: land-based

2,3,7,8-TCDD (2,3,7,8-tetrachlordibenzo-*p*-dioxin): the most toxic form of a group of chlorinated organic compounds generally referred to as dioxins; chlorine bleaching of wood pulp is one source of this compound (see also: dioxins and furans)

2,3,7,8-TCDF (2,3,7,8-tetrachlorodibenzofuran): the most toxic form of a group of chlorinated organic compounds generally referred to as furans; chlorine bleaching of wood pulp is one source of this compound (see also: dioxins and furans)

thermomechanical pulp (TMP) mill: an industrial plant manufacturing pulp from wood that uses heat and mechanical action to break down wood chips into soft pulp

total dissolved solids: a measure of the concentration of solids dissolved in water

total nitrogen: the sum of all forms of nitrogen (both dissolved and particulate) in water

total phosphorus: the sum of all forms of phosphorus (both dissolved and particulate) in water

toxaphene: the generic name for chlorinated camphene; an amber, waxy solid with a mild odour of chlorine and camphor that is toxic by ingestion, inhalation and skin absorption; most uses of toxaphene are now banned

toxic: a substance or concentration of a substance that is harmful to a living organism

toxicology: the branch of medical science devoted to the study of poisons, including their mode of action, effects, detection and counter-measures

tributary: a stream that joins, feeds or flows into a lake or larger stream

trihalomethanes: a general term given to a group of substances that contain three halogens (chlorine, fluorine, bromine or iodine)

trophic level: functional classification of organisms in a community according to feeding relationships; the first trophic level includes green plants, the second level includes herbivores, and so on

turbidity: the cloudiness in a fluid caused by the presence of finely divided, suspended material

typhoid fever: an infectious fever characterized by an eruption of red spots on the chest and abdomen and severe intestinal irritation

upstream: towards the source of a river (i.e., upriver)

waterborne diseases: those transmitted by the ingestion of contaminated water whereby the infectious agent is passively carried in the water supply

watershed: the area that supplies water to a stream by surface or groundwater runoff

weir: a dam across a stream raising the level of water above it

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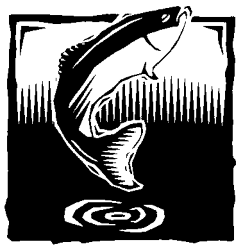

Units of Measure

1 tonne (metric tonne)= 10^6 g= 1000 kg
1 kg (kilogram)= 10^3 g= 1000 g
1 g (gram)= 1 g= 1000 mg
1 mg (milligram)= 10^{-3} g= 1000 μg
1 μg (microgram)= 10^{-6} g= 1000 ng
1 ng (nanogram)= 10^{-9} g= 1000 pg
1 pg (picogram)= 10^{-12} g= 1000 fg
1 fg (femtogram)= 10^{-15} g= 1000 ag
1 ag (attogram)= 10^{-16} g

Approximate Equivalents
1 part in 1 000 parts = 1 g/L= 1 g/kg= 10^{-3} g/g = 1 part per thousand
1 mg/L= 1 mg/kg= 10^{-6} g/g= 1 part per million
1 μg/L= 1 μg/kg= 10^{-9} g/g= 1 part per billion
1 ng/L= 1 ng/kg= 10^{-12} g/g= 1 part per trillion
1 pg/L= 1 pg/kg= 10^{-15} g/g= 1 part per quadrillion

1 L of water= 1 kg at 4°C
1 m^3 of water= 1000 L= approx. 1 tonne

Guide to Abbreviations

2,3,7,8-TCDD: 2,3,7,8-tetrachlordibenzo-*p*-dioxin

2,3,7,8-TCDF: 2,3,7,8-tetrochlorodibenzofuran

AlPac: Alberta-Pacific Forest Industries Inc.

AO: aesthetic objective

BCTMP: bleached chemithermomechanical pulp mill

BOD: biochemical oxygen demand

CASA: Clean Air Strategy Alliance

CCME: Canadian Council of Ministers of the Environment

DDE: dichlorodiphenyldichloroethane

DDT: dichlorodiphenyltrichloroethane

DO: dissolved oxygen

DOSTOC: Dissolved Oxygen Stocastic [Model]

EEM: Environmental Effects Monitoring

EIA: Environmental Impact Assessment

FMA: Forest Management Agreement

GCDWQ: *Guidelines for Canadian Drinking Water Quality*

IEMC: Integrated Ecosystem Monitoring Committee

IFNs: instream flow needs

IMACs: interim maximum acceptable concentrations

MAC: maximum acceptable concentrations

MFO: mixed function oxygenases

MRBBA: *Mackenzie River Basin Board Agreement*

NRBB: Northern River Basins Board

NRBS: Northern River Basins Study

NTU: nephelometric turbidity unit

PAD: Peace-Athabasca Delta

PAH: polycyclic aromatic hydrocarbon

PAPRICAN: Pulp and Paper Research Institute of Canada

PCB: polychlorinated biphenyl

SOD: sediment oxygen demand

STP: sewage treatment plant

TMP: thermomechanical pulp mill

TN: total nitrogen

TP: total phosphorus

WASP: Water Quality Analysis Simulation Program

The Northern River Basins Study

was established to examine the relationship between industrial, municipal, agricultural and other development and the Peace, Athabasca and Slave river basins.

Over four and one-half years, the Study contracted approximately 150 research projects under eight categories including contaminants, drinking water, nutrients, traditional knowledge, hydrology / hydraulics, synthesis and modelling, food chain and other river uses. The results of these projects, and other work and analyses conducted by the Study are provided in a series of synthesis reports.

This Report to The Ministers

summarizes the main scientific findings of the Northern River Basins Study and outlines the Study Board's recommendations to the Ministers.

Project reports, synthesis reports, the Final Report and other NRBS documents are available to the public and other interested parties.

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