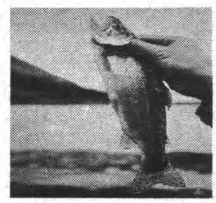
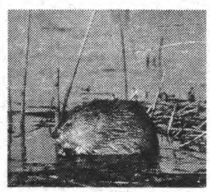
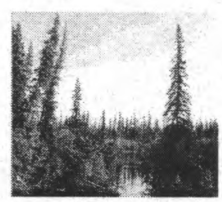
Canada Alberta Northwest Territories

Northern River Basins Study



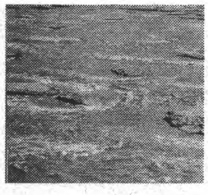


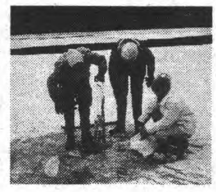




NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 65

THE POTENTIAL EFFECTS OF CLIMATE CHANGE IN THE PEACE, ATHABASCA AND SLAVE RIVER BASINS: A DISCUSSION PAPER







DATE DUE

Prepared for the
Northern River Basins Study
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by

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. 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.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
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F. J. Wrona — 16 Jan 96
(Dr. Fred J. Wrona, Science Director) (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P. Larkin — Jan 8/96
(Dr. P. A. Larkin, Ph.D., Chair) (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Lucille Partington — Jan. 11/96
(Lucille Partington, Co-chair) (Date)

Robert McLeod — 11/01/96
(Robert McLeod, Co-chair) (Date)

THE POTENTIAL EFFECTS OF CLIMATE CHANGE IN THE PEACE, ATHABASCA AND SLAVE RIVER BASINS: A DISCUSSION PAPER

STUDY PERSPECTIVE

In recent time there has been increasing discussion over the probable effects of climate change on the environment, particularly in northern latitudes. The Peace, Athabasca and Slave rivers are subbasins of the Mackenzie River Basin and any significant climatic change will have implications on how these areas are managed. Researchers had determined that the Mackenzie basin has experienced a warming trend of 1°C this century and there was some evidence to suggest it was having an affect on lakes and permafrost. Projected scenarios revealed the possibility of a further 4 - 5°C change by the middle of the 21st century. In 1990 Environment Canada initiated an integrated regional assessments of climate change scenarios. The Mackenzie Basin Impact Study (MBIS) set out to determine the potential impacts of climate change scenarios on the water, land and people of the Mackenzie Basin.

Related Study Questions

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.*

At the onset of the Northern River Basins Study (NRBS), the Study Board expressed interest in larger basin issues affecting the aquatic environments of the Peace, Athabasca and Slave rivers. Climate was one of these areas and the Board's independent scientific advisory committee endorsed the need for some background material to be prepared to address the subject. The leader of MBIS was invited to prepare a paper for NRBS that would outline the findings of MBIS and its application to the Study area.

This discussion document provides an overview of preliminary MBIS findings and an assessment of likely challenges to be confronted by residents, researchers and managers in the years to come. Preliminary assessments of continued warming illustrate a mixed response that includes: longer growing season, greater productivity for forestry, longer ice-free season, reduced energy demand, longer tourist season, reduced cold weather stress on infrastructure, increased erosion due to permafrost thaw, increased frequency and severity of forest fires, extension of pest ranges, altered use of the land for subsistence hunting and trapping, changes in the modes of winter transportation, changes in the composition and structure of fish and wildlife habitats.

Information from this paper will be used to assist in the preparation of a report assessing the effects arising from current and projected development and how these may be accentuated or attenuated by various factors, one of them being climate change.

As acknowledged by the author, climate is a complex agent of change. It presents unique challenges to researchers to explain cause and effect relationships and there is considerable diversity of opinion on the relative significance of various findings and their association with climate change. This discussion paper is written in a style that lends itself to a general exploration of the subject material. For this reason, the Science Advisory Committee cautions readers to the fact that this document reflects the considered views of one respected researcher describing the preliminary assessments of a study coming to completion. Additional sources of information should be sought by a reader to gain a perspective on the issue of climate change.

REPORT SUMMARY

The Intergovernmental Panel on Climate Change (IPCC) has concluded that increased concentrations of carbon dioxide and other trace gases will lead to a warming of the world's climate. The Mackenzie Basin, including the Peace, Athabasca and Slave subbasins, has experienced a warming trend of 1C this century, and there is anecdotal evidence that this has already led to permafrost thaw and lower lake levels in some areas. This does not mean that the "signal" of human-induced warming has been detected, but it does demonstrate that the Mackenzie region is sensitive to current climate variation. Scenarios of climate change, based on outputs from General Circulation Models (GCM) of the atmosphere, indicate that this region would warm by 4 to 5 C by the middle of the 21st century. What impacts would result from these scenarios?

The objective of the Mackenzie Basin Impact Study (MBIS) is to produce an integrated regional assessment of climate change scenarios for the entire watershed, including terrestrial and freshwater ecosystems and the communities that depend on them. Preliminary results are available from some of the research activities contributed to the MBIS exercise. Of relevance to the Northern River Basins Study (NRBS) area are the following climate change scenario effects: a) runoff is projected to decline slightly, with an earlier spring peak, b) levels in Great Slave Lake are projected to decline during the winter months, c) ice on the Peace River is projected to form later in the fall, break up sooner in the spring, and its upstream advance could be reduced by more than 200 km, d) peatlands are projected to disappear from most of the area, though the rate and timing of change has not yet been determined, e) forest fire frequency and severity is projected to increase, and this could affect some wildlife species, and f) caribou could be affected by projected increases in summer temperatures accompanied by increased insect harassment.

These and other possible changes here and in downstream areas (including increased permafrost thaw and accompanying landslides in some places) may be outside the limits of historical experience, and so may have implications for various resource management policies, plans, and agreements. Identification of these implications will require consultation with the region's stakeholders. With

that in mind, the MBIS Final Workshop, planned for May 1996, is expected to include a series of round table discussions on various issues, including interjurisdictional water management, ecosystem sustainability, and sustainability of traditional native lifestyles.

ACKNOWLEDGMENTS

My thanks to the many individuals from all over Canada who have contributed to the MBIS. Any opinions expressed in this paper are my own, and not necessarily those of Environment Canada.

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1.0 CLIMATE CHANGE: A GLOBAL PROBLEM WITH REGIONAL IMPLICATIONS

If one was to sit on an ocean beach and watch the tide advance and retreat day after day, it would be easy to accept the proposition that this and other natural cycles will always be a powerful influence on planet earth, and that humans could not possibly alter or disrupt them. During our years and decades of life, each of us has experienced or heard about floods, heat waves, severe winters and other extreme events, and then everything returns to normal, so it is logical to assume that extremes may come and go, but climate itself is stable. When looking back at centuries and millennia of earth's history, with its many Ice Ages and warm periods, why shouldn't we embrace the hypothesis that climate change has happened before and will happen again regardless of what societies do? According to conventional wisdom, even if climate change happens again, this would develop very slowly, and we have a few more centuries before we have to worry about the next episode.

Against this background of widespread acceptance of climate stability, scientists have been suggesting that humans can affect climate patterns, through industrial activities, intensive agriculture, deforestation and transportation. Emissions of carbon dioxide, nitrous oxide, methane and other trace gases, combined with land use changes that reduce their absorption, have led to increases in atmospheric concentrations of these gases. The recipe of our air is being altered by 5.5 billion cooks, most of them not realizing that they are part of the kitchen staff.

After a series of scientific publications and meetings on the issue of "global warming," governments and international bodies, including the United Nations, agreed to consider this problem at the 1992 Earth Summit. One of the Summit's products, the UN Framework Convention on Climate Change (UNFCCC), is now a part of international law, committing more than 120 nations to action. Its ultimate objective is to stabilize global concentrations of carbon dioxide and other 'greenhouse gases' at a level that does not represent 'dangerous anthropogenic interference' to the atmosphere. At issue, however, is the definition of the term 'dangerous'.

This is an important challenge for climate impact assessment at the regional scale. Global scale atmospheric anomalies, such as El Niño-Southern Oscillation (ENSO), are known to produce region-specific impacts (e.g. Glantz et al., 1987). The same thing is likely to happen with an enhanced greenhouse effect.

There is an international effort underway, through the UN's Intergovernmental Panel on Climate Change (IPCC), to assess potential mitigation options, including carbon taxes and joint implementation measures (IPCC, 1995). The IPCC Second Assessment Report is due to be released in late 1995 or early 1996. This work, and the political negotiations that are also taking place, will take time to complete. Even if mitigation options were to be implemented quickly, some climate change impacts could still occur. What might these impacts be and what might (or should?) be the nature of the adaptive responses?

Regional impact assessment is a complex multidisciplinary research challenge. To make matters even more difficult, we are considering an assessment not of an observed climatic event (such as the 1994 and 1995 forest fire episodes in the Northwest Territories) but of a theoretical warming of the earth's climate by increased concentrations of greenhouse gases. There are many uncertainties associated with the data and methods used to construct scenarios of a future warmer world, and some have argued for the use of analogues (Glantz, 1988; Kearney, 1994) as an alternative to scenarios based on climate model simulations, population projections, and other forecasting tools. There is little doubt, however, that if climate warming occurs, the earth and its people will feel its effects through a variety of "pathways" and "filters," including land and water resources, and the impact assessment needs to account for these.

What makes this concern even more urgent is the recent conclusion by the IPCC that recent climatic trends cannot be ascribed completely to "natural" forces (IPCC Second Assessment Report, in preparation). The human influence on the earth's climate is being felt now.

In 1990, Environment Canada began organizing integrated regional assessments of climate change scenarios. One of these is the Mackenzie Basin Impact Study (MBIS). Its purpose is to determine the potential impacts of scenarios of climate change on the water, land, and people of the Mackenzie Basin. The objective of this paper is to provide a brief overview of the MBIS and to summarize results that may be of interest to the Northern River Basin Study.

1.1 WHAT IS INTEGRATION?

In order to capture the complex linkages between climate and regions, a research framework is needed which effectively combines information about individual sectors so that the result is more than the sum of the parts. The IPCC defines integrated assessment as "the most comprehensive treatment of the interactions of climate and society" (Carter et al., 1994). It addresses the "net" effect of climate-related stress, so that the indirect linkages between atmosphere, land and water resources, resource management and other policy matters, can be considered in a way that can be understood by decision makers. This would reduce the risk that implementation of strategies or policies would assist one group or sector at the expense or detriment of others. Working at the regional scale is important because at larger scales, impacts may offset each other, and the final result may hide critical details (e.g. Rosenzweig and Parry, 1993).

There are two main approaches to integrated assessment: a) computer-based models, including integrated assessment models (IPCC, in press), and b) joint scientist-stakeholder assessments of policy instruments. Although there are few examples of the latter, collaborative efforts at examining policy instruments (e.g. development plans, conservation plans (e.g. Inuvik, 1993)), or regulatory bodies such as river authorities (e.g. Arnell et al., 1994) provide important opportunities to bring a global issue, such as climate change, to the regional level. Rather than relying on only one approach, a regional study could make use of several integrating techniques if they provide unique and complementary assessments. This could be called the "family of integrators" approach.

It is suggested that an integrated assessment should not rely exclusively on integrated assessment models, since most of these do not necessarily involve the stakeholder, nor make direct use of the stakeholder's perception of the climate change issue. This perception is not based solely on whether a climate change has been noticed, but on whether any observed or simulated changes in the landscape or economic production can be linked to observations or simulations (scenarios) of climate change. Stakeholders can be an important source of "ground truth," and that is the frame of reference they would use when considering responses to future scenarios of climate change (e.g. Aharonian, 1994; Bielawski, 1994; Lonergan et al., 1995).

1.2 THE NEED FOR CLIMATE IMPACT ASSESSMENTS OF WATERSHEDS

In order to attract the breadth of expertise and interests needed for an integrated assessment with stakeholder collaboration, some common ground must be laid out. Watersheds may provide an appropriate setting for producing an integrated regional assessment of climate change scenarios.

The regional/watershed focus can be used to attract scientific expertise and diverse stakeholders with local knowledge. The common ground for all of them is an interest in the future of a place, with water serving as an important link. Within this setting, the Northern River Basins Study (NRBS) stands as an example of a scientists-stakeholders collaboration that is designed to generate information about a potential environmental problem. The MBIS is similar, except that instead of being driven by concerns about the impacts of upstream industrial developments, the focus is on future scenarios of increasing temperatures accompanied by changing precipitation patterns.

There are precedents for pursuing watershed-based assessments of future climate change, such as case studies of the North American Great Lakes (Smith and Tirpak, 1990; Mortsch et al., 1993) and a series of international basin studies including the Nile, Indus and Zambezi (Strzepek and Smith, 1995). Arnell et al. (1994) provide a case that focuses on a water management authority in the United Kingdom.

It is expected that climate warming would lead to an acceleration of the water cycle, with increased throughputs along the pathways linking atmosphere, ocean, landscape, freshwater bodies, and society (Falkenmark, 1991). Climate warming may impose its most significant effects on water sensitive sectors, through changes in a) the frequency and severity of extreme events (floods, drought, etc.), b) timing of seasonal and annual events (e.g. spring runoff peak, autumn/winter low flow, ice formation and break up, etc.), c) thresholds and ranges (e.g. maximum summer water temperatures), and d) land cover (e.g. erosion, fire, etc.).

Riverine hydrological systems will exhibit basin-specific adjustments to global climatic changes. Most warming scenarios tend to show increases in precipitation, but this does not necessarily mean wetter land surfaces or more soil moisture. Gleick (1993) concludes that if the future climate will not look like the past, there will be an increase in the overall uncertainty associated with water management and supply. In the NRBS context, this would also include in-stream flow requirements for maintaining freshwater ecosystems.

Understanding impacts is a necessary prerequisite for determining the kind of measures that could promote both mitigation strategies to limit greenhouse gas emissions, and adaptation strategies to reduce vulnerabilities to environmental stresses. Assessing adaptation options requires a greater understanding of how individuals, companies and governments currently operate when faced with environmental stresses (Smit, 1993).

2.0 DESCRIPTION OF MBIS ACTIVITIES

The MBIS is in the final phase of its six-year mandate to assess the potential regional implications of global climatic change (Cohen, 1993, 1994). The program includes studies on water resources, permafrost, vegetation, wildlife, economic activities, resource-based and subsistence-based communities, and applications of remote sensing and geographic information systems (GIS). Attention is also given to the challenges of producing an integrated assessment, and to incorporating traditional ecological knowledge into the MBIS. Since the focus is on impacts, MBIS is dependent on other sources for baseline information on climate, water, land and vegetation. Climate change scenarios have been delivered from GCM outputs and other sources available in 1990-1992.

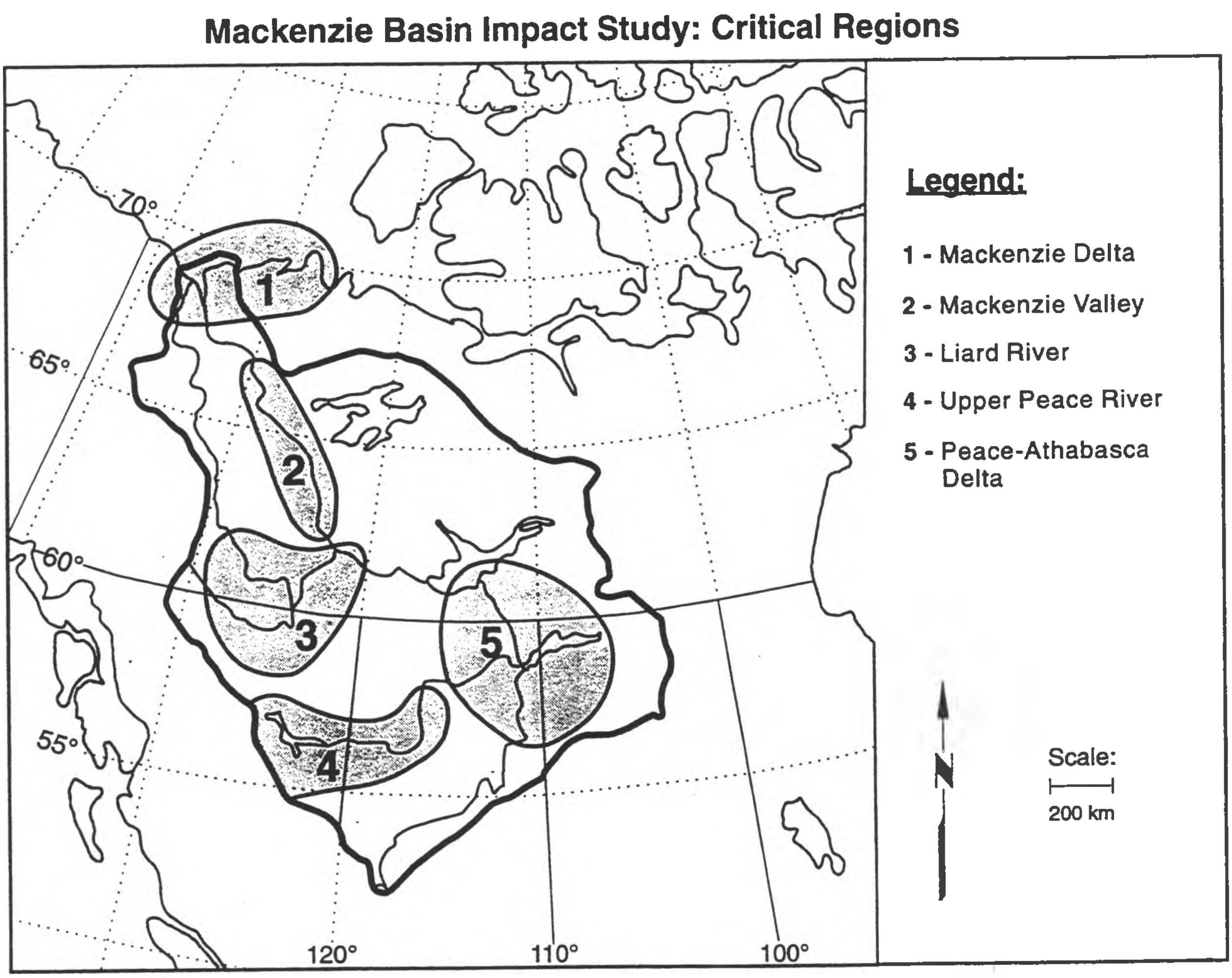
2.1 SETTING

This region was chosen because it is a major high latitude watershed, 1.7 million km^2 in area, with many climate-sensitive landscapes and transition zones: tree lines (Arctic, montane, aspen parkland), discontinuous permafrost, wetlands and deltas, the edge of multiyear sea ice, and the northern limits of commercial forestry and agriculture. Freshwater and terrestrial migratory wildlife might be sensitive to climate-induced changes in the landscape.

The study area is defined by the watershed boundary of the Mackenzie River and its tributaries, plus the southern Beaufort Sea and coastal zone north and east of the Mackenzie Delta. The large size precludes detailed study of all areas, though there are some activities that are conducted on the Basin scale. For the MBIS to achieve its objective, however, the range of impact-related policy questions are limited to the following: a) interjurisdictional water management, b) sustainability of native (aboriginal) lifestyles, c) economic development opportunities, d) maintenance of infrastructure, and e) sustainability of ecosystems.

Additional focus has been provided by defining critical regions within the study area (Figure 1). Each of these represent potential flash points due to the intersection of potential biophysical changes with human activities. For example, the Upper Peace River region includes a major hydroelectric facility (Bennett Dam), agriculture, expanding forestry operations and communities with a history of flooding. The operation of the dam has led to concerns about the viability of the freshwater wetlands and delta, and consequently, the wildlife and subsistence-based communities in the Peace-Athabasca Delta region, located downstream. How would a scenario of climate warming affect dam operations, water levels at the Delta, fisheries, migrating waterfowl, agriculture and forestry operations? Would resource-based and native communities experience the same impacts, or would climate change be felt in different ways depending on lifestyle (wage economy, subsistence/non-wage economy)?

Figure 1: Five critical regions within the MBIS. Source: modified from Cohen (1993).



2.2 OBJECTIVE

If climate warming occurs, governments and their constituents will need advice on how to adapt to the new climate. Since decision making occurs in an environment where different stakeholders compete for resources, any response options will have to account for tradeoffs between these various interests. Land and water use patterns today represent the result of historic and current compromises between these various interests, combined with knowledge gained from research and personal experience. At the scale of most current GCM-based impact assessments (e.g. grid sizes larger than 2° latitude x 2° longitude), land in a grid cell is not necessarily assigned to a single optimal use today, so it is unlikely that this would be different in the future. The assessment, therefore, should not restrict itself to changes in physical capability to support a particular activity (e.g. crop production).

The objective of MBIS is to provide an integrated regional assessment of scenarios of climate warming for regional stakeholders and the scientific community. As a high latitude watershed, the Mackenzie Basin has been seen as an area that might benefit in certain ways by a warmer climate. These include a) longer growing season for agriculture, b) greater productivity for forestry, c) longer ice-free season for navigation, d) reduced energy demand for space heating, e) longer summer tourist season, and f) reduced cold weather stress on infrastructure. Taken individually, economic impacts could be quantified, and these might show substantial benefits for the region. Other factors need to be considered, however, and some of these may constrain the potential benefits. This list includes: a) current use of land for subsistence hunting and trapping, b) current system of land transportation, much of which is based on a stable ice and snow cover for winter roads, c) current ranges and habitats of wildlife, which underpin conservation plans and native land claims, and d) scientific uncertainty which hampers anticipatory responses to projected beneficial conditions.

Potential negative impacts of climate warming must also be considered, because they may offset possible benefits. Examples are: a) increased erosion due to permafrost thaw, b) increased frequency and severity of forest fires, c) extension of mid-latitude pests and diseases into high latitudes, and d) reduction of habitat suitable for cold climate species of vegetation and wildlife, including freshwater fisheries.

2.3 STUDY FRAMEWORK

MBIS is attempting to produce an integrated regional assessment of global warming scenarios, as a way of identifying the indirect linkages between climate and regional policy concerns, such as land and water management. Several exercises are being tried, including 1) resource accounting with input-output modelling, 2) land assessment (including goal programming and multi objective program modelling), 3) review of water resources policy instruments and their sensitivity to hydrologic changes, and 4) study of settlement patterns and their sensitivity to landscape changes. Each of these utilize the outputs of various individual studies in order to address some of the human dimensions of climatic change (Cohen, 1993, 1994).

All of these approaches are being tried because there is no consensus on which method is best for producing an integrated study. System models (1 and 2 above) provide a closed integrated model or set of linked models that describe particular components of the system, but it may be difficult to fulfill the often substantial data requirements. Analyses based on planning/management instruments (3 and 4 above) consist of a mixture of models and expert judgment. These instruments (e.g. plans, policies, regulations, indices) represent the integration of scientific information and stakeholders' preferences, and their performance under climate change scenarios would provide an important measure of impact. The challenge here is to attract stakeholder participation to the study.

3.0 PRELIMINARY RESULTS

One theme that has clearly emerged in the MBIS is that climate is a complex agent of change. Although scientific and political discussions have tended to focus on atmospheric change, the land and its people will likely experience climate warming through changes in streamflow, water levels, ice and snow cover, permafrost, plant growth, wildlife patterns, fire, pests and diseases. Some changes may occur gradually while others may come in the form of large steps or new extremes.

The linkage between changes in air temperature and regional socio-economic concerns is largely through these landscape 'filters.' Biophysical changes are what people will notice before they pay attention to climate statistics. Has the winter road season changed? Is anything new with the caribou migration? Are current fire management strategies still working satisfactorily? What is the status of permafrost along the Mackenzie Valley and the Beaufort coastal zone?

Some preliminary indications of landscape and socioeconomic impacts for the scenarios being assessed by MBIS are shown in Tables 1 and 2, respectively. Many MBIS activities are not yet at the stage where scenario results can be reported, but some information is available. Scenarios of a doubling of carbon dioxide concentrations (radiative equivalent) in the atmosphere, obtained from GCM outputs, indicated a warming of 4°C to 5°C. An analogue scenario, based on proxy and instrumental data (the "composite analogue") indicated a warming of 3°C.

Runoff for the Basin was obtained using a square grid model (Soulis et al., 1994), and for the Williston subbasin with the UBC Watershed Model (Chin and Assaf, 1994). Although increased runoff was anticipated (e.g. see Miller and Russell, 1992), this does not appear to be the case for the GCM-based scenarios (Canadian Climate Centre or CCC, Geophysical Fluid Dynamics Lab or GFDL (R30 version)) for the Basin as a whole. Only the composite analogue scenario shows an increase. Newton (1994) has therefore concluded that scenario spring flood risks for vulnerable communities may not be that different from current climatic conditions. It may be that a more significant problem could be lower water levels during fall and winter (Kerr and Loewen, 1995), which could affect fisheries and reduce the probability of spring flooding in wetlands and deltas.

What is not clear as yet is the implication of hydrologic and landscape changes on water management agreements currently being negotiated by various governments (Felton, 1994). Peace River ice cover, for example, will be affected by both temperature changes and changes in outflow from the Bennett

Dam at Williston subbasin (Andres, 1994; Andres and van der Vinne, 1995). This may not be the final word on runoff impacts, since the Global Energy and Water Cycle Experiment (GEWEX) is pursuing a research program in the Mackenzie (Lawford, 1994).

It would appear that the other main threats to the Mackenzie landscape are a) accelerated erosion caused by permafrost thaw, especially in sloping terrain and the Beaufort Sea coastal zone (Aylsworth and Egginton, 1994; Solomon, 1994), b) increased fire hazard (Kadonaga, 1994), c) change in climate conditions that influence the development of peatlands, leading to reductions in Alberta and Saskatchewan, and expansion in the lower Mackenzie (Nicholson et al., 1994; Gignac et al., in preparation), and d) invasion of new pests and diseases from warmer regions (Sieben et al., 1994). These landscape impacts could lead to changes in plant succession (Wein et al., 1994), thereby affecting wildlife habitat and subsistence activities of native communities. Additional information on ecosystem impacts should become available for the MBIS Final Report in late 1996.

Table 1: MBIS Preliminary Summary of Landscape Impacts of Climate Warming Scenarios

PARAMETER	DETAILED IMPACTS
Permafrost thaw occurs, but rate of change varies with site	- thaw would occur primarily in discontinuous zone - seasonal active layer would increase - rate of thaw in wetland areas would lag behind other sites - slopes and Beaufort Sea coastal zone may experience accelerated erosion.
Water Supply changes slightly, with earlier spring peak	- annual Basin runoff changes -7% to -3% in GCM-based scenarios, +7% in composite analogue scenario - increased precipitation offset by increased evapotranspiration in many subbasins - spring snowmelt peak begins up to one month earlier - longer snowmelt season, lower peak in some subbasins (including Williston, upstream of Bennett Dam) - lower levels during November to March at Great Slave and Great Bear Lakes
Peace River Ice Cover reduced in duration and extent	- ice cover reduced by up to four weeks - upstream progression of ice reduced by up to 200 km - runoff reduction (or reduction of discharge from Bennett Dam) would offset effects of temperature increase on ice cover
Soil Capability for Agriculture increases	- increase in availability of marginal and suitable land for spring seeded small grains and forages due to longer growing season and frost free period - decrease in soil moisture supply
Pine Weevil Hazard increases	- increase in temperature-based pine weevil hazard index - low elevation sites particularly vulnerable - non-temperature factors not yet included
Peatlands' locations shift	- loss of sites in Alberta and Saskatchewan - new sites develop in lower Mackenzie, south of Mackenzie Delta - rate of change has not yet been determined
Fire Weather Index increases	- median index for four GCM-based scenarios corresponds to change of -15% to +81% in burned area

Summarized from Cohen (1993, 1994). Water level impacts obtained from Kerr and Loewen (1995). Additional information on Peace River ice obtained from Andres and van der Vinne (1995). Peatlands' impacts obtained from Gignac et al. (in preparation).

Table 2: MBIS Preliminary Summary of Socio-Economic Impacts of Climate Warming Scenarios

SECTOR/LOCATION	DETAILED IMPACTS
Tourism/Nahanni National Park would experience mixed impacts	- little impact from projected minor changes in streamflow - extended season for water-based recreation would provide economic benefits to communities near the Park - increased Fire Weather Index (fire frequency and severity) could affect runoff, landscape character, visitor safety
Community Vision of Impacts depends on vision of lifestyle	- response to flood hazard varies by community, according to the interplay of individual, community and government responses - significance of landscape impacts depends on whether community maintains subsistence lifestyle, or switches to wage economy - a case study of Wrigley, NWT concludes that if climate change encourages expanded development of oil and gas, economic impacts would be small, but positive, unless workers are forced to relocate to obtain employment.

Summarized from Cohen (1994). Results from Wrigley case study obtained from Lonergan et al. (1995).

First-order and second-order impacts eventually lead to others which are considerably more difficult to address. Will land claims or water resources agreements be affected? Would it be appropriate to artificially maintain historic water levels within this scenario of climate change? Could there be new conflicts over land use, especially if agriculture expands northward to take advantage of improved soil capability to support crop production (Brklacich and Curran, 1994)? What might be the effects on parks and other protected areas (Pollard and Benton, 1994)? Could climate change affect the economics of oil and gas production in the Beaufort Sea (Anderson et al., 1994)?

Expressing socio-economic impacts in monetary terms is going to be difficult, but it should be possible to do so for agriculture, forestry, energy, and some aspects of tourism. In the case of Nahanni Park located in the Liard subbasin (see Figure 1), water-based recreation is expected to benefit from the longer summer, but this could be offset by the threat of increased fire (Staple and Wall, 1994). There is no assessment, yet, on the potential costs of increased fire or fire protection.

Community impacts could be quantified, but the effects of climate warming scenarios may vary depending on whether a traditional aboriginal lifestyle of hunting and trapping is maintained, or a shift to greater reliance on the wage economy occurs. Aharonian's (1994) case study of Aklavik, in the Mackenzie Delta region (see Figure 1), shows that residents can provide detailed visions of both "futures." In their view, community vulnerability to climate warming scenarios will change if their lifestyles change. This may parallel circumstances that could be experienced in some developing countries during the next several decades.

Another aspect is illustrated by a case study from Wrigley, in the Mackenzie Valley region (Figure 1), which suggests that lifestyle changes, within the context of "Two Economies," could be affected by climate change. In this case study, a warmer climate is assumed to encourage oil and gas development. The effect of this scenario on communities could be positive, unless people are forced to relocate to obtain employment. Other forces, particularly in regards to land claims issues, may have far greater impacts than a scenario of fossil fuel industry expansion (Lonergan et al., 1995).

The integration component is currently focused on data collection. One activity is on the development of a resource accounting framework, including a Mackenzie Basin input-output model. This has been used to determine impacts of changes in energy (oil and gas) production on the region's employment and economic productivity (Lonergan, 1994; Lonergan et al., 1995). A second modelling exercise is the integrated land assessment framework or ILAF. Its purpose is to compare changes in land capability with stakeholders' goals in order to identify possible land use conflicts in a climate warming scenario (Yin and Cohen, 1993, 1994). Potential expansion of commercial agriculture and forestry could create a conflict with existing subsistence activities, so there is a need to determine whether this is possible within the scenarios. Additional activities in multi objective programming (Huang et al., 1994) will complement ongoing MBIS studies in agriculture, freshwater fisheries, forestry, energy, tourism and community development (Cohen, 1994).

Impacts and responses will not be felt by individual sectors in an isolated manner. A unit of land (at a scale comparable to GCM output) is not likely to end up becoming exclusively devoted to one kind of land cover or use. This set of research activities will hopefully enable MBIS to address some important cross-cutting issues at a scale comparable to regional stakeholders' interests.

4.0 CONCLUSIONS

A riverine hydrologic system is presented as a setting for integrated regional assessment of climatic warming scenarios. The Mackenzie Basin Impact Study (MBIS) illustrates the application of the "family of integrators" approach, consisting of several integrated system models and analyses of policy instruments.

We have considered the difficulties in producing a fully integrated assessment of climate warming scenarios, and acknowledge that in the case of the MBIS, several aspects are not covered (e.g. marine wildlife in the Beaufort Sea, future economic linkages with the rest of Canada and other countries). MBIS includes population and economic growth scenarios (Lonergan and Difrancesco, 1993), but technological and institutional change scenarios have not been constructed. It is unlikely that MBIS can achieve full integration, but partial integration can provide relevant information on sectoral and cross-cutting regional impacts.

The various scenario results are not the last word on climate change in the Mackenzie Basin. Scientific uncertainties in regional climate projections, cold region hydrologic processes, ecosystem changes, modelling of resource-based and informal (aboriginal) economic activities, etc., have not been resolved. Identification of research gaps will be an important part of the final phase of this study.

MBIS is an exercise in interdisciplinary research with stakeholder collaboration. Maintaining linkages between researchers and stakeholders has been a challenge. It may be difficult at this stage to appreciate the long term value of the MBIS experience, but it is clear that collaboration with stakeholders is vital for there to be any hope of producing an assessment that could be useful and relevant to the region of interest (Cohen, 1995). In fact, partially or fully integrated assessments may be impossible without stakeholder involvement during all phases of research. For example, stakeholders participating in MBIS planning meetings contributed to the selection of economic growth scenarios, and the identification of communities and individuals willing to be interviewed as part of surveys conducted by MBIS investigators.

During the remainder of the MBIS program, investigators will be completing biophysical and socio-economic impact studies, transferring information to the "integrators" (i.e. systems modellers, policy analysts, etc.), and completing integration exercises. The MBIS Final Workshop, scheduled for 5-8 May, 1996, will bring scientists and stakeholders together one more time to consider the results of the science, and to address the "so what" question. This workshop will include round table discussions with stakeholders on each of the main impacts issues. The final report will be published in late 1996.

During the last several years, the MBIS has benefited from informal discussions with the NRBS. The two programs share common interests, including overlapping study areas and concerns about future environmental changes. There has been exchange of information, including this contribution to the NRBS report. The 1996 MBIS Final Workshop provides an important opportunity for NRBS and MBIS to do that, but also to share their perspectives on the "so what" question, and on how the region should respond to the challenge of global climate change.

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