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What If and So What in Northwest Canada: Could Climate Change Make a Difference to the Future of the Mackenzie Basin?

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ABSTRACT. Global climate change, also known as global warming, is one of the most challenging elements of global environmental change. If atmospheric concentrations of carbon dioxide and other "greenhouse gases" continue to increase, global mean air temperatures are expected to rise 1.5˚ to 4.5˚C within the next several decades. High-latitude regions are projected to experience above-average increases. What effects would such a warming have in the Canadian Arctic? In a recently completed study of the Mackenzie Basin in northwestern Canada, regional stakeholders provided their responses to the "what if?" scenario of climate change in their region. This scenario includes more frequent landslides due to permafrost thaw, lower minimum annual river and lake levels, more forest fires, and lower yield from softwoods. These impacts could offset potential benefits from a longer growing and ice-free season. Regional stakeholders, including provincial and territorial governments, aboriginal organizations, and the private sector, felt confident about their abilities to adapt, so long as climate change would be predictable and gradual. Some potential impacts, however, could be very significant for renewable resources and aboriginal communities, and some stakeholders spoke of intervention into national and international policy arenas to raise awareness outside of the Mackenzie Basin.

Key words: climate change, Mackenzie Basin, climate impacts, integrated assessment, stakeholders

RÉSUMÉ. Le changement climatique mondial, qu'on appelle aussi «réchauffement de la planète», est l'un des aspects du changement de l'environnement planétaire qui présente le plus de défis. Si les concentrations atmosphériques en gaz carbonique et autres «gaz à effet de serre» continuent d'augmenter, les températures moyennes globales de l'air devraient s'élever de 1,5 à 4,5˚C au cours des prochaines décennies. Quelles seront les répercussions d'un tel réchauffement sur l'Arctique canadien? Dans une étude récemment achevée, portant sur le bassin du Mackenzie situé dans le nord-ouest du Canada, les parties concernées ont fourni leurs réponses au scénario d'anticipation du changement climatique dans leur région. Ce scénario comprend une augmentation de la fréquence des glissements de terrain dus au dégel du pergélisol, une baisse des niveaux minimaux de l'année des lacs et cours d'eau, une augmentation des incendies de forêt, et une baisse du rendement des résineux. Ces retombées pourraient neutraliser les bénéfices potentiels d'une plus longue saison de croissance et d'inter-glaciel. Les intervenants régionaux, y compris les gouvernements provinciaux et territoriaux, les organismes autochtones et le secteur privé, se sont dit confiants quant à leurs capacités d'adaptation, pour autant que le changement climatique soit prévisible et graduel. Certaines répercussions potentielles pourraient cependant avoir une importance majeure pour les ressources renouvelables et les collectivités autochtones. Des intervenants souhaitaient même une intervention au niveau de la politique nationale et internationale afin de sensibiliser l'opinion à l'extérieur du bassin du Mackenzie.

Mots clés: changement climatique, bassin du Mackenzie, retombées climatiques, évaluation intégrée, intervenants

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PROLOGUE: WHY STUDY GLOBAL WARMING IMPACTS?

If one were 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, but 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,

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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 whom do not realize that they are part of the kitchen staff.

After a series of scientific publications and meetings on 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 150 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."

Human-induced climate change (global warming) was a science question when the first papers on General Circulation Models (GCMs) were published in the 1960s and 1970s (e.g., SMIC, 1971). It became a policy question in the 1980s, linked to the growing interest in sustainable development and global change (WCED, 1987; WMO, 1988). With the ratification of UNFCCC, global warming became recognized as a multidimensional problem that requires multidimensional solutions. Science and policy responses, mostly concerning emission reductions, have received considerable attention from governments, nongovernmental organizations (NGOs), universities, and the private sector. The research effort, however, has not given equal attention to the "other dimension" of global warming—adaptation to the projected impacts of climate change scenarios.

The Intergovernmental Panel on Climate Change (IPCC) has traditionally looked at the policy aspects of climate change as a mitigation problem. Working Group III of IPCC focuses on mitigation options and their various economic and technical constraints (IPCC, 1996). Through Working Group II (Watson et al., 1996), there is recognition that climate change impacts on the physical environment (cryosphere, coastal zone, etc.) and economic sectors (forestry, agriculture, etc.) are important, but the connections between impacts and regional policy response have not been fully explored. This connection ultimately leads to questions about the other dimension of the climate change issue—proactive adaptation.

Since impacts are bound to be unique in each region or country, there is a need to consider impacts on places, not just on crops, trees, wildlife, or rivers (e.g., Rosenberg, 1993; Strzepek and Smith, 1995; Mortsch and Mills, 1996; Yates and Strzepek, 1996). In a warmer climate, the land would change and humanity would adapt, but these responses would not take place in a vacuum. Any response would be influenced by the choices government officials, community residents, and industry leaders made in response to other issues, such as the global economy, political realities, and regional visions (e.g., sustaining aboriginal lifestyles while promoting opportunities in the wage economy).

Regional impact assessment is a complex multidisciplinary research challenge because it must consider people as well as "things." To make matters even more difficult, we must assess not an observed climatic event (such as the 1994 and 1995 forest fire episodes in the Northwest Territories) but a theoretical warming of the earth's climate by increased concentrations of greenhouse gases. Many uncertainties are associated with the data and methods used to construct scenarios of a future warmer world, and some researchers have argued for the use of narratives from the past that may provide insights about the future. Such narratives or "analogues" (Glantz, 1988; Kearney, 1994) would provide 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 concerns about future climate change even more urgent is the recent conclusion by the IPCC that current climatic trends cannot be ascribed completely to natural forces (IPCC, 1996). The human influence on the earth's climate is being felt now.

Meanwhile, mitigation efforts are becoming bogged down. Some countries, including Canada, are pursuing voluntary programs. Several have entered into joint implementation initiatives, which are currently at the pilot stage (Foundation Joint Implementation Network, 1997). At present, however, most countries report that they won't reach their emission reduction targets (IEA, 1995) and political support for such efforts is relatively weak. If greenhouse gas concentrations continue to increase, and if current concentrations are already affecting the climate system, the world may have to face adaptation sooner, rather than later.

INTRODUCTION TO THE MBIS

The Mackenzie Basin Impact Study (MBIS) has been a six-year collaborative research effort to assess the potential impacts of climate change scenarios on the Mackenzie Basin region of northwestern Canada (Fig. 1). As a high-latitude region, and one of the largest watersheds in the world (1.8 million km^2), the Mackenzie Basin provides considerable habitat for terrestrial and freshwater wildlife, as well as raw materials for agriculture and commercial forestry. Nonrenewable resources, including fossil fuels, are being mined throughout the region, and this activity is an important component of the region's wage economy. National parks and wildlife refuges attract an ever-growing tourism trade. But there is another important dimension to this place, and that is aboriginal peoples and their communities. Wildlife harvesting is a subsistence activity as well as part of their traditional lifestyle, so they have an important stake in the future of the region. Through the land claims process, moreover, they are also becoming landowners (e.g., Indian and Northern Affairs Canada, 1984, 1992).

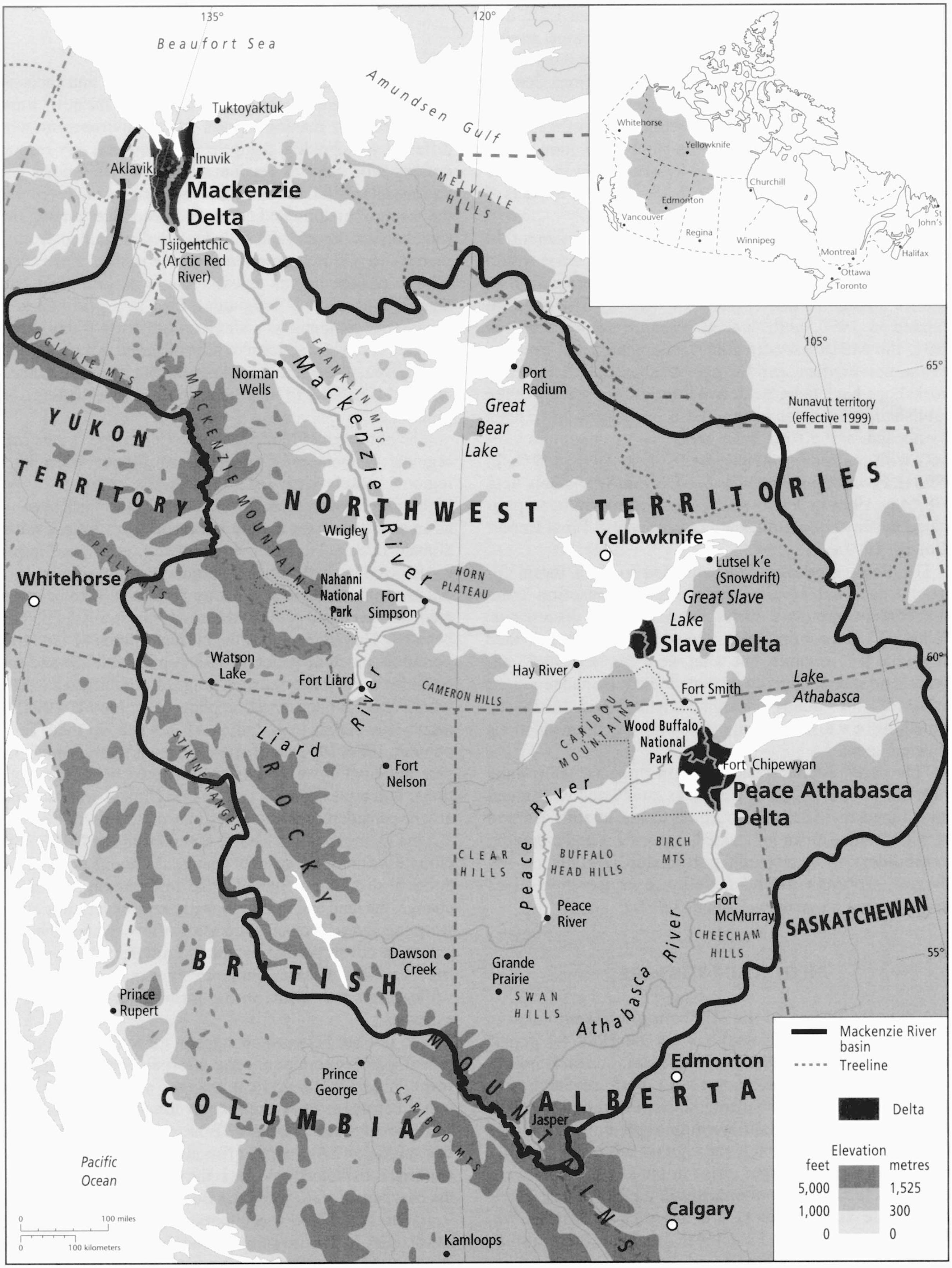

FIG. 1. The Mackenzie Basin, northwestern Canada, 1.8 million km^2 in area.

This area has experienced a warming of about 1.5˚C this century (Skinner and Maxwell, 1994). In some cases, ground temperatures are warming faster than air temperatures (Majorowicz and Skinner, 1997). Projections from General Circulation Models of the atmosphere indicate that if concentrations of greenhouse gases (carbon dioxide, methane, etc.) were to reach a doubling of pre-Industrial Revolution levels, northwestern Canada would warm by 4˚ to 5˚C by the middle of the 21st century (Cohen, 1993). What would the impacts of this warming be?

MBIS was designed to be an integrated assessment, in which information from many research disciplines would be combined to provide a more complete projection of climate change in this region. Initiated by Environment Canada in 1990, with funded research commencing in 1991, the MBIS has attracted participants from governments, universities, and the private sector. Meetings and workshops have been held, two interim reports have been published, five issues of the MBIS Newsletter have been distributed, and efforts have been made to maintain contacts with regional stakeholders (Cohen, 1993, 1994a, b, 1995a). Proceedings from the MBIS Final Workshop, held 5–8 May 1996 in Yellowknife, have recently been published by Environment Canada as the MBIS Final Report (Cohen, 1997a).

The Final Workshop was intended to be a forum for presenting final results, and soliciting reaction from stakeholders through a series of round table discussions. "What if?" was confronted by "so what?" Science provided the "what if?" answers, but what were the "so what?" answers? Did stakeholders agree that the exercise had produced "useable" and "policy-relevant" science? Did MBIS say something new to the region, and would its recommendations be acted upon?

This paper summarizes the main impacts determined from the various research activities conducted within and contributed to MBIS and outlines some lessons learned from coordinating an integrated assessment and engaging stakeholders in a research partnership. Details on the integration framework and modelling exercises themselves are presented elsewhere (Cohen, 1997a).

HISTORY OF THE MBIS

A detailed history of the MBIS program is provided in Cohen (1997b). This history covers the 1989–97 period and includes a list of research participants and stakeholder organizations. The attempt to do both research and stakeholder consultation throughout the duration of MBIS was in itself an important learning experience. Meetings with stakeholders were held throughout this period, mostly in Yellowknife and larger cities in the south. There were also visits to smaller communities in the Northwest Territories (Rae Lakes, Lutsel k'e, Norman Wells, Inuvik, Tuktoyaktuk, Aklavik, Fort Smith), and community studies were conducted in Fort Liard, Aklavik, and Wrigley.

SOME RESULTS FROM THE MBIS AND CONTRIBUTED RESEARCH

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 trade-offs among these various interests. Land and water use patterns today represent the result of historic and current compromises among these stakeholders, combined with knowledge gained from research and personal experience. At the scale of most current climate change impact assessments (e.g., grid sizes larger than 2˚ latitude × 2˚ longitude), land in a grid cell is not necessarily assigned to a single optimal use today, so it is unlikely that this practice 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 has been 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 from a warmer climate (Table 1). Taken individually, economic impacts could be quantified, and these numbers 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 the current system of land transportation, much of which is based on a stable ice and snow cover for winter roads; current ranges and habitats of wildlife, which underpin conservation plans (e.g., Inuvik, 1993) and native land claims (e.g., Indian Affairs and Northern Development, 1984, 1992); and 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.

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 socioeconomic 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?

Landscape and socioeconomic impacts for the scenarios assessed by MBIS are summarized in Tables 2 and 3. Soulis et al. (1994) provided runoff estimates for the Mackenzie

TABLE 1. Hypothesized scenario of impacts of a warmer climate in the Mackenzie Basin region.

Positive Impacts	Other Factors that May Constrain Positive Impacts	Negative Impacts
• longer growing season for agriculture	• current use of land for subsistence hunting and trapping	• increased erosion due to permafrost thaw
• greater productivity for forestry	• current winter transport system	• increased frequency and severity of forest fires
• longer ice-free season for navigation	• current ranges and habitats of wildlife	• extension of mid-latitude pests and diseases into high latitudes
• reduced energy demand for space heating	• scientific uncertainty	• reduction of habitat suitable for cold climate species
• longer summer tourist season		
• reduced cold weather stress on infrastructure		

Basin as a whole, while Chin and Assaf (1994) contributed detailed calculations for the Williston subbasin. Although increased runoff was anticipated for the Mackenzie (e.g., Miller and Russell, 1992), this does not appear to be the case for the GCM-based scenarios. A few subbasins showed increased runoff, including Williston (Chin and Assaf, 1994), but for the basin as a whole, only a composite analogue scenario showed an increase. Newton (1995, 1997) has therefore concluded that scenario spring flood risks for vulnerable communities may not be that different from flood risks under current climatic conditions. A more significant problem could prove to be lower water levels during fall and winter (Kerr, 1997), 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 for the 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 programme in the Mackenzie (Lawford, 1994).

There appear to be four other main threats to the Mackenzie landscape: (1) accelerated erosion and landslides caused by permafrost thaw and extreme events (fire, storm surges), especially in sloping terrain and the Beaufort Sea coastal zone (Aylsworth and Egginton, 1994; Solomon, 1994; Aylsworth and Duk-Rodkin, 1997; Dyke et al., 1997); (2) increased fire hazard (Kadonaga, 1997; Hartley and Marshall, 1997); (3) changes in the climate conditions that influence the development of peatlands, leading to reduction of peatland area in Alberta and Saskatchewan and expansion in the lower Mackenzie Basin (Nicholson et al., 1996, 1997); and (4) the invasion of new pests and diseases from warmer regions (Sieben et al., 1997).

These landscape impacts could lead to changes in plant succession (Wein et al., 1994). Impacts on wildlife are difficult to project, but they appear to be mixed. Researchers were hampered in making firm conclusions by lack of long-term data, complexity of life cycles, and incomplete information on wildlife responses to previous environmental changes (Brotton, 1995; Brotton and Wall, 1997; Gratto-Trevor, 1997; Latour and Maclean, 1997; Maarouf and Boyd, 1997).

In the case of fisheries in the Mackenzie Great Lakes, new data were obtained on habitat sensitivity to current climate, and historical references to the successful commercial fishery of the 1940s and 1950s provided important context for the current low harvests. With respect to climate change, however, an impact assessment of a future scenario was not attempted (Melville, 1997).

First-order and second-order impacts eventually lead to others which are considerably more difficult to address. Will land claims or water resource agreements be affected? Would it be appropriate to maintain historic water levels artificially in the Peace-Athabasca Delta within this scenario of climate change? Could there be new conflicts over land use, especially if agriculture expands northward to take advantage of improved northern soil capability to support crop production (Brunt, 1995; Brklacich et al., 1996, 1997)? What might be the effects on parks and other protected areas (Pollard and Benton, 1994)? Could climate change affect the economics of commercial forestry (Rothman and Herbert, 1997) or oil and gas production in the Beaufort Sea (Anderson and DiFrancesco, 1997)?

Expressing socioeconomic impacts in monetary terms is difficult, but some information is provided for agriculture, forestry, energy, and some aspects of tourism. In the latter case, for example, water-based recreation at Nahanni Park is expected to benefit from the longer summer, but this benefit could be offset by the increased threat of fire (Staple, 1994; Staple and Wall, 1996). There is no assessment here on the potential costs of increased fire or fire protection for tourism. Impacts on sport hunting may turn out to be more serious (Brotton et al., 1997; Brotton and Wall, 1997).

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 shows that residents can provide detailed visions of both "futures." In their view, community vulnerability to climate warming scenarios will change if their lifestyle changes. This may parallel circumstances that could be experienced in some developing countries during the next several decades.

In providing an integrated assessment, MBIS has undertaken some exercises in model development. One such exercise developed a resource accounting framework, including a Mackenzie Basin input-output model. This framework has been used to determine impacts of changes in energy (oil and gas) production on the region's employment and economic productivity (DiFrancesco, 1995; Lonergan et al., 1995). A community survey in Wrigley examined whether lifestyle

TABLE 2. MBIS summary of landscape impacts of climate warming scenarios. Adapted from Cohen (1997a).

Parameter	Detailed Impacts
Permafrost thaw and landslides occur, particularly on sites with high ice content in the ground.	• Thaw occurs primarily in discontinuous zone. • Seasonal active layer increases. • The rate of thaw in wetland areas lags behind other sites. • Forested slopes and the Beaufort Sea coastal zone may experience accelerated erosion due to increased fire and storm surge frequencies, respectively.
Water supply changes slightly, with earlier spring peak; seasonal minimum water levels are reduced to below current extreme low levels.	• Annual basin runoff changes -7% to -3% in GCM-based scenarios and +7% in the composite analogue scenario. • Increased precipitation is offset by increased evapotranspiration in many subbasins. • Spring snowmelt peak begins up to one month earlier. • The snowmelt season will be longer, with a lower peak in some subbasins (including the Williston/Bennett Dam). • Lower levels will occur during November to March at Great Slave and Great Bear Lakes.
Peace River ice cover is reduced in duration and extent.	• Ice cover is reduced by up to 4 weeks. • Upstream progression of ice is reduced by up to 200 km. • Runoff reduction (or reduction of discharge from Bennett Dam) offsets the effects of temperature increase on ice cover.
Soil capability for agriculture increases.	• The longer growing season and frost-free period increases the availability of marginal and suitable land for spring seeded small grains and forages. • Soil moisture supply decreases. • Current cereal varieties may mature too rapidly under higher temperatures.
Pine Weevil hazard increases.	• The temperature-based Pine Weevil Hazard Index increases. • Low elevation sites are particularly vulnerable. • Non-temperature factors are not yet included.
Peatlands' locations shift.	• Sites in Alberta and Saskatchewan are lost; water table depth changes by -70 to -30 cm. • New sites develop in the lower Mackenzie, south of Mackenzie Delta; water table changes by -30 to +30 cm. • The rate of change has not been determined.
Forest growth and yield may change because of higher temperatures and increases in the Fire Weather Index (FWI) and the Pine Weevil Hazard Index; regional productivity declines.	• Median FWI for four scenarios corresponds to a change of -15% to +81% in burned area. • Changes in productivity and yield vary by species and tree age. • The study assumes no change in management practices.

changes within the context of "Two Economies" could be affected by climate change. In this case study, a warmer climate was assumed to encourage offshore oil and gas development in the Beaufort Sea. The effect of this scenario on communities could be positive, unless people are forced to relocate to obtain employment. Other forces, particularly land claim issues, may have far greater impact than a scenario of fossil fuel industry expansion (Lonergan et al., 1995; Lonergan and Kavanagh, 1997).

Other modelling exercises include the Integrated Land Assessment Framework (ILAF). Its purpose is to compare changes in land capability with stakeholders' goals to identify possible land use conflicts in a climate warming scenario (Yin and Cohen, 1994; Yin et al., 1994; Yin, 1997). Results suggest that potential expansion of commercial agriculture would increase soil erosion, and spruce production would fall short of its target. Additional activities in multiobjective programming (Huang et al., 1996, 1997) also focus on potential expansion of agriculture.

Impacts and responses will not be felt by individual sectors in isolation. A unit of land (at a scale comparable to GCM output) is not likely to end up exclusively devoted to one kind of land cover or use. This set of research activities represents a first step toward addressing some important cross-cutting issues at a scale comparable to regional stakeholders' interests.

To make the connection between "what if?" and "so what?", some "real world" questions should be framed in the context of "scenarios." In any study of "futures" such as climate change impacts or sustainable development planning, we may be faced with determining the implications of scenarios of change.

NEW QUESTIONS FOR STAKEHOLDERS

The four scenario cases from the Mackenzie Basin Impact Study described below link some first-order and second-order impacts with management and policy concerns in this particular region.

Scenario Case 1: Changing Water Levels

The Mackenzie Basin includes several large lakes and rivers, freshwater and coastal deltas, and extensive wetlands and peatlands with many small, shallow lakes. One subarea of considerable interest is the Peace-Athabasca Delta, which includes habitat for fish and migratory waterfowl.

TABLE 3. MBIS summary of the socioeconomic impacts of climate warming scenarios. Adapted from Cohen (1997a).

Sector/Location	Detailed Impacts
Commercial forest harvest would be reduced unless there are increased expenditures on fire and pest control.	• Improved growth of hardwoods is offset by increased fire frequency. • The growth of softwoods declines; average tree age declines. • Potential implications exist for annual allowable cut and rotations. • Direct and indirect implications exist for forest-dependent communities in Alberta and British Columbia portions of the Basin.
Wheat production could improve, but expanded irrigation services would be needed.	• Potential increases in wheat yield from elevated CO_2 levels are offset by shorter grain filling time and less favourable soil moisture. • The longer season spring wheat cultivar provides only minor improvement. • The winter wheat cultivar may provide improved yields in the south. • Expanded irrigation would overcome projected deficits in soil moisture.
Tourism would experience mixed impacts.	• Little impact at Nahanni National Park is expected from projected minor changes in streamflow; the extended season for water-based recreation would provide economic benefits to communities near the Park. • The increased Fire Weather Index (fire frequency and severity) could affect runoff, landscape character, and visitor safety. • Potential losses to the Bathurst caribou herd would affect sport hunting north of Great Slave Lake.
A community's vision of impacts depends on its vision of lifestyle.	• The response to flood hazard varies by community, according to the interplay of individual, community, and government responses. • Several NWT communities are in areas of high risk for subsidence and landslides from permafrost thaw. • The significance of landscape impacts depends on whether a community maintains its subsistence lifestyle or switches to the 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.

Although water use in this region is modest, in-stream flow requirements for ecological purposes are very important for fish, birds, and other wildlife. The Peace-Athabasca Delta has recently experienced low water levels, reaching new record minimum levels during 1994–95 (Kerr, 1997), and concerns have been expressed regarding the viability of this habitat for fish and wildlife. Upstream developments by the forest industry also raised concerns among downstream interests. Governments responded by initiating several major research activities, including the Northern River Basins Study (1996) and the Peace-Athabasca Delta Technical Studies (PAD). PAD included experiments at creating artificial ice dams to induce flooding for ecological purposes (PAD Technical Studies Committee, 1994). Initially, the region's climate trends were not considered to be a direct factor. This view may be changing, however, as the current warming trend in the region becomes more noticeable (Skinner and Maxwell, 1994).

Would stakeholders' response to changing water levels be different if they believed that the cause were natural climatic variability rather than a hydroelectric facility? What if the cause were global warming? What if it were a combination of all three? If this scenario were to lead to any changes in water management, what would the financial implications be?

Scenario Case 2: Changing Land Capabilities

The short growing season currently confines agriculture to the southern third of the MBIS region. Potential agricultural sites farther north are limited by cold temperatures. A warming scenario could enable small grains to be cultivated on an additional 10 million hectares of land (Brklacich et al., 1996, 1997).

This land, however, is currently being used for other purposes, primarily for forestry and wildlife habitat. The latter is particularly important to Native communities, which depend on the animals for food, and for articles made of skins and fur (e.g., clothing). Much of this activity is part of the traditional lifestyles of the region's aboriginal peoples and is recognized as a "nonwage" economy. Aboriginal people participate in the "wage" economy, and expansion of agriculture and other activities from the south could provide additional employment opportunities. If land were converted to these other activities, however, would traditional activities be affected? Just because there might be a change in land capability doesn't necessarily mean that land conversion would immediately follow. Such decisions would depend on stakeholders' views being resolved through the process of policy making in the region.

Scenario Case 3: Changing Fire Weather

Fire is a normal component of the boreal ecosystem, and within Canada's Northwest Territories, around 1 million hectares burn in an average year. In 1994, there were 630 fires, covering approximately 3 million hectares (R. McLeod, pers. comm. 1995). In that year the temperature was around 1–1.5˚C above average and rainfall was below average during the growing season. In contrast, a 4–5˚C temperature increase is described within global warming scenarios for the MBIS region derived from GCMs (Cohen, 1993).

Territorial fire-fighting resources were severely tested in 1994, and almost 25% of the fires were not fought. The costs for some fires reached Cdn$1.2 million each, compared with a historic maximum of Cdn$0.5 million (R. McLeod, pers. comm. 1995). The following year of 1995 was also a bad fire year: several Northwest Territories communities had to be evacuated, and there were fire problems in northern Alberta as well.

In a climate change scenario, years like 1994 and 1995 could become more common. The "average" fire season would include a higher Fire Weather Index, increasing the potential area burned (see Hartley and Marshall, 1997; Kadonaga, 1997; Rothman and Herbert, 1997). What effect would this increase have on fire management? This question cannot be considered in isolation from land management objectives, since these objectives would be used to set priorities for selecting which fires to fight. Community protection would always be a high priority, but what about wildlife migration routes? What if commercial agriculture, tourism, and forestry expanded into the region? Just because there could be increased fire potential doesn't necessarily mean that more forested land would burn, or would be allowed to burn. As with the case of possible land conversion, any changes in fire management policy, including associated financial implications, would depend on changes not only in fire potential, but also in land use and stakeholders' views.

Scenario Case 4: Effects of Renewable Resource Impacts on Nonrenewable Resource Development

One interesting aspect that is beginning to emerge is how decisions regarding responses in the energy industry may be affected by impacts on renewable resources. In this scenario, climate change is seen as having a negligible direct effect on exploration and production operations, despite increased risk associated with sea level rise, sea ice changes, permafrost thaw, and associated landslides. However, if climate change were to affect the boreal and tundra ecosystems (including forest growth, wildlife habitats, fire frequency, etc.), would regional stakeholders alter their views on future energy developments? This relates to the additional uncertainties created by climate change impacts (Anderson et al., 1997) and the juxtaposition of the formal wage and informal nonwage economies in this region (e.g., Lonergan et al., 1995). The latter may be significantly affected by climate change, and it isn't clear at the moment whether such effects would encourage or discourage expansion of the wage economy. Aboriginal people want access to both economies, so the challenge is to design a response strategy that meets this goal.

If the nonwage economy were at risk, could this lead to greater restrictions on industrial growth, or would there actually be an acceleration of industrial development, at the expense of a decline in the nonwage economy and traditional aboriginal lifestyles? What would happen to forestry, park management, and other renewable resource-based activities?

RESPONSE OF STAKEHOLDERS

At the MBIS Final Workshop, stakeholders were asked to react to the climate impacts scenario by answering the "so what?" and "what should be done?" questions:

- Does the scenario make a difference to you?
- Does it alter your vision of the future?
- What responses would you recommend?

Discussions were anchored by five themes (see below).

Interjurisdictional Water Management

Regional impacts of the 1994–95 low levels were described, including problems for navigation and hydroelectric power generation. Recent climate trends were now seen as being a factor in the low water conditions that were experienced at the Peace-Athabasca Delta, exacerbating the effects of the upstream Bennett Dam. If this was a sign of things to come, adaptation would still be possible, so long as these changes would be slow and predictable. Rapid changes, however, would create difficulties for aboriginal communities. A new interjurisdictional agreement, the Mackenzie River Basin Transboundary Waters Master Agreement, will provide a mechanism for joint stewardship of the water resource and the ecosystems that depend on it (Mortsch, 1997).

Sustainability of Ecosystems

Stakeholders described recent changes in wildlife patterns and vegetation growth and presented several hypotheses about effects on various species (e.g., caribou) in a climate change scenario. Contaminants could affect the response of fish and wildlife to climate change, and it would be difficult to separate the effects of climate and other factors. This discussion included the role that values and value judgments play in decision making. Public awareness of problems and choices would affect communication between scientists, policy makers, and the public.

Besides improved communication, there were other recommendations:

- establish community-based monitoring, incorporating both western science and traditional (ecological/environmental) knowledge (TK or TEK);
- expand the use of co-management bodies which include aboriginal organizations and all levels of government;
- adopt strategies that would facilitate adaptation, such as adjustable quotas and catch limits; and
- continue with land claim settlements to ensure local control.

A Gwich'in elder noted, however, that even land claim agreements might not be enough for Basin residents to respond effectively to global issues such as climate change, ozone depletion, and Chernobyl. Like many other issues facing the North, response to climate change involves a learning process for everyone (Irlbacher, 1997).

Economic Development

Even as the global economy changes, economic development still depends on the old rules of supply and demand. In the Mackenzie, however, regional stakeholders would demand an equal voice with business and government in future decisions about research and development. Results from the MBIS indicated a mixed set of economic impacts. The forestry is thought to be at greatest risk. Business could not invest on the basis of uncertain knowledge of climate change, but long-term research and monitoring programs should include this in an explicit manner (e.g., forest models). Greenhouse gas emission reduction should also be pursued (Barrett, 1997).

Maintenance of Infrastructure

Permafrost thaw, landslides, fire, water levels, and changing ice conditions could affect transportation routes, pipelines, and other engineered structures. In the long term, there would be a need to monitor and, if necessary, retrofit various structures through insulation or other means. Any changes in runoff and snowmelt would result in revising dates for operating winter roads (ice and snow roads, which are in common use in this region) and might force governments to significantly expand all-season roads. Design standards would have to be reconsidered. As with other issues, predictability and rate of change would be the key elements in determining the most appropriate response, and the costs of such changes are not known. But adaptation would also require a more compatible style of construction, based on local rather than imported materials. "Sustainable construction" could reduce the North's "ecological footprint" (Zdan, 1997).

Sustainability of Native Lifestyles

Climate change joins a long list of factors which affect the lifestyles and livelihoods of people who live in the North. With or without climate change, however, Native lifestyles are in flux, and any potential impacts should be considered in that context. Communities are already being affected by changes in wildlife harvesting opportunities and wage-based employment. Education and transportation have improved, and some Native people are opting for jobs in the wage economy. As the "two economies" lifestyle continues to evolve, communities will be trying to provide opportunities in both traditional and wage-based activities, but if climate change affects wildlife numbers or habitats, traditional patterns of wildlife harvesting will have to be modified. Native people have adapted to change, but it was the predictability of the extent, duration, and speed of change that made adaptation possible. There is a real concern that if future changes were fast, dramatic, and surprising, Native communities would be left in a very vulnerable position. Traditional lifestyles would be at risk of disappearing.

Stakeholders proposed that monitoring and adaptation could be undertaken through more effective partnerships between governments and Native communities. TEK, along with Western science, should be used in modern management practices as well as in traditional activities. Training in renewable resource management for aboriginal youth would be an important component of preparing for the future (Pinter, 1997).

LESSONS FROM THE "COLLABORATIVE" WITH NORTHERN STAKEHOLDERS

Climate is a complex agent of change. If global warming occurs as projected, its effects will depend not only on the direct impacts on land and water resources, but also on how technology, economies, and societies change over time. This complexity represents a significant research challenge, but the potential magnitude of global climate change is too important to ignore, despite the many uncertainties associated with our projections. This kind of challenge needs an integrated approach (Parson, 1995, 1996; Morgan and Dowlatabadi, 1996; Risbey et al., 1996), with stakeholders and scientists working together, sharing knowledge and experiences. Integration with stakeholders is possible, but it is not an easy process.

Three aspects require further elaboration: coordinating the scientists, communicating with stakeholders, and integration of TEK with scientific research about climate change impacts. Although these are objectives that most people genuinely want to achieve, some important and unanticipated problems arose in each case within MBIS.

Coordinating the Scientists

There were a number of examples of information exchange successfully achieved between participating researchers (Cohen, 1997a). Some technical difficulties, however, affected both the transfer of data between investigators and the integration process.

At the outset, several investigators placed a fair bit of confidence in the flexibility of Geographic Information Systems (GIS) to handle data sets produced by other tools (including other GIS). This use of multiple data sets has not been an easy process. In hindsight, it might have been better to specify a common GIS platform. It is fair to say, however, that this decision would have led to some objections from various participants who had already invested time and resources into developing their own databases and expertise on whatever system they happened to be using. This technological problem may persist until GIS databases acquire a more uniform format.

Integrated assessment exercises (including models) were supposed to provide "targets" for output generated by sectoral studies. Incompatibilities turned up here, too. For instance, investigators working on economic impacts could not provide the data required for the resource accounting framework being set up by another MBIS participant. This framework required considerable economic data, and there was a strong desire to provide information on the costs of impacts, but acquiring baseline and scenario economic data proved to be a difficult challenge. Some sectoral impact studies were site-specific (e.g., tourism in Nahanni National Park), so financial impacts were not estimated for larger scales (e.g., the Northwest Territories). A second issue was the need to maintain confidentiality. In a small regional economy, it became necessary to aggregate sectors for the database. Otherwise, individual business enterprises might have become visible in the analysis. As a result, the resource accounting framework would narrow its focus, and not include many of the sectoral impacts addressed in other MBIS activities (e.g., agriculture, forestry, and tourism).

Finally, communication among investigators outside of MBIS meetings or workshops was dependent on their initiative. The widely scattered nature of the MBIS group precluded frequent meetings, so once all the participants had been identified and their plans disclosed, investigators were on their own. They were encouraged to share information, but this was not forced by the project leader, especially since many investigators either were part-time (including students) or were volunteering their results to the Collaborative. Lack of resources for full-time support (either from the MBIS budget or from co-sponsors) sometimes resulted in participants' dropping out prematurely to take on other opportunities. Stronger direction from the project leader was not possible without additional resources to support full-time investigators (such as private scholars or consultants) and a full-time secretariat.

Communicating with Stakeholders

From 1990 to 1996, the project leader held formal and informal meetings with stakeholders, mostly in Alberta and the Northwest Territories. These meetings were supplemented by visits to eight communities in the Northwest Territories: Tuktoyaktuk, Aklavik, Inuvik, Norman Wells, Rae Lakes, Lutsel k'e, Yellowknife, and Fort Smith. In addition, several MBIS projects included field work in these and other communities throughout the study area. The various MBIS meetings and workshops described above, however, were held in the Northwest Territories capital of Yellowknife, or in larger centres in the south (particularly Edmonton). The reasons for this were primarily economic, since most of the investigators were based in the south, and the meeting site had to be easily accessible. Most Native stakeholders had no problem with travelling to Yellowknife or the south as long as travel support was provided. In some cases, however, aboriginal organizations did not have the people available, given the small size of their support staffs and the many other issues that these same individuals were involved in. Over time, however, this situation began to change.

Rapid institutional changes took place during this period, and their impact on communication was noticeable. In 1990, only one aboriginal group, the Inuvialuit, had a settled land claim and an established infrastructure, including a full-time secretariat, which coordinated Inuvialuit participation on resource management boards and joint activities with other parties. The Inuvialuit Game Council became the main contact for MBIS, and consultation was able to continue uninterrupted throughout the MBIS program. Other groups did not have settled land claims at the outset, nor did they have full-time staff focusing on environment or resource management issues. By the time the Mid-Study Workshop was held in 1994, two more groups had settled land claims, and other organizations had full-time environment managers on staff. During this four-year period, frequent turnover in representation from these other groups hampered effective consultation. The current situation is considerably more promising, and at the 1996 Final Workshop, 11 of 28 round table panelists were aboriginal or from aboriginal organizations.

Certain other stakeholders have been more difficult to reach, including some federal and provincial government agencies. Climate change is an issue embraced by some and avoided by others, depending on their mandate, jurisdiction, and perceptions or beliefs about the need for a proactive response to a "theoretical" global-scale problem. Much of the consultation effort in MBIS focused on interested parties in Alberta and the Northwest Territories because their relationship with the study area was direct and obvious. These parties were easy to identify, and most came forth readily to provide their views. The Northwest Territories government also became a research participant and co-sponsor early in the program, while the Alberta government agreed to co-sponsor the MBIS Final Workshop. The Yukon Territory and the provinces of Saskatchewan and British Columbia are also within the study area, but the Mackenzie Basin is not as important to them as other regions. A stronger effort should have been made earlier to include British Columbia, which is the upstream jurisdiction in this watershed. Efforts increased during 1995–96 to attract stakeholders from British Columbia to the May 1996 Workshop.

Integration of TEK and Scientific Research on Climate Change Impacts

TEK can be a valuable source of information on the environment (e.g., Johnson, 1992; Inglis, 1993), but little of this information has reached the mainstream discourse on global climate change. MBIS tried to directly incorporate TEK in the research program (Bielawski, 1994; Bielawski and Masuzumi, 1994). MBIS also included aboriginal stakeholders in the planning process for the overall program, as well as in surveys and interviews conducted as part of community studies (Aharonian, 1994; Newton, 1995, 1997), economic modelling (Lonergan et al., 1995; Lonergan and Kavanagh, 1997), and identification of planning goals (Yin and Cohen, 1994; Yin, 1997).

Was integration of TEK and other aboriginal and Western science knowledge sets achieved? Partially, but not as much as was hoped for at the outset of the study. Aboriginal opinions on current conditions (e.g., flood hazard) and visions of the future were successfully brought into the study framework, where they played an important role in the planning process of MBIS and in the discussion on recommendations. But MBIS only skimmed the surface of the TEK pool. As Bielawski (1994) noted, attempts to raise additional funding for a TEK study using Participatory Action Research (PAR) methods were not successful. Discussion on PAR itself is beyond the scope of this paper, except to say that the funding requirements were larger than what MBIS could support on its own. MBIS therefore integrated aboriginal opinions into the study, but not TEK directly.

The Northern River Basins Study (1996) had a substantial TEK component, with a budget equivalent to 75% of the entire MBIS budget. Does this mean that more money is the answer? Well, it is a necessary but insufficient condition. Integration with TEK will also require development of a meaningful long-term research partnership within the climate change context. Such opportunities could be found with paleoclimatology, regional climate and permafrost studies, and research on marine, boreal and tundra ecosystems, including fisheries and wildlife. Establishment of a regionally based research center on climate-related issues would be an important step towards achieving this goal.

External Review of MBIS

In a review of the collaborative process undertaken by MBIS, Dyer and Stewart (1997) noted that there was little precedent for working with aboriginal people on an issue like global climate change (although there was an attempt to include the Maori in a climate change impact study in New Zealand [NZCCP, 1990]), and there were no established rules on how to approach interactions with this group of stakeholders. The researcher needed to gain the trust of the community by becoming part of the community, a familiar face to residents. The researcher had to demonstrate that scientists are interested in people's daily lives and culture, and not just in producing research that is not shared with the community.

During interviews, aboriginal people familiar with MBIS expressed general agreement with the participatory approach taken by MBIS. However, they felt that visits to the region were too infrequent to keep local stakeholders updated, and that more funding should have been provided for traditional knowledge studies (Dyer and Stewart, 1997).

It is difficult to say whether aboriginal people feel that the MBIS process was a success or a failure. The consultation process had its moments of tension (Cohen, 1995b), and perhaps there are several opinions on this point. Dyer and Stewart (1997) concluded, however, that MBIS was able to get people accustomed to the idea that global climate change, or global warming, was not just a global issue, but also a local one. Stakeholders' expressions of concern about the effects of climate change (e.g., Irlbacher, 1997; Pinter, 1997) are explained by their recognition that this research exercise is telling them a story they cannot ignore, and that they must live with the outcomes.

THE ROAD AHEAD

The Mackenzie Basin Impact Study was an exercise initiated by Environment Canada from outside the region. Many of the researchers were not from the North. Information has been generated, and is being distributed to all parties, but what happens next?

The cases from the MBIS illustrate how climate change may have indirect but profound impacts on land cover, regional resource exploitation, and—consequently—national strategies for climate change adaptation and mitigation. Many gaps and methodological challenges will remain upon its completion, but important lessons are being learned, and new questions are being identified. Who will address these questions, and how?

The MBIS Final Workshop produced several recommendations on how to establish a stronger regional presence in research, monitoring, and archiving of information on climate change and its potential effects. These include:

- establish a co-managed monitoring network, with observations based on empirical knowledge and TEK.
- ensure that climate change is included in the Mackenzie Basin Transboundary Water Master Agreement and other policy instruments
- reduce greenhouse gas emissions
- provide results to the Canadian Climate Program Board, the Canadian Global Change Program, and the Canadian Polar Commission
- communicate results to stakeholders in plain language
- engage regional institutions (e.g., Aurora College) in monitoring, communication, and collaboration between various scientific interests, and hold follow-up workshops on a regular basis.

Regional educational institutions, governments, and communities would need to be part of any future activities, in partnership with the federal government and other stakeholders. Communication in plain language would be an important aspect of this (Kertland, 1997). MBIS has produced plain language summaries, as well as a longer technical report (Cohen, 1997a). It is hoped that plain language communication will lead to a broader northern response to climate change, both in Canada and elsewhere (e.g., through the International Arctic Science Committee; see Weller, 1997; Kuhry and Lange, 1997).

Climate is a complex agent of change acting concurrently with other forces of change. Some have argued that global warming will be a relatively minor agent compared with future technological, demographic, and political changes; yet there is something disquieting about the power of the atmosphere to influence the availability of life's building blocks—water, food, other renewable resources, shelter, and mobility. If society is going to face a climate scenario beyond historic precedent, we need to mount a much broader effort to understand what this might mean in a human, sustainable development context.

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